IUL School of Technology and Architecture

Department of Architecture and Urbanism

On the Preference for Form and Abstract Architecture Spaces with Distinct Geometric Characteristics

Miguel Baptista Tavares Carreiro

Thesis specially presented for the fulfillment of the degree of

Doctor in Architecture of Contemporary Metropolitan Territories

Advisers:
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On the Preference for Form and Abstract Architecture Spaces with Distinct Geometric Characteristics

Abstract

Since at least the Greek classic period that thought, within the western civilizations, has been sharing a strict relationship with Euclidean principles, which have influenced and characterized it, leading to a specific type of reasoning and identity. In turn, as expressions of the mind, the forms that we have been thinking about and have brought to material reality, have been following these same Euclidean principles.

Thought has shared also a closed relationship with architecture and architecture space form. A relationship that became even more pronounced with the incoming phenomenon of the Industrial Revolution with its standardization and mass production techniques and technologies. Ever since, the majority of architecture spaces that we have been thinking about and eventually building, follow and share Euclidean-orthogonal principles and relationships.

However, with the arrival of the 20th and 21st centuries' Digital Revolutions and their novel representation, visualization and production techniques and technologies, the forms that we think about and manage to produce, have achieved an unprecedented range of freedom, in which both Euclidean and non-Euclidean free forms are considered.

This happening opened a pertinent and relevant thinking and discussion on whether humans, in their nature and within a valid freedom of choice, tend to prefer the long settled Euclidean, orthogonal-based architecture spaces, with all the elements that such geometry implies, namely, the presence of angular, sharp edges and vertices, or, on the contrary, they tend to prefer non-Euclidean, curved, rounded architecture spaces.

This thesis proposes to address the problem of the preference for form, namely architecture space form, divided in two sub-problems that the literature review helped to identify: aesthetic judgements and approach-avoidance decisions, two judgements that, in turn, may rely in two knowledge 'databases': a subjective-based one, build through our life time sensible and rational experiences, and, a more objective-based one, which hides behind our genetic legacy and lays on basic evolutionary defense functions or mechanisms.

We will approach this thesis Problem and Research Question, through (i) a free discourse on historic key events that, through our evolutionary stages, may have contributed to the fact that we have been closer to some elements, namely forms and architecture form, with certain geometric characteristics, over others; (ii) the evolution of aesthetics and our basic evolutionary defense functions or mechanisms, through qualitative and quantitative research methodologies, (iii) state-of-the-art review on the topic of preference for elements with distinct geometric characteristics, and (iv) our own developed experimental user study on abstract architecture spaces with distinct geometric characteristics at the contour level, which, based on the thesis two sub-problems, tried to validate our raised hypotheses.

The results of this thesis suggest that humans prefer abstract architecture spaces with curved, rounded elements, rather than those equipped with angular, sharp ones. On the other hand, they were inconclusive on whether we prefer Euclidean-orthogonal or full non-Euclidean abstract architecture spaces, possibly due to familiarity ("mere-exposure") and 'strangeness' effects. These results validate and partial validate hypotheses 'H1' and 'H2', respectively, the two major hypotheses of this thesis.

Keywords: Abstract architecture space form; Preference for form; Aesthetic judgement; Approach-avoidance decisions; Geometry; Euclidean; non-Euclidean; Experimental study.

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Abbreviation List

Cycles per image – CPI

Electromyography – EMG

Electrodermal activity – EDA

Functional magnetic resonance imaging – fMRI

Head-mounted display – HMD

High spatial frequency(ies) – HSF

Low spatial frequency(ies) – LSF

Space-image(s) – SI

Statistically significant differences – SSD

Virtual Reality – VR

Chapter 1

1. Introduction

Abstract. In this chapter we will introduce the thesis, by identifying the motivation for the research, the context of the addressed major problem and the related research question. This major problem will allow us to derive two sub-problems and launch the thesis hypotheses. We will then provide an overview on the document's structure, namely, its chapters, justifying their presence and pertinence. We will conclude with the list of produced peer-reviewed papers, which were produced, submitted and accepted for publication and public presentation in international scientific conferences, within the scope of this thesis, highlighting their contributions.

1.1. Introductory Section

The Revolutions on the Materialization of an Idea. The Reality that Sprout the Problem

During the last decades we have witnessed a revolution in the areas of shape and form design and production, two essential stages for the proper concretization of a product, from an initial mental idea to its representation and lastly, its final materialization. With the arrival of the the 20th and 21st centuries Digital Revolution, we have gradually developed and achieved almost full control over the design of forms in the digital and virtual domains and, subsequently, over the production phases and processes of such forms.

Historically, since we have associated the representation and design stage, in the process of materializing an idea, the final shape and form of a product has been directly depended on at least three phases: (i) the level of thought of the person or persons who mentally construct the idea, (ii) the level of representation techniques and technologies able to communicate the whole complexity of such idea and (iii) the level of production techniques and technologies essential to bring the idea into material reality.

Thinking processes

The mental development of an idea depends on the levels of thought and knowledge of the one that conceives it, but also, often, on external phenomena (e.g. needs), many times essential to trigger the mental process of conceiving ideas. Nevertheless, there are several other factors that influence the reality of what are, at a given time, our thought and knowledge levels. Generally speaking, such thought and knowledge can be enhanced and strengthened by our own experiences and the experiences of others, either from present or past generations, whenever such reality was able to arrive to us and we were able to seize it (e.g. human-to-human testimonies, education, literature). However, they also depend on the means that we can find at our disposal at a given time and space to work our mental processes either at a purely internal level or at an external level, exporting such ideas towards their material concretization. Increasing the level of variety and complexity of the world, provide us more means (e.g. methods, techniques, tools, technologies and mechanisms), to better work and bring forward our ideas in an infinite cycle that repeats itself.

Design Processes

The level of integration of form design processes achieved by digital technologies has contributed to a radical change on such reality. The shift from paper-based platforms to digital-based ones, has significantly changed the paradigm of the design processes, now able to contemplate the vast potentialities of the digital domain. Oriented by such capacities, classic, traditional, conventional or even simply past means of representation, have been embraced by the digital transformation and been a target of evolution towards more intuitive, pragmatic, understandable and controlled approaches. This trend has been marked by a transition from the popular two-dimensional representation of three-dimensional objects, to full three-dimensional representations of such objects that, by considering the whole object's dimensionality, allows better and more complex comprehension, manipulation and development.

Production processes

On the other hand, the paradigm of shape and form production, has also changed framed by such digital potentialities. If the Industrial Revolution already gave an important and significant step towards both simplification and enhancement of an object's production process, through the standardized prototype-mass production methods and techniques, the Digital Revolution took such production methodologies and techniques to a complete new level of freedom. With the access to CAD-CAM process technologies, software and hardware, it is nowadays possible to arrive to the final stage of a product's development process – its material concretization – almost (if not only) through computer-controlled mechanical machine processes, without human labour or interference, and, at the same time, guarantying that the materialization of the object corresponds exactly to its previously worked and represented idea. With the digital transformation of this sector, the two previously divided and distinct sub-processes of the wider process of a product materialization, design and production, can now be two connected phases of the same process.

The General Liberalization of Shape and Form Production

Suddenly, freed from the set of restrictions that historically have limited the shape and form of products, the level of technology that we encounter at our disposal enables us to create a direct relationship between the shapes and forms of our thought and our ability to bring them to reality, first by representing the idea through an understandable language able to communicate all its aspects and characteristics and, afterwards, based on such representation, by materializing such idea.

Broadly speaking, these technological advances associated with the current level of evolution of our thought mean that, today, we are easily able to carry out almost any shape and form that is an object of our thought. In other words, for the first time in our history, we have the means to produce and reproduce any kind of form or shape that we are able to think about. In turn, through the access to small office and home oriented 3D printing technology, nowadays the production of shapes and forms belong not only to the industrial, specialized domain but it is also opened to the common, amateur user.

The Extension to Architecture

For a long time, since the Industrial Revolution, that architecture objects, like many if not most of the objects produced in our days, makes use of standardized, mass production elements, such as iron beams and bricks, in its construction process. The reasons that lead architecture to consider such standardized solutions are the same that made general products to consider them in their production. They are mainly connected with social-economic factors, since those solutions allows to build faster and cheaper, with the intention to simplify the complexity associated with its construction process. However, compared to the restrictions associated with the design and production processes of general objects, the reality of architecture is somewhat more complex. Such reality is due to several factors. On the one hand, each architecture project is generally thought to respect a series of conditioning factors, such as, for example, program, area, site, topography and surroundings. The necessity to follow such premises turn most architecture objects a single, unique example and not something that can subject to mass production. On the other hand, architecture does not stand exclusively by itself. A considerable amount of factors must be taken under consideration, in order to produce useful, realistic spaces and environments. Space must be thought and built as being compatible with what most of the outside market has to offer, namely, doors, windows or furniture. Due to these reasons, despite of specific examples that don't have the necessity to follow utility approaches, it is quite hard for architects and those who are involved in the design and construction of architecture, to have the opportunity to develop it upon purely work of the form, without any restrictions attached. This has led to architecture to follow a mainstream Euclidean geometry approach, with vertical and horizontal plans and elements that make almost anything and directly adapted to its reality.

The standardized and mass production techniques that sprout from the Industrial Revolution, has exercised a considerable effect on the potential geometric freedom of shapes and forms of products in general, from small objects to cars. This reality has evolved with the late developments of the Digital Revolution, and now architecture is more likely to overcome its traditional association and Euclidean geometries, and potentially achieve the same levels of form freedom, that common objects already did. With the arrival of new digital technologies, namely, the adoption of information and communication technologies and processes, such as the CAD-CAM, architects and the other third parties involved in the architecture process, have now new design and construction potentials at their reach, and the opportunity to consider not only the mass Euclidean geometry spaces, with which architecture has been related for a long time, but also non-Euclidean geometry spaces, including rounded, curvilinear elements, or even a balance between both of these approaches.

Moved by the advances on design and production technologies and its potential, the paradigms of form thinking and architecture construction processes, have been changing significantly for the last decades, and are now able to take into account new and more complex realities that were unable to be viably considered without such technological transformation. We believe, then, that now is the right time to bring the topic of architectural space form, its limits, affordances and effects into discussion, to make an effort to better understand them and, since there is yet a lot to achieve, contribute to this field's creation of knowledge.

It is within this context, that the theme of the preference for elements with distinct geometric characteristics, and the more particular topic, of the preference for architecture space form with distinct geometric characteristics at the contour level, came forward and become relevant.

The Preference of Elements with Distinct Geometric Characteristics

As we have seen, designers have now the viable opportunity of considering new forms for architecture spaces. However, the properties of lines, shapes and forms able to trigger potential preference, are as many as the intrinsic properties of such elements. They can vary, for instance, from their sense of order, proportion, symmetry, balance, harmony, colour, contrast, geometric orientation or even texture. Nevertheless, there is one feature shared of lines, shapes and forms that we believe to ultimately define the essence of such constructions: their geometric nature. Within this context, there are two specific geometric characteristics and properties of lines, shapes and forms, that have the literature has pointed to influence preference for such elements: the presence of (i) curve, rounded contour elements and (ii) angular, sharp contour elements.

Early Classification of Elements with Distinct Geometric Characteristics

Among the scope of elements with distinct geometric characteristics, lines were the first ones to be a target of aesthetics evaluation and classification.

In the middle of the 18th century, William Hogarth classified, in 'The Analysis of Beauty', the form of the triangular glass and the serpentine line, "the line that Michelangelo recommended" (Hogarth 2010, p.26), as "the two most expressive figures that can be thought of to signify not only beauty and grace, but the whole *order of form*" (idem). According to Hogarth, such line is the one that, among wavy lines, "truly deserves the name of the line of beauty" and can be called "the line of grace" (idem).

Even though, apparently, Michelangelo had already expressed his judgement towards lines, Hogarth was the first reference that we were able to find, to specifically address the classification of elements with specific and distinctive geometric characteristics, through subjective aesthetic judgements. Later on, in the beginning of the 20th century, Kate Gordon would follow Hogarth's opinion and write in 'Esthetics', with respect to the character of lines, that "curves are in general felt to be more beautiful than straight lines. They are more graceful and pliable and avoid the hardness of some straight lines" (Gordon 1909).

The evaluation of the characteristics of lines would continue to be an active target of study in the course of the 20th century. However, following an historical trend (that we will deeply address further ahead in this thesis document), in the short term, the methods of science would evolve to comprise experimental approaches involving multiple test-subjects. With this methodology, scientific research, involving understanding the phenomena and the creation of knowledge, would swift from purely exclusive subjective-based arguments, to objective and universal approaches and results. Lundholm (1921), Poffenberger and Barrows (1924) and Hevner (1935), are examples of authors that performed experimental studies on the affective tones and values of lines. The results of their studies, show that angular lines are associated with feelings such as 'agitating', 'hard', 'furious', 'serious', robust' and 'vigorous', and curved lines with ones such as 'gentle', 'sad', 'quiet', 'lazy', 'merry', 'gentle', 'serene' and 'graceful'.

State-of-the-Art on the Preference for Lines, Shapes and Forms with Distinct Geometric Characteristics

In the second half of the 20th century and the beginning of the 21st's, the research on the evaluation of elements surpassed the restrict scope of the classification of lines and expanded to the wider topic of the preference for elements with distinct geometric characteristics, which kept comprising lines but also shapes and forms and the more particular topic of the preference for architecture spaces with distinct geometric characteristics. Mainly in the period of the last 15 years, the experimental studies on these topics have increased and enhance the levels of research namely, through the consideration of various and diverse advanced research methodologies. Such approaches allowed to confirm the hypothesis that humans have a tendency to prefer elements with curved geometric contour features, over those with sharp-angled geometric contour features, contributing to a better understanding on the reasons why we have such preferences.

These methodologies have then played an important role in above-mentioned research on preference, their results and current understanding. For this reason, we will next briefly address some of the gathered knowledge already known to influence this topic, which ultimately contributed for structure of this thesis.

Aesthetic Judgements and Approach-avoidance Decisions

On the one hand, experimental studies on the preference for elements with distinct geometric characteristics have unfolded this core topic in two approaches: aesthetic judgments and approach-avoidance decisions. While aesthetics judgements try to understand if we find these elements to be beautiful or not, approach-avoidance decisions try to understand if we find them to be safe or threatening, making us accepting and desiring some, while rejecting and avoiding others.

Experience, Familiarity and Subjective, Empiric and Rational Knowledge

On another perspective, experimental variables such as the “mere-exposure” effect (Zajonc 1968) and the ‘level of expertise’, especially in arts (Silvia 2009), have shown to exercise influence on preference. Based on this results, we know that experience and familiarity are able to interfere with our preference and, thus with our taste and safety judgements, leading us to believe that the knowledge that we gather through sensitive and rational experiences, may contribute to the creation of a kind of 'database', based on memory processes, which is able to affect subjective preference judgments.

Threat and the Amygdala and Pleasure and the Reward and Affective Circuitry

Moreover, recent experimental studies with the access to brain scanning technology, such as functional magnetic resonance imaging (fMRI), allowed the community to go deeper on how we react to external phenomena, and provided the means for deriving plausible explanations on the reasons why we tend to prefer some elements with particular geometric characteristics over others. According to the results of these studies, sharp-angled contour elements that contain sharp, prominent edges and vertices, able to interfere with the physical state of the human body, activate regions of the human brain often associated with the perception of threat and the production of fear, such as the amygdala (LeDoux 2003; Bar and Neta 2007). The perception of such elements, both by the sense of vision and the sense of touch, are able to alert humans to the presence of potential threatening situations, giving us the opportunity to react to the presence of such elements, avoiding their potential danger, harmful effects and pain, guarantying the safety and integrity of our bodies and consequently, the extension of our lives and well-being condition. On the contrary, curved, rounded contour elements, have shown to activate other brain regions that have been often associated with the perception of agreeable, pleasant situations and the production of pleasure, such as the reward and affective circuitry (Vartanian 2013). These results are reinforced by literature that explore the concept of 'baby schema', which defend that a restrict set of facial and body proportions, often found in infants, is able to induce cuteness perception and is in some cases know to modulate the brain reward system, conducting also to pleasure feelings and a motivation for caretaking in adults (Glocker, et al. 2009 [March]; Glocker, et al. 2009 [June]; Borgi, et al. 2014).

Basic Evolutionary Functions and Objective Knowledge

Finally, with experimental study methods such as the restriction of the period of time that stimulus are presented to participants, reduced to subliminal levels (Bar and Neta 2006, 2007), it has been possible to create a correlation between the perception of visual primitives, such as sharp-angled and curved shapes and forms, with primitive sensations of threat and pleasure and the feelings of fear and wellbeing in a state prior to cognition, connecting such quick detection and reaction to our body's primitive defensive system ('fight or flight' controlled by our autonomic nervous system), linking such perceptions with more objective rather than exclusive subjective levels of preference (Bar and Neta 2006, 2007; Leder, et al. 2011; Vartanian 2013).

Objective and Subjective-Based Knowledge 'Databases'

Taking in consideration the information reported by the literature and described above, we can state that preference, namely towards elements with distinct geometric characteristics, may be influenced by aesthetic and approach-avoidance decision judgements. In turn, such judgments rely on two different kinds of knowledge: one, more subjective, which lays on the common but also individual experiences of the self, and another, more objective, which belongs to a primitive defense system shared by all humans, and, maybe, possibly also by other animals that count with at least one central nervous system. While the former is a subjective based knowledge 'database' that is build and updated upon our sensitive and rational experiences, over our living and conscious life-time span (Bar and Neta 2006), the latter constitutes a closed, objective-based knowledge 'database' that is hidden in our genetic structure and legacy, and is a result of basic evolutionary functions or mechanisms[1], such as our primitive defense 'fight or flight' responses[2], as shown by how our nervous system responses to subliminal stimuli[3] with low-level features, such as shape, form and

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[1] Bar and Neta 2006; Carbon 2010; Leder, et al. 2011; Jakesch and Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016.

[2] Leder, et al. 2011.

[3] Bar and Neta 2006 and 2007.

complexity[4]. While our evolutionary-based knowledge may be closed at start and not likely to be a target of update within our life-time span, our subjective-based knowledge may be recreated not only by all natural forms, but also by those that are achieved through human action for their physical and semantic characteristics. Since the production of such forms is a direct result from our thought and the means that, afterwards, we are able to find at our disposal in order to bring them to material reality, ultimately, are these thought and means that are able to shape the contours of our preferences.

1.2. Thesis Problem

This chapter's 'Introductory Section' has identified and contextualized the problem of this thesis.

In brief words, the Industrial Revolution effects on Architecture contributed to an evolution and simplification of its construction processes through standardization and mass production processes, giving a direct answer to its socio-economic concerns, but have also limited the overall appearance and character of its spaces to almost exclusively Euclidean, orthogonal-based geometries. However, the recent Digital Revolution provided access to a set of technological means enabling change in the reality of the discipline of architecture, facilitating the representation and the translation of an idea into production, opening the range of forms of architectural spaces. Freed from previous restrains that limited its form, character and expression, the architecture of today and tomorrow, is not only able to consider the Euclidean orthogonal-based forms of the past, but also Euclidean curved and rounded-based forms and even full non-Euclidean forms, under feasible and socio-economic bases, much like those that were considered before. The fact that today, architecture as established itself as a large, strong and settled economy activity, ultimately aiming at considering human well-being, opens and justifies the pertinence of a discussion on whether such range of forms are targeting the best interest of its users.

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[4] Bar and Neta 2006 and 2007; Silvia and Barona 2009; Leder, et al. 2011; Jakesch and Carbon 2011; Friedenberg 2012; Palumbo and Bertamini 2016; Cotter, et al. 2017.

We believe that the appropriate way to find plausible answers to this problem, is within the framework of the research topic of the human preference for architecture space elements, namely forms, with distinct geometric characteristics. Generally, the literature results of such research point to the hypothesis that humans prefer curved, rounded elements when in comparison with their angular, sharp counterparts. However, although there are already a considerable amount of experimental studies that address the wide topic of the preference of lines, shapes and forms, only a few are dedicated to such preference in specific areas of knowledge, namely architecture. Particularly, on the preference of architectural form, we were able to identify solely the following references: Dazir and Read 2012; Vartanian, et al. 2013 and van Oel and van de Berkhof 2013.

In this context, this thesis proposes, as mentioned, to address the problem of the preference for form, and particularly, of the preference for architecture space form. In our novel approach, we aim to tackle such problem, through the evaluation of the human levels of preference for abstract architecture indoor spaces, with distinct geometric characteristics at contour level, purely based on attributes such as geometry and light, and considering both moderate and extreme geometry levels of evolution, which we believe to constitute an original approach to this topic.

In short, our thesis problem, can be stated as:

- “The problem of understanding the preference for form, namely the preference for architecture space form, with distinct geometric characteristics”.

1.3. Sub-problems

We have highlight that the preference for architecture space form with distinct geometric characteristics, may be influenced by aesthetic judgements and approach-avoidance decisions. Such unfolding of preference into these two categories is logic, since the first judgment addresses how the perceived phenomena affects our taste and sense of beauty, while the second decision, tackles the way it affects our safety or threat sensations. Ultimately, we may express our preference for something because we find it to be:

- Beautiful and safe, or;
- Beautiful and threatening (if the risks of the latter doesn´t overlap the graceful of the former), or;
- Not beautiful but safe (if the safety of the latter doesn´t overlaps the disgust of the former), or;
- Not beautiful and threatening, in which case we most likely will not express a positive preference judgment, leading us to reject and avoid it.

We then propose to approach our thesis problem from two distinct and yet related sub-problems:

- “The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in aesthetic judgements”;
- “The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in approach-avoidance decisions”.

1.4. Research Question

In order to better understand and create knowledge on the human levels of preference for abstract architecture space form, with distinct geometric characteristics, the research of this thesis is framed by the following research question:

- “Do people find architecture spaces with curved, rounded elements to be more pleasing than architecture spaces with angular, sharp elements?”

1.5. Thesis Hypotheses

To properly address our research question, we´ve raised four hypotheses, two major and two minor ones.

Major hypotheses:

H1. People prefer abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts;

H2. People prefer full non-Euclidean-based abstract architecture spaces, rather than Euclidean-based (fully orthogonal) abstract architecture spaces.

Minor hypotheses:

H3. People prefer abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements;

H4. People prefer abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features.

We will proceed with giving a plausible and explanatory answer to each of the hypotheses (‘H1’ to ‘H4’), through experimental verification. Ultimately these hypotheses have been decisive for the definition of the design, structure and methodology of the experimental study that we have conducted under the scope of this thesis.

1.6. Thesis Structure

This document is divided in three main sections. A first introductory section includes the current introduction chapter (Chapter 1), which identifies the thesis problem and sub-problems, and raises its research question and hypotheses. A second development section includes four chapters (chapters 2, 3, 4 and 5) that constitutes the main corpus of this thesis. Finally, a third closing section includes one chapter (Chapter 6), dedicated to the discussion of our research results, conclusions and considerations on the developed work and the work that the doctorate candidate expects to develop in the near future.

Chapter 2: Considerations on Thought and the Revolutions of Form.

As we have described, preference, among other factors, is influenced by two different kinds of knowledge. On the one hand, it is influenced by a close-to-objective 'database' that, besides residing in the subjectivity of the self, hides behind our genetic legacy and lays on basic evolutionary defense functions or mechanisms, shared by all healthy humans. Such a priori 'database' is a rather closed system and a result of long evolution time. We can study and better understand it, but it is not likely that we can change it, at least during our lifetime. On the other hand, preference is also known to be influence by a more subjective 'database' that is a product of our sensitive and rational experiences. As pointed before, all our past and present experiences and achievements are able to contribute to the creation and recreation of this knowledge and thus, all natural and man-made forms. If we cannot control the former (natural forms), we can and do control the latter (man-made forms). However, their achievement depends not only on our will, but mainly on our ability to do so. Their result and influence on preference, is thus limited by the level of our thought, its state of evolution, the way we have learned and got used to structure it, and also by the means that we find at our disposal in order to materialize the products of the mind.

In Chapter 2, we will introduce an historical perspective of the molding of architecture form, enabling the development of preference judgments, particularly, those related with form. We will present an historic storyline through which we will identify and describe a series of key of events that we believe have contributed to the way we construct and produce our mental expressions, possibly leading us to favor some forms with certain geometric characteristics over others. We will go through some considerations on thought and how the revolutions that took place between the 18th century and the present time, on the industrial, digital and geometric domains, have influenced the production of architecture form, at some point restraining it, while later enabling new unprecedented degrees of freedom.

The discourse of this Chapter 2 is complemented by additional material of 'Appendix G'. Here, we will address the western thought identity and structure through its evolution, expression, representation and production methods, techniques, tools and technologies, which have also been able to interfere with our preference on elements, such as shapes and forms, namely, architecture form. The discourse presented in such appendix precedes the one presented in this chapter's section '2.2. The Revolutions'.

Chapter 3: An Evolution of Aesthetics

As we have pointed, historically, we may have been more close to some elements with specific characteristics, including geometric, over others, due to events that have accompanied our evolution and, ultimately, have contributed to the definition of the reality of what we are, as conscious and rational beings. This chapter will then provide an overview on the evolution of aesthetics over time, from subjective grounds towards a more ideal objectivity, specifically oriented to the definition of an aesthetic judgement.

Chapter 4: State-of-the-Art of the Preference for Lines, Shapes and Forms with Distinct Geometric Characteristics

Chapter 4 will specifically contextualize the topic of preference for elements, namely form and architecture space form, with different geometry characteristics, in the context of this thesis two sub-problems: aesthetic judgements and approach-avoidance decisions.

We will address the state-of-the-art of the preference for lines, shapes and forms, including architecture space form, with specific geometric characteristics, through a series of studies that, by adopting experimental research methodologies, have tryed to understand if we actually prefer some elements, with specific geometric features, namely forms, over others and the reasons why we did so. In this literature review, aesthetic judgements and approach-avoidance decisions will come forward as a decisive factor for preference, along with and other variables that will be identified and listed.

We will also focus on the work developed by the candidate on the topic of architecture space form and contextualize the conducted experimental study, described in the thesis.

Chapter 5: Preference for Abstract Architecture Spaces with Distinct Geometric Characteristics - Experimental Study and Results

Chapter 5 closes the thesis' main corpus and focuses in the design of the conducted experimental study, describing it quantitative and qualitative experimental methodology, its results, analysis and conclusions. We´ve performed a within-subject design study that counted with a representative sample of 32 participants, which viewed and evaluated the presented visual stimuli, encompassing an image set representing abstract architecture spaces, with distinct geometric characteristic at contour level (rounded and sharp-angled), and with the presence of elements with different levels of complexity and prominence (non-prominent, edge-prominent and edge-and-vertex-prominent). We´ve conducted two different, yet related, cycles of experiments, which were designed to address the thesis sub-problems: (i) aesthetic judgments and (ii) approach-avoidance decisions. This chapter seeks to find an explainable answer to the previously raised research question and problem and sub-problems, by verifying or not, the thesis hypotheses. The chapter will conclude with the achieve results, that provide better understanding on the topic of preference for architecture space form.

Chapter 6: Discussion, Conclusions and Considerations on the Developed Work and Future Work

The thesis concludes with a final chapter, where we will discuss the results of the developed work, including the conducted experimental study on the preference for abstract architecture space form, drawing conclusions and presenting some considerations on the developed and future work.

1.7. Scientific Papers Published under the Scope of this Thesis

During the time duration of the thesis, the candidate developed, together with other academic colleagues, four scientific papers. All these papers were presented and published in the proceedings of double-blind peer reviewed international conferences, in the areas of architecture and technology. Three of these papers were based on original experimental studies, and all of them have provided contributions to this thesis.

1. CARREIRO, M. and PINTO, P., 2013. The Evolution of Representation in Architecture. In: SOUSA, J. and XAVIER, J.P., eds., 2013. Future Traditions. Rethinking Traditions and Envisioning the Future in Architecture through the use of Digital Technologies. 1st eCAADe Regional International Workshop Proceedings, pp. 27-38. Porto: FAUP Publicações. Faculdade de Arquitectura da Universidade do Porto, Porto, Portugal, 4-5 April 2013. ISBN 978-989-8527-03-5.
   http://papers.cumincad.org/data/works/att/ecaade2013r_001.content.pdf

2. DIAS, M.S., ELOY, S., CARREIRO, M., PROENÇA, P., MOURAL, A., PEDRO, T., FREITAS, J., VILAR, E., D'ALPUIM, J. and AZEVEDO, S., 2014. Designing Better Spaces for People. Virtual reality and biometric sensing as tools to evaluate space use. In: GU, N., WATANABE, S., ERHAN, H., HAEUSLER, M.H., HUANG, W. and SOSA, R., eds. *Rethinking Comprehensive Design: Speculative Counterculture*. *Proceedings of the 19th International Conference on Computer-Aided Architectural Design Research in Asia* (CAADRIA 2014), pp. 739-748. Dept. Of Design, Engineering & Management, Kyoto Institute of Technology, Japan, 14-17 May 2014. ISBN: 978-988-19026-5-8.
   http://cumincad.scix.net/data/works/att/caadria2014_206.content.pdf

3. DIAS, M.S., ELOY, S., CARREIRO, M., VILAR, E., MOURAL, A., PROENÇA, P., CRUZ, J., D'ALPUIM, J., CARVALHO, N., AZEVEDO, S. and PEDRO, T., 2014. Space perception in Virtual Environments. On How Biometric Sensing in Virtual Environments May Give Architects User's Feedback. In: THOMPSON, E.M., ed., 2014. *Fusion. Proceedings of the 32nd eCAADe Conference*, Vol. 2, pp. 271-280. Department of Architecture and Built Environment, Faculty of Engineering and Environment, Newcastle upon Tyne, England, UK, 10-12 September 2014. ISBN: 978-949-1207-07-5.
   http://cumincad.scix.net/data/works/att/ecaade2014_112.content.pdf

4. CARREIRO, M., ANDRADE, M.A.P. and DIAS, M.S., 2017. Cognition and Evaluation of Architecture Environments Based on Geometric Contour References and Aesthetic Judgements. In: JANSSEN, P., LOH, P., RAONIC, A. and M. A. SCHNABEL, M.A., eds., 2017. *Protocols, Flows and Glitches. Proceedings of the 22nd International Conference of the Association for Computer-Aided Architectural Design Research in Asia* (CAADRIA), pp. 581-590. Department of Architecture, Xi'an Jiaotong-Liverpool University, Suzhou, Republic of China, 5-8 April 2017. ISBN 978-988-19026-8-9. http://papers.cumincad.org/data/works/att/caadria2017_056.pdf

The candidate has publicly presented *in loco* the papers referred in points 1, 2 and 4. The integral final published version of such scientific papers can be found in the links posted above.

Contribution of Each Paper to the Thesis Discourse

The content of paper n. 1 was used in Chapter 2, section 2.2., 'The Revolutions', in 'Space, Perception and Representation', and in sub-sections 2.2.3.1., 'The First Digital Revolution', and 2.2.3.2., 'The Second Digital Revolution', in 'Advanced Digital Visualization Methodologies and Techniques', 'Advanced Digital Form Production Processes' and 'Interactive, Responsive Surfaces and Environments'. In the first mentioned section, the paper framed the last achievements of space understanding on the discipline of architecture, namely its techniques of representation, before the reality and effects of the Digital Revolution and, in the latter, accompanied the evolution of technology that, within the domain of the 'First' and 'Second Digital Revolution', contributed to a new comprehension of space and form representation, visualization and production.

Content from papers n. 2 and 3, were used in Chapter 4, in section 4.5., 'Work Developed by Candidate on the Topic of Architecture Space Form', where we have extensively described the developed studies and their achieved results. In this section we also make reference to the 'Producing NURBS' article (Carreiro and Sousa 2008), that the candidate published in a Portuguese architecture focused magazine, explaining the state-of-the-art technologies and techniques applied in the design and production/construction of Villa NURBS, an architecture project that he developed while collaborating with architecture studio CLOUD9/Enric Ruiz Geli.

Finally, material from paper n. 4 was used in Chapter 5 (sections 5.1. to 5.7). It describes the conducted study and discusses the results of Experiment 1, the aesthetic judgement run of the experimental study on abstract architecture spaces with distinct geometric characteristics at contour level. This was the first of the two experiments that, coupled with our conducted Research Ethics Protocol (that included the 'Free Informed Consent', the 'Participation Criteria Verification List', the 'Experiment Guide' and the 'Conscious Response Self-Questionnaire'), addressed the thesis problem, by finding an explainable answer to the research question and validating the raised hypotheses.

Chapter 2

2. Considerations on Thought and the Revolutions of Form

Abstract. This chapter will identify key events of our history that may have contributed to the fact that we have been closer to some elements, namely shapes and forms, with certain geometric characteristics, over others. Since such shapes and forms can also be a result of our thought, we will address to stages of the evolution of the western civilization thought, to how the Industrial Revolution and its context have influenced, and even conditioned, the form of architecture and, finally, to how the discovery of non-Euclidian geometries and the arrival of the Digital Revolution have the potential of opening the scope of such form. This chapter is divided in two main sections: one that frames the overall discourse and another that exposes the above mentioned events and their direct results, namely, as stated, within the reality of architecture. The discourse of this chapter is complemented by the additional material presented in the 'Appendix G' of this thesis.

2.1. Framework on Thought and the Importance of Historic Background[5]

2.1.1. Evolution. "A thing which thinks"

The brain

Some animals integrate a sensorial nervous system of nerve network that, in advanced organisms, conduct collected information into a core processing organ: the brain.

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[5] Introductory note: This first section introduces and contextualizes the overall discourse of current 'Chapter 2' and the additional material presented in this thesis' 'Appendix G'. Through a free speech style we will identify some ground aspects of our historic background and evolution that we believe to have been essential to understand where we stand now as rational human being, namely, as it refers to thought and its means of expression.

The incorporation of such nervous system allowed us to receive information from the environment in which we are inserted, communicate it to a central partition able to interpret it, and, consequently, formulate an adequate response that, through action, allow us to achieve better protection and survival chances. It is this system that is responsible for how we, animals, react to our surrounding environment in a most primitive level. In time, this sensorial network system would be complemented by other senses, also directly connected to the brain, for the same awareness and action-reaction responses purpose.

Knowledge

The evolution of this system would conduct to a state where the brain not only receives and interprets information and formulates and executes an adequate response but also considers a kind of 'database' that stores this collected information in the form of what we understand to be knowledge.

Like many other animals, our existence used to be confined and guided by two kinds of knowledge-oriented behaviours: one possibly innate (not consensual within the scientific community) and another empiric (more consensual within the scientific community). This means that either we were born with the required set of information to carry out basic behaviours, or we have acquired the knowledge and ability to do so throughout experience. While the first may comprehend basic evolutionary functions and mechanisms and the performance of instinctive, basic tasks and reactions (e.g. suckling, shock reactions or defensive 'fight or flight' responses), the second takes under consideration the information that is acquired in the process of sensorial and rational experiences. It understands the happening sequence of a particular sensorial action and consequent reaction and weights the efficiency of its result. This experience is then memorized and when in case of the presence of a potential similar action-situation, anticipates its probable outcome allowing us to act in order to prevent the same previous result.

It is by means of this second's behaviour process that we acquire the vast majority of knowledge that we will afterwards apply. In some cases, if the action-reaction-result is strong and impressive enough, it can develop in more complex and intended behaviours without the necessary presence of a triggering event. In this way, a past-occurred experience can be used with precise and oriented intention to reproduce a previously achieved result. We can refer to a most primary level of thought, as the mental activity process of understanding the consequences of an action-reaction event and the usage of this information to autonomously generate an event in order to reproduce a similar result.

The beginning of good and bad, pleasant and unpleasant

It is within the context of these knowledges that we can find the basis for our protection instincts and well-being condition. Remarkably we have evolved to accept what is good for us and reject what is bad. Our nervous system takes a great importance in this matter since it has learned to recognize what contributes, or not, to our physical integrity and consequent survival. It manifests a feeling of pleasure towards some of the things that are good for us, and unpleasant sensation towards some other things that are not, admitting and seeking the former and rejecting and avoiding the latter. The maintenance of life and wellbeing seemed to occupy a privileged spot in the process of both animal and human evolutions.

Thinking and consciousness

At some point of our evolution, we have been able to develop conscientious thinking.

The advance to complex thought processes, would be achieved with the development of thinking, in the extensive sense of this concept, an ideational mental activity to process perceived phenomena with a certain degree of freedom, through the cognitive creation of ideas, concepts and associations (Saunders 2003, Anon 2009)[6]. Such

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[6] thinking. (n.d.) *Miller-Keane Encyclopedia and Dictionary of Medicine, Nursing, and Allied Health*, Seventh Edition. (2003). Visited on the 25th of January 2017 in http://medical-dictionary.thefreedictionary.com/thinking

thinking. (n.d.) *Mosby's Medical Dictionary*, 8th edition. (2009). Visited on the 25th of January 2017 in http://medical-dictionary.thefreedictionary.com/thinking ability is directly connected to the state of consciousness, a novel, unfolded and enhanced stage of awareness.

As we experienced these new channels we have been able to establish more and more complex relationships. Thinking and consciousness were unprecedented forms that would directly and profoundly interfere with our behaviour. Not only in the way that we used to interact with our surroundings, with each other and everything that exists (an inside-out relationship), but also, at an inner level, in the way that we began to sense ourselves (an inside-in relationship). What happened was no longer almost only reflected on an immediate action-reaction response-based interaction but started to be a product of reflection, sometimes even oriented to digress and inspiration. We would now be able to consider a set of acquired information, understand it and act, either in a physical or a psychological level. In either case, we would be able to use knowledge in an autonomous way, without the necessary presence of a triggering event, and take advantage of its process and results to learn and create new knowledge.

With time and experience, the process of thought would evolve into a more organized, structured form. Thinking would become rational as opposed to irrational and erratic thought. We would be able to think and act in a given specific way and by a given specific reason. It was a way to control knowledge and behaviour, being consciously able to identify a starting point and arrive to another one by applying a particular intention, meaning and sense to the process. Rational thinking, either in abstract or concrete forms, would be directly connected with reason and logic. This ability would change us significantly and radically (Rey 2015).

We were a species clearly distinct from any other. Conscious rational thinking has shown to be one of the most important achievements of our evolutionary history and, ultimately, can very well be the quality that better characterizes and defines us.

In opposition to others, Descartes defines a man, something that he believes himself to be, as “a thing which thinks” (Descartes 1911, p.10), *res cogitans*. A thing with a body confined to a certain place, which fills a given space of his own and of no other (body), which can be perceived and moved, that also senses, “doubts, understands, [conceives], affirms, denies, refuses, which also imagines and feels” (idem) and reflects. “A thing which thinks” because in the case that we entirely cease to think, we should at the same time cease to exist (idem). *Cogito ergo sum*. Not only in the sense that I think, hence I exist but also in that I think, I am aware that I do, hence I exist.

Thought was an attribute that belonged to us since it could not be separated from us. It is what lies inside us in such way that we are immediately aware of it. It can be described as all the operations of the will, understanding, imagination and the senses with exception of those that depend and are a direct consequence of it (Cordón and Martinez 2014, p.283).

2.1.2. Thought, Technique and Technology

Foresight

Roughly 12.000 years ago, in the beginning of the period that is known as the Neolithic stage of the history of our evolution, we have reached a state that would considerably change the way that we used to be in and dwell this world. Such mark is emphasized because, by then, we have developed the ability to be provident. We have understood that, we if made things not randomly and lightly but in a given specific way, aiming for medium and long-term outcomes instead of immediate results of our actions, we would be able to better avoid a whole set of potential inconveniences and therefor better control and assure our chances of survival and improve the quality of our lives.

After transiting from a nomad to a sedentary condition, we had started to make complex arrangements and to no longer extensively depend on what nature provided us. We began to develop early-sophisticated tools, technologies and systems. It was by then that agriculture, domestication and sheep handling and architecture were born.

Russel says that the civilized man distinguishes from the savage mainly by prudence, which is to say foresight. He, the civilized man, is able to accept real-time penalties because he foresights future pleasures when they are yet far to come. Russel believes that true foresight distances from purely instinctive action forms because it has its beginning only when man acts towards something not necessarily connected with impulse. It is led by reason, which is responsible for the prediction of a future beneficial profit. Russel then adds that civilization collides with impulse not only when it matters to foresight, an auto-applied collision form, but also when law, routine and religion are considered, inheriting them from barbarism and converting them from instinctive towards more systematic practices (Russel 1961, p38).

Problem Solving Virtues

Rationality then, gave us the ability to overcome undesired situations not by avoidance but by facing them straightforwardly preferably with anticipation. The one who had the ability to get around problems and at the same time be conscious of the solution and able to communicate it to others, would be openly and directly contributing to the well-being of himself and that of his community in general. If the problem solver is proven to be right, if the problem that he solved remains surpassed for some or quite some time and, he or, at this point, someone, will be able to spread the required solution, it, the solution, will become a virtue of his society more than simply of himself as an individual. Ultimately, it is the solution that will remain. The factors that contributed to its origin will, then, most likely fall into oblivion for it is no longer a critical subject. And more important and urgent ones are to be faced.

Communication

Man, as we will also turn on to further ahead, tend, by nature, to create and enhance knowledge (Aristotle in Abbagnano 2013, p.18). However, the ability to develop knowledge just by thought is considerable limited due to obvious restrictions. In such case we depend only on ourselves and of the mental associations that we do and are capable of doing. Depending only on one-self, is an inner activity restricted to the boundaries of an individual. In order to evolve and acquire a more distinctive character, Man has to consider other actors able to optimize his/her value and contribute to his/her development and improvement. For this to happen, it is indispensable going beyond the boundaries of the self, passing from a subject to another, overtaking the limits of his/her own “specific cultural universe” (Serrão 1993[7]).

Expression. Representation

Probably everything that we have learned about our past comes from information from a previous time that was registered and preserved by natural or applied procedures. If by natural we refer, for instance, to fossil registers, by applied we refer to the manifestation and expression of thought. Expression is an inherent factor to communication, without which the latter cannot take place. By turn, if considered at the margin of basic natural expressions (e.g. facial expressions, body responses), to arise, expression is directly linked to a form of representation. In this way, representation appears as a mean to systematise information, through a simultaneous coding/decoding thought process, with the ultimate goal to express and communicate an idea. Since it overtakes the immaterial state of the ideas, it is mandatory that it be materialized. Such stage is achieved by the use of technology and the application of a technique, a ‘certain way of performing’, something that we can call the subjectivity of expression.

Character

It occurs to us that representations can be either a simply communication of an idea, without any concrete application more than the expression of it, which we can be referred to as purely artistic, or, by the other hand, it can be an expression oriented to a precise function or problem solving activity. However, the fact that it is functional or problem solving-oriented, does not necessary imply that there is no art associated. On the contrary, the ‘artistic’ level of a particular performing task, if we want to

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[7] "Com a morte de cada homem termina um universo cultural especifico, mais ou menos rico mas sempre original e irrepetivel.” Daniel Serrão in Viver, Envelhecer e Morrer com Dignidade, 1993. Colóquio sobre eutanásia / Vasconcellos Marques..[, et al.]. - Lisboa : Academia das Ciências de Lisboa, 1993, found at Biblioteca da Procuradoria Geral da República. Available from: www.dgsi.pt

address it in these terms, can be and be measured by the attention, control and personality levels with which it is executed. In both cases, it is the specific methodology and technique of the style (language) to be applied, that translates the attention and subjective level with which that same task has been handled and marked. We could say that it is at this level, that representation gains character.

Means of Expression

Such performing tasks can take several and distinct forms according to their nature. We can consider these expressions as in (i) the inscription of an artistic will, art in its essence and as we commonly understand it; (ii) more ‘concrete’, oriented applications as the necessary development of techniques and technologies that will allow us to overtake a precise, found problem and the consequently achievement of new liberties and potentialities (e.g. a final product) or; (iii) something in between as, for instance, the conversion of volatile knowledge in more easily preserved and spread states such as the engraving of mental ideas or information previously transmitted in oral forms.

We have then, for quite some time now, applying our thought with the goal to enhance our overall living conditions in search for a safer, easier and better place to be in. Such thought has been applied to the universe of our gathered knowledge, using ideas that can be then either used to produce other mental ideas or channelled outside as expressions of the mind, represented with a given style, technique (in which the applied methodologies are comprised) and the use of technology (tools and/or mechanisms, which in case of the latter can be systems) in order to produce solutions able to overtake potential or concrete problems. Ultimately, they also contribute to the increment and enhancement of its starting point: our levels of knowledge and thought.

Process Conditioning

In this process of thought and knowledge expression, all the phases tend to be dependent and interconnected. Not quite in a simple way but, let us say, more at an intrinsic level. If one of the phases is not developed enough, the others will be directly influenced and restricted by this deficiency. No matter how advanced are our knowledge and thought levels, they will be of little use if the development level of these stages is not aligned with the development levels of the ones that follow it. The existence of a discrepancy in either our technique skills or even in the set of technology necessary to express, represent and produce an idea, will be enough for a break on the harmonic flow of a raised intention and the probable conditioning of its possible result. Likewise, it will also be of little use an advanced level of our technique skills to operate sophisticated technologies, if the reality of our thought and knowledge is unable to follow and make proper use of them.

2.1.3. Architecture, Thought and Meaning

Architecture´s Social and Subjective Consciousness[8]

Since roughly the time that we have begun to develop the aforementioned provident abilities[9], that Man has felt the need to protect himself from the wild, natural world that surrounded him, in a more permanent and consciously oriented way. Given the conditions of such world, the finding of a shelter was an adequate answer to his basics instincts of protection, wellbeing and, ultimately, survival. If in a first stage such solution was found in the natural world, though the use of caves and natural shelters, with further evolution and better and increasing understanding of himself and the world that surrounded him, he has proven capable of building his own 'protection' spaces.

However, for practical and evolution reasons, as we hope to be able to demonstrate in this document, the improvement of our abilities during this evolution process, hasn't been always sufficiently focused to consider the whole range of possibilities that architecture has to offer. In the same way that, still today, the spaces of architecture keep providing us a shelter from the exterior instable conditions of the nature (a

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[8] Extracted from 'Estudo de um Enquadramento da Arquitectura Ocidental', a paper developed in 2013 under the current P.hD. program's 1st year attended academic lectures: Architecture and Social Conscience; Evolution of Man and Architecture, and Semiotics.

[9] See section 2.1.2., 'Thought, Technique and Technology' in 'Foresight'.

self/exterior relationship), by being an object of perception, they also interfere with the way that we sense, perceive and feel the environment that surrounds us (a self/interior relationship). If the former has been an object of overvaluation, something that has contributed for the achievement of better and better safety, basic conditions of comfort and wellbeing, the latter has, due to natural evolutionary processes (e.g. the level of our thought, technique and technology) and side factors (e.g. economy), many times fallen into general oblivion. He have got used to give an answer to our so long valued and cherished basic environmental stability instead of seeking other more complex states of emotion, sensing and feeling more connected with the nature of our human condition, which can ultimately complete the essence of who we are.

In this sense, like philosophy, art and the social sciences, to name some, also architecture, as a discipline at the service of mankind, seeks to interpret the reality of a given social group, in a given space and time. Only in this way it is possible for it to get closer to the reality that it is going to intervene in, understand its state, be conscious of its needs and undertake the necessary efforts to increase the level of its response, justifying its pertinence, enhancing its quality and, by infection, the quality of life of those that will make use of it. Nevertheless, the simple awareness of such reality (man's analysis ability, identification of specific problems and formulation of proper responses), don't serve us much if, in the meanwhile, we are not able to follow and go thru with our own level of though, technique and technology able to put it in practice.

With the evolution of the human species over the time, at an intellectual and social-subjective levels, and the consequent projection of his thought and behaviour complexity levels, Man has naturally, by means of necessity and creativity processes, unveiling and developing techniques and technologies able not only to follow but to increase the level of his thought and capabilities, in a kind of infinite cycle that nurtures itself. Since the advance of his though is (not only but also) directly represented by the technology that he finds in his disposition in a specific time and space and the way he makes use of it, and that architecture, as one of his activity subjects and also a target of a natural and continuous process of development and reflexion, is in all its process oriented by these two unavoidable factors (technique and technology), we can dare to say that the quality of its response is directly influenced by the conscience and control of both. Only in this way we can understand that to its initial and primitive goal of protection, other more complex domains of intervention have been associated to architecture in a way that better reflected and reflect a reality in constant mutation and development.

Within this context on the importance and evolution of thought, it seems somehow coherent that the language that has been mainly associated to architecture since the time of its foundation shares a strict relationship with the basis of such thought.

Thought, Languages, Codes and Representations

On the other hand, addressing to language but, at the same time, also to everything that deals with our cognition and performance abilities, Umberto Eco says that "We are, as individuals, what the form of the world, produced by the signs, makes us be" (Eco 1994, p. 48). Curiously, they speak by us, tell us "who we are and what [or how] we think" (idem).

As we have seen, the way we think, act and react, instinctively or thoughtfully, it's what ultimately characterizes us, either as the collective social group or the individual subjective conscience that we are. As production system of diverse forms of language, our communication system is ruled by thought and the way it is structured and organized.

It was in ancient times and specially around the 6th century B.C., thru philosophy, with the transition from a mythological based thought towards the beginning of a rational based knowledge, that we began to settle the basis of the modern western reasoning and hence, the fundamental principles according which language and conscious behaviour, as expressions of who we are, began to be thought. Rational knowledge contributes in this way to the emergence of a new form of thought with a specific structure and operating modes whose characteristics would provide meaningful constructions that are nothing less that expressions of such thought under forms of languages: Codes, signs, representations.

Remembering Pierce, Julia Kristeva talks about the sign as something that replaces anything to someone. The sign addresses to someone and evokes, in its absence, an object, an idea or a fact. In this case, “the different kinds of social relationships invested by language, culture, codes and the rules of social behaviour, religions, art, etc., may be studied as sign systems, with specific structures, or as many other kinds of languages” (Kristeva 2007, p. 255). As we observe language as a system of signs and consider it the only mean able to order and consequently seize the outside world, such language belongs in the domain of semiotics, the general science of significant systems. By being so, it has the particularity of communicating no more, no less than our own essence.

Quoting Pierce Eco writes, “you don’t mean anything that we haven’t thought you” (Eco 1994, p.48). “My language is the sum total of myself, for man is the thought” (ibidem, p.49).

State of Play and Discourse Approach

Everything that we do, have then precise implied meanings and purposes. The reason why and the ways we behave and perform does not take ground in arbitrary happenings but is, on the contrary, a direct consequence of whatever we have been doing and achieving over time. It is also true that not any and every thing that we achieve is necessarily and clearly connected with something that already exists. Certain events can lead to other events, more defined, in their essence, by a rupture rather than by a harmonic transition. By breaking the easy, apparent logic in the natural flow of a progress, these revolutions in the process of evolution are able to mark a definitive difference and be ultimately recognized as concrete, key events in the flow of history.

As we have seen in this document’s ‘Introduction’, this thesis will try to propose a view on the reason why we have been doing things in a specific way (and not in any other) and how certain key events in our evolutionary history may have contributed for us to ‘prefer’ some forms and organizing models over others. With time, the characteristics of such elements have been not only being expressing the reality of who we are but, at the same time, also directly influencing the way that we behave and perform. As we will address further ahead, it may be that such behaviour and way of performing have, maybe, so much to do with our animal, instinctive side as it as to do with our rational, conscious one.

In Chapter 2 and in the additional material of ‘Appendix G’, we will then understand the rationale of why, in the course of our evolution and production stages, we have been closer to some forms over others, possibly others than the ones that literature on the preference for elements, such as lines, shapes and forms, points to be preferred by humans. We will pass through a chain of key events that we believe to have marked our western society’s perspective towards such rationale. Those occurrences, which have shown to be decisive enough to remain deep-rooted in both history and society, took place in early, ancient times, when early views and understandings began to be engraved, or in events that were able to reach global influence and scale. In this way, the following section ‘2.2. The Revolutions’, along with the additional material of ‘Appendix G’, which complement the current chapter’s discourse, will follow the footsteps of historic key events that we believe to be essential for understanding architecture space form.

2.2. The Revolutions[10]

A Brief Description on the Evolution on Architecture

The expression of an idea is a result of the ability to be formulated (abstract mental process – which is directly related with the development level of its thinker's thought), the ability to be represented (semi-abstract early reproduction process – a trend that has been increasing over time), and afterwards, the ability to be reproduced (material late reproduction process). If any of these processes is not tuned to the point that it allows the process of expression to flow naturally, the chain of reproduction is broken and adjusted to a close, more or even only possible solution, restricting in this way the range of hypothetical results.

Space, Perception and Representation

During the evolution and maturation of the definition of space, many were the concepts and interpretations that, within different fields of knowledge, have been associated to it. The abstract theories explaining what space is and how it is perceived in Western cultures have been evolving towards other important issues of perception connected with more dynamic and sensorial approaches. From the Aristotelian vision of space and time as categories "that enabled the classification of sensory knowledge" (Tschumi 1996, p.29), Descartes proposed space as an absolute object, master and container of senses and bodies (idem). Spinoza and Leibniz questioned later if it was inherent to the whole existing things (idem) and Kant, "returning to the old notion of

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[10] Introductory note: Result of a particularly stretched socio-economic context, the Industrial Revolution interfered with and characterized the form production processes in ways never witnessed before. However, some of its wide potentialities resulted in the restriction of form, namely in the architecture field. Further revolutions on geometry and the more recent digital domains have, in some way, restored this limitations and, with the access to novel, state-of-the-art technology, face form, once again, as never before. In this section we will address these revolutions.

"category"", described it as "an ideal internal structure, a prior consciousness, an instrument of knowledge" (idem).

By this time, in the late 18th century, following the Renaissance' achievements on perspective and the Cartesian conception of space in bi-dimensional axis, Gaspard Monge had developed in Paris, at the *École Polytechnique,* the basis of Descriptive Geometry, a representation technique of three-dimensional objects on a two-dimensional support through a system of coordinates X, Y and Z (Emmons 2012, p.299). In this representation, an abstraction independent of any concrete relationship to the real world, a three-dimensional object is projected in two mutually perpendicular plans, a horizontal and a vertical one, according to an orthogonal projection system. The result of this method is the two-dimensional representation of a three dimensional object.

Geometry is introduced in the teaching of architecture, even during the eighteenth century by Jean-Nicolas-Louis Durant in the École de Paris, which associates the plan, section and elevation to three spatial plans "independent of any concrete relation to the lived world" (idem), X, Y e Z respectively. With the wide diffusion of the Beaux-Arts design methods, starting from the *partie*, sketched by hand in plan and perspective, the design was then projected in a way that, as stated by Durand, "the plan is considered first, then the section" and "the elevation is no more than the result of these two"[11] (Emmons 2012, p.299). Some years later, in 1822, at Cambridge University, Professor William Farish proposes a variation of the previously used, although intuitively, oblique projection technique (the cavalier perspective), the isometric perspective. By the late 1850's, axonometric projections were introduced, allowing, with shadows projected at a forty-five degree angle, a representation technique with a highly accurate sense of depth (ibidem, p.301).

In the late XIX century, the notion of space had evolved from a metaphysic concept and Hildebrand, Schmarsow (van de Ven 1978, p.104) and Riegl (ibidem, p.93) considered it to be an artistic idea. Already in the XX century, Einstein would link it

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[11] Jean-Nicholas-Durand, *Précis of the Lectures on Architecture*, in Paul Emmons *Drawing and Representation.*

to the notion of time, and proposed a measurable three dimensional continuum that still reaches present time.

At the end of 1920´s, the diagram emerged, as an influence of the Bauhaus and other modern trends to "*analyze harmony, balance and rhythm in architecture and their formal and perceptual characteristics*" (Emmons 2012, p.302), shifting to a more scientific approach to design, that didn't depart from an eclectic design, based on a prior proper style, but from one that was summoned by a complex of design circumstances. At the new Bauhaus in Chicago, in the late 1930 and 40s, László Moholy-Nagy would propose "*tactile exercises*" (idem) with new materials and experimental modelling techniques and later, at the Illinois Institute of Technology, former Bauhaus master Mies van der Rohe, would urge the one-point perspective renderings and the use of photomontage and collage techniques. At offices and design schools, these techniques would be introduced as innovative communication tools (idem). Form, materials and space were now connected to human perception studies at architectural schools and the former analytical architecture lessons made way for new introductory courses, where new students learnt about perception and language.

Within Western architecture, *spatium* evolved in the XX century from a literally interior space to an idea of setting limits or making room (Heidegger 1997, pp.100-1). It is therefore a representation of an abstract intellectual idea, a meaningful emptiness, of a certain quantity of the m^3 that involves us, that can be developed and interpreted as a preposition, a "felt volume" (Tschumi 1996, p.30), space of senses.

The Material Reality

Architecture building started as a primitive overlay of raw materials with the primary survival purpose to protect us from the environment's natural conditions, to consider more and more complex and composite materials and techniques that, over time, allowed us not only to satisfy but also enhance the level of such goal, and also consider secondary objectives such as the improvement of well-being conditions, in a process that aimed to perfection in both our physical and psychological fronts.

From early times that the materials and techniques used in order to construct our architecture spaces followed certain intrinsic logics. Some of those logics have since ever restricted the formalization and appearance of our built spaces. It is the case of the unavoidable factors of gravity and its consequent dispersion of forces and bending moments. First through experience and afterwards thru the achievement of scientific knowledge, we have understood that the most practical way to erect the boundaries of architectural spaces was in a vertical axis perpendicular to the existing gravitational forces. This universal factor, together with the architecture's materials, tools and techniques that were available across this subject's time and periods, have directly contributed to the formalization of specific form results. Usually built with overlapping layers from bottom to top, the vertical boundaries of architectural spaces have mainly followed a vertical plan or curved surface, finished afterwards with a roof able to enclose and give the desirable space protection from the natural environmental conditions. The ground plan of such construction followed then, historically, circular (or close-to-circular), triangular, squared or rectangular bi-dimensional base, afterwards erected to set a tri-dimensional cylindrical (e.g. ancient Portuguese *Castros*), conical (e.g. tribal tents), semi-spherical (e.g. Eskimo's igloos), pyramidal (e.g. Egyptian, Central and South American and South Asian culture constructions) or parallelepiped volumes. With time, probably due to the simplification of the construction processes and the enhancement of internal and external distribution purposes, in either their isolated form or integration in the cluster of urban tissue, the latter, the parallelepiped volume, have mostly prevailed.

The paradigm of the Euclidean geometry is, then, the one that, through history, better has represented the architecture of most global civilizations and, particularly, that of western civilizations. Such influence is present in two forms. First, the basis of our western system of thought has a direct correlation with the inductive and deductive methodology that was applied to the axiomatic method on which lays the mathematical demonstrations of the Euclid's 'Elements' and, hence, also the basis of the Euclidean geometry. Since the traditional construction systems, as well as the technique and technology that turn them possible, together with the whole inherent logistic that is associated with the architecture processes, were created and developed under this same logic, it is only logic to deduce that architecture is a direct extension of such model of thought. It presents an intrinsic affinity relationship with the principles and values that fundament the basis of such type of logical reasoning, shares its same ground and follows its basic structure and nature. Secondly, it seems coherent that the language and form that has been predominantly associated to architecture since the time of the foundations of our western system of thought, manifests a strict relationship with the basic principles of such thought, among which those of order, symmetry, centrality, balance, harmony, dimension or even the knowledge that is hidden behind the definitions, postulates and prepositions that construct the principles of the Euclidean geometry. This is the way through which we got used to think and behave, not only in what matters to the reality of the architecture subject, but, in many or most of the domains of knowledge in general[12].

In this context we can say that the principles upon which the Euclidean geometry is constructed, as integrant part of the basis' development of the western thought, have directly contributed to the way we thought and still think architecture, the sprout relationship between these fields, their exploration and natural and consequent systematic optimization.

Architecture has then, been historically depended on the ability to be thought but, also on the materials used in its construction and the available set of tools able to work and give form to such materials. For a long time these materials were simple, raw materials taken directly from what nature could provide us. We are mainly referring to vegetable and mineral source materials. The result of the architecture activity would be the sum of the materials to use, together with the tools used and the techniques applied in the construction process. Later, appeared the composite materials that offered new levels of freedom either in the set of possible achievable forms or the stability of the structure of buildings. Until the 19th century the building construction processes on vegetable, mineral and composite materials have not been applied in the very same way over the centuries, being able to follow the character and identity of the ages. However, these processes have not changed too much either, at least if we compare them with the ground-breaking revolutions that were about to come.

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[12] See 'Appendix G'

2.2.1. The Industrial Revolution, Standardization and Production Methodologies[13]

The first of the revolutions that we are going to address to is the Industrial Revolution, which took place in Britain, on the second half of the 18th century, and kept expanding in the following century, reaching a worldwide repercussion, with high significant presence still noticed in nowadays. Mainly boosted by the development of James Watt's steam engine, this revolution was able to give an incisive response to the 18th and 19th century social and economic reality. Following the steps make centuries before by Johannes Guttenberg, with the invention of the printing press, the development of machine tools has increased substantially and dramatically, and such has contributed to the revolutionary wide transition from hand production methods and processes to machine based ones. However, more than a simple manufacturing evolution, such transition gained special relevance due to the consequences that this new methodology and process brought to production in terms of quantification: Standardization and mass production.

One of the industries that were more affected by this change was the one of iron. Two examples that immediately come to our minds when considering the Industrial Revolution is the development of 'endless' railroad tracks, built by single form elements easily adapted to punctual, curved situations, and, already in the 20th century, the industry of automobile, where several parts produced in series were easily assembled to construct complex, composite machines. This barely new production method had several advantages associated. Through the consideration of prototypes, it allowed the standardization of moulds that, in a further stage, would turn possible the production of elements, normally previously thought for easy assembly, in mass quantities. This methodology and technique would be of special importance when considering the social and economic factors of production. After the development of prototypes and moulds, the span time between the beginning of an

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[13] Introductory note: In this section we will address to the effects of the Industrial Revolution on Architecture. How it allowed its opening towards a new world of potentialities but, at the same time, it has contributed to the standardization of its form.

element's production and its final stage would be drastically reduced by standardization and, since they would be easily produced in mass quantities, also the economic level of such production would be directly and reduced.

With time, in the course of the next centuries, many industries would be influenced by this production methodology reaching a point, further ahead as present times, where most of what we produce and use is achieved by such standardization and mass production techniques. Actually, probably for the first time in the late two and a half centuries, we are beginning to consider viable parallel production methodologies and techniques that are able, in some aspects, to surpass the ones that sprout with the Industrial Revolution. But this will be a subject that we will address to further ahead when talking about what we consider to be the third great production revolution and the second one within the digital domain.

The Architecture of the Industrial-Euclidean Revolution

Among other subjects, architecture was one whose results have been deeply influenced by this revolution. If architecture and the Euclidean thought had already shared an intimate relationship though the ages, this bond would become stronger with the arrival of the Industrial Revolution's reality. As seen, standardization and mass production were probably the main long-lasting effects of this happening. However, due to those time's available mechanisms, such standardization and mass production have not affected the nature of all forms in equally way. It is certain that these processes could and were able to comprise both straight and curved forms, as we can see when considering the previously given examples of the railroads tracks and the production of the various elements that build the complexity of automobiles. However, this happened mostly when the exact same object is to be repeated several times and applied in certain, specific and very restrict circumstances. When the reality of architecture is considered this scenario changes substantially.

The process of architecture development depends on several factors, namely, the morphology of the considered terrain for its construction, its context within neighbour constructions, its program, function or typology, that, most of the times, make from a specific architecture project, a single, isolated case. However, standardization is still able to fit wide architecture cases, especially when precise elements that can be applied several times in the construction of the whole building, or the fragmented space environments that compose it, are considered. This fact has contributed to a growth of Euclidean based architecture spaces.

To better explain this thought, we propose to consider a regular architectural space, whose geometric nature allows its construction through elements that respect a single form, for instance, an iron beam with dimensions able to support its structure's highest compression and flexion moments. Although in some cases this beam could be over-sized, restricting other space factors, it would be possible to erect the whole structure with a 'single' base element. Like the railway rails, a single parameterized machine is able to melt the iron material and produce 'endless' kilometres of the beam section. In order to be applied to the dimensions of a certain space, such beam has only to be divided, with simple orthogonal cuts, into length measures that respect those same dimensions. So, with a single machine that produce a single, continuous iron beam with a specific section measure, and the necessary additional elements to connect those beams in site, we are able to construct the whole set of beams and pillars able to erect the portico skeleton structure that will give stability to the afterwards building complex. Such portico structure will then develop in the tri-dimensional space according to the schemata of the Cartesian space axis: width, length and height or, as they are commonly named, X, Y and Z, contributing to the definition of a basic Euclidean space. And when we refer to those spaces as Euclidean, we are referring to those of parallelepiped form but also to those that embrace other Euclidean form as, for instance, cylindrical forms. That is the case of the 19th century Cristal Palaces.

Integrated in the scope of the iron and glass architecture, these constructions made use of the Industrial Revolution's potentialities in order to achieve their results. The obtained interior space was a novel space, comparable to the one achieved by the religious gothic architecture, but, most important within the logic of our discourse, built with very controlled elements. The whole (Euclidean) space was almost entirely constructed with a very narrow scope of linear and regular curved iron beams, afterwards filled with glass elements. Its façades, the vertical and horizontal walls, pavements and ceilings of parallelepiped void spaces and the characteristic central space canon, are all built almost uniquely with these basic, limited standardized elements and, taking into account the size of such constructions, they were able to be achieved with controlled construction time and costs.

In order to have a better idea of such accomplished results, let us consider the idea of constructing the worst-case scenario of irregular, curved spaces. While there is only one-direction straight line, independently of its position in space, there are literally an infinite number of curves with different radius, if we consider them to be regular arcs. If, on the contrary, we consider complex, multi-direction curves in both bi-dimensional and tri-dimensional spaces, that number becomes exponential. In this way, we can build an entire regular space structure with single beam section elements, but, on the contrary, we would need several, unique, adapted-to-singular-situation elements to build irregular, curved spaces. Such reality does not fit and goes against the social-economic requirements of this time and the achievements and potentialities gained with the Industrial Revolution.

Already in the 20th century, conscientious of the possibilities of the standardized production in iron and reinforced concrete (which had previously been used in the reconstruction of the city of Chicago, after its historic fire), Le Corbusier and his cousin, the engineer Pierre Jeanneret, presented the prototype of the Dom-ino house (standardized as the domino's pieces – Frampton 1997, p.183) in 1922. In this prototype, the Cartesian tri-dimensional system of coordinates is replaced by a system of beams and pillars that define a portico type structure. These elements share between them an orthogonal relation that, by turn, gives way to the definition of orthogonal plan walls able to be easily constructed and adaptable to all situations that share the same basis, ensuring a significant reduction of the work's costs and allowing it to all or most social-economic classes. According to these premises, the resulting space would be an orthogonal, open space, mainly defined by horizontal and vertical plans and elements, capable of giving an answer to those times' economic factor considerations as well as to the emerging interests of space optimization. Three axis oriented rational, Cartesian, Euclidean spaces.

This project together with the project of *Maison Citrohan* (a clear relation with the mass production motor-car brand Citroen), anticipated the formalization of '*les 5 points d'une architecture nouvelle'* definitely gathered in the *Ville Savoye*. Such projects integrate Corbusier's Idea of architecture houses as 'House-Machines', the mass production house morally healthy and beautiful (idem).

In 'Towards a New Architecture', Corbusier writes:

"A great epoch has begun. There exists a new spirit. Industry, overwhelming us like a flood which rolls on towards its destined end, has furnished us with new tools adapted to this new epoch, animated by the new spirit. Economic law unavoidably governs our acts and our thoughts. The problem of the house is the problem of the epoch. The equilibrium of society to-day depends upon it. Architecture has for its first duty, in this period of renewal, that of bringing about a revision of values, a revision of the constituent elements of the house. Mass production is bases on analysis and experiment. Industry on the grand scale must occupy itself with the building and establish the elements of the house on a mass-production basis. We must create the mass-production spirit. The spirit of constructing mass-production houses. The spirit of living in mass-production houses. The spirit of conceiving mass-production houses. If we eliminate from our hearts and minds all dead concepts in regard to the houses and look at the question from a critical and objective point of view, we shall arrive to the 'House-Machine', the mass-production house, healthy (and morally so too) and beautiful in the same way that the working tools and instruments which accompany our existence are beautiful. Beautiful also with all the animation that the artist's sensibility can add to severe and pure functioning elements" (Le Corbusier 1986, p.227).

In the text that follows, Corbusier alludes to and advises the "replacing of the natural materials by artificial ones, of heterogeneous and doubtful materials by homogeneous and artificial ones (tried and proved in laboratory) and by products of fixed compositions" which should replace the natural ones that, following the 'laws of Economics', imply a lot of material lost (ibidem, p.232). Also, respecting this same law but from a time point of view, "it was a common thing in the good old days (which still goes on, alas!) to see heavy horses drawing enormous stones to the yard, and a mass of human labour unloading them, cutting and dressing them hoisting them on to the scaffolding, placing them in position and, rule in hand, making length adjustments to every face; Such building might take two years to construct: to-day a building can be erected in a few months" (ibidem, p.233).

Corbusier also refers to the idea of beauty and connects it with the old relation with proportion, unity, rhythm, order, reason and mathematics: “As to beauty, this is always present when you have proportion; and proportion costs the landlord nothing, it is at the charge of architects! The emotions will not be arouse unless reason is first satisfied, and this comes when calculation is employed (…) Unity in the constructional elements is a guarantee of beauty. A lends itself to design on a large scale and to real architecture rhythms. A well of calm, order and neatness, and inevitable imposes discipline to the inhabitants”.

The social-economic trend of architecture production would still find another exponent in the second half of the 20th century. Allied to the previous advances of mass-production concepts, pre-fabrication constructed elements would, once again, and even more, contribute to the increasing closeness to Euclidean based spaces from the architecture that was developed after the Industrial Revolution. Pre-fabrication not only included the standardized and mass-production construction of basic structures that would afterwards orient the building of orthogonal walls, floors and ceilings but, considered final product elements able to be directly applied to the constructions sites. By definition, pre-fabrication fragmented even more modules of space delineation, in small, controlled and single elements that, similarly to standard tiles, when considered all together, could be superposed and build architecture objects. They were able to be set in very brief periods of time, and with considerably small costs of production, respecting the previously referenced Corbusiers’ ‘law of Economics’. Like some of the previous given examples and due to the same reasons that oriented the building towards orthogonal, Cartesian and Euclidean spaces, also pre-fabrication followed this trend, due to the fact that the construction of spaces through vertical and horizontal plans could give optimal answers to the previous referred time and cost factors and their application was compatible with a wide, almost universal, range of situations. At least, of course, if other geometries were not considered.

However more and such important revolutions were to arrive within the periods of the 2nd half of the 19th century, the 20th century and the few years of the current one. We will address next to a revolution that isn’t directly linked to production or representation domains but whose nature proofed to have a profound influence in the physical theories of the 20th century and might as well contributed to the theoretical scope of architecture of the late last and current centuries. We are speaking of the discovery of non-Euclidean geometries.

2.2.2. The Geometric Revolution of non-Euclidean Forms[14]

A few years before the direct influence that the Industrial Revolution had over the architecture of the second half of the 19th century and the beginning of the 20th century, there was found an answer to the historically doubt that surrounded the Euclid's Elements' fifth postulate, almost since its suggestion, for instance by Ptolemy and Proclus (Franco de Oliveira, 1995, pp.37-8). This postulate didn't seem to share the same degree of evidence of the other four and was, for this reason, even proposed, by Proclus, to be excluded from this list. Standing untouched, at least by means of mathematical proof, for more than two millenniums, during the 19th century emerged two main theories able to dethrone the Euclid's paradigm.

Without the fifth axiom, the one that became known as the 'parallels postulate', the Euclid's geometry is known and called 'absolute geometry', in an allusion to its universal, proven demonstrations. At this point, and since we have addressed to it a while ago, it may be useful to remind the basis that surround the logic of Euclid's geometry, in the field of mathematics, but also, as we have seen, in the field of general thought, its structure and 'behaviour'. In the words of Franco de Oliveira, "a mathematical theory is, as a general rule, an organized speech over a certain structure or intentional structure, expressed in a determined language (…). The axioms (or postulates) of a theory impose certain restrictions that must be satisfied by the intentional structures, and the theorems (demonstrated or demonstrable propositions)

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[14] Introductory note: Apart from casual updates to the Euclid's Geometry, this field has maintained quite stable for more than 2 millennia. However, the discovery of the so called non-Euclidean geometries, as those not consider by this thinker, has freed form and changed the way we not only think it but even our understandings and theories about the universe. Once again, geometry and mathematics were means through which we were able to understand and comprehend the incommensurability of 'everything there is'. We will dedicate this next section to these geometric revolution of non-Euclidean forms.

of the theory are other properties that these same structures satisfy or accomplish for the simple reason of satisfying or accomplishing the theory's axioms. In fact, once that in the theorems' demonstrations there are only used logical principles of universal validity and inference rules universally valid, that is, that preserve the truth of premises to conclusion, it is clear that every time that the axioms of a theory are satisfied or accomplished on a structure (which means, truthful in its context, semantically speaking), also all the demonstrated propositions stem from these axioms are satisfied or accomplished (semantically truths) in this same structure. The advantages of the axiomatic method used in the presentation of mathematical theories comes from their generality and application context: a demonstrated theorem from certain axioms is autonomous satisfied in all structures that satisfied these same axioms" (ibidem, p.49). In this context, the role of logic in a mathematical theory is that of supplying the logical principles, rules and methods that give structure to a valid reasoning. And such valid reasoning of argument is that which assures that the arrived conclusions are as true as the premises from which they are extracted. In the specific case of the Euclid's' fifth postulate, as a premise, it had been for several years under scrutiny without anyone been ever able to demonstrate it. For one way, the difficulty of arriving to the demonstration of an apparent obvious axiom or, at least, the fact that no one was able to mathematically demonstrate it, only shows the true power of mathematics and logic (also applied to our western thought structure). If it is not proven, it does not mean that its consideration is fallacious or an error but that no one could ever been able to arrive to its solution. By staying an opened matter for so long and, as we will see in the next paragraph, afterwards resolved, it only proves the exactitude and honesty of the so truthful mathematical structure.

This problem was, however, soon to change. After the ancient doubts and attempts to solve it, by Ptolemy and Proclus, Saccheri, a Jesuit priest from the early 18th century, discovers, by chance, the non-Euclidean geometry. His work would however remain 'hidden' for around a century and a half. Also Karl Gauss, among other mathematicians, developed geometry under the same basis of Saccheri, that is to say, denying the Euclid's fifth postulate, without however being able to arrive to a mathematical basis contradiction (ibidem, pp.43-4). However lately faced as impossible or intangible within human reason, such accomplishes would be achieve some years later by Nicolai Lobachewsky and János Bolay, in 1829 and 1831, respectively. Firstly called ‘imaginary’ and afterwards ‘pangeometry’, this geometry was to be definitely known as Hyperbolic Geometry. In contract to what happened with Gauss in this subject, Bolay admits the negation of the Euclid’s parallel postulate as a non-absurd hypothesis and proposes a new postulate to join to the others four of the absolute geometry (ibidem, p.44). A few years later, in 1954, Bernhard Riemann presents the Elliptic Geometry. Together, these Hyperbolic and Elliptic geometries compose the set of the non-Euclidean geometries.

Putted in a simple way, the difference between these three main modern kinds of geometries, the Euclidean, and the non-Euclidean’s Hyperbolic and Elliptic geometries, the former considers plan surfaces, with zero degree curvature, the second, curved surfaces with negative curvature and the latter, also curved surfaces but with positive curvature. In a practical example point of view, taking in account the parallel postulates, two straight lines parallel to each other, or in other words, that when intersected by a third one create a set of 90 degrees angles, remain at a constant distance from each other in the bi-dimensional space of the Euclidean Geometry; curve away from each other in the Hyperbolic Geometry and curve towards each other in the Elliptic Geometry. Another good and easily understandable example is that the sum of the angles of a triangle inscribed in the surface of such geometries’ examples, is equal to 180 degrees in the Euclidean Geometry, inferior to 180 degrees in the Hyperbolic Geometry and superior to 180 degrees in the Elliptic Geometry.

However, although their mathematical supposition and demonstration only occurred in the 19th century, non-Euclidean forms already existed and there was a wide knowledge of them. In respect to this, it is enough to say that the example that better represents or systematizes the Elliptic Geometry is the well, long known spherical form, found in so vast examples of material forms and physics theories. In this way, their most significant expression took place within the millennial logic of the Euclidean thought basis and the theories that, from there, were afterwards developed, with special focus on the 20th century’s physical hypothesis of the reality of the macro universe. Non-Euclidean geometries were basically inconceivable and contrary to the Kantian theory of space that ruled, and in many ways still rules, the philosophy of knowledge (idem). “To Kant, space exists intuitively in the human mind and the Euclidean postulates are a priori judgements imposed to the mind without which is not possible any kind of coherent reasoning about space. Hyperbolic geometry appears as one for which it is not possible to consider any possible ‘space’ and, in the hypothesis of existing such space, it wouldn’t be from this world and wouldn’t, hence, be an object of knowledge. New developments on mathematics and physics would have to arise to make justice to all of the pioneers of the new geometries. What was in stake was not only a revolution in geometry but one in the mathematical thought. The nature of mathematics, and especially that of geometry, would have to be rethought. The axiomatic method moulded in the Euclid’s ‘Elements’ would have to be reviewed and expanded in its scope and applicability. The physical tri-dimensional space, privileged motivation of the Euclidean conceptions, would for ever lose its privileged absolute reign in the physical interpretations of the geometric theories” (ibidem, pp.44-5). And in the same way that it did to geometry, mathematics and physics, as fields of knowledge, it also interfered with knowledge itself, its structure and scope of activity.

Architecture and the Digital Domain

Next we will address to the last two revolutions that we consider to have actively change the course of the production of form and that, ultimately, together with the previous exposed ideas, have contributed to the consideration of this thesis. Those revolutions come in the sequence of the Industrial one and act directly in the digital territory, its advances and potentialities, namely, in the main subject of this thesis: Architecture.

As a subject oriented to material construction, architecture is a product directly conditioned by man’s thought, the available tools and technology that he can find at his disposition in order to bring it to reality, the physical properties of material, construction and structure systems and by a series of other factors, namely, of economic order.

This reality has contributed for the architect’s long-lasting trend to get closer to the architecture spaces that he controls and manages to build and move apart from those that, even though also able to traduce the reality of his thought, show to be difficult or even impossible to bring to reality.

However, with the appearance of the innovative digital technologies a brave new world (Huxley 2013)[15] presented before him and what we can consider to be, in our days, the complement domain of today's architecture: Virtual Reality.

Contrarily to real world, an environment with a specific logic, independent from the laws of nature, which orient and limit our action and where we mainly assume an adaptation posture, the virtual world appears as an alternative environment with a sophisticated, flexible structure, defined and controlled by man, and, capable of projecting him to new degrees of freedom and experience. A kind of half world where the body occupies a physic space and is, because of this, subjected to the conditionings of the material world but, where reality is folded (Deleuze 1988) in such ways that other being, felling and experiencing modes may be considered. In this limbo, where information is configurable, the notion of what is impossible becomes relative and acquires potential infinite contours.

With the polyvalent world of the Digital Revolution at his reach, freed from a series of constrains that, until not long ago, limited his action, man and, by turn, also the architect, have found in the virtual world a tool able to contour an unavoidable reality and to give answer to a series of pursued wills so often abandoned due to factors of technical response.

In a short period of time of approximately sixty years was then given to the architect the opportunity of working his intentions at a level only compared to the freedom of some language systems, as drawing and writing, which depend almost exclusively from thought and widely controlled tools. Ideas that were until now difficult to achieve, as the 'new' non-Euclidean geometries, were rapidly able to arise, inclusive with relative ease, and a series of new and potential evolutions were embraced at a technological and thought levels.

This under evolution processes rapidly evolved to consider a kind of virtual materiality world achieved thought the access of the Immersive Digital Environments technology, and, also, the domain of materiality, with the instaurations of the CAD-

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[15] With the same dubious sense that the author wishes to maintain.

CAM processes, first at industrial grounds and more recently, with the emergence of 3D personal printers, at a much wider level.

2.2.3. The Digital Revolution[16]

The modern world had become to change in a way and velocity never witnessed before. If the effects of the Industrial revolution had a direct influenced in this increasingly changing environment, the 20th and 21st centuries 'First' and 'Second Digital Revolution' accelerate and left a profound mark in the identity of the times to come. While the Industrial Revolutions had a direct influence, mainly, on the production and social-economic aspects of architecture, the Digital Revolution would significantly change not only these domains but also those of the study and representation of space, its form and ultimately, its character based on interactive behaviours.

The born and development of computers conducted to a massive transformation on the way the process of architecture development was regarded. On the one hand, the 'First Digital Revolution' was characterized by a transition and adaptation from the conventional platforms, used to work and develop ideas, towards the domain of the new digital technologies. In other words, the base platform has changed but the way we used to perform suffered no significant transformation and was mostly a target of a mere adaption and reproduction processes. On the other hand, with the growth of the knowledge and potentialities of the digital technologies, the 'Second Digital

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[16] Introductory note: This chapter's final section addresses to the Digital Revolutions and how they affected the form production process in all its phases, from thinking to representation, visualization and, finally materialization, with breakthroughs comparable to those achieved with the previous Industrial Revolution. However comparable, the Digital Revolutions have been demonstrating to enclosure the potentiality of not restricting form but, on the contrary, explore and increase its all dimensions, more and more close to a total freedom of form. Ultimately, it were these revolutions and its products that conducted us to the problem of this thesis, at least in the sense that we can nowadays count with the necessary means to find a solution to it. This section will accompany these revolutions and its effects mainly in the field of architecture.

Revolution' of the late 20th century and the beginning of the 21st, brought a profound change on the way we used to face the whole design and construction processes of form handling.

According to our point of view, the substantial effects of the Digital Revolution in architecture can be shortened into two main subjects: (i) representation of space, which include the traditional and innovative representation methods and techniques through which architecture is thought within the digital technologies and, (ii) production of form, which comprises the production mechanisms and communication protocols that allow digital source forms to be reproduced in a physical, material way. Such subjects are divided among what we have previously identified as the 'First' and 'Second Digital Revolution'. While the former, (i) the representation of space, will participate in both 'First' and 'Second Digital Revolution', although assuming completely different forms in one and another, standing in the first as a mere extension of traditional, non-digital methodologies and techniques and, in the second as a nouvelle approach much well fitted in the character and potentialities of these digital domains, (ii) the production of form will mainly happened within the 'Second Digital Revolution' environment and will be characterized by innovative methodologies and techniques on the construction and production development processes of form.

2.2.3.1. The First Digital Revolution

Both 'First' and 'Second Digital Revolution' shared the same ground and started with the discovery of computers. Their development started in the 1930's with the first electronic digital Atanasoff-Berry Computer (ABC) and from there moved forward towards more general-purpose digital realities with the Electronic Numerical Integrator and Computer (ENIAC), integrated and run through vacuum tubes. The second wave of computer development considered the replacement of the vacuum tubes by transistors and in 1951, the first computer built for commercial use was developed: the Universal automatic Computer (UNIVAC1). By this time, computers began to have memories and operating systems. The third generation of computers was characterized by the invention of integrated circuits. This contributed to the computers' loss of size and lead to the spread of personal computers, suitable for home and office use, a reality of wide scale and accessible to almost everyone in our days.

In the beginnings of 1960's, representation began to be associated with the new and soon revolutionary technology of computers. In 1963, Ivan Sutherland developed a state of the art graphic interface technology called *Sketchpad*, where a user could develop virtual drawings through the use of an innovative digital pen (Steenson 2012, p.302) and, during next decade the *computer-aided design* (CAD) programs would slowly spread through architectural schools in a similar but digital approach to the traditional representation drawings. AutoCAD®[17] would be released in the beginning of 1980 (Smith 2007, p.12), and during this decade and the next one, once again, schools and professional offices would gradually adopt digital form representation tools.

In AutoCAD® and similar characteristics' software, architecture and forms in general would generally follow the traditional methodologies of representation. However, instead of the use of conventional paper frame, through the use of digital based sources accessible through peripheral controls and virtual screens, for the information's visualization. The object representation would respect the Euclidean-orthogonal projections of plan, section and elevation representations but, as happened with the former, more traditional frames, they wouldn't share any kind of intrinsically connected relationship, being, within the three representation forms, developed with a complete degree of autonomy. With time, tri-dimensional representations of an object would turn possible but, again, without a strict relationship with the bi-dimensional representations of the object, being, in this sense, also an autonomous construction. This tri-dimensional representation would permit the study and visualization of the represented object as a whole and allow the delivery of one-point perspective to simulate punctual, singular points of view over the object's subject. Through digital-imaging software such as Photoshop®, the early 20th century's photomontage and collage techniques jumped into the digital domain of potentialities, contributing to its consideration on digital, easy to control, form.

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[17] AutoCAD is a computer assisted design software by Autodesk.

However, at the end of the 1980s arose a new representation technology of three-dimensional objects, the *Building Information Modelling* (BIM). Still based on the method of Monge, its major innovation was the fact that it could integrate comprehensive building information and display the represented object in its virtual three dimensions, and observable from any possible point and angle. We overpassed the previous CAD software limited, autonomous characteristics and begun to create three-dimensional operative virtual models with an extensive level of information (e.g. Autodesk's Revit®[18]). Through the use of this type of programs, it was now possible to develop an architectural projects with clear awareness of its three-dimensional shape and easily detect, still in the design process, complex situations that until then were difficult to predict and required a strong mental effort of elements' combination.

A concrete example of the usefulness of such programs is the distribution of an air conditioning facilities project throughout a large-scale building. As it is known, this type of systems can hardly spread in a linear way across the building's entire length. Representing it under a system of representation based on plans, sections and elevations was quite a complex task and likely to contain errors of continuity. With the open access to BIM programs, despite the building systems' complexity, their project becomes even quite easy to control. It is possible to preview it as it will be build, in its three dimensions, and follow its whole continuity. It can be watched isolated on the computer screen, without any additional elements that could interfere with its clear interpretation and fitted in the building, and together with all the other building's specialties and elements.

Although BIM software was already able to connect both bi and tri-dimensional considerations of an object's representation, the 'First Digital Revolution' would be largely characterized, as said, by the transition, under the same basis, from non-digital to digital frames. Due to this reality, the limitations inherent to spread bi-dimensional representation have, however, maintained essentially unaltered. The simple

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[18] Autodesk Revit is Building Information Modeling Software by Autodesk.

consideration of such representation methodology favours the consideration of specific characteristic objects, in the sense that it is simpler to reduce and interpret an Euclidean-orthogonal based object transformed into orthogonal projection's bi-dimensional representations than it is to follow the same process with complex, irregular or non-Euclidean forms, exactly because of their complex form degree. To do so, more advanced interconnected methodologies and representations techniques should be considered, something that we considered to be the first step of the yet to come 'Second Digital Revolution' reality.

As happened through the course of history, the prevalence and promotion of particular characteristic forms have followed the transition of non-digital to digital frames that characterize the first Revolution, essential due to the restrictions imposed by the regarded methodologies of representation. Such reality would change with the following 'Second Digital Revolution'.

2.2.3.2. The Second Digital Revolution

As we understand, the main results of the Digital Revolutions on architecture and the work and production of form have, for now, manifested in four areas of these subjects that specially contributed to a distinction between the 'First' and 'Second Digital Revolution': digital methodologies and techniques of (i) representation and form-shaping, (ii) visualization and (iii) production of form and (iiii) interactive, responsive surfaces and environments.

Advanced Digital Representation and Form-shaping Methodologies and Techniques

Gradually, the software of architecture and form representation departed from the conventional bi-dimensional representations and entered in the domain of tri-dimensional objects, whose representations could also be considered but, now, with an interconnected dependency with the whole digital form. The classic bi-dimensional representation would be faced more like a product of information's systemization from a tri-dimensional whole digital, virtual object other than as the mere isolate and basic information that is necessary to its communication and consequent materialization process. Such tri-dimensional virtual object seeks to digitally (re)produce an imaginary or existing object, representing it with the highest level of reliability and, eventually, (re)produce it in material, physical form.

Computer animation and modelling software such as 3d Studio Max®, RenderMan®, through which was developed the first, fully-digital feature-length computer-animated film (Toy Story, 1995), or Maya® allowed the consideration of tri-dimensional complex, free-form objects and environments able to be then transformed either in digital-animation or material products. In all three of these selected cases from a much wider possible selection, although their main object form is considered in tri-dimensions, able to be controlled by user friendly commands, it is also possible to visualize it (not transform since we are talking of real-time accessible information option) in all forms of vertical or horizontal orthogonal projections including, as expected, plans, sections and elevations.

When it comes to 3d modelling both 3d Studio Max® or Maya® have great potentiality when we consider the construction of virtual objects or environments from scratch, either via bi or tri-dimensional representation methods, but also when we define attributes for such object or environment's complex information, allowing the afterwards reproduction of high-level, close-to-reality renderings of such object or environment, and even considering animation, as a result of a controlled sequence of such renderings in time.

However, it would be another modelling software, Rhinoceros®, that would be more widely linked with the specific development of architectural spaces and environments, either in school or in professional office's environments. Like the former mentioned software, also Rhinoceros® allows the consideration of an object or environment under its more natural tri-dimensional composition but also allows to follow this subjects in bi-dimensional representation formats. Objects and environments can be built and transformed either via its bi or tri-dimensional representations. And since they are intrinsically connected, each transformation made in one of those representation forms has an immediate direct consequence on the others and in the whole object. In this way, it is quite simple to follow the result that a change in the tri-dimensional object has in the bi-dimensional representation forms and vice-versa.

Since it is NURBS oriented, Rhinoceros® not only allows the design of Euclidean-orthogonal architecture spaces but also free-from ones with a complex geometry level.

But still another level of form-shaping would become available: the one to be achieved through algorithm design. Grasshopper® is as graphical algorithm editor integrated with Rhinoceros® 3d modelling tools that allows the design of a form through complex mathematical based instructions. Such software allows complex structures to be achieved with almost no design activity, in its literal sense, but through algorithmic instructions able to produce exact digital representations of perfect mathematical expressions.

It is the possibility to build free-form objects controllable in its natural, yet virtual, bi and tri-dimensional states, surpassing the difficulties of representing complex objects in exclusively bi-dimensional formats, that we consider to be, within the advanced digital representation methodologies and techniques, the great ground-breaking of the 'Second Digital Revolution' towards the consideration of other than Euclidean-orthogonal forms. However, other sections of such revolutions have also contributed in this way.

Advanced Digital Visualization Methodologies and Techniques

With the gradual and increasing interest of new geometry spaces, where the plans that define it abandon their usual orthogonal nature and become a game of multiple relationships that can ultimately lead to a single connected surface (with the ability to adopt infinite variations), the traditional representation systems are no longer satisfactory to translate and communicate the complexity inherent to these kinds of spaces.

The evolution of architecture representation to the domains of *virtual reality* (VR) and *immersive digital environments* (IDE) reached, in turn, new and more significant capabilities in regard to the understanding of virtual spaces of architecture. Unlike the aforementioned approximation techniques of reality such as collage, photomontage or rendering, the access to immersive virtual reality technology enabled not only the development of visual products of designed spaces but also true intense experiences of those spaces.

Within the main IDE systems, the ones that stand out are, mainly, the media rooms, "*a physical facility where the user's terminal is literally a room into which one steps*"[19] (Steenson 2012, p.269), such as the *Cave Automatic Virtual Environment* (CAVE) (Dias, et al. 2010), and the *Head-mounted Display* (HMD), which consist of one or more displays embedded in a kind of virtual goggles that send information directly and only a few millimetres away from its user's eyes. A good example of this kind of technology is the Oculus Rift[20], demonstrated at the 2013 International CES show at Las Vegas[21], or any other of the similar technologies that have lately arise almost everywhere around us.

Though very close to the type of experience they provide, these technologies are actually slightly different.

The CAVE, a reference to the Plato's Allegory of the Cave (Pape 2004), is a room made of four, five or six screen walls where digital information is projected in a way that the user, or users, get surrounded by the projected environment. Through the use of liquid crystal shutter glasses, the user that stands inside the room has the ability to convert the projected stereoscopic images into an immersive three-dimensional space that grants him an incredible sense of presence in the virtual reality world.

In the case of the CAVE-HOLLOWSPACE of the *Centro de Ciência Viva da Mina do Lousal*, located in the *Grândola* county, district of *Setúbal*, Portugal, the chosen enclosure environment was the scenario with four screen walls: one front wall with 5.6 meters, two side walls with 3.6 metres and the floor surface which, contrary to the previous ones that are back-projected, is directly projected from a top structure. The

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[19] Richard A. Bold, Put-That-There: Voice and Gesture at the Graphics Interface, in Paul Emmons Drawing and Representation.

[20] The Oculus Rift is a headset of virtual reality for video games - www.oculusvr.com.

[21] CES stands for *Consumer Electric Show*, takes place once a year in Las Vegas, USA, and is broadly considered the most important electronic and digital tech show in the world.

whole system consists of a total of 12 synchronized projectors (Dias, et al. 2010). Once inside the room, the user interacts with the projected virtual environment with the aid of the aforementioned 3D converter glasses and a small human-computer interface (e.g. Wii remote[22], Kinect[23]), which allow him/her to control the environment he/she is located in.

The Oculus Rift, on the other hand, is a small-sized headset object that is placed right in front of the user's eyes, where two optic displays project exclusive stereoscopic images for each of the user's eyes and, in so doing, simulate the 3D virtual environment and the feeling of body immersion in space. Unlike the experience of the CAVE, where the user stands mainly still and it's the space that *walks* towards him, with the use of HMD, the inclusion of a positioning sensor system and the necessary levelled and obstacle free ground surface, the user is able to undertake any random voyage through the previously built 3D architecture virtual model.

In this technology, wherein the used 3D virtual model is essentially the same one that is used to produce the common hyper-realistic photomontages or virtual walkthroughs presented in two-dimensional formats, the major difference is that the user is directly projected into the virtual space. Once inside, he will study and experience the space of architecture in the same way that he is used to do with those of the real world. He will be able to make his own decisions (with almost total freedom)[24], choose where he wants to look or decide which path he wants to follow. An experiment conducted with the same trust that we got used to assign to our day-to-day experiences, in first-person, in a mechanically, intense and subjective way. "*A novel form of spatial representation…which substitutes for the actual experience*"[25] (Steenson 2012, p.269).

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[22] Wii remote is a controller for the Wii video game console by Nintendo.

[23] Kinect is a motion sensing input device by Microsoft.

[24] As previously mentioned, the user is conditioned by free obstacle available area.

[25] Robert Mohl, Cognitive Space and the Interactive Movie Map: An Investigation of Spacial Learning in Virtual Environments, Molly Wright Steenson Computing, Computer-Aided Design, Media.

With access to this kind of technology, when someone seeks an architect in order to design his *castle*[26], he/she no longer has to interpret the traditional plans, section and elevations, nor look into printed photomontage or virtual walkthroughs on the computer's screen. He will be able to stand in his yet to come living room, go, on foot, from there to the kitchen, visit the bedrooms and, by doing so, get a much clearer understanding of those spaces and if they really are as he/she truly expects them to be. In fact, with the access to this kind of technology, the greatest discrepancies between the representation of the virtual space and its subsequent physical construction depend, mainly, on the development level and visual detail of the former.

But yet another level of the relationship between real and virtual has emerged in the last recent years: The one of *augmented reality* (AR) and the old science fiction – but now more than ever realistic – concept of *hologram*. A *real world* reality that, in the inability to be more than what it actually is, is enhanced by its fusion with the one classified as virtual. Once again, the barrier that separates physical and virtual fades and the two realities get closer. However, contrary to what happens in the IDE's, where the 3D immersive systems and the quality level of the represented project are the ones that bring both realities closer, in these cases of augmented reality and holograms, it´s the virtual reality that invades the material world, converting it into a hybrid space, where both realities share the same environment.

The technologies previously described, in which the virtual world experience blends with the one of the real world, are the ones which will probably, among diagrams, prevail one day as decision tools and the common architecture methodology of space definition. Once we overcome the barriers that have limited and led us for many years to transform the communication of a three-dimensional space into two-dimensional representation methods, perhaps a new era in the culture of representation is about to open up to the discipline of architecture. Many abstract representations of architecture spaces may fade away giving rise to new methods of space thinking. The architect may even get the opportunity to get rid of the traditional tools that he got used to

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[26] "The house of an Englishman is to him as his castle". Sir Edward Coke (1552-1634).

employ during this process and assume a *man-to-space*[27] relationship, where space actually arises in front of him, coming from nowhere but, with the exact forms, relations and proportions that he/she wants it to have.

Advanced Digital Form Production Processes

The previously described ‘Advanced Digital Representation and Form-Shaping and Visualization Methodologies and Techniques’ made available new and complex forms of considering not only an object’s representation but also its whole virtual experience through easy handling digital tri-dimensional form and immersive digital environments software and hardware. As pointed, such technology has been of great importance since it was able to include more comprehensive considerations of an object beside its basic, traditional bi-dimensional representations, which contributed to the development and thought of new levels of information, especially when NURBS oriented and algorithm design software were contemplated, leading to the emergence of curved, non-Euclidean forms, which in their geometric nature are more complex than the basic Euclidean-orthogonal ones, for both means of their representation and production processes. On another hand, IDE technology comprised the possibility of such complex (or simple) forms to be experienced in more natural, empiric way, as if, instead of virtual digital forms, they were actually material objects. However, despite of such great achieved potentialities, the representation and visualization of a digital object was still enclosure within the virtual, digital domain. At least until ‘Advanced Digital Form Production Processes’ were considered, something that happened when CAD-CAM processes were available, first within specific advanced industries and later with software and hardware compatible with home and office use.

While CAD stands for Computer-Aided Design and CAAD for Computer-Aided Architectural Design, CAD-CAM stands for Computer-Aided Design and Computer-Aided Manufacturing. As the acronym designates, it is a set of combined software and hardware technology able to transform a form developed in digital, virtual ground,

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[27] As in the term ‘man-to-man’.

through the use of computer technology, into its physical, material state, by easy accessible computational information protocols that connect the software of both designing and manufacturing platforms. With the use of such technology there is no need for an object’s representation information to be subjectively interpreted nor the need to, based in this information, independently proceed to the production or construction of the regarded designed piece into a physical, material state. Design and manufacturing processes are interconnected and, like the algorithm design software that allowed the precise design of mathematical based expressions, the production result of the designed piece follows its exact geometric characteristics.

Computer Numeric Control milling and laser and water cutting machines were the first CAM technology to spread in the manufacturing, initially specialized focused, industries. Such technology allowed the manufacturing of digital based forms through sharp rotating tools (in the case of CNC milling machines) or cutters (the basic process of laser and water cutting machines) that, through subtractive methods, removed from a given block or board of solid material the additional amount of unnecessary material in order to shape the intended form.

However, still in such advanced production technology, and once again, the production of plan, Euclidean based forms had a clear advantage when in comparison with the production of curved, non-Euclidean geometry forms. This advantage resulted from the fact that Euclidean geometry forms are by their geometric nature, due to its mostly plan based configuration, more easy to be fragmented and divided into more simple geometric shapes that fit the planar configuration of the boards of material used in this immaterial-material transformation. In this way, the use of boards to be chopped and cut easily allowed the manufacturing of Euclidean, planar shapes that could afterwards be assembled together. The also fact that the continuous surface of non-Euclidean based shapes isn’t, by its geometric nature, so easily divided, or at least its division in parts doesn’t necessarily conduct to the task’s simplification, contributed for the consideration of alternative scenarios, which, in the difficulty or impossibility of delivering perfectly shaped forms (even though they had to be afterwards assembled), aimed to a better-under-the-conditions result. Due to this restriction, when curved, non-Euclidean geometry forms were considered, side techniques had to be employed in order to achieve the best possible results. Such techniques often included additional work on the digital design and post-production processes. In order to ensure that the result, produced form fitted the digital designed one, the latter had to pass through a side unfolding process that would digitally transform the tri-dimensional form in bi-dimensional planar sections which, later produced in planar board materials, would afterwards gain its curved appearance through the application of other side techniques, such as additional cuts or material heating for flexibility purposes and form delivery.

The use of tri-dimensional blocks instead of planar board materials for the digital-material transformation process would reduce the usage of side-techniques even when curved, non-Euclidean forms were considered. Since the material block already presented a tri-dimensional configuration, the production of Euclidean or non-Euclidean geometry forms could be easily achieved through the chopping processes of CNC milling machines, which would subtract the extra, unnecessary material and unveil the final form through finishing processes. In this case, the final product depended, certainly, on the form's level of complexity and detail but, also on the machine's characteristics to answer to such requirements. This response level would be achieved with the ability and potentiality of the rotational arms drill to perform three or five-axis manoeuvres. While the former, the three-axis mechanism, allowed the chop of a material piece through a fixed top-down process that worked in the Cartesian-Monge X, Y, Z axis space, the five-axis mechanism, not only allows the drill to move in such tri-dimensional space but also allows the performance of rotation manoeuvres in two additional axis, which permitted the inclusion of form depressions and inside-empty spaces.

A new production technology with new potentialities would, however, shortly come to reality: that of 3D printing. With 3D printing almost every restriction and side effects of CAD-CAM processes would be surpassed for both Euclidean and non-Euclidean geometry form production. Unlike CNC milling and cutting machines, which, as said, worked over a board or block of material through subtractive methods, 3D Printing is able to reproduce a digital shape in physic material through addiction methods. Since it works by depositing a source material from zero to full result, it allowed the consideration and construction of simple and complex geometry forms, including Euclidean and non-Euclidean geometry forms. Its main limitations are the amount of space that it is able to cover in each width, length and height dimensions, and the existing scope of printing materials. Starting with home scale devices, they would soon expand to industrial sizes able to comprise large-scale constructions. Even though we believe that this technology have just began to take its first steps, the construction of full-sized houses based on it is already today a possibility within our reach.

From a social-economic point of view, if the Industrial Revolution presented us the methods of standardization and mass production based in a previous developed, studied prototypes, the CAD-CAM processes of the 'Second Digital Revolution', have shown us that we can develop a wide range of prototypes able to be produced with cost benefits close to those of the standardization and mass production. Although such technology is still in an initial stage of development, this is a scenario that we can address to as the production of 'mass prototype production', which is able to fit and give an answer to every standard and non-standard situations passible to occur, for instance, in many architecture projects. This reality brings forward the yet difficult, but clearly not-as-before-scenario, of totally or partial curved, non-Euclidean architecture realities.

Interactive, Responsive Surfaces and Environments

Let us now consider a space that, instead of being a static object, unchangeable in its geometry and all other parameters that define it, has the capability to evolve, take on new shapes and develop an interactive relationship with the person who experiences it. In any such space, the user is compelled to forsake the usual comfort position he has become accustomed to assume as the controller of space and to adopt a relationship that is not a monologue (between a subject and an object), but a true and genuine dialogue. A unique and constant communication between two active participants, where each one is able to act and react to the stimuli of the opponent and that projects the user's experience into unprecedented virtual world levels, either in a mechanical or perceptual-cognitive and sensitive ways.

If the experience of static spaces via IDE was already extraordinary, it will probably be through the use of this technology that a full representation and experience of interactive architectural virtual spaces will be achieved. If we consider the possibility of representing a space of this kind in two-dimensional formats like plans, sections and elevations, we will quickly realize that it is almost impossible to include all the necessary significant information in order to allow its full understanding. The space does not have one, but multiple shapes and it's only through the introduction of the user's variable into the experience equation that space and its consequent representation begin to change. Spaces like these hardly allow reductions, abstractions or representations other than the ones that fully reproduce it, including all its three dimensions and the unfolded evolutions that characterize it.

To think and project a space of this nature, it is no longer satisfactory for the user to be projected into the space itself or for him to freely roam through the space of architecture. In these spaces, it will be imperative for the user to interfere with the space that surrounds him. To play with its geometry, change it, reform it, reorganize it and, by doing so, since a new reality has appeared ahead of him, to rethink any possible moves that he had formerly thought.

This topic have been achieving greater and greater relevance and expression on the state-of-the-art of today's architecture. Within the former three scenarios of digital representation and form-shaping, visualization and production methodologies and techniques, it is able comprise the design, study and production of any geometry form, Euclidean and non-Euclidean, independently of their complexity, and experienced in a recursive cycle never before achieved or made possible.

The Effects of Full-range Geometry Form Consideration and Production

If the Industrial Revolution exercised influence in the civilizations that were affected by it, and, particularly, in the subject of architecture, the Digital Revolution would increase such effects.

Also framed by social-economic factors of a society more and more characterized by the will of unveiling the unknown, the Digital Revolution, based on computational technology, would open the spectrum of potentialities and achievements of such thirsty society. The development of technology to suit the 'needs' of industrial and personal markets was growing at a speed never witnessed before, to the point that conscious thought on technology arrive later than its development. This situation contributed and keeps contributing to the fact that the adverse and benefit effects of technologic advances are most of times, at least in their complete form, only achieved in late, a posteriori phase of a product's development and its wide entry in the market. This means that, when reaching a ground-breaking point, we make use of the technology that is in our reach not because it is good or bad or contributes or nor to our wellbeing but, just because we can. The effects of such behaviour can be harmful or benefit to ourselves and society in general but, most of the time, they are just a blurry spot from which we know few or nothing about. In the context of what we have been addressing to, the reasons why, from an historical point of view and from our evolution and production stages, we have been building, constructing, producing and using specific kinds of forms, preferring some over others, this thesis aims to rectify this gap on knowledge through the production and enhancement of this same knowledge.

Historically, there are evidences that show that we have been preferring planar, Euclidean forms over curved, non-Euclidean ones. Through the present developed work, we have found some plausible explanations able to answer to the reasons why we might have been doing so. From where we stand now, such level of preference may be linked with (i) our intrinsic structure, from an animal, primitive point of view, (ii) the evolution of our thought, its structure and development levels and (iii) the available tools and technology that we have been having at our disposition in order to, based on our thought's ability, produce one or another kind of forms. Some of these points may, however, enter in direct confrontation with others.

On the current chapter of this thesis we have been mainly addressing to the second and the third reasons but will, in Chapter 4, give more attention to the first. Nevertheless, with the information that we have worked on this chapter, we can say that such could be linked with the fact that we have a sensible body composed by a central nervous system that allows us to know when we feel pain and pleasure, avoiding the former and seeking the latter. For these reasons and safety and wellbeing conditions, we have probably brought ourselves closer to curved, smooth shapes instead of sharp, hard ones, which are able to interfere with our body's integrity, causing us harm. As said, this topic will be of further study in this thesis' Chapter 4, "State-of-the-Art of the Preference for Lines, Shapes and Forms with Distinct Geometric Characteristics".

However, our preference for shape and form has also to do with our thinking ability, which, ultimately, rules the spectrum of what we are able and unable to achieve. The second plausible reason for such preference has to do with the evolution of our thought, with the ideas and concepts that have from early beginnings been associated to it and to its evolution. The importance of this topic in the preference for form has to do with the fact that, while conscious thinkers, most of what we do is done by a specific reason, no matter how deep inside it can be hidden. And it has to do with will and the ability to take such will forward. Since such things depend on thought, it is only logic to consider that the basis on which though settles, and from there develops, have a great say in this matter. In this way, key concepts of order, unity, proportion, symmetry, balance, harmony and beauty, together with the logic and mathematical structure of thought that have characterized not only the times when it began to be structured but also those that followed, left an decisive mark in the way we look at things in general. Although sometimes in an unconscious way, we have accustomed ourselves to think in a certain, specific manner. This, inevitably, has conducted to a way of doing and performing within the range of our possibilities. In opposition to what we believe to happen within our intrinsic primitive nature, such way of thinking and performing, together the set of tools and technologies that we have been constructing and having at our disposition in order to transform our will into final shaped forms, have lead us to more controlled, even basic geometric shapes when in comparison to the complexity level of curved, non-Euclidean ones. At least, until the reality that have shown to us with the advances of the Digital Revolution.

Our primitive, unconscious side should be, ultimately, able to command our protection, wellbeing and survival instincts. However, as conscious rational thinkers, history have shown us that we have, most probably, been bypassing such instincts. Contrary to our more primitive appeals, on a conscious level we have been aiming to other, more abstract and rational goals. Such has not only to do with the products that, consciously, we are able, and in a cultural way, even compelled to achieve, but also with the means that we find available, at a given space and time, in order to complete the development's cycle of a mental idea towards its material reproduction. No matter the evolution level of our thought, it would be of little use if we were unable to complete this cycle with tools and technology that we could count on. And the same applies to the opposite reasoning: no matter the evolution of our tools and technology, they would be of little use if we are unable to think in a level that allows us to make proper use of them. The perfect scenario stands somewhere within a balance between both realities. This led us to the third identified point able to interfere with the preference for form: the necessary tools and technology advances in order to bring forward the products of our thought.

Although the key concepts, methodologies and techniques, under which lay our thought activity, have historically contributed to the definition of the so called Euclidean based thought processes, which ultimately have been mostly resulting in also Euclidean based shape and form development, the consideration of curved, non-Euclidean forms is settled under these same Euclidean based though processes however in a different stage of evolution. Some attempts to produce non-Euclidean architecture have been made, although with an extreme degree of difficulty, due to the fact that the necessary means to take them forward were not developed enough, say, inadequate, to achieve standard flow processes of production. From this point of view, we can talk about the Frederick Kiesler's non-Euclidian project 'Endeless House' or the more contemporary Kengo Kuma's 'Phenomenologies' experiments. Both framed in the already mid and late 20th century, it is notorious the subjective will to produce other geometry forms than the ones that were mostly faced for production, as well as it is notorious the technical and technological difficulties that such subjects had to face in order to bring them to reality. The relevance of a Digital Revolution under the shape and form production scope has to do exactly with the release of such technical and technological restriction in order to turn to reality a wide range of mental built ideas, including those of complex non-Euclidean forms.

With the Digital Revolutions, where the 'First Digital Revolution' stands mainly as the ground necessary basis to the equation and reality of the second one, we have finally achieved the means to correspond to other thinking abilities, not considered before. With the new achieved digital advanced techniques and methodologies for an object's representation in its composed tri-dimensional form; the ability to work such object through either its bi-dimensional representations or its 3D configuration; the possibility of creating complex structures through algorithmic, mathematical and geometrical based instructions; the possibility of experiencing forms and objects in Immersive Digital Environments able to comprise levels of experience close to those that we are used to use in our every-day life experience and; the simplification and direct methods of production based on computational information protocols that came forwards with the beginning and evolution of the CAD-CAM processes, allow us, today and more than ever, to have a wide spectrum of technology able to embrace and give answer to other complex mental ideas in the domain of form rather than those that we already control.

If today and for a long time the large majority of spaces that we build are still based in 'basic' Euclidean-orthogonal geometric relationships, with the achieved advances of the last couple of decades this reality may and have at least the grounds to change considerably. The fact is that today, with the necessary will to do so, we are able to build orthogonal-Euclidean based architectural spaces as well as curved-non-Euclidean spaces. It is exactly at this point that the pertinence of this thesis stands, with the fact that, for the first time in our evolutionary history, we have reached a point when planar and Euclidean forms are almost as easy to bring to reality as curved, non-Euclidean shapes and the discussion about the geometry and characteristics of form that, within such reality, arises.

Since we are already conscious of the effects of orthogonal-Euclidean architecture space environments, if not by scientific knowledge at least by sensible and empiric ones, gained through the amount of time that have been confronted and framed by it, conducting to a relationship perhaps closer to pragmatic and habituation factors rather than to a best-overall-case-scenario, the kicking in of (more) easily achievable curved, non-Euclidean shapes came to open the discussion of which kind of forms are more suitable to our every-day environments.

Whereas the current chapter of this thesis tried to find some reasonable, factual explanations for the historically trend to develop orthogonal-Euclidean based shapes and forms, mainly within the architecture subject, the third chapter of this thesis main corpus will try to understand the methodologies, techniques and technologies that have been used in order to study how we have been regarding elements with distinct geometric characteristics, namely lines, shapes and forms, including architectural forms, and how they influence our preference, mainly though aesthetic judgements and approach-avoidance decisions. In the fifth and last chapter of this thesis main corpus, we will describe the developed experimental study, based on abstract oriented architectural spaces with distinct geometric characteristics and moderate and extreme geometric levels of evolution, and analyse the achieved results, in order to create new knowledge on this study's topic of form and architecture space form and their level of subjective preference.

Chapter 3

3. An Evolution of Aesthetics

Abstract. Current Chapter 3 will specifically address to the evolution of aesthetics. We will first make an overview on the evolution of aesthetics and the definition of beauty from classic times to the Age of the Enlightenment, focusing on the objective and subjective character of beauty, and will latter address to modern aesthetics. Within this topic, we will highlight the figures and works of William Hogarth (for his work on the analysis and principles of beauty), Gustav Fechner (the founder of psychophysics and a key figure of experimental psychology, a field in which he is noted for the introduction of quantitative methods, and the measurement of subjective and aesthetic judgement aimed towards objective quantification) and Kate Gordon (who in her 1909's Esthetics presents how aesthetics where regarded in the very early 20th century).

3.1. Overview on the Evolution of Aesthetics and the Definition of Beauty. From Classic to the Age of the Enlightenment[28]

As a field that seek the knowledge about beauty and taste, under the philosophy of art or that of beauty (Taliaferro 2011, loc.88/2086), aesthetics come from the ancient Greek meaning those things perceptible by the senses (Kul-Want and Piero, 2012, loc.66/1333) and have been under the scope of thinkers since at least the Greek Classical Period. Disciplines such as philosophy and natural and social sciences have made efforts to unveil and push forward the understanding of these concepts.

For a long time the discussion around beauty as focused on what is beauty and the properties of what is consider to be beautiful. However, one of its main focus area has been centred on whether beauty is an objective feature of beautiful, pleasant and perfect structures things, an absolute concept detached from individuality and a property of things themselves or, on the contrary, belongs to the subjective domain,

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[28] Introductory note: In this section, we will develop an overview on how aesthetics and the definition of beauty evolved over time, from classic times to the Age of the Enlightenment.

"depends upon the taste of the person who observes" (Gordon 1909), in other words, is "located 'in the eye of the beholder'" (Sartwell 2016).

3.1.1. View on the Classical Conceptions

In the Classic Period, beauty was already an open topic of debate. Its understanding and the places where it dwells were active subjects of this time's reference studies and dialogue methodology, so commonly employed to control, analyse and expand knowledge. Moreover, it was often associated with perfection. It is to be found in apparent discrepant fields that could go from mathematics to the youth's spirit and physical bodies, the elders' sober character or the excellence of the divine. From Pythagoras, to Socrates, Plato, Aristotle and Plotinus that the mathematical concepts of order, unity, proportion, symmetry, good and virtue were some of the main ideas that have ever since been associated with the concept of beauty or the beautiful.

Pythagoras saw everything there was as mathematics (Seife 2000, p.68)[29]. Beauty, in his view, was reduced to ratios and proportions (ibidem, p.66). The tetraktys' number 10 was to him the ultimate perfection among the natural only-believed-to-be numbers. As the discover of the ancient musical scale, Pythagoras also found beauty, as perfection, within the proportions of the classic proportions 1:2, 2:3 and 3:4 of the octave and the perfects fifth and fourth, respectively.

Socrates, by turn, associated the notion of beauty with virtue and good, the noblest and highest of all inspirations, from above this world but also found in this one:

> *"(...) in general all things capable of being used by man are regarded as at once beautiful and good relatively to the same standard."*
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> Xenophon, Memorabilia[30], 4th century BCE

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[29] *"All is number."*

[30] Xenophon, 2013 [4th century BCE].

> *"(...) when he sees the beauty of earth, is transported with the recollection of the true beauty; he would like to fly away, but he cannot; he is like a bird fluttering and looking upward and careless of the world below; and he is therefore thought to be mad. And I have shown this of all inspirations to be the noblest and highest and the offspring of the highest to him who has or shares in it, and that he who loves the beautiful is called a lover because he partakes of it."*

Plato, Phaedrus[31], 4th century BCE

> *"But of beauty, I repeat again that we saw her there shining in company with the celestial forms; and coming to earth we find her here too, shining in clearness through the clearest aperture of sense. For sight is the most piercing of our bodily senses; though not by that is wisdom seen."*

Plato, *Phaedrus*[32], 4th century BCE

Like Socrates, Plato believes that true Beauty lays on true good and virtue:

> *"If anyone got to see the Beautiful, absolute, pure, unmixed, not polluted by human flesh or colours or any other great nonsense of immortality… only then will it become possible for him to give birth not to images of virtue (because he's in touch with no images), but to true virtue (because he is in touch with the true beauty)."*

Plato, *Symposium*[33], 4th century BCE

However, on the other hand, Plato considered it to be an Idea, an abstract and absolute, insensible Form apart from all tangible bodies. The notion of beautiful or

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[31] Plato 2008 [IV BCE].

[32] Idem.

[33] Found in Taliaferro 2011, loc. 150/2086. Referenced to Plato 1994. Symposium. *The Collected Dialogues of Plato Including the Letters*. Hamilton, E. and Cairns, H. (Ed.s). Princeton, NJ. Princeton University Press.

beauty is then an ideal form that exists in all beautiful things, love and desire (Sartwell 2016). To him, the beauty of an object is an idea seen as an objective property of the beautiful things such as their size and shape properties, a "normative relationship of that which ought to give rise to aesthetic delight" (Taliaferro 2011, loc. 254/2086).

To Aristotle, beauty returns to the ideals of Pythagoras and Socrates. It is order and symmetry and definiteness, as specially seen in the abstract mathematical thought, the balanced arrangement of the parts of a whole structure and it is found in virtue and everything that is truly good (Sachs 2002):

> *"To be beautiful, a living creature, and every whole made up of parts, must ... present a certain order in its arrangement of parts."*
>
> Aristotle, *Poetics*[34], 4th century BCE

> *"Since the good and the beautiful are different (for the former always implies conduct as its subject, while the beautiful is found also in motionless things), those who assert that the mathematical sciences say nothing of the beautiful or the good are in error. For these sciences say and prove a great deal about them; if they do not expressly mention them, but prove attributes which are their results or their definitions, it is not true to say that they tell us nothing about them. The chief forms of beauty are order and symmetry and definiteness, which the mathematical sciences demonstrate in a special degree. And since these (e.g. order and definiteness) are obviously causes of many things, evidently these sciences must treat this sort of causative principle also (i.e. the beautiful) as in some sense a cause."*
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> Aristotle, *Metaphysics*[35] 4th century BCE

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[34] Found in Sartwell 2016. Referenced to "Aristotle, *The Complete Works of Aristotle*, in two volumes, Jonathan Barnes, ed., Princeton: Princeton University Press, 1984 [4th century BCE text]".

[35] Book XIII. Aristotle 1908 [4th century BCE].

Vitruvius and Plotinus close the spectrum of the classical understandings of beauty. To Vitruvius beauty lays on the order, proportion, symmetry, unity and harmony found in the mathematical structures of nature, the ideal canon, which, also found in the perfection of the human form, constitute a goal to aim and achieve through the constructions of man and also found in the perfection of the classical understandings of the numbers 6 and 10.

> *"(...) beauty, when the appearance of the work is pleasing and in good taste, and when its members are in due proportion according to correct principles of symmetry."*

Vitruvius, *De Architectura*[36], 1st century BCE

Plotinus writes that beauty is not only present in the order, proportion and measure for it may also include the unity and essence of simple Forms (Plotinus 2015 [3rd century AD], pp.55-63[37]; Sartwell 2016). While "the Good is the primary beauty" (idem), Plotinus associates beauty with the delight, shock and overwhelm that induces pleasure:

> *"This is the spirit that Beauty must ever induce: wonderment and a delicious trouble, longing and love and a trembling that is all delight."*

Plotinus, *Ennead*[38], 3rd century AD

> *"For those are the emotions one should experience in regard to that which is [truly] beautiful: astonishment, and a sweet shock, and longing, and erotic thrill, and a feeling of being overwhelmed with pleasure."*

Plotinus, *Ennead*[39], 3rd century AD

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[36] Book I, Chapter III. Vitruvius, 1914 [1st century BCE]

[37] Book I, IV.

[38] Book I, III. Found in Sartwell 2016. Referenced to "Plotinus, *The Six Enneads*, Stephen McKenna and B.S. Page, trans., Chicago: Encyclopedia Britannica Publishing, 1952 [3rd century CE text]".

3.1.2. View on the Medieval Conceptions

Through historical times the notions of beauty either kept some common basis as it have changed considerably according to individual perspectives and the philosophy of thought that attempted to understand and set a clearer subjective view over what it was believed to be more objective reality.

After the Roman Republic and close to the apogee of the Eastern Roman Empire, Augustine of Hippo goes towards the actions of Constantine I and looks at beauty as form, order, proportion and unity of a God, a higher order, Father of all Christians (Kul-Want and Piero 2012, loc.205/1333). Following Plato, Augustine connects beauty with an underlying metaphysical form and order of the universe, a result of the work and as the image of higher order and entity, creator of all things (ibidem, loc.223/1333). In '*De Veritate Religione*' Augustine wonders about the relationship between beauty things and delight, whether things are beautiful because they give delight or they give delight because they are beautiful (Sartwell 2016). Also, the felling and sentiment of pleasure, associated with smell or taste was questioned since it supposedly lacked any intellectual qualities (Kul-Want and Piero 2012, loc.211/1333).

In the 13th century, Thomas of Aquino proposes that the "experience of beauty is closer to the intellect than to the senses, contributing, by doing so, to mark a difference in the theological view over this matter, from an esoteric, ethereal point of view to a more rational, acceptable one" (Kul-Want and Piero, 2012, loc. 226/1333). Following and Aristotelian view, Aquinas saw beauty in perfection, proportion and clarity:

> *"There are three requirements for beauty. Firstly, integrity or perfection-for if something is impaired it is ugly. Then there is due proportion or consonance. And also clarity: whence things that are brightly coloured are called beautiful."*

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[39] Book I, IV. Plotinus, 2015 [3rd century AD], p.59.

Thomas of Aquinas, *Summa Theologica I*[40], 13th century AD

3.1.3. View on the Renaissance Conceptions

The central idea of the Renaissance period focuses on that of perfection borrowed from the ancient classical period and widely present in the Italian Renaissance painting and architecture (Sartwell 2016) but, contrarily to what happened in the previous Medieval period, centres it on man, his scale and dimension, the *uomo universalis* (Payne 1994, p.327).. According to the art historian Heinrich Wolfflin such perfection is intrinsically connected with the proportion among the parts of a whole that, despite contributing to such unity, are seen as independent, articulated "living parts" [41].

To Leon Battista Alberti and Andrea Palladio, real beauty lays exactly in such proportion of the parts:

> *"I shall define Beauty to be a Harmony of all parts, in whatsoever Subject it appears, fitted together with such Proportion and Connection, that nothing could be added, diminished or altered, but for the Worse."*

Leon Battista Alberti, *De Re Aedificatoria*[42], 15th century AD

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[40] Summa Theologica I, 39, 8. Found in Sartwell 2016.

[41] "The central idea of the Italian Renaissance is that of perfect proportion. In the human figure as in the edifice, this epoch strove to achieve the image of perfection at rest within itself. Every form developed to self-existent being, the whole freely co-ordinated: nothing but independently living parts…. In the system of a classic composition, the single parts, however firmly they may be rooted in the whole, maintain a certain independence. It is not the anarchy of primitive art: the part is conditioned by the whole, and yet does not cease to have its own life. For the spectator, that presupposes an articulation, a progress from part to part, which is a very different operation from perception as a whole." Wölfflin 1932, 9–10, 15. Found in Sartwell 2016.

[42] Book VI, II. Alberti 1755 [15th century AD].

> *"Beauty will result from the form and the correspondence of the whole, with respect to the several parts, of the parts with regard to each other, and of these again to the whole; that the structure may appear an entire and complete body, wherein each member agrees with the other, and all necessary to compose what you intend to form."*
>
> Andrea Palladio, *Quattro Libri*[43], 16th century AD

3.1.4. View on the Enlightenment Conceptions

From Plato (or even before) until the Age of the Enlightenment, beauty has been faced upon according to ideas from the metaphysical world and their relationship with nature or the mind. In the mid-18th century, William Hogarth writes 'The Analysis of Beauty' (1753), a work "centrally concerned with demonstrating the sources of beauty – why objects are beautiful" (Davis in Hogarth 2010, p.4[44]). Hogarth seeks "to consider the variety of lines which form bodies, that is, three-dimensional forms or volumes, in the mind (…) [through] general principles of beauty [that] constitute the background against which Hogarth wants his formal principle of beauty to be seen. It is a coordinate, multi-component system in which the elements are "duly blended together" or balanced with or against one another (…) [where] beauty is determined by multiple criteria reconciled and embodied in an organic whole" (Davis in ibidem, p.5).

According to Hogarth, there are then 6 fundamental principles of beauty, "which are generally allowed to give elegance and beauty, when duly blended together, to compositions of all kinds whatever; and point out to my readers, the particular force of each, in those compositions in nature and art [mainly ancient statuary (Davis in Hogarth 2010, p.5)], which seem most to *please and entertain the eye*, and give that grace and beauty" (Hogarth 2010, p.38): Fitness, variety, uniformity [regularity or symmetry], simplicity [or distinctness], intricacy and quantity; – "*all which co-*

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[43] Book I, Chapter I. Palladio 1965 [1570]

[44] Found in Hogarth 2010 [1753].

operate in the production of beauty, mutually correcting and restraining each other occasionally" (Hogarth 2010, pp.5-6 and 38). And these can be specially found in the composition, proportion and variety of the triangular glass and the serpentine line:

> *"The symbol in the triangular glass, might be similar to the line Michelangelo recommended; especially, if it can be proved, that the triangular form of the glass, and the serpentine line itself, are the two most expressive figures that can be thought of to signify not only beauty and grace, but the whole order of form."*

Hogarth, *The Analysis of Beauty*[45], 1753

> *"For as among the vast variety of waving lines that may be conceived, there is but one that truly deserves the name of the line of beauty, so there is only one precise serpentine line that I call the line of grace (...) which in the scale of them is number 4, (...) [that that] would better fit a well-formed woman['s body beauty]".*

Hogarth, *The Analysis of Beauty*[46], 1753

"The eighteenth century in Britain was [also] the century of the sublime. And in eighteenth century England 'greatness' is nearly a synonym for the sublime. (…) We reach the sublime as an aesthetic category of expression and pleasure. Here nearly the entire standard vocabulary of the sublime is unleashed: "huge shapeless rocks", "a pleasing kind of horror", "the wide ocean awes us", "horror is softened into reverence", "uncommon grandeur", "awful dignity". The English garden with its curves and spirals lay under the spell of the sublime. Hogarth's position is ambivalent, for "*Je ne sçai quoi*, has become a fashionable phrase for grace" (pp. vi, xv), co-opted, that is, by the connoisseurs as a threadbare catchphrase, and it was a dead-end that defied explanation. But Hogarth is not opposed, when "it is quantity which adds greatness to grace" (p. 30). Beauty, plus greatness is the sublime. Grace and elegance

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[45] Hogarth 2010 [1753], p.26.

[46] Hogarth 2010 [1753], Chapters IX and X, pp.59 and 60.

are sublime. The indescribable "line of grace" (serpentine) is the line of sublimity ("the sublime in form", p. 51). And sublimity also lies in the infinite variety of parts" (Davis in Hogarth 2010, p.13).

A few years later (1757), the empiricist David Hume detaches from the notion that beauty is an intrinsic property of things themselves and suggests that "beauty may be in the eye of the beholder", a matter from the subject, although "it is important that the beholder actually sees and experiences the art or natural object (a candidate to be judged beautiful)" (Taliaferro 2011, loc. 338/2086). As an Empiricist, Hume believes that "sensory experience is our most important and reliable means of knowledge" (ibidem, loc.355/2086) and thus, opposes and stands apart from "platonic ideal of permanent beauty which the soul should ascent to; he held instead that matters of beauty and ugliness were reflections of individual taste and temperament" (Taliaferro 2011, loc.349/2086).

> *"All sentiment is right; because sentiment has a reference to nothing beyond itself, and is always real, wherever a man is conscious of it. But all determinations of the understanding are not right; because they have a reference to something beyond themselves, to wit, real matter of fact (...) A thousand different sentiments, excited by the same object, are all right because no sentiment represents what is really in the object (...) Beauty is no quality in things themselves: It exists merely in the mind which contemplates them; and each mind perceives a different beauty. One person may even perceive deformity, where another is sensible of beauty; and every individual ought to acquiesce in his own sentiment, without pretending to regulate those of others."*

David Hume, *On the Standard of Taste*[47], 1757

However, although Hume considered beauty to be a subjective matter, he also believed that aesthetics and ethics were fields of study where standards could be considered, and where there should be a way to identify trends when the judgment of

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[47] Hume 1910 [1757], pp. 217-8.

art and ethical virtues were considered. He believed that these subjects could be a target of judgement of an ideal through, existing, an impartial spectator or observer (Taliaferro 2011, loc.349/2086, Radcliffe 1994). Such observer theory was interpreted by some philosophers in such way that beauty, and ethics, could be analysed by an ideal, impartial observer, one that had knowledge of all facts about the state of affairs, and is able to effectively grasp all its emotive features (idem). From this hypothetical perspective, "the state of affairs is beautiful if it gives rise to aesthetic delight in the ideal observer, whereas it is ugly if it gives rise to displeasure (or disgust) (Taliaferro 2011, loc.235/2086).

In the same year of 1757, Edmund Burke would return to the ideas of the Sublime and the Beautiful. In his treatise 'A Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful', Burke makes the distinction between the enjoyment of beauty which is founded on our enjoyment of things that give pleasure, and the enjoyment of sublimity, which is, in turn, "founded on the enjoyment of things which inspire fear and awe, things which remind us of pain and danger" (Gordon 1909).

> *"Whatever is fitted in any sort to excite the ideas of pain and danger, that is to say, whatever is in any sort terrible, or is conversant about terrible objects, or operates in a manner analogous to terror, is a source of the sublime; that is, it is productive of the strongest emotion which the mind is capable of feeling. (...) When danger or pain press too nearly, they are incapable of giving any delight, and are simply terrible; but at certain distances, and with certain modifications, they may be, and they are, delightful, as we every day experience."*

Edmund Burke, *A Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful*[48], 1757

To Immanuel Kant, the appreciation of beauty belongs to the subjective domain.

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[48] Burke 1914 [1757]. Sect. IV.

> *"The judgement of taste (...) is not a cognitive judgement, and so not logical, but is aesthetic – which means that it is one whose determining ground cannot be other than subjective."*
>
> Immanuel Kant, *The Critique of Judgement*[49], 1790

According to Kant, beauty, or the beautiful, can be defined derived from 4 moments of the judgement of taste: (i) A Moment of Quality ("taste is the faculty of estimating an object or a mode of representation by means of a delight or aversion apart from any interest. The object of such a delight is called beautiful"); (ii) a Moment of Quantity ("the beautiful is that which, apart from a concept, pleases universally"); (iii) A Moment of the RELATION of the Ends brought under Review in such Judgements ("beauty is the form of finality in an object, so far as perceived in it apart from the representation of an end"); and (iv) a Moment of the Modality of the Delight in the Object ("the beautiful is that which, apart from a concept, is cognized as object of a necessary delight") (Kant 1911 [1790]; Kant 2015 [1790], p.131-46[50]).

To Kant, the ideal Beauty, "the archetype of taste, is a mere idea, which each person must beget in his own consciousness, and according to which he must form his estimate of everything that is an object of taste, or that is an example of critical taste, and even of universal taste itself. (…) Only what has in itself the end of its real existence – only man that is able himself to determine his ends by reason, or, where he has to derive them from external perception, can still compare them with essential and universal ends, and then further pronounce aesthetically upon their accord with such ends, only he, among all objects in the world, admits, therefore, of an ideal of beauty, just as humanity in his person, as intelligence, alone admits of the ideal of perfection. But the ideal of the beautiful (…) is only to be sought in the human figure. Here the ideal consists in the expression of the moral, apart from which the object would not please at once universally and positively." (Kant 2015 [1790], pp.142-3[51])

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[49] Kant 1911 [1790] and Kant 2015 [1790], p.131. § I.

[50] §1-22.

[51] §17.

Kant shares de idea that “sublime is the name given to what is absolutely great” (Kant 1911 [1790], §25) but, there are core differences between what can be considered to be the beautiful and the sublime:

> *“The beautiful in nature concerns the form of the object, which consists in [the object's] being bounded. But the sublime can also be found in a formless object, insofar as we present unboundedness, either [as] in the object or because the object prompts us to present it, while yet we add to this unboundedness the thought of its totality. So it seems that we regard the beautiful as the exhibition of an indeterminate concept of the understanding, and the sublime as the exhibition of an indeterminate concept of reason. Hence in the case of the beautiful our liking is connected with the presentation of quality, but in the case of the sublime with the presentation of quantity. The two likings are also very different in kind. For the one liking ([that for] the beautiful) carries with it directly a feeling of life's being furthered, and hence is compatible with charms and with an imagination at play. But the other liking (the feeling of the sublime) is a pleasure that arises only indirectly: it is produced by the feeling of a momentary inhibition of the vital forces followed immediately by an outpouring of them that is all the stronger”*

> *“But the most important and vital distinction between the sublime and the beautiful is certainly this: that if, as is allowable, we here confine our attention in the first instance to the sublime in objects of nature (that of art being always restricted by the conditions of an agreement with nature), we observe that whereas natural beauty (such as is self-subsisting) conveys a finality in its form making the object appear, as it were, preadapted to our power of judgement, so that it thus forms of itself an object of our delight, that which, without our indulging in any refinements of thought, but, simply in our apprehension of it, excites the feeling of the sublime, may appear, indeed, in point of form to contravene the ends of our power of judgement, to be ill-adapted to our faculty of presentation, and to be, as it were, an outrage on the imagination, and yet it is judged all the more sublime on that account.”*

> *“In the division of the moments of an aesthetic estimate of objects in respect of the feeling of the sublime, the course of the Analytic will be able to follow the*

> *same principle as in the analysis of judgements of taste. For, the judgement being one of the aesthetic reflective judgement, the delight in the sublime, just like that in the beautiful, must in its quantity be shown to be universally valid, in its quality independent of interest, in its relation subjective finality, and the latter, in its modality, necessary"*

Immanuel Kant, *The Critique of Judgement*[52], 1790

3.2. Modern Aesthetics[53]

3.2.1. Gustav Fechner and the Measurement of Subjective (and Aesthetic) Judgement[54]

The study and understandings of the beautiful and aesthetics comprises a lot more than what we have been addressing to. However, to the future discourse of this document, it was important to have an overall vision of the evolution of beauty and aesthetics over time, especially to gain awareness that such notions have changed significantly. From classic times and leaving behind the beauty of behaviour, beauty has mainly evolved from the idea that it was a property of all beautiful things with

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[52] §23-4, Kant 1911 [1790].

[53] Introductory note: Previous section has been dedicated to an overview on the evolution of aesthetics and the definitions of beauty from classic times until the Age of the Enlightenment. From this section on, we will dedicate our attention to Modern aesthetics. How this field has changed with Gustav Fechner's work and how it was regarded in the beginning of the 20th century.

[54] Introductory note: In this section we will focus on the figure and work of Gustav Fechner. Fechner is pointed as the founder of psychophysics and a key figure of empirical research and experimental psychology, field in which he is noted for the introduction of quantitative methods. Such contributions allowed him to lead the measurement of subjective and aesthetic judgement towards objective quantification.

intimate underlying mathematical and metaphysical roots, something able to cause an effect of delight and pleasure on the one who, by the senses, perceives it but, nevertheless, belonging to the object itself (a vision that was a target of recurrent recovering over time), to more rational and empirical approaches that considered it to be “no quality in things themselves” (Hume 1910 [1757], p.218) but something that exists “in the mind which contemplates them” (idem), something that dwells in the eye of the beholder, of subjective character. However, despite of Hume’s intent of extract a more objective level of information from such subjective matter, through the involvement of an ideal, impartial observer, it would be Gustav Fechner, around a century later, that would make significant advances in the field of aesthetics and the quantification of beauty and get closer to the objective side of such individual, subjective form.

Fechner, “a German physicist, psychologist, and philosopher”, is “best known to historians of science as the founder of psychophysics (the experimental study of the relation between mental and physical processes) and the grandfather of experimental psychology” (Heidelberger 2004, Heidelberger 2001, p.143), field in which he is “noted for the introduction of quantitative methods” (Heidelberger 2001, p.142). His pioneer studies on proportions “within a psychophysical context by systematically analyzing the physical properties of simple stimuli and aesthetic appreciation” (Carbon 2010, p.233) would mark the “beginning of empirical research on the arts” (Silvia and Barona 2009, p.1).

The way we used to examine “real matter of fact” (Hume 1910 [1757], p.217) would change considerably in the late 19th century starting from the point when Fechner contributes to the definition of statistical methodology and connects “psychophysical parallelism and individual indeterminacy” (Heidelberger 2001, p.144). In his 1860’s Elements of Psychophysics, Fechner defines “psychophysics as the ‘exact science of the functional or dependency relations between body and mind, or more generally: between the bodily and the spiritual, physical and psychical, world.’ (Fechner 1860, I, 8) His goal was to measure sensations experimentally and thus to arrive at a quantitative science of psychophysics. (…) Fechner conceived of psychophysics as a fundamentally statistical enterprise. The rationale behind his reasoning seems to have been the following: If human beings are free in their actions and if mind and body are correlated in the way as conceived by psychophysical parallelism, then there will be an individual variation in the response of a subject to a physical stimulus. This response will be physical and manifest itself in a certain bodily reaction, but it will also be mental and express itself in a certain judgement.” (idem).

In the ‘Vorschule der Aesthetik’ from 1876, Fechner tries to understand subjective judgments through methods of extreme ranks (ibidem, p.144). Later he developed the notion of the median, introduces it into the formal analysis of data and “delved into experimental aesthetics and endeavoured to determine the shapes and dimensions of aesthetically pleasing objects” (idem). In 1897’s ‘Kollektivmasslehre’, a posthumously published book on the measurement of collective, Fechner “defined a ‘collective’ or ‘collective object’ as a collection of an indefinite number of individual objects, subject to random variation, and embraced under a single specific or generic concept” (ibidem, p.145). About the object of enquiry he wrote that “the establishment, by mathematical proof and empirical verification, of a generalization of Gauss's law of accidental variations, whereby the law is enabled to transcend the limits of symmetrical probability and comparative smallness of the positive and negative deviations from the arithmetical mean, and new relations of uniformity are brought to light (Fechner 1897, vi)” (idem). Random variations of collectives could fall in “ideal laws of chance”, where chance is regarded as “an objective category and not just the expression of ignorance” and “variation due to factors other than chance” could be distinguished from pure, random chance (idem).

The study of aesthetics had begun to stand apart from being something only concentrated in the subjective domain, from where it may actually very well depart, to get closer to a more objective evaluation. This means that, believing to belong to the subjective domain of humans, beauty and the beautiful were now beginning to be able to be weight by quantifiable means, something which brought us closer to the truth that hides behind the subjective until then ‘apparently’ immeasurable reality.

3.2.2. Aesthetics in the beginning of the 20th century[55]

In 1909, Kate Gordon gathers, in her book *Esthetics*, the ideas that until then have been associated and developed within the fields of the beauty and aesthetics and describes the essence of such concepts, their supposedly rational origins and implications in vast, every-day-live aspects. This contribute is important and relevant to this discourse since it was a testimony written between Fechner's quantifiable 'tools' for the evaluation of beauty and the objectivity aimed studies that began to be developed in the beginning of the 20th century around this subject and are the predecessors of yet today's work on such subject, including the one which incorporates this thesis.

According to Gordon, "beauty depends upon the taste of the person who observes" (Gordon 1909) the objects able to conduct to the sprout of the beautiful. Aesthetics however can be divided in two apparently antagonistic sections: subject and object. Subjectively, Gordon says, "esthetics is the science of the feelings which are concerned in the production and appreciation of beautiful things. Objectively, it is the analysis and classification of the beautiful objects which occasion those feelings" (idem). To her, "esthetics has for its subject-matter the beauty both of art and of nature" but especially that of art since the appreciation of nature itself lacks the element of personal expression, important for the aesthetic experience. And since it pursues the "finding of general laws and beauty theories of beauty" (idem) it also participates of 'criticism'. "Criticism is the act of passing judgement and it implies the possession of a standard or test of beauty" (idem) in order to understand, kwon or feel, if a given work is good or bad and it "may be called the esthetics of particular cases" (idem).

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[55] Introductory note: In this section we will dedicate attention to how aesthetics were faced in the beginning of the 20th century before the first experimental studies on angularity and curvature of elements took place. We will address to Kate Gordons main opera on aesthetics, 'Esthetics' and highlight, as we did before with Hogarth's 'line of grace', the ideas of Gordon on the character of straight, angular and curved lines due to their pertinence to the present thesis.

Otherwise, aesthetics also belongs to the science branch and, within this, also to the psychology area. It is a science since “it pursues the methods of science: the esthetician gathers specimens, observes and compares them, classifies and tries to explain; when possible he examines them under conditions of control. The worker in esthetics has for his specimens emotional experiences, and judgments of ‘beautiful’ and ‘not beautiful’. He observes the person who makes the judgment, observes the object about which it is made, notices attendant circumstances. He compares the judgment of other persons on the same object, and of the same person on other objects; varies one by one the characteristics of the object, takes the subject in a variety of moods, and when he is able to find a constant result of any kind, there he has the rudiments of an esthetic law” (idem). On another hand, once the objects of beauty deal with affections, feelings, emotions and moods processes, aesthetics have also to do with psychology, the science of mental processes as such. These processes and “the conditions of their arousal may be considered a part of the larger science of psychology” (idem) and in this way the aesthetician can be regarded “as a psychologist who limits his attention to one branch of his subject” (idem) and “esthetics as a branch of an advanced psychology” (idem).

Weather if aesthetics is a ‘positive’ or ‘normative science’, the two existing kinds of science, Gordon states that it is as positive as it is normative since, in a way, a positive science is also normative science and a normative science also a positive one. “A positive science tells us merely the nature of things, what they are; whereas a normative science tells us also what things ought to be” (idem). Within the purpose “to help us to clarify and become conscious of our own tastes” (idem), aesthetics tries to understand and analyse metal life as it finds it, pointing out the proper exercise of taste and what we ought to find beautiful. Through logic, distinguishing the difference between false and true judgements, it aims to determine what a ‘normal’ human mind is when beauty and taste are considered and it does so trying to set up standards and norms, a goal and characteristic of every science including that of psychology.

As to its methods, they “are the methods of psychology, namely, observation, introspection and experiment” (idem). “Observation may be regarded as the objective method” (idem) and it’s applicable towards the expressions “of the one who sees or hears something beautiful (…) so we learn something of the laws of beauty by observing the things that are accepted as beautiful. Introspection is the subjective method. This must tell what it feels like to find a thing beautiful (…) Experiment is introspection and observation under controlled conditions" (idem).

The phases of aesthetics are, by turn, opposite to the phases of the production of art. While the production of a work of art is a progress 'from emotion – feeling – to form', the appreciation of art, beauty and taste is a progress 'from form to emotion'. Emotion is a complex form of affection and affection, by turn, is an elementary aspect of felling and it addresses to "certain fundamental or elementary aspects of consciousness, namely, pleasantness and unpleasantness" (idem). To better explain 'affection', Gordon compares it with cognition. All mental processes, she writes, "are divided into two great classes: knowing or the cognitive class and feeling or the affective class. In the former belong the processes of sensation, perception, imagination, memory, reasoning; in the latter, agreeableness and disagreeableness, feelings, emotions, moods, passions, sentiments. To distinguish these two classes it is common to say that cognition has an objective reference, that it tells one about the objects, events, conditions of an external world; whereas feeling has a subjective reference, and expresses a personal reaction, or records the subject's manner of receiving a cognitive stimuli. Moreover, cognitive processes can be referred to some specific sense-organ, while affective processes involve more markedly the organism as a whole" (idem). Affection is then associated in extreme ranks with pleasure and pain and its attributes are intensity, duration and quality.

As to the aesthetic senses they are the eye or vision and the ear or hearing and the elements of beauty are often pointed as warmth, coolness, softness of a colour; sweetness of a tone; smoothness, strength, vigour, elasticity in line.

It is exactly at this point that the reference of Gordon's Esthetics gains another relevance to the discourse of this document. In Chapter IX of Esthetics, Gordon talks about 'The Character of Simple Lines and Forms' and addresses to the character of straight and curve lines. For all we were able to understand, this is the first documented reference made to the distinctive characteristics of the 'severe' straight lines versus the 'grace' of curved ones.

Gordon starts by saying that “mathematically a line has no substance or quality, only length and direction” (idem). But, in the artistic domain, it can acquire a more substantial status and quality. “In sketching, the quality of a line as broad or narrow, dark or light, rough or smooth may be made to indicate the texture of the object portrayed” (idem). For instance, a fine grey line is able to suggest delicacy of texture; a fine black line, precision and hardness; broad rough lines, homeliness and solidity; and broad black lines, a character of distinctiveness and independence. Among its character and direction, lines can be vertical, evoking ‘straightness’ and ‘uprightness’, synonymous of moral reliability; horizontal, the line of quiescence and repose suggesting quietness and relax; diagonal, the lines of action; and they can compose patterns as stripes, “the simplest as well as one of the strongest forms of composition” (idem), and create forms such as triangles, “the simplest of all enclosed forms” (idem) whose “diagonal and sharp corners give it an active, vivacious and incisive character” (idem) and in case of the isosceles triangle, communicating an harmonious symmetrical balance; the square, giving impression of “solidity and strength”; or oblongs, such as the golden section rectangle, “the most beautiful of all proportions (…) the most perfect expression of unity in variety” (idem).

However, “of greater importance than the quality of line is the direction of line and its character, as straight or curved” (idem). Before actual talking about curve lines, Gordon says that “there is a severe controlled grace in certain upright lines, which to some tastes may be more pleasing than the grace of curves” (idem). The simple fact that she considers some straight, upright lines to share of a grace possible even more pleasing than the one of curves, already denotes that grace is a character of curve lines. A bit further ahead, when specifically addressing to curve lines, she would state that “curves are in general felt to be more beautiful than straight lines. They are more graceful and pliable, and avoid the hardness of some straight lines” (idem). In such cases we might consider the circle, a symbol of completeness and impression of fullness and finality; the arc; or the serpentine line, which to Hogarth represents the most perfect ‘line of grace’. “The variety of direction, he justly thought, was an element of importance in its beauty”[56] (idem). Gordon then adds that “attempts have

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[56] “For as among the vast variety of waving lines that may be conceived, there is but one that truly deserves the name of the line of beauty, so there is only one precise serpentine line that I

been made to explain our liking for this type of line" (idem). The first explanation advanced that the feeling associated with more smooth, continuous line movements was more agreeable. "The ease of eye-movement was made the basis of our pleasure" (idem). Further studies and experiments (e.g. by Stratton) have however discredited this theory. "He recorded on a photographic plate the eye-movements of subjects as they looked along a smooth serpentine curve, and his results show that these eye-movements are not at all smooth and continuous in their character; in fact they do not differ essentially from the movements made in following the ugly broken line. This tends to prove that the feeling of eye-movement cannot be the ground of the esthetic judgment" (idem).

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call the line of grace (...) which in the scale of them is number 4, (...) [that that] would better fit a well-formed woman['s body beauty]". Hogarth 2010, pp.59 and 60.

Chapter 4

4. State-of-the-Art of the Preference for Lines, Shapes and Forms with Distinct Geometric Characteristics

Abstract.

In the current chapter we will first briefly address to the first experimental studies on angularity and curvature and afterwards to the state-of-the-art of the preference for lines, shapes and forms, including its sub-topic of the preference for architecture space form, with distinct geometric characteristics, namely, at contour level. We will also address to late-stage collected references and to the work developed by the candidate on the topic of architecture space form and elements. We will go through scientific experimental studies that unfolded the topic of preference in what we have identified as subjective and objective-based knowledge 'databases' that exercise influence in our aesthetic judgement and approach-avoidance decision, the two sub-problems of this thesis. We will close this chapter with a context of the conducted experimental study.

4.1. 20th Century Experimental Studies on Angularity and Curvature and the Affective value of Lines[57]

"Much of the early research on aesthetics studied people's preference for lines, forms, colours and shapes" (Silvia and Barona 2009, p.1). It would be in 1921 that Helge Lundholm would begin the experimental studies on Angularity with 'The Affective Tone of Lines: Experimental Researches'. In Lundholm's experiment, which counted with 8 test-subjects, participants were asked to draw lines that characterized feelings.

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[57] Introductory note: The current section is dedicated to the 20th century experimental studies, namely on the affective value of angular and curved lines (Lundholm, Poffenberger and Barrows and Hevner) and the emotional meaning of typographic characters (Kastl and Child). Such studies, especially the former, mark the beginning of the study of aesthetics through experimental studies that make use of a sample of test-subjects in order to reach close-to-objective information on the addressed topics of research.

Afterwards the lines were categorized according to their angularity character. Among the universe of angular and curved lines, "angular lines were associated with feelings such as 'agitating', 'hard' and 'furious' and curved lines were associated with feelings such as 'gentle', 'sad', 'quiet' and 'lazy' (idem).

A few years later, in 1924, Albert Theodor Poffenberger and B. E. Barrows "studied the experience of people viewing curved and angular lines" in a study called 'The Feeling Value of Lines'. In this study 500 adults, "a huge sample for that time", were asked to view a page with 18 lines. "The lines were curved and angular, and they varied in the number of curves or angles per line. People were given 13 different classes of feelings (e.g. 'sad', 'quiet', 'merry', 'gentle', 'harsh', 'serious'), and they connected each class to one or more of the lines. The findings replicated Lundholm's (1921) study: Angle lines were rated as 'agitating', 'furious', 'hard', and 'serious'; curved lines were rated as 'sad', 'quiet', 'lazy', 'merry' and 'gentle'" (ibidem, p.2).

The first 20th century studies and experiments on angularity and curves, closes in 1935, with Kate Hevner's 'Experimental Studies on the 'Affective Value of Colours and Lines'. "Hevner conducted a series of experiments that improved upon the design and materials used by Poffenberger and Barrows (1924). To avoid the contrast effects caused by viewing all objects on the same page, she used a between-group design. Instead of using simple lines, Hevner developed a set of abstract displays composed of curves (circles and wavy lines) or angles (squares or angular lines). People viewed a design for three or five minutes and they rated it by checking off which adjectives described their feelings. In summarizing her experiments, Hevner concluded that 'curves are found to be 'serene', 'graceful' and 'tender-sentimental'. Angles are 'robust', 'vigorous' and somewhat more dignified'" (idem).

Further ahead in the 20th century, in 1968, A. J. Kastl and I. L. Child performed an experiment on angularity, in this case oriented by typography characters. In the study 'Emotional meaning of four typographical variables' the results support the ones already achieved at this time by the previous described ones: "round letters are experienced as more pleasant and angular letters are experienced as more serious" (idem).

After Hogarth, Fechner and Gordon, theoretical work on the experimental psychology of aesthetics would continue, namely with Charles Wilfred Valentine's 'The Experimental Psychology of Beauty' (1962) or Daniel Ellis Berlyne's 'Studies in New Experimental Aesthetics' (1974).

4.2. State-of-the-Art: Collected References on the General Topic of the Preference for Lines, Shapes and Forms (2005-2015)[58]

Giving continuity to Fechner's work, with the arrival of the Digital Revolution that took place in the 20th century, a set of innovative tools become available to measure subjective based knowledge at a completely different level. More than ever, the study of such knowledge and subjects in general was closer to an objective and quantitative point of view, rather than a more subjective, fallible and less accurate one[59]. Furthermore, state-of-the-art tools such as biometric sensing technology (electrocardiogram/hearth beat, electrodermal-response, electromyography or electroencephalography) and brain scanning technology (fMRI), opened a whole new

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[58] Introductory note: Current section is the widest of this chapter. Here we will address to the literature that exposes the state-of-the-art of the preference for lines, shapes and forms, from the beginning of the 21th century to the point when, after a solid initial review, around the year 2015, we began designing and developing this thesis experimental study on the preference for abstract architecture spaces with distinct, extreme and moderate, geometric characteristics at contour level. Due to our interest in better define and control the referred experimental study, we will extensively describe the presented scientific papers, registering any relevant information on the topic of preference considered by this thesis, the methodology of the described experimental studies, their results, discussion and achieved conclusions.

[59] "All sentiment is right; because sentiment has a reference to nothing beyond itself, and is always real, wherever a man is conscious of it. But all determinations of the understanding are not right; because they have a reference to something beyond themselves, to wit, real matter of fact; and are not always conformable to that standard." In Hume 1910 [1757].

era on the understanding, definition and evaluation of the perception and cognition of external phenomena.

When we have initially raised the research question, problem, sub-problems and hypotheses of this thesis, we have identified its problem as the preference for lines, shapes and forms and the preference for architecture space form based on distinct geometric characteristics at contour level. As we have pointed out, scientific literature on this topic, has stated that preference for such elements may be influenced by aesthetic judgements[60] and approach-avoidance decisions[61] [62], which, we have identified as this thesis' two sub-problems. While the former settles on our concepts of beauty and taste, a knowledge that is built on our thought and our methods of reasoning and performing, from communicated achievements to self-experience, the latter is more based on inherited genetic knowledge rather than on empirical, scientific or rational ones. The access and use of the above mentioned tools and technologies and experimental studies on humans has been crucial to the achievement of this believe due to the fact that, together, they have conducted us to a better understanding on how our brain works, external phenomena are perceived by our senses, interpreted by our brain and how, posteriorly, we react mentally and physically to their presence. In the following sections, we will address key state-of-the-art studies that point into this direction and allows the linking of aesthetic judgements and approach-avoidance decisions to the topic and problem of the preference for shapes and forms, mainly according to their curved and angular geometric characteristics.

We will, then, next address the methodologies, design and results of key selected and recent experimental studies on the preference of curved and angular based lines,

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[60] Hevner 1935; Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Carreiro, et al. 2017.

[61] Approach-avoidance decisions, motivations or behaviour. See Chapter 4, section 4.5.2.

[62] Bar & Neta 2006; Bar & Neta 2007; Dazkir & Read 2011; Vartanian, et al. 2013; van Oel & van de Berkhof 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Velasco, et al. 2016; Cotter, et al. 2017; Carreiro, et al. 2017.

shapes and forms, including architecture space form. This state-of-the-art review will follow a linear, chronologic order.

Dimensions such as form (straight, original and curved), complexity and innovativeness in the appreciation of car interior design. Leder and Carbon 2005

In 2005, Helmut Leder and Claus-Christian Carbon investigated the interplay between stimuli properties and perceiver characteristics in the appreciation of car interior design. As the authors pointed out, the appearance of a product is nowadays of major importance for the consumer, "aesthetics and design are decisive buy-arguments in markets in which the technical level of competing products is very similar" (Leder and Carbon 2005, p.603). On the other hand, "the impact of design might also depend on different personalities" and hence, people can prefer some designs over other, in this case, associated either with innovative and modern design or rather conservative or conventional design appearances. Although, the exterior design of cars is often dominated by technical constrains, such as the air drag coefficient, "interior designs often allow designers to use more individual and aesthetically justified designs" (idem).

Following Berlyne (1970), Leder and Carbon state that "there are a number of variables known to affect aesthetic appreciation". One of such variable is the level of complexity of the product under study. Using artificial patterns, Berlyne found back in 1974, that "complexity psychologically refers to the arousing potential of a stimulus" and that "preference is related to medium levels of complexity which do not arouse too much (which on the other hand, very complex objects do) and on the other hand are not boring (as very simple objects are)" (ibidem, p.604). By turn, "the variation of complexity in terms of design principles ranges from the variation of physical stimulus properties to references of psychological grouping principles" (idem). While the former include "variation in the number of steering elements, number of colours and shapes", the latter include "design principles such as symmetry and prototypicality which both affect the perceived complexity but are also known to affect aesthetic preference and cognitive appraisal of visual complexity and balance" (idem).

The Zajonc's related "mere-exposure" effect (Zajonc 1968) is another variable to keep under control. Contrarily to what happens with today's western architecture and was confirmed by the results of our experimental study that will be latter reported in this thesis, where the "mere-exposure" effect shows to be associated with straight, angular shapes and forms, in this particular case of car interior design, such effect for familiarity is more directly connected with predominant curved styles, which might reflect the preference for this kind of shapes. Also directly related to this familiarity effect is innovation, "one of the most important dimensions of aesthetic appreciation" found in this study. Although such appreciation might depend on personal characteristics, it is expected to "find individual differences in the appreciation of different levels of innovativeness depending on interest and expertise with design or art", as reported in Eysenck (1972) and Tobacyk, et al. (1979).

In this study, Leder and Carbon propose to "investigate the role of curvature, complexity and innovation as well as the interest in art and design for the appreciation of modern car-interior design (...) in which the effects of the different design dimensions are investigated simultaneously" (ibidem, p.606). It is expected that curvature elicits higher positive emotional reactions and, therefore, higher appreciation ratings due to the fact that "softer, curved shapes are more often associated with cuteness, beauty and approach, while sharp, straight designs are presumably more related to technical, analytical and cold reactions" (idem), in accordance with Etcoff's pattern of appreciation in faces (1999) and Arnheim's description of design principles in the Gestalt-Psychologists approaches (1954).

The authors considered two experiments. Experiment 1used a fully factorial design with three levels of complexity, curvature and innovativeness combined. Twenty-four test-subjects participated in the experiment, half female and half male, with an average age of 25.6 years. All participants were asked to rate the levels of perceived attractiveness, complexity (low, medium, high), curvature (straight, original, curved) and innovation (low, medium, high) in twenty-seven drawings of interior car design (3x3x3) using a seven-point scale. The stimuli consisted of line drawing version, in which varied the above mentioned three dimensions and were presented on a CRT computer screen of 21''. After the experiment *per se*, participants were asked to answer to three paper and pencil questionnaires, on sociometric, interest in design and expertise and knowledge about design.

Generally speaking, curved and less innovative designs were rated as "being particularly attractive" (ibidem, p.616) – a result that is in accordance with the "mere-exposure" effect – and when attractiveness was considered alone, ratings per participant show that curved versions were rated as more attractive than medium curved versions and these also higher than the straight versions and innovative versions were not perceived as being attractive. On another hand, when curvature ratings were considered, curvature was rated more attractive when lower levels of innovation were considered. Also, "persons more interested in art preferred curved design more than other people did", showing the expected interdependency between art and curvature appreciation.

Experiment 2 was similar to the previous one. However, "due to the results of Experiment 1, complexity was omitted as a dimension and a new version of the highest level of innovativeness was created" (ibidem, p.611) In this way, in Experiment 2 participants only rated the perception of attractiveness and the two dimensions of curvature and innovation. Given Experiment 1's relatively small effects of individual differences in art and design expertise, the sample of Experiment 2 was enlarged and students as well as non-students were tested, increasing the age range.

As Experiment 1, Experiment 2 also used a fully factorial design in which three levels of curvature and innovativeness were combined. This study counted with forty-eight participants, half female and half male, with an average age of 28.8 years. All participants were asked to rate the levels of perceived attractiveness, curvature and innovation in nine drawings of interior car design (3x3) using a seven-point scale. After the Experiment itself, all participants fulfilled a paper-based questionnaire similar to the previous one.

Results from Experiment 2 replicate the results of the previous experiment: "More curved and less innovative versions were seen as being more attractive" (ibidem, p.616). Moreover, the analysis on the ratings of attractiveness on curvature revealed that "curved versions received generally higher attractiveness ratings than the medium and these were higher than the straight versions (...) Concerning innovativeness there was a significant attractiveness advantage for the least innovative versions" (ibidem, p.615).

Preference for curve and sharp-angled real, everyday objects, English characters and meaningless patterns counterparts. Bar and Neta 2006

In their 2006 work, Moshe Bar and Maital Neta state that "people constantly make snap judgement about objects encountered in the environment" and that such rapid judgement must be based on the physical yet unknown properties of this same objects. This raise the question: "what are the physical elements in a visual stimulus that make one like it, dislike it or respond fearfully to it?" (Bar and Neta 2006, p.645).

Such judgement may be affected by factors like symmetry, prototypicality, contrast, complexity and perceptual fluency and "given how quickly such impressions can be formed, they must rely on visual primitives that can be extracted from the image extremely quickly" (idem). Bar and Neta hypothesized that one key visual primitive able to mediate the formation of such rapid impressions, is the curved characteristics of an object's contour and features. In this way, supporting previously studies (e.g. Zebrowitz 1997), where people judging other people faces considered rounded faces (e.g. 'baby faces') to be more liked and generally perceived as more attractive than more angular faces (ibidem, p.648), they predicted that "emotionally neutral objects with primarily pointed features and sharp angles would be liked significantly less than corresponding objects with curved feature" (ibidem, p.645), due to fact that sharp contour transitions might consciously or unconsciously convey a sense of threat and trigger a negative bias.

For this Experiment, the authors considered 140 pairs of real objects. All items were everyday objects without inherent positive or negative valence and were assembled in pairs with the same semantic meaning and general appearance, varying mainly the curvature level of their contour. The sample of pictures to be presented also included 23 pairs of English characters with sharp and rounded fonts, 140 pairs of curved and sharp meaningless patterns, included to control the possible role of semantic meaning, familiarity and associations in preference formation, and 80 real control condition objects with a balanced mixture of curved and sharp-angled features. All items were presented in grey neutral valence colour over grey neutral valence background. This study included fourteen test-subjects from 18 to 40 years of age, with normal or corrected-to-normal vision and no information about the purpose of the experiment. Each picture was presented for 84 ms and participants were asked to make a like/dislike force-choice decision based on their immediate, 'gut' reaction. Preference was measured by calculating the proportion of 'like' responses out of the total responses.

Results show that test-subjects liked significantly more the curved objects, meaningless patterns and letters to their sharp-angled correspondences: "Participants liked the curved objects significantly more than the control objects (67.2%) and liked the sharp-angled objects significantly less than the control objects (50.6%) and thus, the curved objects were liked significantly more than the sharp-angled objects" (ibidem, p.646). The responses of meaningless patterns and single characters point to the same result: curved meaningless patterns were liked significantly more (37.9%) than sharp-angles ones (24.8%) and the same happened with letters with curved contours over their sharp-angled counterparts. Additionally, authors did not find significant differences in the response time of curved and sharp contour objects, dethroning the hypothesis of preferred objects being explained by perceptual fluency, as being processed more readily, or by a gestalt-like good continuity. Finally, result data show an overall preference for real objects when in comparison with meaningless patterns, regardless of the contour type, supporting the studies main hypothesis.

Although, based on the short period of time that each stimuli was presented and the average time of the like/dislike answers, both in the scale of milliseconds, aiming towards more unconscious than conscious answers, not all curved items were preferred over sharp-angle ones. People disliked some curved objects (e.g. snake) and liked some sharp objects (e.g. chocolate bar), most probably due to the strong affective valence associated with these kinds of objects. This thesis is corroborated by the fact that real objects, passible of having a familiarity, "mere-exposure" effect associated, were preferred over meaningless, novel patterns (Zajonc 1968). On another hand, and at a different scale, even objects as harmless as a watch were preferred in their curved version over their sharp version, conducting to the known hypothesis that a negative bias towards a visual stimuli can be induced not only by their semantic meaning, but also by their low-level perceptual properties. Much in the same way of earlier studies, namely on "human facial expressions and interpretation of movement, that suggested that sharp primitive elements (e.g. a V-shaped corner) convey threat and round primitives convey 'warmth'" (Bar and Neta 2006, p.647), the authors investigated if sharp-angled items might be a target of low preference, due to the feeling of threat that they communicate. Their results support the hypothesis that "preferences can be driven by a threatening impression conveyed by contour, and furthermore that such preferences are influenced by the sharp angles themselves, rather than by the mere straightness of the contour" (Bar and Neta 2006, p.647).

Bar and Neta conclude their study stating that basic features, such as the 'baby schema' effect, may affect people's attitudes towards the environment and that, although people may be aware of the perceptual features of a stimulus, they are not necessary aware of how such features influence their impressions, since many first impressions are determined within a nonconscious state. "By giving a high priority to the processing of threat-specific physical primitives, possibly using rapidly available low-level sensory information (Bar, 2003), the human cortex might be designed for detecting such features quickly" (ibidem, p. 648).

Amygdala's activation through curved and sharp-angled real objects and novel patterns counterparts using low and high space frequencies and fMRI brain scanning technology. Bar and Neta 2007

In 2007, Bar and Neta presented a following scientific publication in which they demonstrate the hypothesis that sharp-angle elements trigger a brain spotted threat sense.

Here the authors raised two fundamental questions: (i) "What are the basic visual cues that determine our preference towards mundane everyday objects?" and (ii) "what is the origin of this bias for preferring objects with curved visual elements significantly more than objects with sharp-angled elements?"

They hypothesised that this bias for preference was a result of an elevated level of arousal triggered by sharp-angled features, and that such arousal was directly associated with threat and danger feelings, with origin in the bilateral brain amygdala. In the study, conditions of curved and sharp-angled items were presented to participants. Like the prior 2006 experiments, the authors considered multiple conditions: (i) pairs of real everyday objects, consisted of a primarily sharp-angle contour and its curved corresponding features counterpart; (ii) novel meaningless patterns divided in the same way; and (iii) control baseline objects containing mixed sharp and curved features. Since the amygdala has previously been implicated in process information related to fear and arousal, functional magnetic resonance imaging (fMRI) was used in order to detect and record the effects of such three conditions on the amygdala. Furthermore, since humans extract quicker low spatial frequencies (LSF) of an image than its high spatial frequencies (HSF) and LSF have shown to modulate the amygdala response in fear-related situations, they hypothesised that the contour-based preference formation is mediated by LSF rather than by HSF. Such hypothesis was tested in their Experiment 2, predicting that the preference of curved objects over sharp-angled ones would be stronger when viewing LSF of an image rather than their HSF version. In turn, Experiment 3 tried to show evidences that support the hypothesis that the perception of sharp-angled contour triggers threat sensations. The results of all three experiments, supported the hypothesis that people tend to like less sharp elements when in comparison with its curved version, due to the perception of potential threat triggered by the former.

Experiment 1 counted with 140 pairs of real objects, 140 pairs of meaningless patterns and 80 control objects performing a total of 140 sharp angled items, 140 curved items and 80 mixed sharp and curved real objects. Much like the 2006 experiments, all items were presented in grey scale colours over a grey background. When viewing these stimuli, 16 healthy participants, among which 8 were female and 8 were male, were asked to take a forced like/dislike decision based on the question "Do you get a good (like) or bad (dislike) feeling from this image?" Images were showed for 85ms and participants had 1915ms to give the feeling answer.

Results showed that participants "liked the curved objects significantly more than the control objects and liked the sharp-angled objects significantly less than the control objects" (Bar and Neta 2007, p.2193), conducting in this way to an overall significantly preference for curved objects over sharp-angled ones. Additionally, "preference for real objects was significantly higher than for novel patterns, regardless of the contour type" (idem) pointing, as the previous experiments, to a familiarity/"mere exposure" effect on the real everyday objects able to act on bias and preference levels. These results are also supported by the fMRI scan of both left and right hemisphere amygdala, regardless of the participant's gender. In both of them the authors found significantly greater activation for objects with sharp contours rather than for objects with curved contours, as well as when real objects and novel patterns were considered. Overall results point to the more and more probable fact that "sharp-angled objects are liked less because of an increased perception of threat convey, consciously or not even for visual stimuli whose semantic meaning is emotionally neutral" (ibidem, p.2194).

Due to the fact that there were two variables able to trigger the amygdala activation, "mere liking" (a continuous variable) and "contour" (a discrete variable), such factors were a target of further study. Results showed that, when comparing each participant's like with dislike responses, no significant difference was found in the amygdala signal change percentage, but when comparing each participant's sharp and curved contour, a significant difference in such signal was found, demonstrating that the threat arousal triggered by the amygdala's response, increased for sharp-angled stimuli due to its intrinsic sharp features, and not because of the liking percentage. Beyond the amygdala, several other brain regions were activated mainly when sharp-angled objects, rather than their curved contour counterparts, were perceived.

Experiment 2 tried to demonstrate the study's second hypothesis (that contour-based preference formation would rely more on the LSF of an image rather than on its HSF version), expecting a significantly stronger preference bias for curved over sharp-angled objects when participants viewed LSF of the images rather than their corresponding HSF versions. The layout of the experiment was similar to Experiment 1, except for the fact that novel patterns were excluded from the stimuli sample and 32 instead of 16 participants were recruited. From these, 16 participants viewed the LSFs at 10 cycles per image (CPI) and the other 16, the corresponding HSF versions at 24 CPI. This experiment results support the ones found from the previous

Experiment 1. “The bias in preference for curved objects over sharp objects was significantly greater for the LSF version of the objects than the HSF version” demonstrating that “the bias in preference against the sharp-angled objects is more readily influenced by the information conveyed by the LSFs of an image (…) therefore, the rapidly extracted LSFs of an image seem to play a dominant role in shaping our contour-based visual preferences” (ibidem, p.2197).

Experiment 3 was conducted in order to find a correlation between the contour type and the actual perception of threat. This experiment counted with two different groups of eleven participants each, one of which would view the same images of Experiment 1 during 85 ms, while the other would view the same images but with an exposure of 150 ms. Instead of Experiment 1 and 2’s required ‘like’ or ‘dislike’ answers, all participants were asked to respond ‘threatening’ and ‘non-threatening’ for each item.

The results of this last experiment showed that in both groups, sharp-angled objects were rated as significantly more threatening than their rounded counterpart versions. However, in the 85 ms group, control objects were rated as more threatening than curved and sharp-angled objects and, in the 150 ms group, control objects were still rated as more threatening than the curved objects but not more than sharp-angled ones. These last results do not, however, invalidate the fact that sharp-angled contour objects are perceived as relatively more threatening than their curved pairs and support the proposal that amygdala activation, and the consequent effect on liking, results from the threat conveyed by contour elements, namely those with sharp-angled features.

Overall, after this study’s three experiments, Bar and Neta’s findings indicate that humans like neutral semantic meaning objects and novel patterns more than their curved versions. Additionally, these same results can be applied when threat-based instead of like-based responses are considered, linking this feeling with sharp-angled feature objects. fMRI analysis on the brain’s amygdala support these same results. On another hand, the authors demonstrated that LSF versions of an image are more rapidly detected by our brains, simplifying the identification of potential dangers from sharp-angled features. Generally, these findings support the initial proposal that “objects may be perceived as threatening based on the nature of their contour” (ibidem, p.2200).

Expertise and aesthetic preference for curved and angular balanced geometric controlled arrays and asymmetrical random polygons. Silvia and Barona 2009

In their 2009 study, Paul Silvia and Christopher Barona try to understand if "people prefer curved lines, shapes and objects over angular lines, shapes and objects" (Silvia and Barona 2009, p.1). The authors conducted two experiments with the objective to examine whether angularity affects preference. This study's main goal was to understand the effects of angularity when confounded with features such as symmetry and typicality. Additionally, they studied whether expertise (in arts) was able to moderate the effects of angularity.

Silvia and Barona start by making a brief introduction to the low-level features that, integrated in the psychology of art, are able to influence aesthetic perception and preference. In this section they give special attention to angularity and aesthetic preference, focusing on early 20th century studies and experiments on this topic (also addressed in this document), namely those conducted by Gordon (1909), Lundholm (1921), Poffenberger and Barrows (1924) and Hevner (1935). Moreover, they make reference to the overall human preference for objects with curved contour over those with sharp-angled ones and associate such fact with the effect that angularity exercises on the activation of the amygdala due to the sense of threat that it conveys and analyse mainly the core variables of typicality, symmetry and the level of expertise in arts, able to interfere with aesthetic judgment.

In Experiment 1, Silvia and Barona tested the angularity effects on preference when variables as symmetry and balance were controlled. The stimuli consisted of circles and hexagons and had four appealing features for examining angularity and preference: First, circles have rounded forms and hexagons are angular; second, both circles and hexagon are symmetrical along their vertical, horizontal and diagonal axis, although circles are also symmetrical in all other diametrical axis; third, the degree of balance in the array can be evaluated, controlling such variable and; fourth, typicality was also controlled by including an equal number of circles and hexagons at each level of balance. The design of this study was a 2 (angularity: circles, hexagons) x 3 (level of imbalance: low, medium, high) design with both variables manipulated within subjects. The level of expertise or artistic training was taken into account as a continuous between-person quasi-dependent variable.

This study counted with a total of 40 students (35 female and 5 male) enrolled in General Psychology. Participants were asked to view a series of images and rate them individually, from 1 (not at all pleasing) to 9 (very pleasing) according to how much they liked each image, through the question 'How pleasing is this picture?' 18 images from Wilson and Chatterjee's (2005), where presented. Preference for Balance Test. From these 18 pictures, 9 were of arrays of circles and the remaining 9, of arrays of hexagons. Each of the two sets of 9 images had three levels of imbalance (low, medium and high), making each level to have three images. After the experiment per se, participants were asked to complete a brief questionnaire, where their level of expertise in the arts was questioned and measured.

The multilevel analyses of this experiment are consistent with past research and showed a significant within-person effect of angularity, on preference. Overall, people found the circle, rounded shapes more pleasing than the hexagon, sharp ones. On another hand, imbalance didn't affect preference and the interaction of angularity and imbalance was not significant. On the contrary, the level of the test-subjects' expertise on arts did affect preference but differently to what was expected. People with low levels of expertise in arts, preferred the rounded shapes to the angular ones, and people with high levels of expertise preferred equally both circles and hexagons shapes.

Silvia and Barona conducted afterwards a second experiment where they have "sought to replicate the effects of angularity and expertise on preference" (ibidem, p.8). In this experiment they used black-and-white asymmetrical polygons as stimuli. All polygons were randomly generated with sharp angles, half of which were later digitally rounded.

All 41 eligible participants (25 female and 16 male), undergraduate students enrolled in General Psychology, completed a self-report able to measure their level of expertise in arts according to Smith and Smith (2006) aesthetic fluency scale. Participants were divided in groups ranging from 2 to 8, before viewing a set of 12 random polygons for a not limited period of time. They were then asked to evaluate the balanced set of angular and rounded polygons accordingly to pleasantness and complexity, in a scale from 1 to 7.

The results of this second experiment showed that angularity significantly affected preference, with people preferring rounded polygons to the angular ones, and expertise predicted preference since participants with high fluency levels liked the polygons more often. Expertise has also moderated the effect of angularity on preference, although marginally and with different result from experiment 1. In this case, participants with low levels of expertise in art preferred equally rounded and angular polygons and those with high levels of expertise in arts preferred rounded to sharp polygons. These results show then that the role of expertise in arts, “was not straightforward” (ididem, p.12).

In this study, Silvia and Barona examined angularity, “an old variable in the history of psychological aesthetics. This was consistent with historical and contemporary research [they] found strong support for an overall effect of angularity” on preference (idem), when both regular and irregular shapes and imbalance and complexity variables were considered. However, due to the variance and inconsistency that some secondary variables trigger on the preference for angular and rounded shapes, they wind up with the interesting following statement: “All told, there is some scientific comfort in knowing that angularity, one of the oldest variables in the psychophysical study of aesthetics (Gordon 1909), remains vexing and intriguing” (ibidem, p.13).Curvature and appreciation of exterior car models. Carbon 2010

According to Carbon (2010), “humankind is on a long journey to fundamental, universal and stable properties of beauty and the associated psychological concepts of liking and appreciation of and preference for objects with such properties” (Carbon 2010, p.233). Towards this statement, the author emphasizes the importance of Gustav Fechner as probably “the first to approach this topic in his famous [and previously addressed in this document] ‘‘Vorschule der Ästhetik” (1876) within a psychophysical context by systematically analyzing the physical properties of simple stimuli and aesthetic appreciation” (idem), namely through pioneering researches on proportion, namely the golden section, whose preference was later unveiled as originating from familiarization effects” (idem).

However, although the preference of humans for curved forms is quite demonstrated, Carbon questions if such preference is applicable to all domains and times, especially when we consider artificial, human-made objects, case in which it is uncertain if their processing follows evolutionary-shape programs or alternative rules (ibidem, p.234). Carbon fundaments the discrepancy that may exist in the preference and processing of natural and artificial objects or forms with three straight examples: Matting purposes, prototypicality and personal taste and fashion. First, "there are certain natural properties that are strongly preferred, if they have angular contours or sharp attributes" (idem), for instance when it is considered the choice for a potential partner of the opposite sex; second, according to the prototype and fluency theories (idem), the "angular forms that naturally emerge as a result of the production processes" (idem), often sharp-angled shaped to fit assembling and optimization purposes (e.g. furniture, architectural elements), "should be preferred, regardless of its specific appearance (idem) due to their prototypical properties and; third, since "in a historic context it is quite clear that humans have changed their preferences towards specific outward appearances within many different classes of objects (…) personal taste accounts for part of this effect, but fashion has an even stronger impact" (idem). The geometric and symmetric lines used in the baroque gardens that later felt in disuse may be an example of the latter (idem).

In his experimental study, Carbon investigates long-term dynamics of design properties. He conducted four main experiments in which he used grayscale photographs of car exteriors of six major car brands (Audi, BMW, Ford, Opel, Mercedes-Benz and Volkswagen) and classes, produced continuously in Germany over a span time of 50 years, from 1950 to 1999 (ibidem, p.235), a period in which "the degree of curvature changed dramatically" (ibidem, p.237) from very curved in the 1950s and 1960s, to ultra-angular in the 1970s and 1980s and back to a pronounced curved form in the late 1990s (idem). In all main experiments, participants were asked to rate the 60 stimuli (6 brands x 10 lustra) on 7-point-Likert scales (from '1': "very weak", up to '7': "very strong"), according to how much they liked them, controlling key "variables for design appreciation, such as curvature, complexity, quality, innovativeness and security" (ibidem, p.234). In Experiment 1 participants were not provided with specific information about the historic context of the stimuli (ibidem, p.242). In Experiment 2, to control Zeitgeist-dependent effects (ibidem, p.234), participants were provided with historic information about the era (lustrum) of the presented stimuli (presented in blocks/lustrum, with all the models/lustrum randomized within each block and the blocks/lustrum across participants), and “instructed to act as if they perceived the cars from the historic perspective” (ibidem, p.237). In Experiments 3 and 4 the author added prior adaptation paradigms known to be able to change long-term representations and liking (ibidem, p.234), with the purpose to identify potential and plausible cognitive mechanisms of preference change underlying, again, Zeitgeist-dependent appreciation effects (ibidem, pp.234/42), through the use of highly innovative, futuristic car concept designs in the former experiment and angular design concepts from the 1970s to 1990s in the latter experiment (two images of twelve cars in each stage). Still in reference to these last two main experiments, Experiment 3 was realized as a direct control for Experiment 1 “to reveal the potential cognitive mechanisms underlying dynamic changes in preference” (ibidem, p.238) and Experiment 4 was used as an extension of Experiment 3 “to gain deeper insights into the adaptability of aesthetic appreciation” (ibidem, p.239). Experiment 1 counted with 38 participants, from 18 to 37 years old (32 female), Experiment 2, with 40 participants, from 18 to 28 years old (31 female) and Experiment 3 and 4, with 38 participants, each from 19 to 28 and 19 to 60 years old, respectively (30 female each).

The results of Experiment 1 shows an overall u-shaped trend across all the variables of design appreciation (liking, curvature, complexity, quality, innovativeness and safety) and the presented stimuli, “with maximum curvature ratings for the first (1950–1955) and last lustrum (1995–1999) and with a minimum around the period of 1970–1980” (ibidem, p.236). The conducted analyses “demonstrated the close relationship between curvature and liking across different brands” (idem) with curvature being the best predictor for liking (ibidem, p.242). The results of Experiment 2 shows again a u-shaped distribution across mean evaluations and brands (ibidem, p.237). However, the additional given information on the models’ era turned out to exercise effect on the participants’ ratings, showing a reduction of the relationship between curvature and liking, with innovativeness standing out to be the major predictor for liking, as already seen in previous studies (ibidem, p.238). As happened in the results of Experiment 2, the results of experiment 3 have also shown to be influenced by the applied methodology. In this sense, the introduction of highly innovative and futuristic car design adaptive stimuli, showed a decrease of liking and innovation ratings in respect to those verified in Experiment 1, for the same more recent lustra, demonstrating changes in preference. Curvature was, nevertheless and once again, the most important predictor for liking (ibidem, p.239). Finally, the results of Experiment 4, in which an adaptation was made towards angular stimuli, show also an effect on preference and that, contrarily to what was observe in Experiment 1 and 3 and much like in Experiment 2, innovativeness was the best predictor for liking (ibidem, p.242).

Carbon concludes that "according to evolutionary psychology, people prefer curved objects" (ibidem, p.233). However, the author provides "evidence that preferences for curved objects might be biologically motivated, but can also be, at least partly, modulated by fashion, trends or Zeitgeist [and taste] effects" (ibidem, p.233/42). In this way, people may reject at first sight new and unusual (mainly artificial) designs, due to the fact that they are not in concordance with our 'visual habits' but, after a period of adaptation and, if they don't convey a potential direct sense of threat, we increase the rate of "mere-exposure" and, thus, also liking (ibidem, p.243). In respect to this, Carbon and Leder (2005) developed a simple 'repeated evaluation technique' (RET) that simulates everyday phenomena and helps people getting familiar with new material (idem). Results using this technique show that participants typically reject innovative designs in favor of familiar, more conservative ones before the RET but, this evaluation pattern reverses after being exposed to this technique. "Thus, the RET can trigger dynamics of aesthetic appreciation and can demonstrate changes in taste within a very short period of time as proved by behavioral as well as psychophysiological measures" (idem). On another hand, according to the Most Advanced Yet Acceptable (MAYA) design principle, people prefer novel, innovative designs as long as the change from familiar ones is not abrupt (ibidem, p.234). We should not then totally discard that, in specific scenarios, certain angular forms may also be an object of preference. "General preferences for visual objects might be based on evolutionary-shaped processes, such as heuristics that tell us where more or less danger is to be expected. Angular forms might provide such cues for danger, but angular forms might also increase our arousal, which could trigger appreciation (Berlyne 1974). (…) Considering all the aforementioned facts, although humans might generally be pre-shaped by evolution to prefer specific properties preventing them from danger, they are specifically shaped to explore innovative and challenging properties" (Carbon 2010, p.243).

Preference for neutral, positive and negative emotional valence stimuli.

Leder, et al. 2011

Leder, et al. conducted an experimental study on the preference for shapes and forms to give an answer to a gap left opened by previous ones in the search for knowledge on this topic: the fact that such experimental studies take under consideration mainly shapes and forms neutral in emotional valence. In this way, these authors propose to address this subject taking into account visual stimuli with neutral but also positive and negative emotional valence, the former two associated with semantically non-threatening information and the latter with potential threatening semantic cues.

In the introduction to the exposition of the experimental study, Leder, et al. make reference to a series of knowledge and variables, mostly already addressed in this document, namely, the importance of contour in the definition on how an object is perceived, that people tend to prefer symmetrical rather than asymmetrical, complex rather than simple ("often, but not always") (Leder, et al. 2011, p.649) and larger rather than small stimuli. Additionally, accordingly with Bar and Neta (2006, 2007 and 2008), they associate the preference for curved rather than for sharp-angled shapes and forms with the potential sense of threat and greater activation of the amygdala they produced, "an area of the brain linked to the fear response and general arousal" (ibidem, p. 650).

Moreover, the authors associate such levels of preference with factors such as fashion and previous experiences but also as a basic visual primitive associated with responsive mechanisms (e.g. fight or flight), which have been subjected to adaptive refinement during the course of human evolutionary history and hence, an evolutionary based function.

To better understand this topic of the preference for curvature, Leder, et al. conducted two experiments: one that counted with neutral valence stimuli and another in which they use stimuli with positive and negative valences.

In Experiment 1, the one that counted with neutral emotional valence stimuli, 37 young adults psychology students (24 of which were female) viewed three sets of stimuli neutral in emotional valence and used previously in Bar and Neta's 2006 and 2007 experimental studies. The stimuli were presented in greyscale on a grey background based on the parameters previously used by the same referenced authors (2006). Participants were asked to answer to the stimuli according to a dichotonic 'like and 'dislike' response, using two buttons on the keyboard. Its results were calculated according to the proportion of 'like' to the total number of responses. The results have confirmed those achieved by Bar and Neta (2006 and 2007) and Silvia and Barona (2009). Curved objects were liked more than their sharp correspondent counterparts, for both real-objects and abstract patterns variants.

As said, Experiment 2 counted with positive and negative valence stimuli. In this study participants were the same of Experiment 1, and were asked to see and evaluate twenty pairs of real objects with positive valence and twenty pairs of real object with negative valence, each pair consisting of a round and a sharp version, in three different blocks and phases according to 'like'/'dislike', 'pleasant'/'unpleasant' and 'calm'/'exciting' answers. General results show that contour features are able to modulate preference when neutral or positive valence are considered but not when the object has a negative valence associated, case in which semantics superimposes the object's basic visual geometric characteristics. In the first case, participants liked more the rounded version of objects rather than their sharp corresponding counterparts. However, contour-based liking bias was not found in the second case of negative valence.

Haptic evaluation of 3D curved and angular forms based on complexity and shape. Jakesch and Carbon 2011

Jakesch and Carbon (2011) work, had the goal to introduce[63] touch in the aesthetic appreciation of curved and sharp-angled 3D forms, focusing in low-level features like

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[63] "... eventhough multisensory evaluation strategies are used e.g. in the product design area to measure preferences" (Jakesch and Carbon 2011)

their shape (sharp-angled/curved) and complexity (low/high). The authors designed tridimensional virtual models of curved and sharp-angled forms and printed them so that they would be suitable for haptic appreciation. Altogether, with the purpose to balance and control complexity and shape factors, twenty forms were created: five objects with high complexity level and five others with low complexity level for both curved and sharp-angled conditions.

The authors conducted two main experiments that mainly differ in their judgement response method. In Experiment 1, 26 participants (21 female and 5 male) explored all stimuli in random order and were then asked to rate them according to a force-choice like/dislike response. On another hand, in Experiment 2, the same number of 26 participants (25 female and 1 male) rated the stimuli in a 7-point scale after exploring the set of stimuli in random order. The authors conducted a third control experiment mainly to understand the relationship between liking and the perception of threat. In this experiment, 10 persons (4 female and 6 male) were asked to rate liking (criterion), curvature, roundness, sharpness, complexity, comfort and threat (predictors), in a 7-point scale.

The results on these experiments show that, overall, participants preferred the curved forms significantly more than their sharp-angles correspondent counterparts. Even though complexity effects were not found in Experiment 1, the more differentiated Experiment 2's scale, unveiled modulating effects of complexity. Experiment 3 results also point to curvature to be the best predictor for liking. The authors suggest that, contrarily to what was advanced by Bar and Neta (2007), "threat might not be the driving force in judging meaningless unfamiliar objects" (Jakesch and Carbon 2011).

Preference for rounded and angular product containers and graphics designs. Westerman, et al. 2012

In 2012, Westerman, et al. conducted an study through two experiments to test "whether a general relative preference for objects with rounded rather than angular form can be applied in the context of the design of consumer products". In these experiments they used images of products packages (chocolate – Experiment 1; water and bleach bottles – Experiment 2), whose shape was manipulated at both contour and graphics level. Results show that the participants preferred rounded designs and that these were more likely to be a target of purchase.[64]

4.3. State-of-the-Art of the Preference for Interior Architecture Environment Form with Distinct Geometric Characteristics[65]

While previous addressed experimental studies focused on the general topic of the preference for lines, shapes and forms, the following three experimental studies, the last ones that we will extensively address to, discuss the preference for forms in the particular topic of interior architecture environments.

Emotional responses as pleasure and approach behaviour towards furniture and interior architecture environment form. Dazkir and Read 2011

As far as we know, Dazkir and Read (2011) conducted the first[66] experimental study on the preference for form within interior architecture environments. More specifically, these authors have studied how curvilinear and rectilinear based furniture forms in interior environments, influence our emotional state and response.

In their study, Dazkir and Read have tested the 'pleasure' and 'approach' reactions of 111 undergraduate participants, towards four computer-generated, variable-controlled room interiors: two rooms equipped exclusively with curved, rounded furniture and two others with only straight-edge and sharp-angled furniture, arranged in two

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[64] Contact with this paper was limited due to the fact the candidate was only able to access its abstract, found at the 'Wiley Online Library' in https://onlinelibrary.wiley.com

[65] Introductory note: This section specifically addresses, within the topic of the preference for elements and the preference for architecture space form with distinct geometric characteristics.

[66] The paper with oldest publication data that the candidate was able to find during his state-of-the-art review, including other papers references' review.

different layouts (Dazkir and Read 2011 and Jarrett 2011[67]). The participants were asked to rate each of the rooms throughout an online survey in accordance to "how each one made them feel in terms of pleasure (e.g. how happy, hopeful) and approach (how much time they'd like to spend in the room; how sociable the room made them feel)" (Jarrett 2011). The results show that, although students have overall "rated the rooms negatively because they found them boring" (idem), probably due to their neutral, controlled environment, the rooms with curvilinear furniture features received significantly more 'pleasure' ratings than those with rectilinear ones, eliciting "higher amounts of pleasant-unrousing emotions (such as felling relaxed, peaceful and calm)" (Dazkir and Read 2011). The results on the approach reaction show that the participants have desired to approach the rooms with curvilinear furniture more than the rectilinear versions (idem).

According to Jarrett (2011), the results of this study are just preliminary and require further research to control cross-cultural sample, given that, although not rated as more pleasant and approachable, "rectilinear-themed rooms may have their own benefits for purposes other than relaxing and socialising" (Jarret 2011). Jarret end its review on Dazkir and Read paper pointing out that these results may guide designers to create "more welcoming and pleasant environments with the use of curvilinear lines" (idem)[68].

The Impact of contour on aesthetic judgement and approach-avoidance decisions in architecture. Affective complex level architecture photographs measured with fMRI technology. Vartanian, et al. 2013

One of the things that immediately stood out in this paper, directly related with this thesis, was the authors' statement that "some architects might be skeptical about the extent to which empirical data gathered by behavioural scientists, can be used to

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[67] Jarrett 2011. Why you should fill your rooms with rounded, curvy furniture. Found at 'Research Digest' published by 'The British Psychological Society' in https://digest.bps.org.uk

[68] Contact with this paper was limited due to the fact the candidate was only able to access its abstract, found at 'SAGE Journals' in http://journals.sagepub.com

optimize the planning, designing and building of spaces. This study represents an attempt to overcome these methodological and principal/philosophical constrains by establishing an empirical driven dialogue between architecture and psychology" (Vartanian, et al 2013, p.10446), in this case, via neuroscience. This was the main purpose of the current thesis, from its very beginning, with the obvious inherent limitations of a one-man individual work.

To better understand the subject of architecture and contribute to its development and gathered knowledge, the authors propose to examine the impact and affective response of interior architecture spaces with curvilinear and rectilinear contour features on human behaviour and neural activities.

To do so, considering behaviour, Vartanian, et al. have focused on the participants' aesthetic judgements and approach-avoidance decisions for two reasons: "Both outcomes are of interest to architects and users of spaces alike" and "from and evolutionary perspective, there is reason to believe that the environment signals that give rise to aesthetic judgement might be borne out of those that regulate biologically more fundamental behaviours, such as approach-avoidance decisions" (ibidem, p.10447), an idea that is based "on what the geologist Jay Appleton called 'habitat theory', according to which, the aesthetic satisfaction one derives from contemplating a natural landscape is proportional to the extent to which its physical features signal environmental conditions favourable or unfavourable to survival" (idem).

At a neurobiological level, literature on neuroaesthetics show that "aesthetic judgements activate a distributed neural network, including the brain's reward and affective circuitry" and "based on the results of the largest met-analysis of neuroimaging studies of aesthetic appraisal to date (2013), Brown, et al. defined a 'core circuit for aesthetic processing'" (idem) that, "not unlike what has been proposed for the experience of core affect in emotion" (idem), include four structures: orbitofrontal cortex, basal ganglia, anterior insula and cingulate cortex. Regarding approach-avoidance decisions, "approach motivations are lateralized predominantly to the left hemisphere" (ibidem, p. 10448) and "electrical stimulation of brain regions that receive projections from midbrain dopamine neurons – including the nucleus accumbens as well as mesial prefrontal cortex – elicit approach behavior" (idem), "whereas avoidance emotions are lateralized predominantly in the right hemisphere" (idem) and "electrical stimulation of the anterior insula and basolateral amygdala elicits avoidance behavior" (idem).

The experimental study counted with 18 (12 female and 6 male) participants that viewed 200 photographs of interior spaces with variations at contour level, half of which consisted in rectilinear spaces and the other half in curvilinear spaces, in an fMRI scanner for 3,000 ms. Aside from contour, two other variables where analysed: Ceiling height and openness. The study took place in two runs: a beauty judgment run, in which participants were instructed to respond "beautiful" or "not beautiful" to the stimuli, and an approach-avoidance decision run, in which participants were instructed to respond "enter" or "exit" to the same stimuli. After the experiment with access to fMRI, participants were asked to rate the stimuli that they had previously seen according to pleasantness and beauty on a 5 point scale.

In accordance with the findings of previous studies on the preference for shapes and forms, regarding behaviour, the authors hypothesized that architecture spaces with curvilinear contour features would elicit more "beautiful" and "enter" judgements than the stimuli with rectilinear features, in both beauty and approach-avoidance decisions runs, respectively. By turn, regarding neural activity the authors hypothesized that curvilinear spaces would "activate structures coextensive with the brain's reward and emotions network" (idem), and that the perception of rectilinear based spaces and the reverse contrast (i.e. rectilinear-curvilinear) would activate the amygdala, "suggesting that sharpness might serve as an early warning signal for potential danger". On another hand, regarding approach-avoidance decisions, the authors hypothesized that curvilinear environments would activate "networks associated with approach motivations or regions implicated in motor imagery or execution" (idem), when compared with the viewing of rectilinear spaces and the reverse contrast (i.e. rectilinear-curvilinear) "would activate networks associated with avoidance motivation" (idem).

As expected, regarding behaviour, participants liked more architecture environments with curvilinear rather than rectilinear contour. However, this independent variable variation, didn't affect approach-avoidance decisions judgments. On another hand, pleasantness was a significant predictor of beauty judgment in both inside and outside scanner beauty judgements, and a significant predictor of approach-avoidance decisions (inside the scanner). Neuroanatomically, curvilinear contour stimuli in the beauty run activated the anterior cingulate cortex exclusively, “a region strongly responsive to the reward properties and emotional valence of objects” (ibidem, p.10446). However, contrarily to what was expected, rectilinear stimuli didn’t activate the amygdala, probably due to a high exposure time, which may have contributed to the triggering of other cognitive processes. As to the approach-avoidance decision, although curvilinear spaces have shown to activate the visual cortex, there were not observed the predicted activations in brain areas known to be associated with voluntary motor movement and hence neither an intention of approaching nor of avoiding the presented curvilinear and rectilinear stimuli, could be seen. These results suggest that, at least considering aesthetic judgements, the effects of contour on preference of forms with distinct geometric characteristics achieved by previous experimental studies, may be extended to the subject of architecture.

Consumer preferences for curvilinear and orthogonal roof forms and straight or curved layouts, among others, in the design of airport passenger areas. van Oel and van de Berkhof 2013

This work is included in this state-of-the-art review, and was taken in consideration in this thesis experimental study, due to the fact that it addressed the evaluation of architecture spaces with curvilinear and rectilinear geometric characteristics, although not at an exclusivity level.

This study was held in order to better understand “how consumers value the design of passenger airport and retail areas” (van Oel and van de Berkhof 2013, p.2), in other words, to examine the passengers level of “satisfaction with the design of passenger areas and to investigate whether pleasure and arousal levels were affecting their satisfaction with the design of passenger areas” (idem). These authors have conducted an experimental study that counted with 346 Dutch and foreign passengers in the departure and transfer areas of the Amsterdam Airport Schiphol. It consisted of 72 multilevel images divided in two sets of 36 dual images. Although the authors have arrived to the conclusion that such 32 sets were the “optimal number of discrete choice sets of two images” (ibidem, p.11), they have considered this number to be “too much for one person to deal with" (idem) and, for this reason, "made three versions of the questionnaire with 12 discrete choice sets each" (idem) (24 in total).

They therefore investigated how design characteristics were valued by passengers using a questionnaire with visualizations of hypothetical passenger areas, and evaluated the influences of emotional states on the appreciation of these design characteristics. Participants "were asked to choose between [the] two images of a passenger area" (idem).

Such "discrete choice experiments were used to investigate passenger preferences for eight [architectural] design characteristics" (ibidem, p.1) according to their physical attractiveness, which was at turn related to approach or avoidance behaviour (ibidem, p.3): Exterior factors – (i) curvilinear and orthogonal roof forms; General interior factors – (ii) materialization (cold and warm), (iii) colours (light [white] and dark within their hue saturation and value dimensions) and (iv) light (cold and warm); Layout and design factors – (v) straight or curved layouts and (vi) dimensioning (narrow or wide) and; Point-of-purchase and decorating factors – (vii) greenery and (viii) the distinctiveness of Holland. Additionally, human factors were considered in a separate part of the questionnaire: Emotional response dimensions: (i) pleasure (evaluation) and (ii) arousal (excitement). Although also considered a human variable, dominance was left out of the study.

This study's results showed that, "in general, passengers preferred an area with a curvilinear roof, a curved hallway, the presence of greenery, no decoration emphasizing the distinctiveness of Holland, the use of warm lighting, a wide dimensioning and an emphasis on white materials" (ibidem, p.15). With respect to architecture geometric characteristics, participants preferred curvilinear forms to orthogonal ones (ibidem, p.14). Additionally, the results also showed that architectural design features like form, layout and dimension, namely curvilinear roofs and wide and curved hallways, were relatively strongly valued when compared to other examined features (idibem, p.17). By turn, curved layouts were also strongly valued when compared to dimension and other examined features, with exception of that of greenery (ibidem, p.14), a feature towards which passenger felt attracted to (ibidem, p.17) as it "adds a sense of comfort" (ibidem, p.16). Architectural design features like form, layout and dimension (curved rather than orthogonal or straight and wide rather than narrow) and greenery played an emphasized important role in the participant's choices.

4.4. Late-stage Collected References[69]

The previous scientific papers were extensively addressed due to the fact that they are important to the context of the preference for elements with distinct geometric characteristics at contour level and have exercised a significant role in the design, methodology, and achieved results of this thesis. In the course of a late-stage state-of-the-art revision, it came to our attention other contributions from the literature that directly address the subject of this thesis. Given the fact that it has been an active concern of the author to achieve a solid, well-documented work, we will next briefly address such update.

Bertamini, et al. (2015) and Friedenberg and Bertamini (2015) focus the preference for shapes on their vertices and concavities features, following Nadal, et al.'s (2010) previous study. Bertamini, et al. (2015) were particularly interested in the following factor: curved and angular shapes in within reach and outside reach of the peripersonal space. In their experimental study, they have conducted four experiments with curved and angular shapes to understand the relationship between curvature and articulation and complexity (Experiment 1), peripersonal space (Experiment 2), pleasantness (Experiment 3) and approach behaviour (Experiment 4) using abstract, irregular shapes (Experiments 1, 2 and 4) and patterns of lines (Experiment 3). Results of Experiment 1 have shown that people prefer curved shapes to angular ones but didn't associate the level of such preference with perceived complexity, although this is seen as an important factor to consider when addressing the preference for shapes (and forms). Results of Experiment 2 support the conclusion that people prefer curved shapes to angular ones but also showed that "such preference was not modulated by the location on the screen or by perceived distance (within reach or outside reach)" (Bertamini, et al. 2015, p.167). In Experiment 3 the abstract shape

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[69] Introductory note: In this section we will focus on late-stage literature review. Due to the fact that such literature on the preference for lines, shapes and forms was published after the design of this document's experimental study, the information here found did not exercised any influence in this study. However, since such literature came to our knowledge, we have opted to address it looking for the best interest of this document.

stimuli were replaced by sets of coloured lines: curved, angular and straight presented in squared and circled apertures. Results of this experiment show that “curvature is preferred over angularity even for simple elements such as lines” (ibidem, p.169) but associate this preference with curvature itself and not with the presence of angularity since “stimuli with angles were disliked as much as those with straight lines and no angles” (idem). This points to the hypothesis that “curves have a pleasant appearance” (idem) not dependent to their lack of angularity. By turn, Experiment 3’s hypothesis that angular shapes trigger an avoidance response was not verified. Overall, the experiments’ results suggest that curved shapes and lines are visually pleasant and not a product of a “negative response to angularity” (ibidem, p.175). The authors “conclude that the curvature effect is likely to be caused by intrinsic characteristics of the stimuli, rather than what they might signal” (idem) (e.g. a sense of threat).

In the same year (2015), Palumbo and Bertamini conducted another study, with very similar design and methodological characteristics, where they have tried to understand aesthetic preference for curved and angular shapes through “two alternative forced-choice response (like or dislike)” (Palumbo and Bertamini 2015, p.35) (Experiment 1), and the measurement of the liking and attractiveness that they elicit through rating scales (Experiments 2 and 3). Results on Experiment 1 “confirmed the well-established and systematic preference for curved shapes” (ibidem, p.42) and that participants liked more shapes with fewer vertices when in comparison with those with more vertices, suggesting that “preference for curvature is related to the amount of smoothness in the shape” (idem), and prefer stimuli with balanced or intermediate levels of complexity (idem). The results of Experiment 2 partially overlap those of Experiment 1. Participants have preferred curved shapes, shapes with less vertices and more concavities and shapes with intermediate levels of complexity. Results on Experiment 3 replicate those of Experiment 2. Participants found curved shapes and those with fewer vertices and more concavities to be more attractive. This suggests a connection between liking (a positive aesthetic judgement) and attractiveness (an approach behavior).

Gómez-Puerto, et al. (2016) paper is focused on the preference for curvature’s historical and conceptual framework. After exposing most of the state-of-the-art achievements and theories on this topic and a table listing the terminology used throughout the relevant literature references on curvature, they list a series of conclusions considered to be the most relevant within previous published research. This paper is concluded with statements defending the importance of studies on the preference for curvature, for its "aesthetic, psychological, evolutionary, and epistemological [also cultural] implications, but also because of its practical consequences" (Gómez-Puerto 2016, p.6).

Velasco, et al. (2016) developed an experimental study divided in four experiments in order to clarify the "exact nature of the relationship between curvature/symmetry and approach/avoidance motivation (Velasco, et al. p.1). The results of this study show that participants are more found to match more symmetrical shapes with approach words (Experiment 1), and symmetry was significantly higher on the approach dimension than on asymmetry (Experiment 2). In two other experiments, they studied if an object's valence, curvature (Experiment 3) and symmetry (Experiment4) "would lead to different associations to approach and avoidance words" (idem). Results show that only valence "had a significant influence on the participants' ratings, with positively-valence objects being more closely associated with approach words than their negative-valence counterparts (idem), results that point to the complex relationship between the visual properties of objects, "their valence, and appetitive and aversive categories" (idem).[70]

In 2017, Cotter, et al. conducted an experimental study on the preference for curvature and angularity using irregular polygons (with three level of combination factors – number of vertices, range and curvature) and the regular polygons from the Preference for Balance Test (Wilson and Chatterjee 2005), the same used in Silvia and Barona's study (2009). The use of irregular polygons aimed to study the effects of curvature (and angularity) on meaningless shapes and the use of regular polygons on possible familiar ones. In this work they also measured potential individual differences able to interfere with the preference for shapes and curvature, namely: Art expertise and openness to experience (Cotter, at al. 2017, pp.5-8). Additionally, they analysed if curvature is able to affect the stimuli's viewing time and interest. Overall,

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[70] Contact with this paper was limited due to the fact the candidate was only able to access its abstract, found at 'Motivation and Emotion' in https://link.springer.com

results show that participants preferred curved over angular polygons. However, they found evidences that point to the fact that individual differences may influence the preference for curvature. On another hand, the preference for curvature was higher for participants with more knowledge in arts and more open to experience with irregular polygons but “was not evident for the arrays of circles and hexagons” (ibidem, p.1). The stimuli’s “viewing time was influenced by some classic predictors, such as complexity and imbalance” (ibidem, p.12) and “people spent more time viewing the angular shapes” (idem). Although it was expected, according to literature, that angular shapes could be seen as “more intriguing and interesting” (ibidem, p.12) than curved ones, they found no evidence pointing in that direction.

Blazhenkova and Kumar (2017) developed a study to systematically examine the correspondence between curved and angular shapes and sensory modalities (vision, audition, gustation, olfaction and tactile) and higher level attributes (emotions, gender and name). Participants were asked to match curved and angular abstract shapes to these sensory modalities and higher level attributes, which were presented as written labels in study 1, and real sensory experiences in study 2. The results demonstrated that the prevalent correspondences were non-arbitrary and robust across all the considered variables within both studies. “Participants associated curved shapes with sweet taste, quiet or calm sound, vanilla smell, green color, smooth texture, relieved emotion, female gender, and wide-vowel names. In contrast, they associated angular shapes with sour taste, loud or dynamic sound, spicy or citrus smell, red color, rough texture, excited or surprise emotion, male gender, and narrow-vowel names” (Blazhenkova and Kumar 2017). This research also “examine the relationship between the shape correspondences and individual differences in emotional processing, assessed by self-report and performance measures” (idem). The results on this second exam “suggest that emotional ability is associated with making shape attributions” (idem)[71].

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[71] Contact with this paper was limited due to the fact the candidate was only able to access its abstract, found at ‘SAGE Journals’ in http://journals.sagepub.com

4.5. Work Developed by the Candidate on the Topic of Architecture Space Form[72]

4.5.1. Professional and Academic Work[73]

During the recent years, the candidate developed relevant professional and academic work directly related with the topic of architectural form addressed by this thesis, namely: (i) the development, together with a multidisciplinary team, of Villa NURBS, a non-Euclidean based architecture project and building that used, in its processes, state-of-the-art architecture design and construction/production technologies and techniques; (ii) a study on the evolution of the representation in architecture, mainly focusing representation, visualization and construction/production methodologies, techniques and technologies; (iii) a pilot experimental study which aimed to detect and identify users' emotional arousal when in contact with virtual reality architecture spaces with specific root characteristics using semi-immersive and biometric sensing technology and; (iv) an experimental study which aimed to understand the emotion of fear that virtual reality architecture spaces with and without protection guards induce in users, through the use of hearth beat technology and a semi-immersive environment. In reference to point (i), a publication in the Portuguese architecture magazine 'Arquitectura e Vida', under the title 'Producing NURBS' (Carreiro and Sousa 2008), describes the technologies and techniques that were applied in the design and construction/production of Villa NURBS. Regarding items (ii), (iii) and (iv), material from the paper 'The Evolution of Representation in Architecture' (Carreiro and Pinto 2013) was included in Chapter 2. Other publications (Dias, et al. 2014 and 2015) will be briefly described given their relation with the topic and design

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[72] Introductory note: In this section we will address relevant work developed by the author, which, directly or indirectly, frames within the topics of this thesis. Furthermore, we will present an overview and taxonomy on the topic of the preference for lines, shapes and forms and, particularly, on interior architecture environment form.

[73] Introductory note: in this section we will address to the candidate's professional and academic work on the topics of this thesis.

and methodology of this thesis experimental study, on the preference for abstract architecture spaces with distinct geometric characteristics. Additionally, it´s worth mentioning, that partial results of such experimental study was submitted and accepted for publication in the proceedings of the of the 22nd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2017, under the title ‘Cognition and Evaluation of Architecture Environments Based on Geometric Contour References and Aesthetic Judgements’ and publicly presented *in loco* by the candidate.

We will next briefly address the scientific papers referred in points (iii) and (iv).

Evaluation of Architecture Spaces with distinct typology characteristics through the use of biometric sensing technology. Dias, et al. 2014.

In 2014, Dias, et al. developed a pilot experimental study with the main goal of improving architectural design by understanding the emotional response of potential inhabitants, regarding the designed environmental spaces (Dias, et al. 2014, p.2), by means of biometric sensory data analysis technology. The authors designed a set of architecture spaces with specific, distinct characteristics (an accelerated perspective space, a very narrow corridor, a decelerated perspective space, a very deep moat surrounded with several flights of stairs, a deep gap that users had to cross through a narrow board and two dead-end spaces), with the purpose to provoke limit reactions on those who experienced them (such as claustrophobia, relief, fear of heights, dizziness, surprise, disappointment or frustration). As the experiment’s participants went through the series of spaces, their physiological data was collected through electromyography (EMG) and electrodermal activity (EDA) biometric sensing technology, in search for emotional arousals that could point towards comfortable/positive or uncomfortable/negative sensations.

The whole VR environment was designed in a neutral greyscale tone and the authors used “an ambient abstract sound with very few variances and a constant rhythm, with the purpose to keeping the user focused on the experiment” (Dias, et al. 2014, p.4), mask distracting further sounds and also reinforcing the idea that the user was experiencing an abstract, yet reality aimed, virtual environment.

The study counted with 18 volunteers aged between 21 and 53 (6 male and 12 female), which experienced the VR architectural environment in a semi-immersive 3D environment, referred to as "PocketCAVE", through two methods of navigation: Free navigation for participants who had avatar control experience (4-axis navigation) and controlled navigation for those who didn't. The experimental stage was then followed by an after-experience self-questionnaire.

In the study, the authors raised one main and two secondary hypotheses:

- "Basic user sensations of "comfortable/positive" and "uncomfortable/negative" architecture spaces can be derived through objective measurements of biometric data (i.e., skin conductance, surface electromyography);
- "The navigation condition (free or controlled) will influence the participants' response to the environmental visual stimuli" and;
- "The participants' expertise in games will influence their response to the environ-mental visual stimuli" (ibidem, p.3).

The interpretation of the gathered user's physiological data shows consistent results for EDA measurements, pointing to the fact that the participants reacted differently to different spaces, being able to discriminate between 'positive' and 'negative' architecture spaces. These results support the primary raised hypothesis, demonstrating that "we can objectively discriminate arousal responses related to 'positive' or negative' emotions from neutral condition" (ibidem, p.10), in VR experiences of architecture spaces, using biometric data such as EDA. The data analysis of the self-questionnaire answers, shows that the decelerated perspective space was the one that arouse more positive sensations, followed by the accelerated perspective space and the bifurcation that led to the two dead-ends. The second dead-end, the one that participants faced after being already confronted with the other one, was the place that provoked more negative sensations, followed by the claustrophobic narrow corridor, the first dead-end, the narrow bridge and the stairway pit. On the contrary, EMG signals proved to be quite variable and require further research. Hypotheses 2 and 3 were not verified, showing that the author´s design did not introduce undesired artefacts in the experimental settings.

This study reached its initial main goal by being able to provide architects with basic information on how the spaces that they might design may interfere with people's emotional state (ibidem, p.1), particularly, with positive or negative emotions, contributing in this way to the design of better spaces for people.

Safety evaluation of Architecture Spaces with distinct 'construction barriers' through the use of biometric sensing technology. Dias, et al. 2015.

In 2015, Dias, et al. conducted another experimental study focused on how architecture spaces with certain design characteristics may influence a specific emotional state of its users': the fear of falling. This study was held with the purpose to create knowledge and, once again, provide architects with high-level information on the users' potential behaviors in space, contributing, in this way, to improved, user friendly, design solutions.

In this particular case, Dias, et al. have studied how senior people reacted to "construction barriers" (e.g. stairs and ramps) (Dias, et al. 2015, p.3), considering two experimental conditions, 'safe' and 'unsafe' (e.g. stairs and ramps with and without guards), and focusing on the single emotion of fear, more specifically, the fear of falling.

The authors designed a virtual reality environment, built to consider "the presence of stairs and ramps as architectural elements that could affect users´ physiological states and perception of fear of falling" (ibidem, p.1). This model was afterwards worked to fit the two experimental safety conditions. The result was two identical virtual models with the one exception that stairs and ramps didn't have protection guards in one of them and had in the other.

This study counted with the participation of 31 senior persons, aged between 66 and 91 years old, which were assigned to the two experimental conditions. They were then asked to navigate across the 'building' through a pre-defined walking-path, using stereoscopic, semi-immersive visualization technology (PocketCAVE). During this task, their heart rate was monitored through non-invasive sensors and collected for analysis, namely the comparison of biometric arousal levels among the different ‘building’ spaces. Aside from this objective instrument of data collection, after the VR experience, participants were asked to fulfill subjective self-questionnaires aimed to measure their self-sense of perception and presence (ibidem, p.5).

This study raised two hypotheses:

- “Facing selected architectural elements (i.e., stairs and ramps, with and without handrails), within the virtual environment, will trigger a physiological activation that can be measured by sensing the Heart Rate, that is significantly different from the same type of physiological data acquired from neutral parts (i.e., rooms), and that can be related to the emotion of "fear of falling" reported by Tiedemann, Sherrington and Lord (2007)” and;
- “The physiological activation based in Heart Rate and the fear and anxiety of falling reported by the participants, will be higher for insecure situations (i.e., when the architectural elements are presented without handrail/railings)” (ibidem, p. 3).

Additionally, to verify the hypotheses, the authors adopted a 2x6 mixed design experimental methodology:

- “A between-subject related to the secure factor (two experimental conditions called safe and unsafe conditions)” and;
- “A within-subject related to the architectural factor (six elements: neutral room, stairs, ramp descending, middle of ramp descending, ramp ascending and middle of ramp ascending)” (idem).

Results on the objective assessment for the analysis of the between-subject variable (safe/unsafe condition), doesn’t show statistically significant differences between conditions in the precise events of interest” (ibidem, p.8). On another hand, results for the analysis of the within-subjects variable (different architecture spaces), show very strong statistical significances in the reported measures, having been observed significant higher arousal “at the beginning of the stairs and at the middle of the ascending ramp in comparison to that observed in the neutral room” (idem).

Regarding the subjective assessment, results show “significant differences in fear of falling between the two conditions (…) with participants declaring less fear in architecture spaces with handrails (safe condition)” (ibidem, p.7) and thus, “more fear while interacting with the unsafe condition” (ibidem, p.1). This shows “that users recognize and point out stairs and ramps without handrails as being insecure places to be” (ibidem, p.7).

Overall, these results partially verified both hypotheses 1 and 2. Additionally, participants reported the same degree of presence in both conditions.

4.5.2. Overview and Taxonomy of the Preference for Elements and Interior Architecture Environment Form with Distinct Geometric Characteristics[74]

In the previous sections, we reviewed the literature on the preference for lines, shapes and forms, and for architecture space form with curvilinear and rectilinear (and also straight[75]) geometric characteristics at contour level.

From our analysis, we can conclude that most studies showed that the experiment’s participants prefer curvilinear based stimuli to rectilinear or straight based ones[76]. Due to the diverse nature of stimuli used in such experimental studies, we are able to

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[74] Introductory note: In this section we will structure the multi-level variables that, throughout the state-of-the-art literature review, we found to influence the preference for lines, shapes and forms with specific characteristics at a contour or geometric level, and highlight those that showed to be most relevant within the experimental studies on this topic. Additionally, we will present an extensive list of the identified variables and the references where they can be found.

[75] Leder and Carbon 2005 and Bertamini, et al. 2015.

[76] Lundholm 1921; Poffenberger and Barrows 1924; Hevner 1935; Kastl and Child 1968; Leder and Carbon 2005; Bar and Neta 2006; Bar and Neta 2007; Silvia and Barona 2009; Carbon 2010; Leder, et al. 2011; Dazir and Read 2012; Vartanian, et al. 2013; van Oel and van de Berkhof 2013; Bertamini, et al. 2015; Palumbo and Bertamini 2015; Velasco, et al.2016; Cotter at al. 2017; Carreiro, et al. 2017; Blazhenkova and Kumar 2017.

state that such preference does not applies to unique or restricted scope of the design elements' lines, shapes or forms but, on the contrary, it is valid to a large, almost universal context[77]. Among the diversity of the used stimuli we can find lines[78], typography characters [79], controlled geometric shapes [80], abstract shapes and meaningless patterns[81], everyday common objects[82], objects with strong emotional valence[83], car design[84], product's containers and graphics designs[85], peripersonal space[86], 3D physical objects[87], interior architecture environments[88] and abstract architecture environments[89]. In their essence, such stimuli belonged to two core categories: real, everyday-common objects and abstract, meaningless shapes and forms. While real, everyday objects are able to merge both low-level primitives, such as shape and complexity, and high-level features, such as emotional valence and

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[77] The preference for angular forms in the context of the choice for a potential partner of the opposite sex, is one identified exception. See Carbon 2010, p.234.

[78] Lundholm 1921; Poffenberger and Barrows 1924; Hevner 1935; Bertamini, et al. 2015.

[79] Kastl and Child 1968; Bar and Neta 2006.

[80] Silvia and Barona 2009; Cotter, et al. 2017.

[81] Hevner 1935; Bar and Neta 2006; Bar and Neta 2007; Silvia and Barona 2009; Leder, et al. 2011; Bertamini, et al. 2015; Palumbo and Bertamini 2015; Velasco, et al. 2016; Cotter at al. 2017; Blazhenkova and Kumar 2017.

[82] Bar and Neta 2006; Bar and Neta 2007; Leder, et al. 2011; Westerman, et al. 2012; Velasco, et al. 2016.

[83] Leder, et al. 2011; Velasco, et al. 2016.

[84] Leder and Carbon 2005 [interior]; Caron 2010 [exterior and also the evolution of curvature through time].

[85] Westerman, et al. 2012.

[86] Bertamini, et al. 2015.

[87] Jakesch and Carbon 2011.

[88] Dazir and Read 2012; Vatanian, et al. 2013; van Oel and van de Berkhof 2013.

[89] Carreiro, et al. 2017.

semantic meaning and familiarity, abstract, meaningless shapes and forms incorporate mainly low-level features. Everyday objects are them able to create a bridge between the stimuli and common, everyday phenomena but may also contribute to the creation of other undesirable associations able to interfere in their evaluation, due to their possible associated emotional valence and semantic meaning and familiarity. Abstract shapes and forms, may not contribute so directly to the creation of such bridge between perceived stimuli and familiar phenomena and are less plausible to enable the construction of further associations, than those communicated by their simple geometric shape or form.

In our review, we have also found, as expected, that there are a considerable amount of "variables" or factors, that the literature identify as being able to interfere and influence the preference for lines, shapes and forms with distinct geometric characteristics at contour level. These factors may vary from: (i) the 'object domain' – the stimuli or external phenomena, such as their design properties, together with the additional found property of density; (ii) the 'subject domain' – the human (or animal) dimension, such as the participants physical distinctive characteristics, their knowledge and expertise levels, culture, subjective judgments and natural biological responses; and (iii) the 'methodology domain' – the methods applied in the experimental studies, including the data collection methods, techniques and technologies. In the following sections we propose a taxonomy to classify the reviewed literature on the topics of this thesis.

Object Domain

In the 'object domain' we associate all variables that define and characterize the object of the study. This comprises the object's properties, namely, its (i) design and (ii) density. According to our review, the object's properties that we have identified to be more relevant, within this topic of the preference for lines, shapes and forms, are the object's geometric contour nature (curvilinear, rectilinear, and straight), its low-level features, in which shape and form and their level of complexity[90] are included, symmetry, balance and proportion. In experimental studies such as the ones that we have been addressing and the one that we have developed under this thesis, the properties of the object are reflected in the stimulus and are set as 'independent variables', since, they vary across our experimental conditions and influence measurements.

Subject Domain

In the 'subject domain' we include all the variables that speak about the individual. Such variables include the subject's characteristics at a (i) 'physical level', such as the participants' physical distinctive characteristics; (ii) 'expertise level', such as the participants' knowledge and culture, and (iii) 'psychological and neurological levels', such as the participants' subjective judgments and natural biological responses. According to our review, the 'subject's variables' that we have identified to be more relevant are, regarding the 'physical level', gender, age and dominant hand; for the 'expertise level', the "mere-exposure" effect (or familiarity), typicality (or prototypicality), emotional valence and semantic meaning, innovation and expertise, namely in arts, and concerning the 'psychological and neurological levels', aesthetic judgements and approach avoidance-decisions[91], brain activity, especially located in the amygdala, and the reward and affective circuitry, perception and cognitive fluency and basic evolutionary-response functions or mechanisms and behaviour.

In the context of experimental studies, the participants' physical distinctive characteristics and their expertise, knowledge and culture are usually set as 'extraneous variables', variables to keep under attention and control but whose variation is not likely to significantly interfere with the study's results (otherwise they would be set as 'independent variables'), their psychological and neurological

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[90] Often divided in three levels [low, medium or high] and comprising elements such as vertices and concavities.

[91] Aesthetic judgements and approach avoidance-decisions are aligned with the thesis sub-problems.

reactions are usually set as ‘dependent variables’, as their state, which is under measurement, depend on the ‘independent variables’.

Methodology Domain

Finally, the ‘methodology domain’ comprises the methods, techniques and technologies used in the design and execution of the experimental studies, including the presentation of the stimuli, measurements of the dependent variables and evaluation of the results. Again, according to our review, the methodology’s dependent variables that we have identified to be more relevant, are the force-choice dichotomic responses (like/dislike and beautiful/not beautiful, for aesthetic judgements, and enter/exit and attractive/not attractive, for approach-avoidance decisions), Likert-point-scales, self-questionnaires and the stimulus’ exposure time.

A Taxonomy of the Preference for Elements and Interior Architecture Environment Form with Distinct Geometric Characteristics

We have found a number of variables that influence the preference for lines, shapes and forms, hereafter listed in the following taxonomy.

Object domain variables

- **Stimuli**
  - **Lines** (Lundholm 1921; Poffenberger & Barrows 1924; Hevner 1935; Bertamini, et al. 2015 [also straight lines]. External reference: Salgado-Montejo, et al. 2015 as in Bertamini, et al. 2015, p.2)
  - **Typography characters** (Kastl & Child 1968; Bar & Neta 2006)
  - **Controlled geometric Shapes** (Silvia & Barona 2009; Cotter at al. 2017)
    - **Preference for balance test** (Silvia & Barona 2009; Cotter, et al. 2017. External references: Wilson & Chatterjee 2005 as in Silvia & Barona 2009, p.3 and Cotter, et al. 2017, p.5; Locher 2006 as in Silvia & Barona 2009, p.3)

    - **Abstract shapes and meaningless patterns** (Hevner 1935; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Leder, et al. 2011; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Velasco, et al. 2016; Cotter at al. 2017; Blazhenkova & Kumar 2017)
    - **Everyday common objects** (Bar & Neta 2006; Bar & Neta 2007; Leder, et al. 2011; Westerman, et al. 2012; Velasco, et al. 2016)
    - **Car design** (Leder & Carbon 2005; Carbon 2010)
    - **Objects with strong emotional valence** (Leder, et al. 2011; Velasco, et al. 2016)
    - **3D physical objects** (Jakesch & Carbon 2011)
    - **Product's graphics and container designs** (Westerman, et al. 2012)
    - **Peripersonal space** (Bertamini, et al. 2015)
    - **Interior architecture environments** (Dazir & Read 2012; Vartanian, et al. 2013; van Oel & van de Berkhof 2013)
    - **Abstract architecture environments** (Carreiro, et al. 2017)
- **Design properties**
    - **Geometric contour nature: curvature vs angularity (and straightness)** (Hogarth 1753; Gordon 1909; Lundholm 1921; Poffenberger & Barrows 1924; Hevner 1935; Kastl & Child 1968; Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Westerman, et al. 2012; Dazir & Read 2012; Vartanian, et al. 2013; van Oel & van de Berkhof 2013; Bertamini, et al. 2015 [also straightness]; Palumbo & Bertamini 2015; Gómez-Puerto, et al. 2016; Velasco, et al.2016; Cotter at al. 2017; Carreiro, et al. 2017; Blazhenkova & Kumar 2017. External references: Guthrie & Wiener 1966, Aronoff, et al. 1992 as in Bar & Neta 2006, pp.645/7; Spencer 1873, Santayana 1896, Stratton 1902, Valentine 1913, Frantz & Miranda 1975, Quinn, et al. 1997, Allen 1877, Alken 1998, Gómez-Puerto, et al. 2013, Larson, et al 2007, Hess, et al. 2013, Jadva, et al. 2010, Martin 1906, Uher 1991 and LoBue 2014 as in Gómez-Puerto, et al. 2016, p.1/6)
        - **V-Shape** (Bar & Neta 2006; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016)

        - **Baby schema effect** (Leder & Carbon 2005; Bar & Neta 2006; Glocker, et al. 2008; Glocker, et al. 2009; Botgi, et al. 2014. External references: Etcoff 1999 as in Leder & Carbon 2005, p. 605; Zebrowitz 1997 as in Bar & Neta 2006, p.648)
            - **Neoteny** (Bertamini, et al. 2015; Gómez-Puerto, et al. 2016)
    - **Contour** (Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Westerman, et al. 2012; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Friedenberg & Bertamini 2015; Gómez-Puerto, et al. 2016; Carreiro, et al. 2017)
    - **Low-level features** (Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Leder, et al. 2011; Jakesch & Carbon 2011; Friedenberg 2012; Palumbo & Bertamini 2016; Cotter, et al. 2017. External reference: Bar 2003)
    - **Level of complexity** (Leder & Carbon 2005; Bar & Neta 2006; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; van Oel & van de Berkhof 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Friedenberg & Bertamini 2015; Carreiro, et al. 2017. External references: Berlyne 1970 as in Leder & Carbon 2005, p.604, Bertamini, et al. 2015, p.159 and Palumbo & Bertamini 2016, pp.38/49/50; Berlyne 1971 as in Silvia & Barona 2009, p.8 and Cotter 2017, pp.8/13; Berlyne 1974 as in Leder & Carbon 2005, p.604, Carbon 2010, p.243 and Palumbo & Bertamini 2016, p.37; Locher & Nodine 1991, Locher, et al. 2001 as in Leder & Carbon 2005, p. 604; Reber, et al. 2004 as in Bar & Neta 2006, p.645; Silvia 2006b and Turner & Silvia 2006 as in Silvia & Barona 2009, p.8; Imamoglu 2000 and Phillips, et al. 2010 as in Leder, et al. 2011, p.649; Stamps III 1999 as in van Oel & van de Berkhof 2013, p, 3; Birkhoff 1932, Eysenck 1941 and Nadal, et al. 2010 as in Bertamini, et al. 2015, p.159)
        - **Arousal** (Leder & Carbon 2005; Carbon 2010; Palumbo & Bertamini 2016. External reference: Berlyne 1974 as in Leder & Carbon 2005, p.604, Carbon 2010, p.243 and Palumbo & Bertamini 2016, p.37)

    - **Vertices rate** (Bertamini, et al. 2015; Palumbo & Bertamini 2015; Friedenberg & Bertamini 2015; Carreiro, et al. 2017. External reference: Nadal, et al. 2010 as in Palumbo & Bertamini 2015, p.37)
    - **Concavities rate** (Bertamini, et al. 2015; Palumbo & Bertamini 2015; Friedenberg & Bertamini 2015. External reference: Nadal, et al. 2010 as in Palumbo & Bertamini 2015, p.37)
    - **Edges rate** (Carreiro, et al. 2017)
    - **Architecture** (van Oel & van de Berkhof 2013. External reference: Herzog & Shier 2000 as in op. cit., p.3)
- **Symmetry** (Kastl & Child 1968; Leder & Carbon 2005; Bar & Neta 2006; Silvia & Barona 2009; Leder, et al. 2011; Vartanian, et al. 2013; Friedenberg & Bertamini 2015; Velasco, et al.2016; Carreiro, et al. 2017. External references: Locher & Nodine 1991 and Locher, et al. 2001 as in Leder & Carbon 2005, p. 604; Reber, et al. 2004 as in Bar & Neta 2006, p.645; Jacobsen & Höfel 2002 and Tinio & Leder 2009 as in Leder, et al. 2011, p. 649)
- **Balance** (Leder & Carbon 2005; Silvia & Barona 2009; Vartanian, et al. 2013; Cotter, et al. 2017. External references: Locher & Stappers 2002, Wilson & Chatterjee 2005 and Locher 2006 as in Silvia & Barona 2009, p.1/3)
- **Proportion** (Silvia & Barona 2009; Carbon 2010; Friedenberg 2012; Carreiro, et al. 2017)
    - **Golden section** (Carbon 2010. External reference: Russel 2000 as in op. cit., p.233)
- **Gestalt principles** (Leder & Carbon 2005; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016. External references: Armheim 1954 as in Leder & Carbon 2005, p.605; Kanizsa 1979 and Wagemans, et al. 2012 as in Bertamini, et al. 2015, p.155/159/173)
- **Contrast** (Bar & Neta 2006;; Silvia & Barona 2009; External reference: Reber, et al. 2004 as in Bar & Neta 2006, p.645; Specht 2007 as in Silvia & Barona 2009, p.1)
- **Size** (Leder, et al. 2011; External reference: Silvera, et al. 2002 as in op. cit., p.649)

    - **Geometric orientation** (Friedenberg 2012; Bertamini, et al. 2015. External reference: Miller 2007 as in Silvia & Barona 2009, p.1)
    - **Colour** (Bar & Neta 2006; van Oel & van de Berkhof 2013. External reference: Frank & Gilovich 1988 as in Bar & Neta 2006, p.647; Polzella, et al. 2005 as in Silvia & Barona 2009, p.1)
    - **Ceiling height** (Vartanian, et al. 2013)
    - **Openness** (Vartanian, et al. 2013)
    - **Feng Shui** (Dazkir & Read 2011[92])
  - **Density property**
    - **Smoothness** (Bertamini, et al. 2015; Palumbo & Bertamini 2015; Cotter at al. 2017)

Subject domain variables

- **Physical level**
  - **Gender**
  - **Age**
  - **Dominant hand**
  - **Evolutionary stage**
    - **Infants** (Bertamini, et al. 2015; Quinn, et al. 1997 and Jadva, et al. 2010 as in op. cit., p.157; Gómez-Puerto, et al. 2016; Fantz & Miranda 1975 and Hubel & Wiesel 1968 as in op. cit., p.2)
  - **Species other than humans**
    - **Great apes** (Gómez-Puerto, et al. 2016; Munar, et al 2015 as in op. cit., p.5)
  - **Geographic distribution**
    - **Non-western cultures** (Gómez-Puerto, et al. 2016; Gómez-Puerto 2013 as in op. cit., p.5)
    - **Cross-cultural participant sample** (van Oel & van de Berkhof 2013; Cotter, et al. 2017)

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[92] According to Jarrett 2011, due to the fact that, as said, the contact with this paper's information was restrict due to the fact the candidate was only able to access its abstract and third party analyses.

- **Expertise level**
    - **Mere-exposure effect and familiarity** (Zajonc 1968; Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Carbon 2010; Jakesch & Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Gómez-Puerto, et al. 2016; Carreiro, et al. 2017. External references: Bornstein 1989 as in Leder & Carbon 2005, p.604; Hekkert 1995 as in Bar & Neta 2007, p.233; Hekkert 1995, Hekkert 2003 and Cutting 2006 as in Carbon 2010, p.233/34/43)
    - **Cultural phenomena and heritage** (Hogarth 1753; Gordon 1909; Carbon 2010; Gómez-Puerto, et al. 2016; Cotter, et al. 2017)
    - **Prototypicality** and **typicality** (Leder & Carbon 2005; Bar & Neta 2006; Silvia & Barona 2009; Carbon 2010; Vartanian, et al. 2013; Bertamini, et al. 2015. External references: Reber, et al. 2004 as in Bar & Neta 2006, p.645; Martindale, et al. 1988 and Whitfield 1983, 2000 as in Silvia & Barona 2009, p.2; Winkielman 2006 as in Carbon 2010, p.234)
    - **Emotional valence and semantic meaning** (Kastl & Child 1968; Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Carbon 2010; Leder, et al. 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Gómez-Puerto, et al. 2016; Velasco, et al.2016; Cotter, et al. 2017: External reference: Gottfried, et al. 2003 and Paton, et al. 2006 as in Bar & Neta 2007, p.2199; Ekman, et al. 1983 as in Leder, et al. 2011, p.650; Larson, et al. 2007 as in Gómez-Puerto, et al. 2016, p.5)
    - **Innovation and novelty** (Leder & Carbon 2005; Bar & Neta 2006; Silvia & Barona 2009; Carbon 2010. External references: Blascovich, et al. 1999 as in Bar & Neta 2006, p.647; Hekkert, et al. 2003 as in Carbon 2010, p.234)
        - **Fashion** (Leder & Carbon 2005; Carbon 2010; Leder, et al. 2011)
        - **Most Advanced Yet Acceptable (MAYA) design principle** (Carbon 2010)
        - **Repeated Evaluation Technique (RET)** (Carbon 2010 [towards familiarity])
    - **Expertise, namely in arts** (Leder & Carbon 2005; Silvia & Barona 2009; Vartanian, et al. 2013; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016; Cotter, et al. 2017. External references: Eysenck 1972, Tobacyk, et al.

    1979 and Leder 2003 as in Leder & Carbon 2005, p.606; Locher 2007, Smith & Smith 2006, Augustin & Leder 2006, Hekkert & van Wieringen 1996, Wiston & Cupchik 1992, Axelsson 2007, Locher, et al. 2001, Silvia 2006a, Locher 2006, Kozbelt 2006, Lindauer 1990, 1991 and Locher & Nagy 1996 as in Silvia & Barona 2009, p.1/3; Parsons 1987, Cleeremans, et al. 2016, Locher 1996, Lunder 2010 as in Cotter, et al. 2017, p.3)
  - **Empiric knowledge** (Bar & Neta 2006. External reference: Feist & Brady 2004)
  - **Openness to experience** (Cotter, et al. 2017; External references: Oleynick, et al. 2017, McRae 1996, Silvia 2007, Kaufman 2013, McRae & Sutin 2009 and Nettle 2009, as in op. cit., p.3)
  - **Personality** (Leder & Carbon 2005)
    - **Personal taste** (Carbon 2010)

- **Psychological level (subjective judgements)**
  - **Aesthetic judgement** (Hogarth 1753; Gordon 1909; Hevner 1935; Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Carreiro, et al. 2017)
  - **Approach-avoidance decisions, motivations or behaviour** (Bar & Neta 2006; Bar & Neta 2007; Dazkir & Read 2011; Vartanian, et al. 2013; van Oel & van de Berkhof 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Velasco, et al. 2016; Cotter, et al. 2017; Carreiro, et al. 2017)
  - **Attractiveness** (Leder & Carbon 2005; Vartanian, et al. 2013; van Oel & van de Berkhof 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Friedenberg & Bertamini 2015 [angularity]. External reference: Mehrabian & Russel 1974 as in van Oel & van de Berkhof 2013, p.3)
  - **Pleasantness** (Kastl & Child 1968; Leder, et al. 2011; Dazkir & Read 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Cotter, et al. 2017. External reference: Graf & Landwehr 2015 as in Cotter, et al. 2017, p.3)
  - **Interest** (Palumbo & Bertamini 2015; Cotter, et al. 2017. External references: Berlyne 1974 as in Palumbo & Bertamini 2015, p.37; Graf & Landwehr

2015, Markovic 2012, Silvia & Kashdan (in press) and Silvia 2006 as in Cotter, et al. 2017, p.3)

- **Neurological level (biological and neural response/neuroaesthetics)**
    - **Threat, danger, fear and/or arousal** (LeDoux 2003; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Gómez-Puerto, et al. 2016. External references: Aronoff, et al. 1992, Frank & Gilovich 1988, Blascovich, et al. 1999 and Feist & Brady 2004 as in Bar & Neta 2006, pp.647/8; Bar & Neta 2008 as in Leder, et al. 2011, p.649; Coss 1972, Ellsworth & Aiken 1998, et al. 1972, as in Gómez-Puerto, et al. 2016, p.5)
    - **Amygdala** (LeDoux 2003; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Gómez-Puerto, et al. 2016. External references: Vuilleumier 2005, Vuilleumier, et al. 2003, Gottfried, et al. 2003 and Paton, et al. 2006 as in Bar & Neta 2007, p.2192/9; Whalen 1998, Adolphs, et al. 1999a, 1999b and Adolphs 2002 as in Jakesch & Carbon 2011, p.650; Larson, et al. 2007/2009 as in Palumbo & Bertamini 2015, p.36)
    - **Pleasure, preference and/or safety** (Bar & Neta 2006. External references: Aronoff, et al. 1992 and Feist & Brady 2004 as in op. cit., pp.647/8)
        - **Orbifrontal Cortex** (Bar & Neta 2007. External references: Gottfried, et al. 2002, Ishai 2007, Kringelbach, et al. 2003, Lewis, et al. 2006, O'Doherty, et al. 2003, Rolls, et al. 2003 as in op. cit., p.2199)
    - **Reward and affective circuitry: emotional salience and aesthetic processing** (Vartanian, et al. 2013. External references: Barrett & Wagner 2006, Barrett, et al. 2007 and Brown, et al. 2011 as in op. cit., pp. 10447-8)
        - **Anterior Cingulate Cortex** (Vartanian, et al. 2013. External references: Taylor, et al. 2009 as in op. cit., p.10448)
        - **Orbitofrontal Cortex** (Vartanian, et al. 2013. External reference: Kringelbach 2005 as in op. cit., p.10448)
        - **Basal Ganglia** (Vartanian, et al. 2013. External reference: Berridge & Kringelbach 2008 as in op. cit., p.10448)
        - **Anterior Insula** (Vartanian, et al. 2013)

- **Perception and/or cognitive fluency** (Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016. External references: Bar, et al. 2006 as in Bar & Neta 2006, p.645 and Carbon 2010, p.233;
- Reber, et al. 2004, Ambady, et al. 2000, Banaji & Greenwald 1995, Bargh & Pietromonaco 1982, Fazio, et al. 1986 and Bar 2003 as in Bar & Neta 2006, pp.645/8; Winkielman 2006 as in Carbon 2010, p.234; Treisman & Gelate 1980, Wolfe, et al. 1992, Alvarez, et al. 2002 and Ruta, et al. as in Gómez-Puerto, et al. 2016, p.3)
    - **Low and high space frequency** (Bar & Neta 2007; Gómez-Puerto, et al. 2016. External references: Bar 2003, Bar, et al. 2006, Bullier 2001, Merigan & Maunsell 1993, Shapley 1990, Vuilleumier 2005 and Vuilleumier, et al. 2003 as in Bar & Neta 2007, pp.2192/5/200)
- **Basic evolutionary response mechanism and behaviour** (Bar & Neta 2006; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016. External references: Cosmides & Tooby 2000, Tooby & Cosmides 2005 as in Leder, et al. 2011, p.650; Allen 1877, Uher 1991 and Isbell 2006 as in Gómez-Puerto, et al. 2016, p.4/5/6)
    - **Fight-or-flight responses** (Carbon 2010; Leder, et al. 2011)
    - **Innate or universal Knowledge** (Gómez-Puerto, et al. 2016)
    - **Choice for potential partners of the opposite sex** (Carbon 2010; Prum 2012. External references: Enlow 1990 and Thornhill & Gangestad 1999 as in Carbon 2010, p.234)
    - **Appleton's 'habitat' theory', environment and survival** (Vartanian, et al. 2013. External references: Appleton 1975, Appleton 1996, Kellert and Wilson 1993, Nasar 1988 and Sagan & Druyan 1992 as in op. cit., p.10447)

Methodology domain variables (methods, techniques and technologies used in the reviewed experimental studies)

- **Fellings or associations** (Lundholm 1921; Poffenberger & Barrows 1924; Hevner 1935; Velasco, et al. 2016; Blazhenkova & Kumar 2017)
- **Aesthetic Judgement**

  - **Like/dislike** (Silvia & Barona 2009 [scale]; Carbon 2010 [scale] Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013 [liking]; Bertamini, et al. 2015; Palumbo & Bertamini 2016; Carreiro, et al. 2017)
  - **Beautiful/not beautiful** (Vartanian, et al. 2013)
- **Approach-avoidance decisions**
  - **Like/dislike (subliminal)** (Bar & Neta 2006; Bar & Neta 2007)
  - **Enter/exit** (Vartanian, et al. 2013; Carreiro, et al. 2017)
  - **Attractive/not attractive** (Leder & Carbon 2005; van Oel & van de Berkhof 2013; Palumbo & Bertamini 2015; Bertamini 2015 [angularity])
  - **Manikin task – approach/avoid** (Bertamini, et al. 2015. External references: Palumbo & Bertamini 2015; Gómez-Puerto, et al. 2016)
  - **Sample of words** (Velasco, et al. 2016)
- **Basic sensory modalities** (Blazhenkova & Kumar 2017)
- **fMRI** (Bar & Neta 2007; Vartanian, et al. 2013)
- **Eye-tracking** (Gómez-Puerto, et al. 2016; External reference: Stratton 1902 as in op. cit., p.1-2)
- **Forced-choice response** (Bar & Neta 2006; Bar & Neta 2007; Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013; Palumbo & Bertamini 2015; Carreiro, et al. 2017)
- **Discrete-choice response** (van Oel & van de Berkhof 2013)
- **Ratings in a Likert scale** (Leder & Carbon 2005; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Friedenberg & Bertamini 2015; Cotter, et al. 2017)
- **Stimulus' exposure time, visual detection and processing (difficulty and time)** (Bar & Neta 2006; Bar & Neta 2007; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo & Bertamini 2016; Gómez-Puerto, et al. 2016; Cotter, et al. 2017; Carreiro, et al. 2017. External references: Guthrie & Wiener 1966, Bornstein & d'Agostino 1994 and LoBue 2014 as in Gómez-Puerto, et al. 2016, p.3-5)
- **Psychopy software** (Pierce 2007; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Carreiro, et al. 2017)

Methods used to moderate preference for curvature by measuring individual differences

- **Aesthetic Fluency Scale** (Silvia & Barona 2009; Cotter, et al. 2017. External references: Smith & Smith 2006 as in Silvia & Barona 2009, p.3)
- **Implicit Association Test** (Palumbo & Bertamini 2015)
- **HEXACO 100 Personality Inventory-Revised** (Cotter, et al. 2017)
- **NEO-Five-Factor Inventory** (Cotter, et al. 2017)
- **Big Five Aspects Scale** (Cotter, et al. 2017)
- **Need for Cognition** (Cotter, et al. 2017)
- **Types of Intuition Scale** (Cotter, et al. 2017)

4.6. Context of the Conducted Experimental Study

In Chapter 1 we have highlighted the fact that state-of-the-art methods, techniques, tools and technologies, have the potential to change the way we have been thinking and building architecture, in the direction of a reality where its spaces can adopt a much wider range of forms than those that were until recently considered, including those commonly addressed as free forms. Such degree of freedom opened a discussion on whether such forms might or might not be in the best interest of those who use architecture spaces and thus, architecture itself. Within this context, we have proposed to address the preference for form and architecture space form with distinct geometric characteristics, by means of our experimental study.

Aesthetic Judgement and Approach-Avoidance Decisions

Through an early-stage literature review on this thesis topic, we soon became aware that aesthetic judgements and approach-avoidance decisions are key factors to take into consideration. In other words, we realised that our levels of preference towards external phenomena with specific geometric characteristics, could be ruled by our taste or sense of beauty, and safety or threat sensations or feelings. The first factor, deals directly with beauty concepts, namely, if we find the object of perception[93] to be beautiful, accepting and desiring it, or not beautiful, rejecting and not wanting it. The second, deals with more primitive safety and threat sensations, particularly, if we find the object of perception to be safe, accepting and approaching it, or threatening, and therefore rejecting and avoiding it, especially if it contains low-level features, such as sharp-angles that could interfere with our well-being, physical integrity and chances of survival.

Knowledge

The literature review has shown us that preference for elements, such as shapes and forms, may be influenced by two different kinds of knowledge.

On the one hand, preference is known to be affected by basic evolutionary functions or mechanisms[94] of our genetic structure and legacy, in which is framed our primitive defence 'fight or flight' response system[95], as shown by how our nervous system reacts to subliminal stimuli[96] with low-level features, such as shape and form, namely angularity, and complexity[97]. Besides belonging to the dimension of the individual, such knowledge is close to an objective-based 'database', shared by all healthy humans, that is a result of a long evolutionary stage of adaptation towards the environment that surrounds us. This knowledge is responsible for our unconscious

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[93] Whether beauty resides on the properties of the object of perception or inside the one who perceives it is an ancient theme of debate that we have previously addressed in previous chapters 2 and 3 of this thesis and the additional material of 'Appendix G'.

[94] Bar and Neta 2006; Carbon 2010; Leder, et al. 2011; Jakesch and Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016.

[95] Leder, et al. 2011.

[96] Bar and Neta 2006 and 2007.

[97] Bar and Neta 2006; Bar and Neta 2007; Silvia and Barona 2009; Leder, et al. 2011; Jakesch and Carbon 2011; Friedenberg 2012; Palumbo and Bertamini 2016; Cotter, et al. 2017.

approach-avoidance decisions and instinctive behaviour when we found ourselves in presence of potential threatening phenomena (Bar and Neta 2006, p.648).

On the other hand, the knowledge that we gather through our sensitive and rational experiences is also known to exercise influence on preference, as demonstrated by how factors such as familiarity[98] and expertise (namely in arts[99]) and the object's emotional valence and semantic meaning[100], are able to affect our subjective judgements. In opposition to the previous addressed one, this knowledge constitutes a rather opened than closed subjective-based 'database' able to be built and updated upon our life-time learning experiences and influence both our aesthetic judgements and approach-avoidance decisions, either if their manifestation occurs at a conscious or subconscious state.

Thought

Since these experiences take place in the world that surrounds us, which either fits in the domain of nature or is a result of human action, which we consider apart from the previous due to our ability to develop rational thought, it is ultimately this thought that, besides natural phenomena, is responsible for the definition of our subjective-based knowledge 'database' and hence, also for our subjective preference judgements.

The shape of this non-natural world is the result of a continuous process that shown to take mainly under consideration the level of development of our thought, at a given time and space, and the means that we are able find at our disposal, at the same time and space, in order to answer it and give form to its products. Together, these thought

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[98] Zajonc 1968; Leder and Carbon 2005; Bar and Neta 2006; Bar and Neta 2007; Carbon 2010; Jakesch and Carbon 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo and Bertamini 2015; Gómez-Puerto, et al. 2016; Carreiro, et al. 2017.

[99] Leder and Carbon 2005; Silvia and Barona 2009; Vartanian, et al. 2013; Bertamini, et al. 2015; Gómez-Puerto, et al. 2016; Cotter, et al. 2017.

[100] Kastl and Child 1968; Leder and Carbon 2005; Bar and Neta 2006; Bar and Neta 2007; Carbon 2010; Leder, et al. 2011; Vartanian, et al. 2013; Bertamini, et al. 2015; Palumbo and Bertamini 2015; Gómez-Puerto, et al. 2016; Velasco, et al.2016; Cotter, et al. 2017.

and means work in a kind of synergy that contributes to the development of one and other.

The Discourses that Contextualize our Experimental Study

Along this thesis and the additional material of ‘Appendix G’, we have been interested in the reasons why historically we have been closer to some shapes and forms with certain specific characteristics over others, and why we have preferred some forms over others. In this discourse we have focused our attention on events that have shown to contribute to the evolution of rational thought, its structure, settlement and complexity level, the evolution of shape and form thinking, representation and production, and the means (methods, techniques, tools and technologies) used in order to give form, to the products of the mind. Furthermore, we have also followed closely the general evolution of the methods of science since they are able to exercise influence on how we understand external and internal phenomena. Due to the fact that previous achieved knowledge was able to influence future events, this discourse followed a chronologic order.

On another hand, since this thesis specifically addressed the topic of the preference for elements, such as lines, shapes and forms, and architecture space form with distinct geometric characteristics, we have developed a second discourse centred on the review of this topic. This discourse was contextualized by an exposition of the general evolution of the concept of beauty, how it was understood thought historical times and thus alludes more to aesthetic judgement rather than approach-avoidance decisions. The reason why we did so with for aesthetics judgements and not for approach-avoidance decisions, has to do with the fact that the latter has demonstrated to be a more primary and less intellectual subject of study and, on the contrary, as shown in the development of the previous referred discourse, aesthetics have proved to be a rather complex and intellectual subject of study, having intimately accompanied the evolution of our rational thought. This discourse has also followed closely the evolution of the methods of science and a chronologic order.

The Essential Historical Context

After a period where the understanding of this world was characterized by the irrational suppositions of the myth and the arbitrariness of the divine intervention, both of illogical and inscrutable character (Cordón and Martinez 2014, p.27), philosophy emerges as a 'novel' scientific method based on autonomous, rational research and explanation (Abbagnano 2013, p.19)[101], with intimate associations with the abstract thought of mathematics. Throughout the Greek classic period, rational thought was to be gradually improved, first with Thales' mathematical proof[102], then with Socrates' inductive, statistical reasoning[103], Aristotle's deductive, demonstrative and logic reasoning[104] and, finally, with the axiomatic method[105], so well translated in the Euclid's Elements. For a long period of time, Greek's philosophy would be humanity's most perfect mean to understand exterior and interior phenomena, search for the truth about things and create, develop and establish western knowledge and thought.

The search for a definition of beauty or aesthetics, as a field that seeks the knowledge about beauty and taste, have been under the scope of thinkers since at least the Greek Classical Period. Philosophers such as Pythagoras, Socrates, Plato, Aristotle or Plotinus have associated beauty with mathematical concepts of order, unity, proportion, symmetry and definiteness or human principles like good and virtue. Beauty was seen as an objective quality and property of the object, "an ideal form that exists in all beautiful things" (Sartwell 2016), which ought to give rise to delight[106].

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[101] See 'Appendix G', section 2.2.2., 'Philosophy – A Novel Scientific Methodology for the Examination of the Real. The Greeks'.

[102] See 'Appendix G', section 2.2.2., 'Thales, Geometry and the Mathematical Proof'.

[103] See 'Appendix G', section 2.2.2., 'The Essence of Induction'.

[104] See 'Appendix G', section 2.2.2., Deductive 'Mathematical' Proof and Abstraction.

[105] See 'Appendix G', section 2.2.2., 'The Axiomatic Method'.

[106] See Chapter 3, section 3.1.1., 'View on the Classic Conceptions'.

During the Medieval period the notions of beauty followed basically those inherited from the Greek classical period with the exceptions of the inclusion of God in these concepts (and these concepts in God) and Aquinas proposing that beauty could be closer to the intellect than to the senses and thus participate of the subjective dimension[107]. The Renaissance period follows this overall trend and replaces the intangible figure of God by that of man (and nature), his scale and dimension[108].

The classic autonomous and rational based research methodology, would be restored and gain new strength in the late 16th and beginning of the 17th centuries with Bacon recovery of the inductive and deductive reasoning as scientific methods of examination and verification of the truth and Galileo's resolute-composite methodology, in which the experimental condition stands out significantly[109].

In 1753, Hogarth writes the 'The Analysis of Beauty' with the purpose to demonstrate "the sources of beauty – why objects are beautiful" (Davis in Hogarth 2010, p.4[110]). He addresses for the first time, as far as we have been able to identify, to the character of elements with distinct geometric characteristics, namely lines, within the domain of aesthetics judgements. To Hogarth, the 6 fundamental principles that he proposes to "co-operate in the production of beauty" (Hogarth 2010, p.38), fitness, variety, uniformity (regularity or symmetry), simplicity (or distinctness), intricacy and quantity (ibidem, pp.5-6 and 38) can be specially found in the triangular glass and the serpentine line, "the two most expressive figures that can be thought of to signify not only beauty and grace, but the whole order of form" (ibidem, p.26)[111].

Later, the empiricist Hume deviates from the platonic idea that beauty is an intrinsic objective property of things themselves and suggests it to lay "in the eye of the

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[107] See Chapter 3, section 3.1.2., 'View on the Medieval Conceptions'.

[108] See Chapter 3, section 3.1.3., 'View on the Renaissance Conceptions'.

[109] See 'Appendix G', section 2.2.6., 'Modern Era Discourse on Thought, Objectivism and Subjectivism over Rationalism, Empiricism and Illuminism'.

[110] Hogarth 2010 [1753].

[111] See Chapter 3, section 3.1.4., 'View on the Enlightenment Conceptions'.

beholder" (Taliaferro 2011, loc. 338/2086) and thus a matter that mainly relies on the subjectivity of the individual. Beauty, he wrote, "is no quality in things themselves: It exists merely in the mind which contemplates them; and each mind perceives a different beauty" (Hume 1910 [1757], p.218[112]). However, he also believed that subjective judgements, as those of beauty and ethics, could be, a target of standard evaluation and proposes for that and ideal, impartial observer (Taliaferro 2011, loc.349/2086, Radcliffe 1994)[113].

However, the way we used to examine "real matter of fact" (Hume 1910 [1757], p.217) would change considerably in second half of the 19th century with Gustav Fechner's contributions to psychophysics, experimental psychology and quantitative methods. Among his work and within the purposes of the current context, it is important to highlight the facts that, in 1876's 'Vorschule der Aesthetik', he uses methods of extreme ranks to understand subjective judgments and, in an paper published two years later, he developed the notion of the median, introduces it into the formal analysis of data and "delved into experimental aesthetics and endeavoured to determine the shapes and dimensions of aesthetically pleasing objects" (Heidelberger 2001, p.144)[114].

At this point the study and evaluation of subjective judgments in general and aesthetics in particular, began effectively to stand apart from the subjective reasoning that since this point have characterized scientific research to getting closer to more ideal, close-to-objective, quantitative approaches.

In the beginning of the 20th century, Gordon (Gordon 1909) writes another treaty on aesthetics that demonstrates how this subject was regarded in this important time and context. In its discourse, as Hogarth did, Gordon makes reference to the character of simple lines and forms and, as Hogarth did, among the universe of lines, shows her

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[112] Found in Hume 1910 [1757], pp. 217-8.

[113] See Chapter 3, section 3.1.4., 'View on the Enlightenment Conceptions'.

[114] See Chapter 3, section 3.2.1., 'Gustav Fechner and the Measurement of Subjective (and Aesthetic) Judgement'.

preference for curved lines that "are in general felt to be more beautiful than straight lines. They are more graceful and pliable, and avoid the hardness of some straight lines" (Gordon 1909), which smooth, continuous line movements was more agreeable than, in her words, "the ugly broken line" (idem)[115].

The study of subjective preference and affection for angular and curved elements beyond purely based subjective interpretation (e.g. Hogarth 1753 and Gordon 1909), takes place in the beginning of the 20th century with the development of experimental studies on these subjects. As far as we have been able to identify, Lundholm have started this cycle in 1921, with an experimental study on 'The Affective Tone of Lines', followed by Poffenberger and Barrows with their 1924's 'The Feeling Value of Lines' and Hevner's 1935's 'Affective Value of Colours and Lines'. The results of their studies shows that angular lines are associated with feelings such as 'agitating', 'hard', 'furious', 'serious', robust' and 'vigorous' and curved lines with ones such as 'gentle', 'sad', 'quiet', 'lazy', 'merry', 'gentle', 'serene' and 'graceful'[116].

Recent Literature Contributions

Over the past 20th and the current 21st century, the topic of the preference for lines, shapes and forms with distinct geometric characteristics has been an active focus of debate and the target of several experimental studies. These studies have tried to better understand and create knowledge on our levels of preference for geometric elements in general and the more particular case of architecture space form with distinct geometric characteristics based mainly on their angular, sharp or curved, rounded feature elements. These experimental studies counted with samples of participants that were asked to subjectively evaluate their preference for a set of presented stimuli with distinct geometric features at contour level, namely, angular, sharp and curved, rounded elements, according to aesthetic judgements and approach-avoidance decisions.

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[115] See Chapter 3, section 3.2.2., 'Aesthetics in the beginning of the 20th century'.

[116] See Chapter 4, section 4.1., '20th Century Experimental Studies on Angularity and Curvature and the Affective value of Lines'.

Overall, the results of these studies point to the fact that humans prefer curved, rounded lines, shapes and forms and architectural form, rather than their angular, sharp direct correspondent counterparts.

Moreover, with the increasing use of advance technologies on such experimental studies, based on the direct analysis of brain activity via scanning technology, such as functional Magnetic Resonance Imaging (fMRI), it has been possible to approach and measure subjective judgements, namely preference, at a completely different level than before, through a more objective and quantitative way, and map the source and dynamics of this preference directly in the brain of the participants under study. The results of experimental studies with the aid of this technology, have shown that the level of preference for curved or sharp-angled shapes and forms is directly associated with the activation of particular regions of the brain related with the perception of potential threatening or agreeable situations and the posterior sensations and feelings of fear, or pleasure. Angular, sharp-angled shapes and forms that include ‘v-shape’ elements such as vertices, and sharp edges have proved to activate the brain’s Amygdala, a region often associated with the perception of threat and the production of fear (LeDoux 2003, Bar and Neta 2007), leading us to reject and avoid them for their potential danger and harmful effects and in this way ensure both the safety and integrity of our body, and our well-being condition. Curved, rounded shapes and forms, on the other hand, have shown to activate the brain’s reward and affective circuitry (Vartanian 2013), a system associated with the perception of satisfying situations and production of pleasure, leading us to accept and desire such featured elements.

Furthermore, with the reduction to the stimulus exposure time to subliminal levels, it has been possible to connect these low-level features with sensations of threat and pleasure and the feelings of fear and wellbeing in a state prior to cognition, and thus, connect such reactions to those basic evolutionary functions and defense mechanisms that we have referred to early before in this context section, such as our ‘fight and flight’ response system, and those subjective and objective-based knowledge ‘databases’.

These results are supported by other experimental studies that explore the effect that ‘baby schema’, a set of facial and body proportions, including rounded forms, often found in infants, exercises on preference (Glocker, et al. 2009 [March]; Glocker, et al. 2009 [June]; Borgi, et al. 2014). Such studies also associate these forms to evolutionary functions, in this particular case of enhancing offspring survival, and are also known to activate the brain's reward system (Glocker, et al. 2009 [June]), inducing pleasure and motivating caretaking in adults.

The Reality of Architecture

We could expected that the way we have been thinking about shapes and forms, a direct product of our relatively long settled western thought, tended to run parallel to the reported achieved results on the subjective preference of such same shapes and forms. However, the shapes and forms that we think about and manage to bring to reality, are not necessarily the same that have being pointed as an object of our preference.

This reality becomes more evident if we focus on the forms that have been associated with and worked under the reality of architecture. Historically, but especially after the arrival of the Industrial Revolution to Architecture, the environments created by this discipline have been mainly based on vertical and horizontal plans and their more direct intersections, which mostly result in prominent and non-prominent sharp-angled edges and vertices. Although curved structure elements as arches and vaults, domes or, for instance, some of the structures developed by Antoni Gaudí, have showed us that non-linear structures respond better to the vertical forces of gravity than orthogonal-based structures, the general tendency in architecture is still much biased towards the development of horizontal and vertical based structures than of curved-based ones. The reasons that led to these orthogonal-based structures, language and general appearance, most likely have to do with precise pragmatic factors like viability, economics, space management optimization or our natural locomotion system, rather than to their optimal force dispersion behaviour, aesthetic appearance and potential presence of threatening elements. It is easier and cheaper to build regular horizontal and vertical plans based on regular elements as bricks, stones or beams than to construct irregular curved structures based on irregular elements designed specifically for every singular exception situation. This trend gained new strength with the consideration of standardized, mass-production elements. By turn, space management is an important factor to control especially because it also deals directly with viability and economy. Such management affects distinct aspects that can go from the limits of a property, to the divisions within this property, the creation of additional upper floors or the necessary compatibility that have to exist between the raw space of architecture and everything else that complement it, namely furniture. Following these ideas, a space composed by horizontal and vertical plans and their immediate intersections, standardize and limit the amount of singularities that are raised in the architecture space, something that does not happen when we consider curved based surfaces. Another factor that we have to make reference to, is our natural locomotion system. We move more easily and effectively in planar horizontal grounds rather than in inclined or curved ones.

However, although the fact that the social-economic triggered Industrial Revolution and its standardization and mass production effects have largely and directly contributed to the standardization of the architecture space, as said, with its orthogonal, vertical and horizontal plan relationships and the presence of prominent and non-prominent edges and vertices, an approximation or adaptation to the achieved results on the preference for forms could be possible within this same settled reality but mainly through the novel, state-of-the-art achievements of the recent Digital Revolution. This revolution advances on the domain of representation, visualization and production stages of the form materialization process, introducing novel methods, techniques and technologies influencing the way we face, nowadays, tri-dimensional form. 3D-based CAD software, immersive virtual reality, interactive technologies and CAD-CAM processes, to name some, have being allowing us to accomplish complex, innovative results, far distant from those that until quite recently were possible to achieve, through easy and ‘user-friendly’ interconnected approaches. This reality has contributed to the fact that ‘free forms’ may currently be easily achieved, under practically the same economic basis of standardized and mass production processes, and have the potential to substantially change the way how we think and produce general form and architecture form in particular[117].

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[117] See Chapter 2, section 2.2.3.2., ‘The Second Digital Revolution’.

Consideration of the Experimental Study

It is within this wide context of the evolution of our thought, beauty and science concepts and the state-of-the-art of the methods, techniques and technologies accessible to architecture and used in the research for subjective judgement on the preference for lines, shapes and forms, including architecture space form, with distinct geometric characteristics, that fits the current experimental study on the preference for abstract architecture spaces with distinct geometry characteristics at contour level.

Overall, the main facts that…

- the products of the Digital Revolution have been increasingly affecting the discipline of architecture, namely resulting in the opening of the forms of its spaces to full freedom consideration;
- recent experimental research on the topic of this thesis, have shown that human tend to prefer curved, rounded contour elements to angular, sharp ones either based on aesthetic judgements or approach-avoidance decisions;
- these results do not point towards the forms that we have been developing and exploring in architecture, under empiric and rational ground knowledge and that;
- we believe to be of the outmost importance for the understanding of architecture, which are its limits, what it has to offer and how it can better assist our conscious and unconscious needs and feelings;

…demand an update and clarifying exercise on the potentialities of the architecture of today and its effects on its users, namely in what concerns to the form of its spaces.

Furthermore, although several experimental studies have already addressed the preference for lines, shapes and forms with distinct geometric characteristics through different approaches and methodologies, the attention that has been given to the preference for the form of interior architecture environments with such characteristics is quite recent and still lacks variants in the approach. So far, our research has allowed us to identify only 3 studies dedicated to this specific, particular topic: Dazir and Read 2012, Vartanian, et al. 2013 and van Oel and van de Berkhof 2013. Although such contributions have addressed the preference for curvilinear or rectilinear interior architecture environments, they considered a whole set of other variables of the space of architecture beyond space itself: Dazir and Read (2012) focused on the forms of furniture, Vartanian, et al. (2013), on complex photographs of interior spaces and van Oel and van de Berkhof (2013), on the design of airport passenger and retail areas. Although it is our believe that such studies attempted to control and desirably cancel potential variables able to create noise in the to-be-achieved results (e.g. Dazkir and Read through the closeness and medium complexity level of the stimuli [furniture] and Vartanian, et al. through an extensive set of 200 stimuli), neglecting potential secondary effects able to occur when complex rather than simple stimuli are considered for presentation and evaluation, we can argue that there is the remote possibility that the sample of curvilinear and rectilinear architecture spaces and forms and its evaluation, may have been infected by other space properties.

Within this particular context, we design a novel approach to tackle the thesis problem, which was widely considered in the literature, for the case of preference for general elements: to study the said problems, in the context of abstract, close to meaningless shapes and forms[118]. The experimental study of this thesis, was then designed to consider abstract architecture spaces with controlled space variables, namely (i) the primary target of geometric contour elements and (ii) the indispensable light in order to make the stimuli perceivable. We believe that the results achieved with this approach, are able to complement the previous achieved results on the topics of the preference for shapes and forms and architecture space form.

Additionally, the ideas that we are proposing, which may have an impact in today´s and tomorrow’s architecture, don’t necessarily have to be radical and too much apart from the reality of present architecture. The literature results of the studies on the preference of shapes and forms and architectural form, clearly associate sharp edges and vertices with potential threatening situations and sensations and fear feelings (LeDoux 2003, Bar and Neta 2007), and curved surfaces with agreeable situations and

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[118] Hevner 1935; Bar and Neta 2006; Bar and Neta 2007; Silvia and Barona 2009; Leder, et al. 2011; Bertamini, et al. 2015; Palumbo and Bertamini 2015; Velasco, et al. 2016; Cotter at al. 2017; Blazhenkova and Kumar 2017.

sensations and pleasure feelings (Vartanian, et al. 2013), but do not link any of these states with the perception of planar elements[119]. It is possible then, that the consideration of such results by the architecture sector could be rather specific (e.g. planar intersections) than general. The experimental study of this thesis, addresses this possibility, by considering complete orthogonal-based architecture spaces with prominent and non-prominent sharp edges and vertices, completely non-Euclidean surface spaces, with no prominent and non-prominent sharp edges and vertices, but also intermediate spaces composed by plans and soften rounded transitions instead of sharp edges and vertices.

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[119] Bertamini, et al. 2015 showed that "curvature is preferred over angularity even for simple elements such as lines" (Bertamini, et al. 2013, p.169) but associate this preference with curvature itself and not with the presence of angularity since "stimuli with angles were disliked as much as those with straight lines and no angles" (idem). However, as straight lines are by definition, sharp elements, we should not extend these findings to plans, since they are to be considered continuous rather than edge-cutting, fragmented surfaces.

Chapter 5

5. Preference for Abstract Architecture Spaces with Distinct Geometric Characteristics - Experimental Study and Results

Abstract. This chapter presents the outline and the achieved results of a novel experimental user study developed to understand the differences on how abstract architecture indoor spaces with distinct geometric characteristics at contour level, are perceived and evaluated. The goal of this study is to understand the impact, in one hand, of curved, rounded and, on the other hand, angular, sharp elements, on the human perception of architecture environments. To achieve such goal, we have created 18 synthetic architecture spaces which were evaluated by 32 test-subjects according to 'like/dislike' aesthetic judgments (assessed in experiment 1) and 'enter/do not enter' approach-avoidance decisions (assessed in experiment 2). The images of such spaces under evaluation comprised: (a) six variations of geometric contour elements, including Euclidean and non-Euclidean geometry elements, and; (b) three variations of prominent and non-prominent elements with edges and vertices. The main innovation of this study's visual stimulus appropriate for space preference evaluation, resides in the fact that it incorporates abstract, controlled architecture environments, specially designed for aesthetic judgment and approach-avoidance decisions, with the inclusion of both moderate and extreme variation of geometric features. Our results confirmed the literature view, whereas tested subjects showed a higher level of preference and acceptance for spaces with curved, rounded contour elements. On the other side, when the level of space curvature was high, considering the whole space surface and not just the contour of planar transitions, the level of preference and acceptance decreased significantly, probably due to a 'strangeness effect', the opposite of the Zajonc's "mere-exposure" effect (Zajonc 1968). These results support the idea that curved, rounded elements are more liked, more approachable and hence preferred, over their angular, sharp counterpart versions, and create new knowledge on the how the levels of such preference are more noticeable for moderate, rather than for radical curvature rates.

5.1. Research Question and Hypotheses

In Chapter 1, 'Introduction', we have formulated the problem, sub-problems, research question, and raised hypotheses for addressing such problems, that frame this thesis.

The experimental study described in this chapter, follows this approach.

For a matter of clarity, we re-state the research question which oriented this study:

- "Do people find architecture spaces with curved, rounded elements to be more pleasing than architecture spaces with angular, sharp elements?"

This research question highlights the problem addressed in this thesis:

- "The problem of understanding the preference for form, namely the preference for architecture space form, with distinct geometric characteristics".

As previously pointed in Chapter 1, the judgement of the preference for form may be influenced by two core judgements, leading us to derive two sub-problems, from the initial major problem:

- "The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in aesthetic judgements".
- "The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in approach-avoidance decisions".

In order to address our thesis problem and sub-problems, we have raised four hypotheses, two major and two minor ones:

Major hypotheses:

H1. People prefer abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts;
H2. People prefer full non-Euclidean-based abstract architecture spaces, rather than Euclidean-based (fully orthogonal) abstract architecture spaces.

Minor hypotheses:

- H3. People prefer abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements;
- H4. People prefer abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features.

The demonstration of these hypothesis was addressed through the development of an experimental study, encompassing two experiments, which sought unconscious responses from the participants regarding visual stimuli and subsequent analysis, followed by a self-questionnaire aimed to collect and analyse the conscious participants' response towards the same stimuli.

5.2. Experimental Study

The goal of our experimental study is to validate hypothesis 'H1' to 'H4'. We seek to identify how abstract architecture spaces with distinct geometric contour natures and distinctive characteristics elements are perceived and evaluated, regarding preference and to evaluate quantitatively the degree of such subjective choices. In our approach, a sample of random participants were presented with a series of carefully designed 3D spaces composed by plans, prominent and non-prominent edges and vertices, curved surfaces and a mixture of these elements arranged together. Our study of preference for form, was addressed through the analysis of the measurement of aesthetic judgements and approach-avoidance decisions taken by the participants, in line with the two raised sub-problems of this thesis. Based on these results, we expect to contribute to an improvement of the process of architecture design and construction in particular, and of the general process of form design and production.

5.3. Description of the Stimuli / Architecture Spaces

In order to answer to these goals, we designed 18 visual stimuli, composed of architecture space imagery, referred henceforth as space-images or SIs. All space-images were derived from the same base: an orthogonal three-dimensional virtual space with twenty units of length, five of width and three of height, as shown in 'Figure 1'.

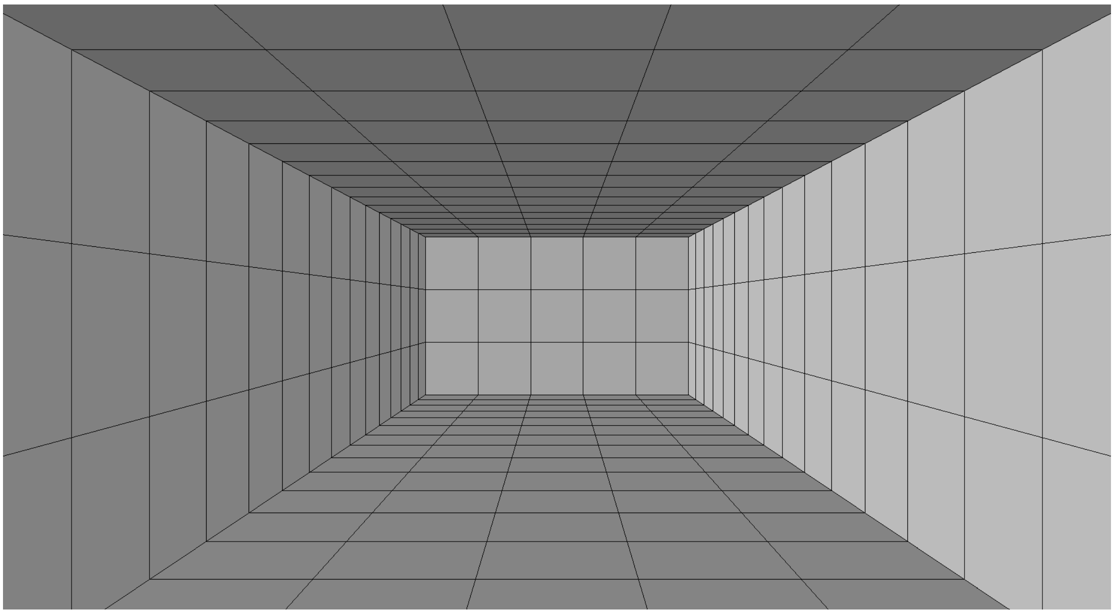

Figure 1. Base space.

The other spaces were found through two main low-level features [e.g. form (sharp-angled/curved) and complexity (low/high)] degrees of transformation: (i) transformation of the spaces' geometric contour features, with six variations, and (ii) transformation of the spaces' geometric element complexity, with three variations.

Geometric contour features variation, considers the following contour level transformations:

- Type 1 (henceforth, sharp-high) - 90° angle at planar intersections;
- Type 2 (sharp-tight) - 45° angle plan chamfer with a 10 cm base radius at planar intersections;
- Type 3 (rounded-tight) - rounded surface with a radius of 10 cm at planar intersections;
- Type 4 (sharp-loose) - 45° angle plan chamfer with a 20 cm base radius at planar intersections;
- Type 5 (rounded-loose) - rounded surface with a radius of 20 cm at planar intersections;

- Type 6 (rounded-high) - a complete transformation from a Euclidian to a non-Euclidian geometric nature at plan intersection. At this level, contour embraces the totality of the space surface.

Geometric element complexity variation, considers the following element level transformations:

- Type a (non-prominent) - negative, non-prominent edges or rounded surfaces;
- Type b (rail-prominent) - negative, non-prominent and positive, prominent edges or rounded surfaces;
- Type c (spot-prominent) - negative, non-prominent and positive, prominent edges and vertices or rounded surfaces.

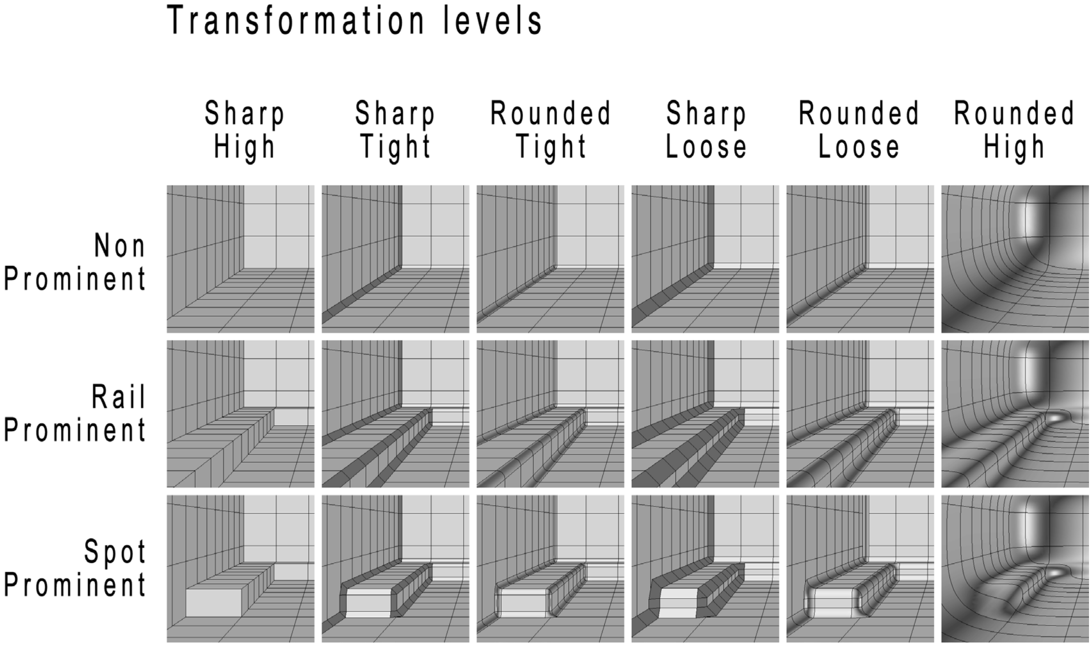

Figure 2. Transformation levels of the 18 space-images.

As showed in 'Figure 2', this configuration sets up a two-dimensional matrix of 3x6 space-images, $x(i,j)$, $1 \leq i \leq 3$ and $1 \leq j \leq 6$, where the geometric element complexity variation (i), and the geometric contour character variation (j), can be studied and analysed either separately or linked between each other. $x(i,j)$ corresponds to our independent matrix variable of the study.

The reader should notice, that within the comprised element complexity level ('non', 'rail' or 'spot-prominent'), that corresponds to a given line i of $x(i,j)$ SI, elements 'sharp-tight' and 'rounded-tight', which vary along column j of $x(i,j)$, share a direct correspondence with the way they are built, regarding the same controlled variables, including a plan transition of 10 cm base radius. For example, in the case of 'sharp-tight', a 45° plan chamfer and in the case of 'rounded-tight', a rounded plan transition with Euclidean and non-Euclidean elements, as can be seen in figures 3, 4 and 5, the only difference between them is the geometry nature that is applied at the level of plan intersection, its geometric contour character.

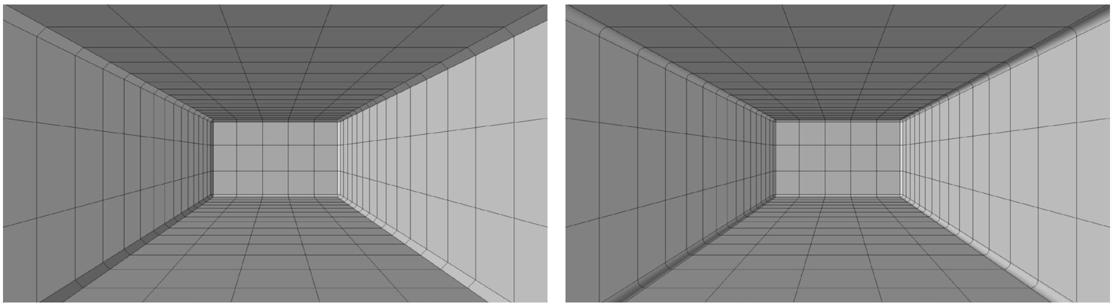

Figure 3. Non-prominent sharp-tight vs non-prominent rounded-tight.

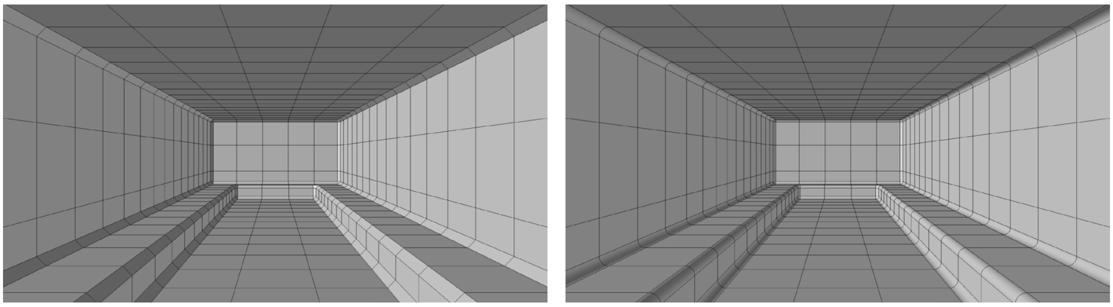

Figure 4. Rail-prominent sharp-tight vs rail-prominent rounded-tight.

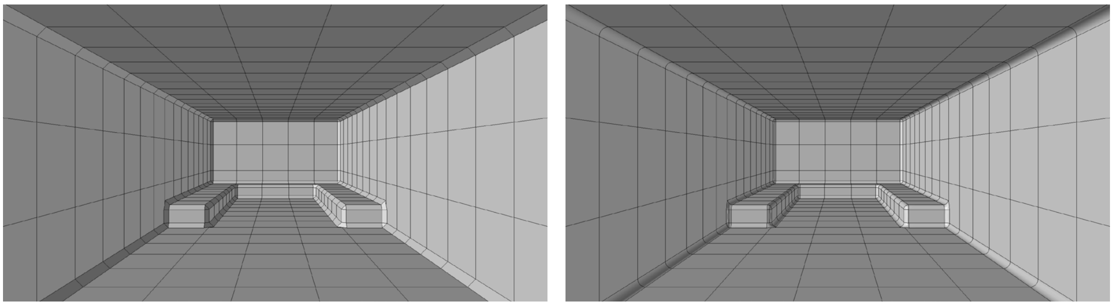

Figure 5. Spot-prominent sharp-tight vs spot-prominent rounded-tight.

The same principle applies to 'sharp-loose' and 'rounded-loose' SI with the difference that, instead of a 10 cm base radius, we have considered a 20 cm base radius. This plan transition enhancement can be seen in figures 6, 7 and 8 (especially when comparing with previous ones 3, 4 and 5), as well as in ‘Figure 2’. Such differentiation adds different levels of moderate geometric variations, to help us understand if a significant change in the transition’s scale would interfere or not with the reported level of preference between the same transformation properties, possibly conducting to a preference of less or more pronounced plan transitions or, in other words, contour.

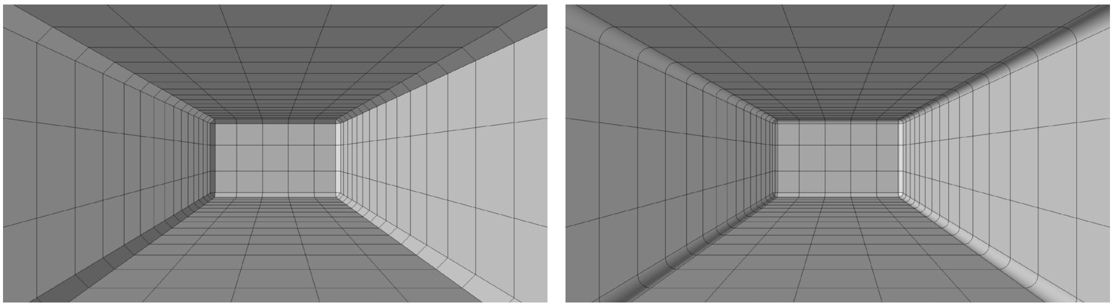

Figure 6. Non-prominent sharp-loose vs non-prominent rounded-loose.

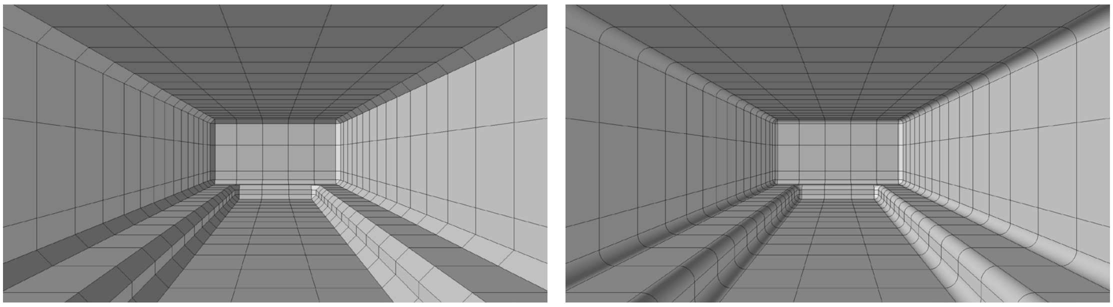

Figure 7. Rail-prominent sharp-loose vs rail-prominent rounded-loose.

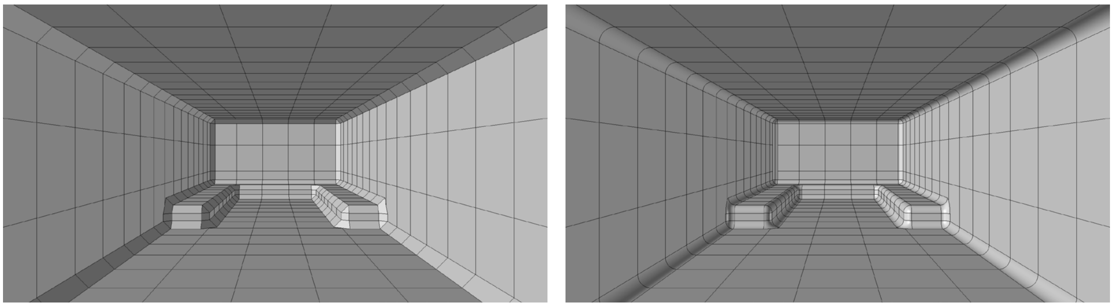

Figure 8. Spot-prominent sharp-loose vs spot-prominent rounded-loose.

On the other hand, ‘sharp-high’ and ‘rounded-high’ SI correspondence is not as direct as in the previous cases, in the sense that they follow the controlled aforementioned transformation levels, but their result is too far apart for a direct correspondence. ‘Sharp-high’ SI take under consideration 90° plan transitions and are relevant for the study in the way that they are a close analogy to most of the spaces that we build and are used to. By doing so, they also tend to fall in the area of the psychological phenomenon of “mere-exposure” effect (Zajonc 1968). Contrarily, ‘rounded-high’ SI represent non-Euclidean geometry spaces, standing apart from most of our built spaces and, by being so “strange”, tend to fall in the opposite scope of ‘sharp-high’. Figures 9, 10 and 11 represent such “indirect” correspondences.

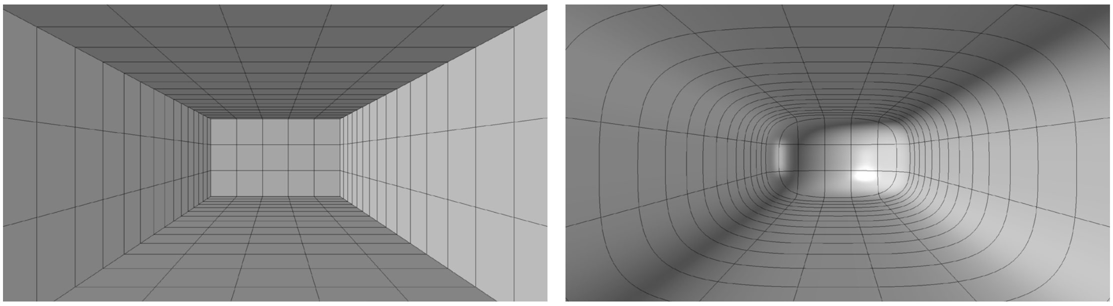

Figure 9. Non-prominent sharp-high vs non-prominent rounded-high.

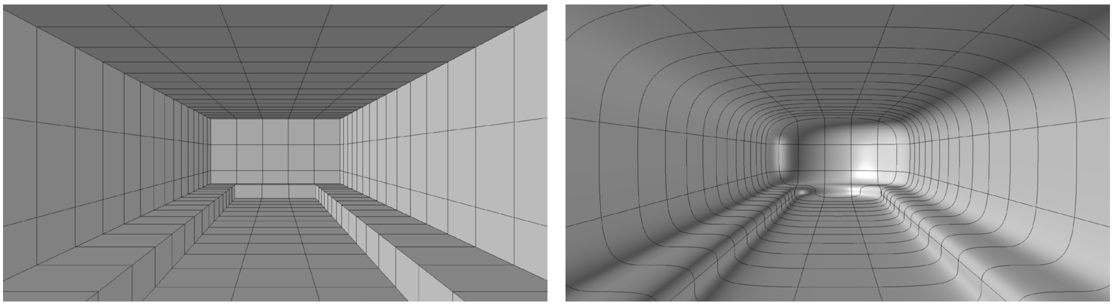

Figure 10. Rail-prominent sharp-high vs rail-prominent rounded-high.

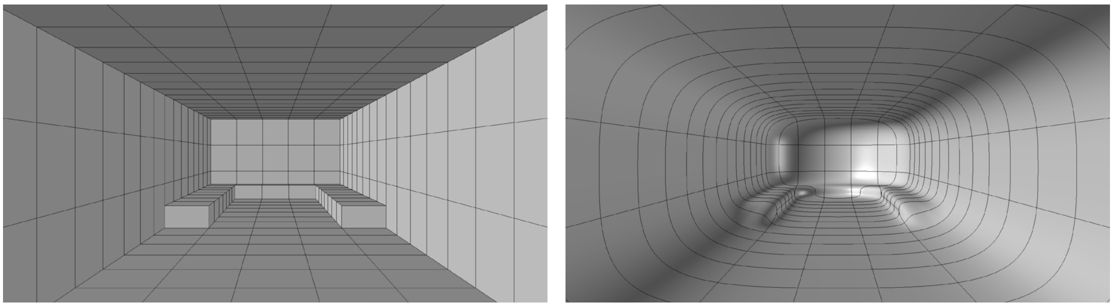

Figure 11. Spot-prominent sharp-high vs spot-prominent rounded-high.

Within the same geometric contour features level (‘sharp-high’, ‘sharp-tight’, ‘sharp-loose’, ‘rounded-tight’, ‘rounded-loose’ or ‘rounded-high’), that corresponds to a given column i of $x(i,j)$ SI, elements ‘non’, ‘rail’ and ‘spot-prominent’, which vary along line i of $x(i,j)$ share a direct correspondence with each other.

As said, we developed 18 SI (the $x(i,j)$ independent matrix variable), which together constitute the stimuli of our experimental study. Through eidetic, abstract representations, different levels of planar transitions and surface contour, including sharp and rounded variations and moderate and extreme geometric levels of evolution, and different levels of prominence elements, including non-prominent, edge-prominent and edge-and-vertex-prominent elements, we have developed an user experimental study enabling the demonstration of our hypotheses.

In order to be addressed in fully controlled conditions, hypothesis 'H1' takes into account directly related SI within the same geometric element complexity level. In this sense, 'non-prominent' 'sharp-tight' SI enters in direct evaluation with 'non-prominent' 'rounded-tight' SI, 'rail-prominent' 'sharp-tight' with 'rail-prominent' 'rounded-tight', and 'spot-prominent' 'sharp-tight' with 'spot-prominent' 'rounded-tight'. The same applies to the 'loose' contour transformations. 'Sharp-loose' SI compete against 'rounded-loose' SI, within the same geometric element complexity levels of 'non-prominent', 'rail-prominent' and 'spot-prominent'. Looking into the $x(i,j)$ domain, we compare $x(1,2) \leftrightarrow x(1,3)$, $x(1,4) \leftrightarrow x(1,5)$, $x(2,2) \leftrightarrow x(2,3)$, $x(2,4) \leftrightarrow x(2,5)$, $x(3,2) \leftrightarrow x(3,3)$ and $x(3,4) \leftrightarrow x(3,5)$. 'Figure 12' exemplifies the valid combinations to assess, while evaluating the 'H1' hypothesis.

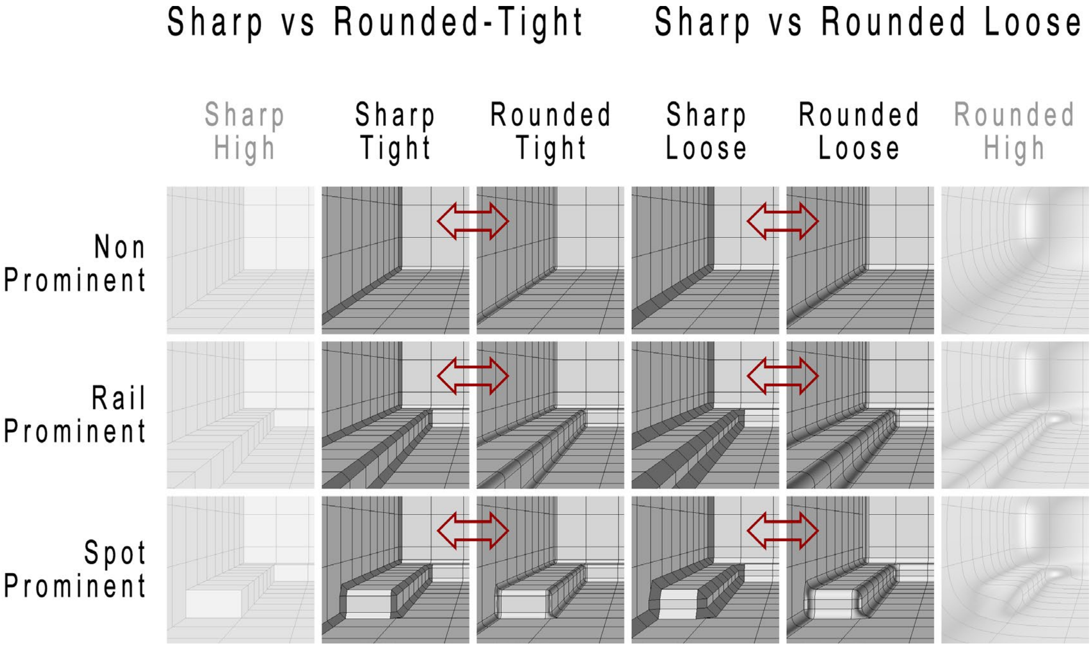

Figure 12. Valid comparisons when evaluating hypothesis 'H1': $x(1,2) \leftrightarrow x(1,3)$, $x(1,4) \leftrightarrow x(1,5)$, $x(2,2) \leftrightarrow x(2,3)$, $x(2,4) \leftrightarrow x(2,5)$, $x(3,2) \leftrightarrow x(3,3)$ and $x(3,4) \leftrightarrow x(3,5)$.

In turn, hypothesis 'H2' takes into consideration 'sharp-high' versus 'rounded-high' SI, from the same geometric element complexity level. In this case, we compare $x(1,1) \leftrightarrow x(1,6)$, $x(2,1) \leftrightarrow x(2,6)$ and $x(3,1) \leftrightarrow x(3,6)$, as shown in 'Figure 13'.

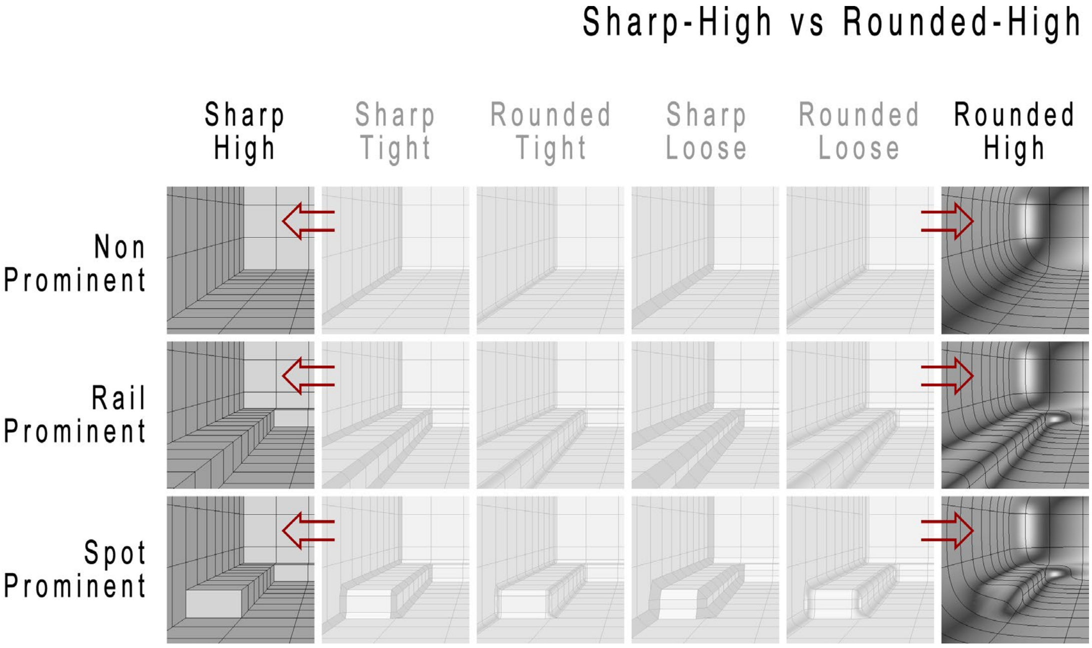

Figure 13. Valid comparisons when evaluating hypothesis 'H2': $x(1,1) \leftrightarrow x(1,6)$, $x(2,1) \leftrightarrow x(2,6)$ and $x(3,1) \leftrightarrow x(3,6)$.

Finally, hypotheses 'H3' and 'H4' compare the three geometric element complexity levels within the same geometric contour variation levels.

Hypothesis 'H3' takes into account 'non-prominent' and 'rail-prominent' SI and 'non-prominent' and 'spot-prominent' SI, within the same geometric contour levels. For this case, we compare $x(1,1) \leftrightarrow x(2,1)$, $x(1,2) \leftrightarrow x(2,2)$, $x(1,3) \leftrightarrow x(2,3)$, $x(1,4) \leftrightarrow x(2,4)$, $x(1,5) \leftrightarrow x(2,5)$ and $x(1,6) \leftrightarrow x(2,6)$, as shown in 'Figure 14', and $x(1,1) \leftrightarrow x(3,1)$, $x(1,2) \leftrightarrow x(3,2)$, $x(1,3) \leftrightarrow x(3,3)$, $x(1,4) \leftrightarrow x(3,4)$, $x(1,5) \leftrightarrow x(3,5)$ and $x(1,6) \leftrightarrow x(3,6)$, as shown in 'Figure 15'.

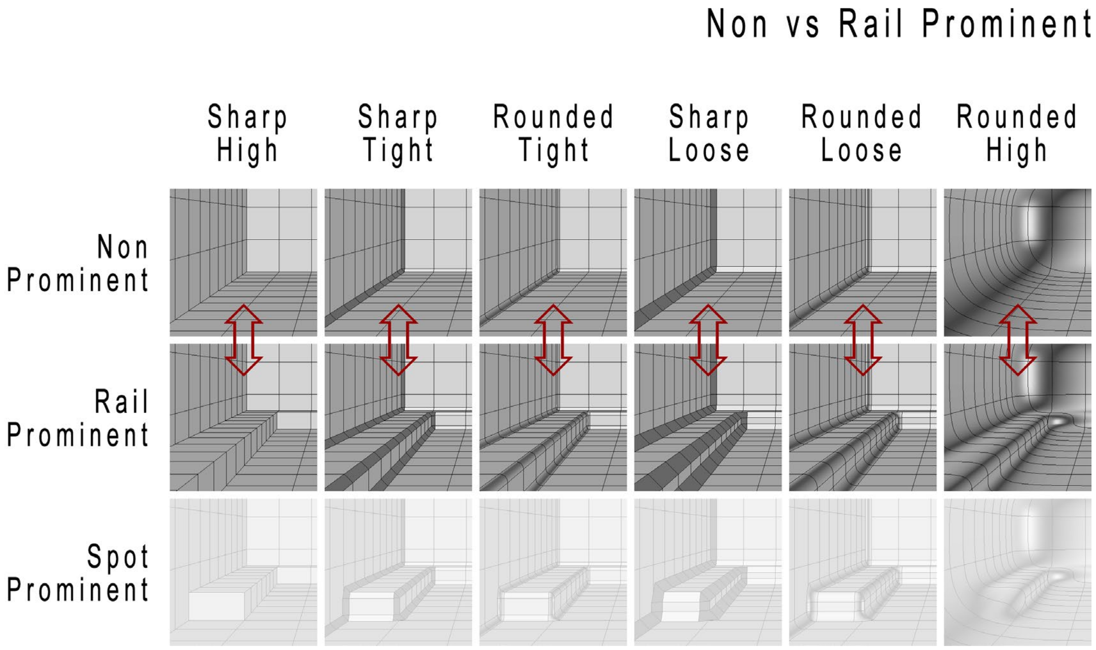

Figure 14. Partial valid comparisons when evaluating hypothesis 'H3': $x(1,1) \leftrightarrow x(2,1)$, $x(1,2) \leftrightarrow x(2,2)$, $x(1,3) \leftrightarrow x(2,3)$, $x(1,4) \leftrightarrow x(2,4)$, $x(1,5) \leftrightarrow x(2,5)$ and $x(1,6) \leftrightarrow x(2,6)$.

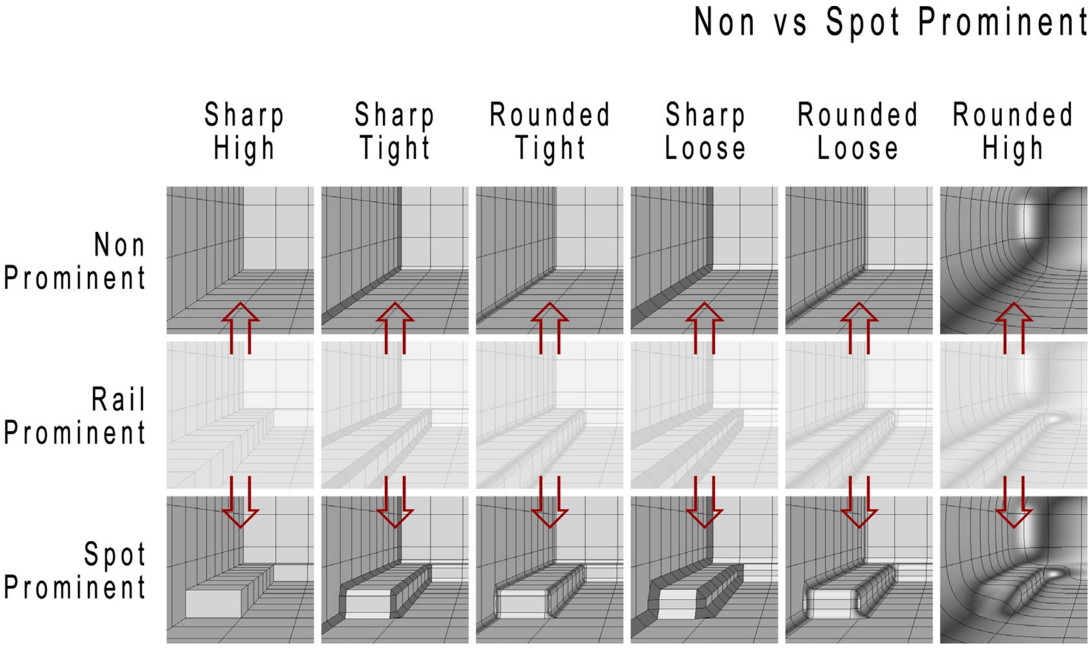

Figure 15. Additional valid comparisons when evaluating hypothesis 'H3': $x(1,1) \leftrightarrow x(3,1)$, $x(1,2) \leftrightarrow x(3,2)$, $x(1,3) \leftrightarrow x(3,3)$, $x(1,4) \leftrightarrow x(3,4)$, $x(1,5) \leftrightarrow x(3,5)$ and $x(1,6) \leftrightarrow x(3,6)$.

In turn, hypothesis 'H4' takes in consideration 'rail-prominent' versus 'spot-prominent' SI, from the same geometric contour variation levels. In this case, we compare $x(2,1) \leftrightarrow x(3,1)$, $x(2,2) \leftrightarrow x(3,2)$, $x(2,3) \leftrightarrow x(3,3)$, $x(2,4) \leftrightarrow x(3,4)$, $x(2,5) \leftrightarrow x(3,5)$ and $x(2,6) \leftrightarrow x(3,6)$, as shown in 'Figure 16'.

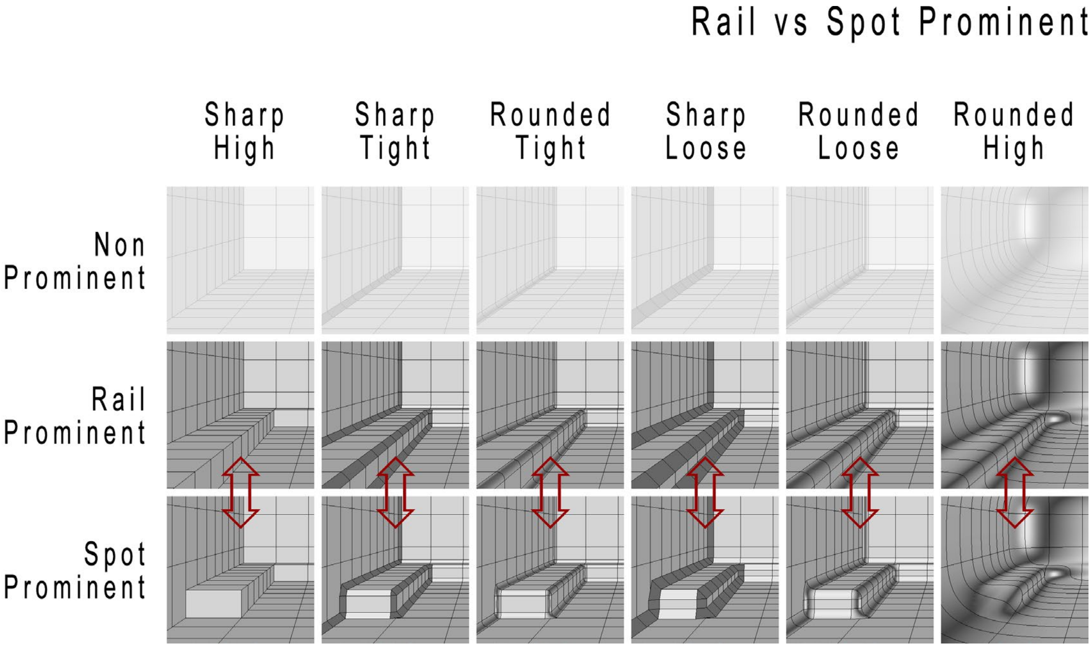

Figure 16. Valid comparisons when evaluating hypothesis ‘H4’: $x(2,1) \leftrightarrow x(3,1)$, $x(2,2) \leftrightarrow x(3,2)$, $x(2,3) \leftrightarrow x(3,3)$, $x(2,4) \leftrightarrow x(3,4)$, $x(2,5) \leftrightarrow x(3,5)$ and $x(2,6) \leftrightarrow x(3,6)$.

The level of information that each space contains was designed for deliberately focus each participant attention, towards neutral bias and neutral affective valence. Any other type of information able to distract the subject of the hypotheses under study, thus infect each collected data sample, was abolished. For this reason, all space-images appear in tones of grey, without expressive colour, texture and additional indoor spatial elements, such as doors or windows, which normally occur even in the simplest architecture spaces. In addition to the geometric contour variations (‘sharp’ and ‘rounded’) and the comprised complexity level of present elements (‘non’, ‘rail’ and ‘spot-prominent’), the only parameter that was included, was a simple variation of light, which was controlled and set constant for all SI, due to the fact that it directly interferes with the perception of the three-dimensional nature of our space-images.

All spaces were built from scratch in their full three-dimensions in the NURBS oriented software system Rhinoceros® 3D, version 4.0 SR8. In their design, in order to aim to controlled and steady results with neutral bias, we took under consideration basic principles such as those of unity, proportion, symmetry, harmony or balance that, as described in chapters 3 and 4 and the additional material of ‘Appendix G’ of this thesis, which have been key guiding principles of our western based thought, since its classical foundations, and have ever since, through the evolution of time and given the importance that they close, been pursued and preserved. As a reference, the transversal section of each space is a rectangle of 3x5 units. The choice of such measures relied on its proportion, since this ratio is the one that, among natural numbers ratios, better approximates the Euclidean classic golden number (Euclid 2008[120]), often pointed as an example of a perfect proportional system (1,618). After completed, these virtual three-dimensional spaces were used to generate the set of SI that would constitute the stimuli to be perceived and evaluated in the experimental study. All SI were taken from a virtual observer camera located in the beginning of the 3D spaces' longitudinal axis and centred in relation with its transversal axis. The camera orientation was set to aim to the other flank of the previously mentioned longitudinal space axis with a 0 degree inclination, which means that it 'travelled' perpendicularly to the observer's plan and parallel to the horizontal floor plan. The observer's height of the space-images was set to 1.675 mm, the average height of the Portuguese female and male adult population born between 1971 and 1980 (Garcia and Quintana-Domeque 2007), corresponding to the average born dates of this study´s eligible participants. Figures 17 and 18 show an overview of the set of virtual tri-dimensional spaces that gave place to the space images that we have considered in this experimental study and a detail showing the observer's and the camera's height set, as said, to 1.675 mm.

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[120] Book II, Proposition 11 and Book VI, Definition 2

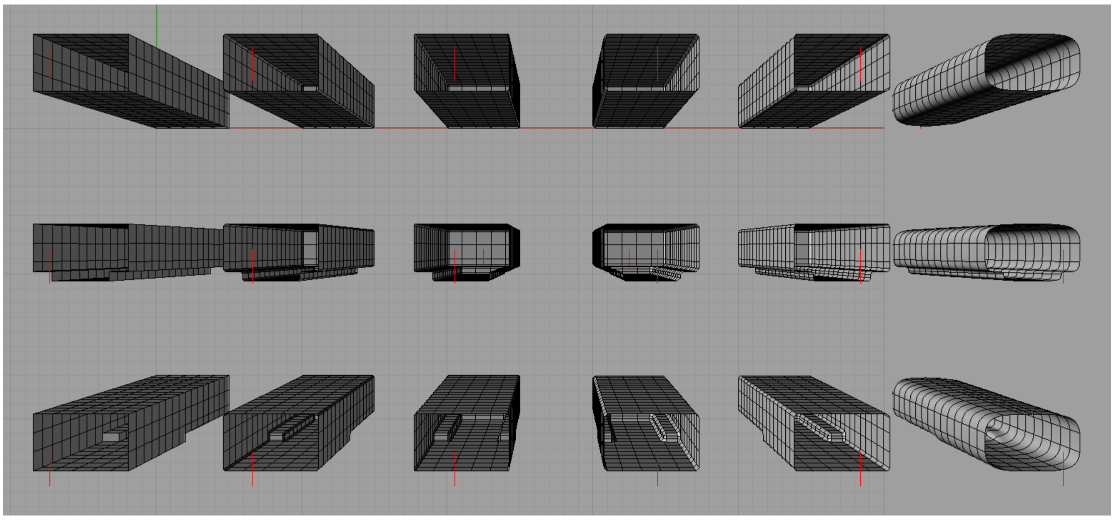

Figure 17. Overall view of the set spaces that gave place to the considered space-images.

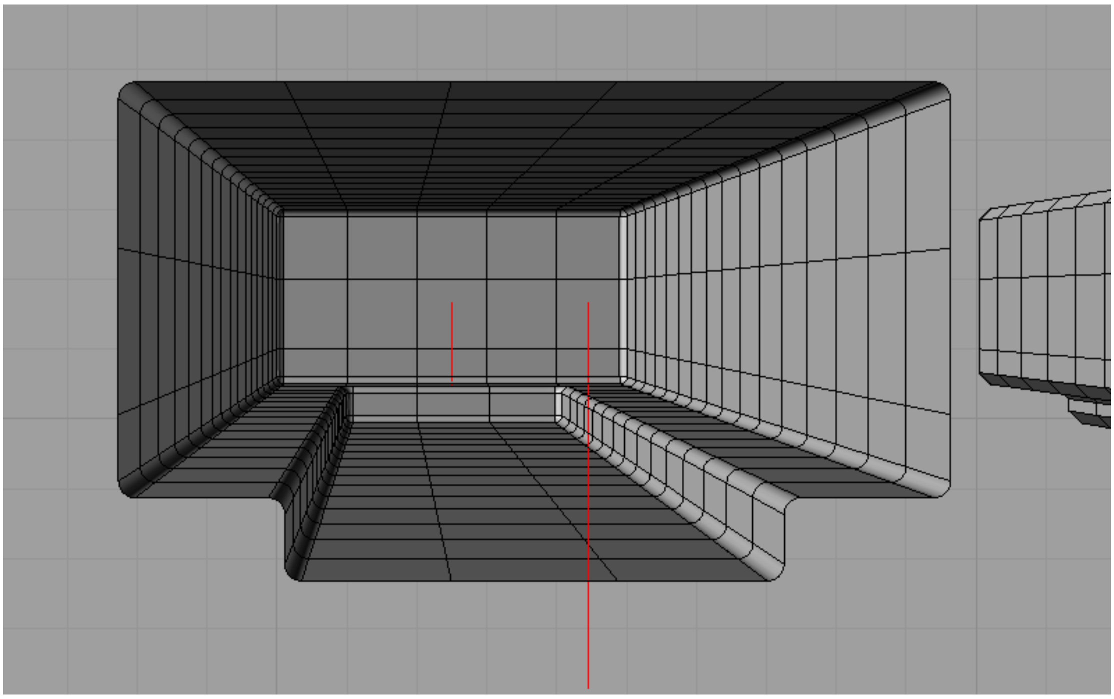

Figure 18. Detail of the observer's and the camera's target height set to 1.675 mm.

After being generated, all SI were subjected to digital edition on Photoshop® software, exclusively in their 'exposure' and 'opacity' levels (increased to the values 20 and 70, respectively), in order to fit the optimized levels that we believed to be necessary for their clear and neutral bias perception.

5.4. General Variables

The control of the study's variables is an important part of our formulation. Such control guaranties that the study is conducted in perfect or close-to-perfect conditions, defending, a priori, the study's main object. This usually means the control all variables able to interfere with the study's main object.

Our study considers three types of variables: Independent, depended and moderating (extraneous, control) variables. Independent variables are controlled by the author and correspond to the conditions that vary along the experiments. In our case, they represent the elements that change across the SI imagery set. The independent variable of this study is the two-dimensional matrix $x(i,j)$, $1 \leq i \leq 3$ and $1 \leq j \leq 6$, where:

- i: is the geometric element complexity variation;
- j: is the geometric contour features variation.

Dependent variables are the variables that are under measurement. In an experimental design study, it is expected that changes in the independent variables produce changes in the dependent variables. The dependent variables of this study correspond to the evaluation of participants, when viewing this study's presented stimuli. They are:

- The aesthetic judgement triggered by SI stimuli, captured by a dichotomic 'like' and 'dislike' response pair (in experiment 1);

- The approach-avoidance decision triggered by SI stimuli, captured by the dichotomic 'enter' and 'do not enter' response pair (in experiment 2);

In our study, we considered the necessity to evaluate the imagery stimuli according to two different core judgements, namely, aesthetic judgement and approach-avoidance decisions, both previously identified as essential to a complete consideration of the topic of the preference for shapes and forms, in which one complements the other. Additionally, we considered the methodological impossibility of conducting both judgments within the same experiment, due to the fact that each elicit different feelings or sensations. As a result, we decided for the unfolding of this study in two distinct experimental studies, experiment 1 and experiment 2, aimed and oriented to the same purpose, but where dependent variables being measured are different.

Our study also considered two extraneous (control) variables, given the ability that they have, if left uncontrolled, to interfere or cause an impact on the independent or on the dependent variables, causing undesired effects on the study's results. These control variables should be a target of an a priori and posteriori control. In this way, the extraneous (control) variables of this study are:

- The gender of the participants (32), divided in female (18) and male (14) (best effort);
- The age of the participants divided in young adults, with ages from 18 to 40 years old, and middle-aged adults, with ages from 41 to 64 years old (best effort).
- The stimulus exposure time (set to 3.0 seconds).

5.5. Research Ethics Protocol

Due to the fact that this study counted with external participants, in order to assure that it was conducted within standard ethic procedures, fully respecting such third parties, we have developed for this experimental study, a Research Ethics Protocol. This protocol includes the written 'Free Informed Consent' to be read and agreed by the test-subjects who would participate in both stages of the experimental study, the 'Participation Criteria Verification List', the 'Experiment Guide' and the 'Conscious Response Self-Questionnaire', to be filled by all participants after the second and last experiment of the study. The Research Protocol document was submitted to the Ethics Committee of ISCTE-IUL, the host institution of the Ph.D. program, and was analysed and approved by this committee. This committee's final report states that "the presented study (…) satisfies the required ethical standards for scientific research projects of this nature, having received the agreement of the Ethics Committee". Both documents can be found in Appendix A and B of this thesis.

5.6. Free Informed Consent

Before beginning the first stage of the experimental study, Experiment 1, each participant was asked to read a ‘Free Informed Consent’, with general information about the experimental study to be conducted and to sign it, if he/she was in agreement with the written terms. All participants agreed with the information present in the written ‘free informed consent’ and signed such written terms.

5.7. Experiment 1

5.7.1. Context

As previously pointed, we believe that the preference for shapes and forms and, particularly, the preference for architecture space form, can be decomposed into two abstraction levels: (i) aesthetic judgements, which include our sense of beauty, a matter of personal taste, towards perceivable external phenomena and, (ii) approach-avoidance decisions, which, mostly associated with unconscious processes, will lead us to accept or refuse such perceivable external phenomena.

Beauty has been pointed to be a subjective property of things (Hume 1910 [1757], p.218) and, in this way, not a universal, objective one. In this sense, aesthetic judgements belong to the subjective knowledge domain, a kind of ‘database’ that is built over time through our sensible and rational experiences, and of the ones of those who preceded us and that may have influenced us, and manifest mainly at a conscious level. Such judgements refer directly to the aesthetic emotions that humans feel when in presence with distinct characteristic stimuli, namely, visual. In other words, how, at an aesthetic level, we interpret these external phenomena.

On another hand, approach-avoidance decisions are, as the name indicates, decisions that humans take in order to protect themselves from the surrounding environment. Although having their grounds in the individual self, such decisions belong to a more objective knowledge domain, in the sense that they are closer to an objective rather than to a subjective realities between individuals, able to manifest at unconscious, subliminal levels. (Bar and Neta 2006, 2007). The bases of such decisions are placed deep inside our brains in regions such as (i) the amygdala (LeDoux 2003; Bar and Neta 2007), or (ii) the reward and affective circuitry (Vartanian 2013). Approach-avoidance decisions are known to be activated by (i) the perception of potentially threatening and danger situations, such as visual and haptic perceptions of external phenomena with sharp edges and vertices, which are environment features able to jeopardise our body's integrity, well-being, protection and survival conditions, and are normally responsible for the production of fear and unpleasant sensations and feelings or (ii) the perception of rounded and smooth appearance stimuli, which, most likely as an opposition to the former, are interpreted as harmless, and thus agreeable, and responsible for the production of pleasure.

Experiment 1 performs the evaluation of the preference for abstract architecture spaces with distinct geometric contour elements, by eliciting aesthetic judgements. It aims then to understand and evaluate the aesthetic sensations and feelings of test-subjects, when faced with SI stimuli. We seek to investigate how participants judge the presented SI, with their distinctive geometric contour features, which include moderate and extreme levels of evolution and geometric element complexity, according 'like' and 'dislike' judgements.

Based on our literature review, on the preference for lines, shapes and forms[121] and on the particular topic of the preference for architecture space form, with distinct geometric characteristics[122], we would be expecting that participants would like abstract architecture spaces with rounded plan transitions, and would dislike abstract architecture environments with sharp edges and vertices and, within such cases, would like abstract architecture spaces with low element complexity levels (non-

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[121] Lundholm 1921; Poffenberger and Barrows 1924; Hevner 1935; Kastl and Child 1968; Leger and Carbon 2005; Bar and Neta 2006; Bar and Neta 2007; Silvia and Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch and Carbon 2011; Westerman, et al. 2012; Dazir and Read 2012; Vartanian, et al. 2013; van Oel and van de Berkhof 2013; Bertamini, et al. 2015 [also straightness]; Palumbo and Bertamini 2015; Gómez-Puerto, et al. 2016; Velasco, et al.2016; Cotter at al. 2017; Carreiro, et al. 2017; Blazhenkova and Kumar 2017.

[122] Dazir and Read 2012; Vartanian, et al. 2013; van Oel and van de Berkhof 2013.

prominent), over abstract architecture spaces with higher element complexity levels (rail and spot-prominent).

Additionally, we would be looking at uncertain results, when considering if participants would like more rounded-high abstract architecture spaces than sharp-high abstract architecture spaces. Such incertitude has to do with our belief that participants are more likely to like rounded abstract architecture spaces than its correspondent sharp counterparts but, at the same time, would like 'sharp-high' abstract architecture spaces more than 'rounded-high' abstract architecture environments, due to the previously reported "mere-exposure" (Zajonc 1968) and 'strangeness' effects.

In the following sections we describe, in more detail, Experiment 1.

5.7.2. Experimental Methodology

5.7.2.1. Variables

The independent variable of Experiment 1 is the two-dimensional matrix $x(i,j)$, $1 \leq i \leq 3$ and $1 \leq j \leq 6$, where:

- i: is the geometric element complexity variation;
- j: is the geometric contour features variation.

The dependent variable of Experiment 1 is:

- The aesthetic judgement triggered by SI stimuli, captured by a dichotomic 'like' and 'dislike' response pair.

The extraneous (control) variables are:

- The gender of the participants (32), divided in female (18) and male (14) (best effort);

- The age of the participants, divided in young adults, with ages from 18 to 40 years old, and middle-aged adults, with ages from 41 to 64 years old (best effort).
- The stimulus exposure time (set to 3.0 seconds).

5.7.2.2. Hypotheses

The hypotheses of both Experiment 1 and 2, seek to understand if people find abstract architecture spaces with curved, rounded elements to be more pleasing than architecture spaces with angular, sharp elements. In particular, Experiment 1 addresses this thesis following sub-problem: "The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in aesthetic judgements". The experiment envisages demonstrating the following major and minor hypotheses, which are a variant of 'H1' to 'H4':

Major hypotheses:

H1a. People like more abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts;

H2a. People like more full non-Euclidean abstract architecture spaces, rather than Euclidean-based (fully orthogonal) abstract architecture spaces;

Minor hypotheses:

H3a. People like more abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements.

H4a. People like more abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features.

5.7.2.3. Experiment’s Sample

Experiment 1 counted with 32 participants, 18 of which female and 14 male, aged between 18 and 64 years old, divided in young adults, with ages from 18 to 40 years old, and middle-aged adults, with ages from 41 to 64 years old, with an average of 36 and a median of 35 years old.

5.7.2.4. Conducting Experiment 1

The set of SI to be evaluated, were presented in random order to the test-subjects, with a within-subject action-response experimental protocol. For every SI showed, subjects were asked to answer to the question “Do you like or dislike the presented abstract architecture SI?” Participants had to choose one from the two dichotomic response pair: ‘like’ (“I like the presented abstract architecture SI”) or ‘dislike’ (“I dislike the presented abstract architecture SI”).

The participants were asked to response by pressing two grey identical buttons, with a diameter of 5 cm, centred over the computer’s keyboard and located over the ‘d’ and ‘return’ keys. In order to better assist the participants in their action-responses, we added a grey horizontal bar with ‘+’ and ‘-’ symbols at the bottom of each SI. The position of such symbols pointed the side where ‘like’ and ‘dislike’ action-responses should be made: ‘+’ for ‘like’ and ‘-’ for ‘dislike. ‘Figure 19’ shows a SI stimulus example with the aid-bar added to ultimately guide the participants in their action-responses.

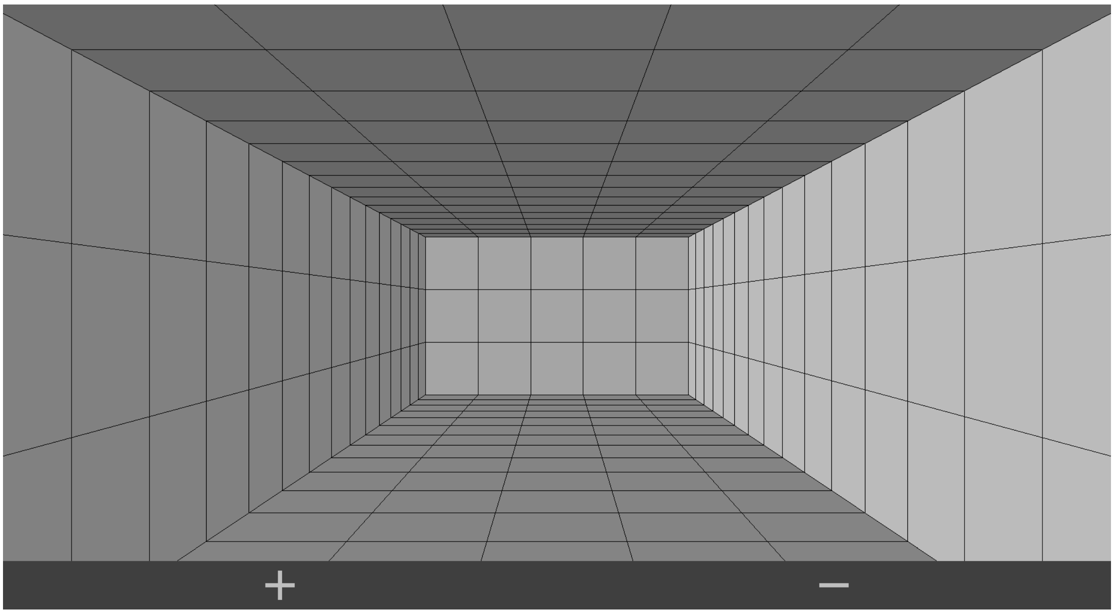


Figure 19. SI stimulus example with the aid-bar to ultimately guide the participant's action-responses.

In order to ensure that each participant went through the same experimental conditions, in within-subject design, we constructed two sequences of the set of images to be presented: a 'regular' sequence, whose order was randomly calculated at www.random.org, and its corresponding inverse order sequence. These sequences can be found in 'Appendix C'.

Each of the 18 SI was presented 5 times for a total of 90 SI within each sequence, and the transition between such SI stimuli was made by a neutral grey image with a centred black 'X' (Figure 20).

Figure 20. Transitory image with a centred black ‘X’.

SI stimuli were presented to the experiment participants for a maximum time span of 3.0 seconds and they were asked to evaluate and respond to these stimuli within this period. This limit of the stimuli’s exposure was set in order to get from the participants a more subconscious rather than conscious response. If his/her answer did not take place within this predefined time, it would be considered invalid and thus ignored and not suitable for result analysis purposes. In case such circumstance would occur, the SI stimuli would pass automatically to the transitory neutral image. Contrarily to SI stimuli that required a ‘forced’ action-response evaluation from the participant, transitory images did not require any kind of participant’s action. Since the participant’s response to the stimuli depended only on him/herself, if occurred within the 3.0 seconds period of exposure, in order to avoid that he or she adopted a repetitive rhythm of response able to distract them from their task, each of the transitory images were shown for a variable time span that went from 1.85 to 2.15 seconds (2.0 seconds minus and plus 150 ms).

To ensure neutral bias in the action-response protocol, participants were divided into four groups of eight test-subjects, according to the order that the space-images were presented (first ‘regular’ then ‘inverted’ or first ‘inverted then ‘regular’) and the location of the action-response buttons (‘like’ on the left side and ‘dislike’ on the right side or ‘dislike’ on the left side and ‘like’ on the right side) (Figure 21).

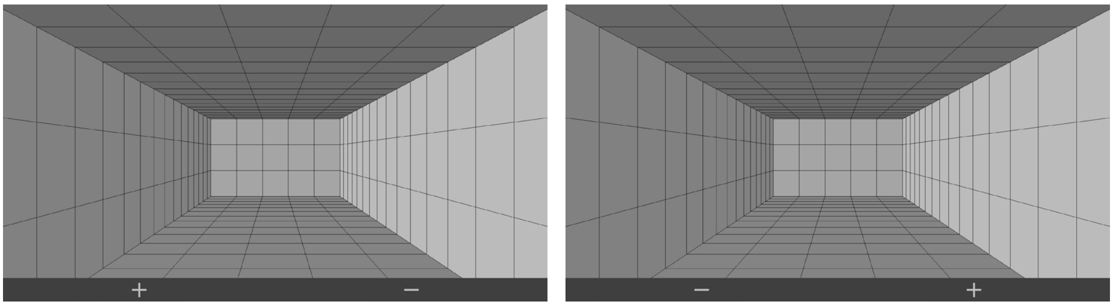


Figure 21. SI stimuli examples with the aid-bar to ultimately guide the participant's responses. A sample left image for 'like' and 'dislike' action-response on the left and right sides, respectively, and a sample right image for 'dislike' and 'like' action-response on the left and right sides, respectively.

Each group saw the presented stimuli in a specific order (first 'regular' then 'inverted', or first 'inverted then 'regular'), and were asked to answer to the raised question through the two response buttons ('like' on the left side and 'dislike' on the right side or 'dislike' on the left side and 'like' on the right side). Following 'Figure 22' illustrates the general experimental study design and Experiment 1 detailed design.

General study information:

Study design: Within-subject;
2 sequences of 90 (18x5) stimuli (regular and inverted);
32 test-subjects divided in 4 groups of 8 persons each;
2 response buttons (left and right; positive or negative);
2 experimental stages (not less than 3 months apart).

Independent variables: Two-dimensional matrix x(i,j), 1≤i≤3 and 1≤j≤6:
i: Geometric element complexity variation;
j: Geometric contour features variation.

Control variables: Gender (divided in male and female - best effort);
Age (divided in young and middle-aged adults - best effort);
Response time (3.0 s).

Experiment 1

Dependent variable: Aesthetic judgement (like/dislike).

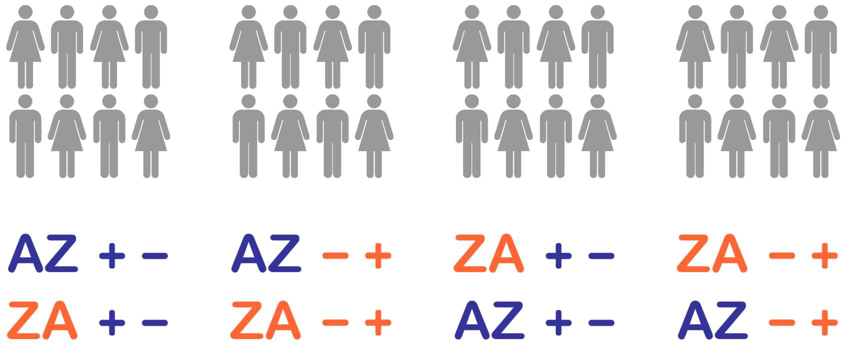


Figure 22. General experimental study design and Experiment 1 detailed design.

Group A saw first the ‘regular sequence’ and secondly the ‘inverted’ one and responded with ‘like’ on the left and ‘dislike’ on the right. Group B equally saw the ‘regular sequence’ first and the ‘inverted sequence’ afterwards and responded with ‘dislike’ on the left and ‘like’ on the right. Group C saw primarily to ‘inverted sequence’ and then the ‘regular’ one and responded with ‘like’ on the left and ‘dislike’ on the right. Finally, group D saw first the ‘inverted sequence’ followed by the ‘regular’ one, as the previous set, and responded with ‘dislike’ on the left and ‘like’ on the right. The participants sample was divided between two geographic areas: a metropolitan city and a peripheral small city.

To run this experiment we have used PsychoPy, an open source software package oriented to psychological and psychophysical studies, version 1.84.1.

Before the experimental stage took place, participants were informed of the experiment's essential procedures, in a need-to-know basis, in order to be able to perform the task that they were asked. This 'Experimental Guide' can be found in 'Appendix A'.

5.7.2.5. Pre-test

The experimental stage was preceded by a standard, neutral pre-test. The objective of this pre-test was to prepare the participants for the upcoming decisive experimental phase, namely to help them understand if they were able to follow and control the logic and physical mechanics of the required dichotomic left and right action-responses.

We presented 14 concepts in written form, to be evaluated by the participants according to a 'like'/'dislike' judgement, the same type of judgement that would be subsequently asked to the participants, during the actual experimental, and whose results, contrarily to this pre-test, would be considered in the final analysis. To understand if the participants were able to interiorize the logic of what was asked, and also able to respond in accordance with their judgement, this pre-test was followed closely by the study's host/facilitator, but without, such control being perceived by the participants, thus ensuring no interference in the responses. Although such evaluation was subjective and depended exclusively on the participants taste choice and aesthetic judgement, this pre-test, allowed the host to realise if the logic and physical mechanics of the experiment, were being properly followed. Notwithstanding, the fact that the action-responses were based on purely subjective aesthetic judgements and, hence, it would be impossible for the host to undoubtedly certify the participants' answers, we have included in the sample of the 14 words to be evaluated, three 'like' and three 'dislike' words (a kind of a test set), to which the participants were asked to answer in accordance: 'like' to the 'like' words and 'dislike' to the 'dislike' words. By doing so we have ensured that the participants were responding ‘like’ and ‘dislike’ whenever they intended to, without interfering neither in their judgements nor in their responses.

The concepts were presented via a fixed list of words naming the animal kingdom, included the ‘like’ and ‘dislike’ words, and respected the same order of appearance among all the participants, which was as followed:

- Cat;
- Scorpion;
- ‘Like’;
- Lion;
- Mosquito;
- Wasp;
- ‘Dislike’
- Kangaroo;
- Butterfly;
- Cockroach;
- Eagle;
- ‘Dislike’
- ‘Like’
- Mouse;
- ‘Like’
- Slug;
- ‘Dislike’
- Dog;
- Hummingbird;
- Louse.

All the words were directly parameterised in the PsychoPy software, displayed in white colour over neutral grey background, in Arial font type, with a scale value of 0,1 and located in the position (0,0). Similarly to what would happen in the experimental stage, the parameters were presented for a maximum time span of 3 seconds or until the occurrence of a participant’s action-response and were interspersed by neutral grey images with a centred black ‘X’, which were displayed for a variable time, that went from 1.85 to 2.15 seconds (2.0 seconds minus and plus 150 ms).

5.7.2.6. Technical Specifications

For the Experiment 1 it was used a laptop computer for the display and evaluation of the architecture spaces. The specifications of this component are: Laptop computer Intel® Core™ i7-4700HQ CPU @ 2.40GHz processor with 16.0 GB installed memory (RAM), 64-bit Operating System, x64-based processor, Intel® HD Graphics 4600 and an nVIDIA® GeForce GTX 850M Graphic Card, with a screen resolution of 1920x1080 pixels. SI stimuli were generated with Rhinoceros 3D software, version 4.0 and subject to digital image work with Photoshop CS6, version 13.0 x32. The experimental and pre-test stages were run using PsychoPy, an open source software oriented to psychological and psychophysical studies, version 1.84.1. Statistical analysis was performed using IBM SPSS version 22 statistics software package.

5.7.3. Experiment Walkthrough

In this section we depict a series of illustrative pictures of Experiment 1 (figures 23 to 40). These pictures correspond to the group of participants that, within this aesthetic judgement 'like/dislike' run, saw the 'regular' sequence first and then the 'inverted' one, and were asked to respond 'like' on the left button and 'dislike' on the right button. This case corresponds to the one illustrated on the left end of previous 'Figure 21'.

Pré-teste

Durante o pré-teste tem 3 segundos para responder se gosta (+) ou não gosta (-) dos parâmetros apresentados.

Nos casos em que aparece no ecrã 'gosto' ou 'não gosto', deve pressionar a tecla de resposta correspondente.

Quando estiver pronto para o pré-teste, pressione um dos dois botões de resposta.

Figure 23 (left). Introduction to the pre-test. Text: “Pre-test. In the pre-test you have 3.0 seconds to answer if you ‘like’ (+) or ‘dislike’ (-) the presented parameters. In case the word ‘like’ or ‘dislike’ is displayed, you should answer accordingly, with the correspondent button. Press one of the two response buttons when you feel ready to begin the pre-test.”

Figure 24 (right). Pre-test stimulus example. Text: “Hummingbird” (illustrative).

Figure 25 (left). Neutral transitory image.

Figure 26 (right). Stimulus ‘like’ towards which the participants should respond with a “like” action-response.

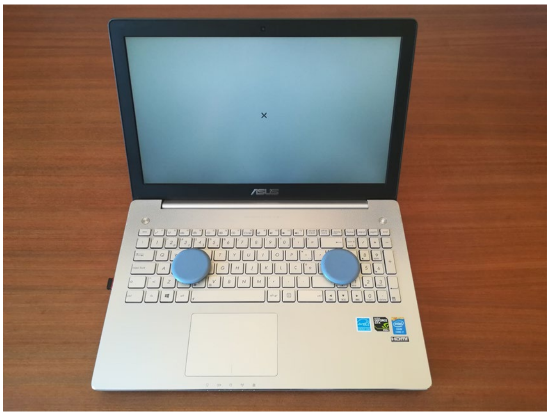


Figure 27 (left). Neutral transitory image.

Figure 28 (right). Stimulus ‘dislike’ towards which the participants should respond with a “dislike” action-response.


Experiência-teste

À semelhança do pré-teste, durante a experiência-teste tem 3 segundos para responder se gosta (+) ou não gosta (-) dos parâmetros apresentados.

Quando estiver pronto para a experiência-teste, pressione um dos dois botões de resposta.

Figure 29 (left). End of the pre-test and beginning of the actual experimental stage. Text: “Experiment stage”.

Figure 30 (right). Introduction to the experimental stage. Text: “Experiment stage. As the pre-test, in the experiment stage you have 3.0 seconds to answer if you ‘like’ (+) or ‘dislike’ (-) the presented parameters. Press one of the two response buttons when you feel ready to begin the experiment stage.”

Figure 31 (left). SI stimulus example.

Figure 32 (right). Neutral transitory image.

Figure 33 (left). SI stimulus example.

Figure 34 (right). End of the first stimuli presentation sequence and half-time break. Text: “break”.

Experiência-teste

À semelhança do pré-teste e da experiência-teste anteriores, durante o próximo ciclo tem 3 segundos para responder se gosta (+) ou não gosta (-) dos parâmetros apresentados.

Quando estiver pronto para continuar, pressione um dos dois botões de resposta.

Figure 35 (left). Beginning of the second stimuli presentation sequence. Text: “Experiment stage. As the pre-test and the previous experiment stage, in the next cycle you have 3.0 seconds to answer if you ‘like’ (+) or ‘dislike’ (-) the presented parameters. Press one of the two response buttons when you feel ready to begin the experiment stage.”

Figure 36 (right). SI stimulus example.

Figure 37 (left). Neutral transitory image.

Figure 38 (right). SI stimulus example.

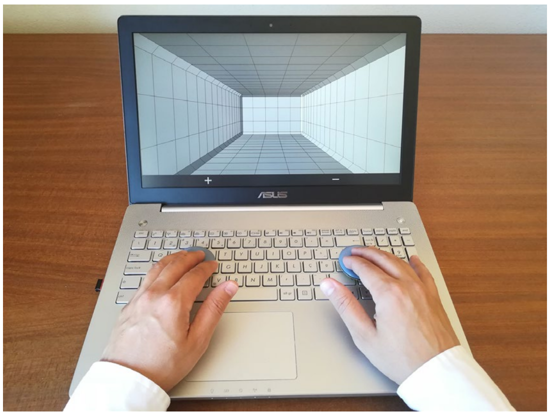


Figure 39 (left). End and thank you note.

Figure 40 (right). Correct position of the participants’ hands during the experimental stages.

5.7.4. Results

As described in the previous ‘Conducting Experiment 1’ section, during the course of Experiment 1 each participant viewed the SI stimuli through two sequences, each composed by five blocks of the eighteen singular SI stimuli, a regular one and its inverted counterpart, first the regular sequence and then the inverted, one or first the inverted and then the regular one. Although these sequences counted with eighteen original stimuli to be evaluated by the participants, the analysis of the results focused only on the participant’s responses on the SI that share a direct correspondence, which is the case of ‘sharp-tight’ and ′rounded-tight’ and ‘sharp-loose’ and ‘rounded-loose’ SI, or an indirect correspondence, which is the case of the ‘sharp-high’ and ‘rounded-high’ SI, as explained in previous section 5.3., ‘Description of the Stimuli/Architecture Spaces’.

The analysis described in the current ‘Results’ section took in consideration all the participant’s valid action-responses, those that were made within the stimuli exposition time span period of 3.0 seconds, and focused on two forms of examination: (i) the percentage of valid action-responses across the above-described correspondent SI and their element complexity transformation levels, in order to understand if the participant’s preference level towards abstract architecture spaces with sharp and rounded geometric characteristics; and (ii) the one-way analysis of variance (ANOVA) across the same correspondent SI and their element complexity transformation levels, in order to understand if, within these results, statistically significant differences (SSD) would be found, leading, expectantly, to the rejection of the null hypotheses. The ANOVA tests counted with three different Post Hoc methods: Tukey HSD, Scheffe’ and Bonferroni and the significance level (alpha) was set to 0.05. This last test was specially introduced to specifically attend and better respond to the relatively low eligible participant’s sample of the consistent-response’s analysis (see section 5.7.4.2). These statistical analyses were performed with the collaboration of Prof. Marina Andrade, Assistant Professor of ISCTE-IUL’s Department of Mathematics.

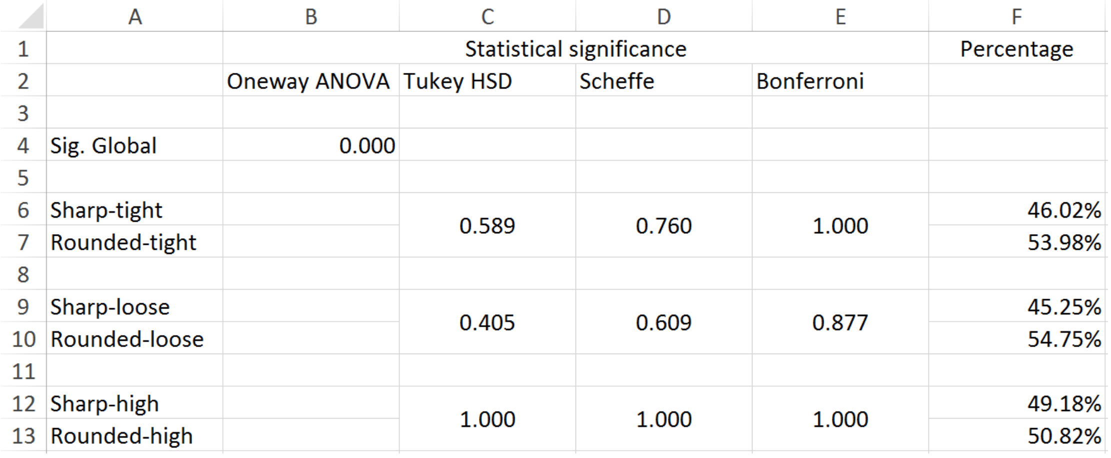
5.7.4.1. General Sample Analysis

General sample analysis shows a preference based on aesthetic judgements for rounded over sharp space contours, although in small rates due to what was considered noise interference.

5.7.4.1.1. First Sequence Analysis

As shown in Table 1, the average of this aesthetic-based judgement preference across the first viewed sequence and among SI that shared a direct correspondence, was of 53.98% against 46.02% for 'rounded-tight' and 'sharp-tight' SI and 54.75% against 45.25% for 'rounded-loose' and 'sharp-loose' ones, respectively. ANOVA results for hypothesis 'H1a' show p-values equal to 0.589 (Tukey HSD), 0.760 (Scheffe') and 1.000 (Bonferroni) for 'sharp-tight' and 'rounded-tight' SI and 0.405 (Tukey HSD), 0.609 (Scheffe') and 0.877 (Bonferroni) for 'sharp-loose' and 'rounded-loose' SI. These results don't indicate strong evidence against the null hypothesis.

On the other hand, considering hypothesis 'H2a', the average of preference across the indirect related 'sharp-high' and 'rounded-high' SI was of 49.18% for the former and 50.82% for the latter. ANOVA test results between these two SI types show a p-value equal to 1.000 in each of the three conducted tests, failing also to reject the null hypothesis.



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.589	0.760	1.000	46.02%
7	Rounded-tight					53.98%
8						
9	Sharp-loose		0.405	0.609	0.877	45.25%
10	Rounded-loose					54.75%
11						
12	Sharp-high		1.000	1.000	1.000	49.18%
13	Rounded-high					50.82%

Table 1. Preference based on aesthetic judgements and result significance for the first viewed sequence among contour features transformation levels[123].

As for the results on the element complexity transformation levels, we were expecting a preference for 'non-prominent' over 'rail-prominent' SI and, by turn, the latter over 'spot-prominent' SI (hypotheses 'H3a' and 'H4a'). Contrary to this, participants reported to like more 'rail-prominent' (56.10%) and 'spot-prominent' (55.00%) than 'non-prominent' SI (43.90% and 45.00%, respectively). ANOVA analysis on these results shows alpha values inferior to the alpha (0.050) between 'non-prominent' and 'rail-prominent' and 'non-prominent' and 'spot prominent' SI, however, contrarily to what was expected, with a preference level for the latter and no SSD between 'rail-prominent' and 'spot-prominent' SI, failing to reject both null hypothesis 'H3a' and 'H4a'. These results can be explained by some of the participant's in person reports, who declared to have been more negatively affected by the abstract emptiness of 'non-prominent' SI, when in comparison with the more complex composition of the 'rail' and 'spot-prominent' SI types (Table 2).

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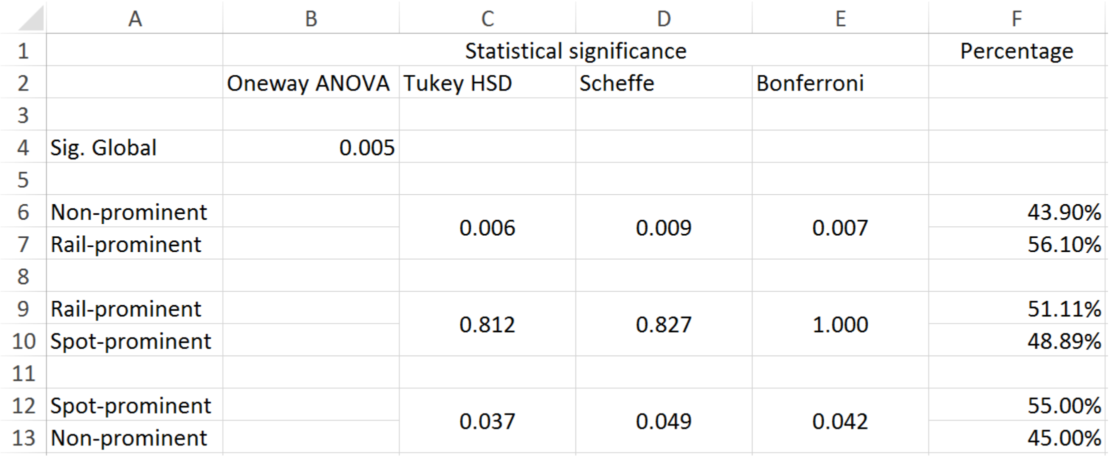
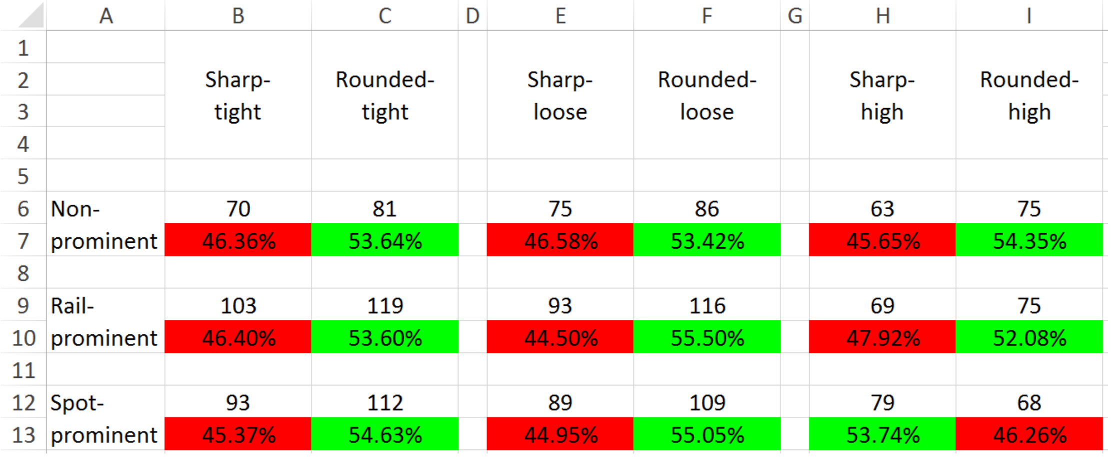
[123] As we can see in Table 1, although the ANOVA Post Hoc Tests did not show SSD among the correspondent SI, the value of the Global Significance is 0.000. Such is due to the fact that such Global Significance took under consideration all the analyzed SI and not only those that share a direct correspondence. The same applies to the rest of the tables that represent the ANOVA Post Hoc Tests results.



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.005				
5						
6	Non-prominent		0.006	0.009	0.007	43.90%
7	Rail-prominent					56.10%
8						
9	Rail-prominent		0.812	0.827	1.000	51.11%
10	Spot-prominent					48.89%
11						
12	Spot-prominent		0.037	0.049	0.042	55.00%
13	Non-prominent					45.00%

Table 2. Preference based on aesthetic judgements and result significance for the first viewed sequence among element complexity transformation levels.

Although the results didn’t show SSD towards the null hypotheses, participants have liked more the ‘rounded’ versions of the SI stimuli when in comparison with their ‘sharp’ counterparts with the exception of ‘spot-prominent’ ‘high’ SI stimulus, in which ‘sharp-high’ version was liked more than its rounded counterpart. Next Table 3 shows the amount and percentage of the participant’s ‘like’ action-responses (in relation with the total shown SI stimuli) within both contour features and element complexity transformation levels.

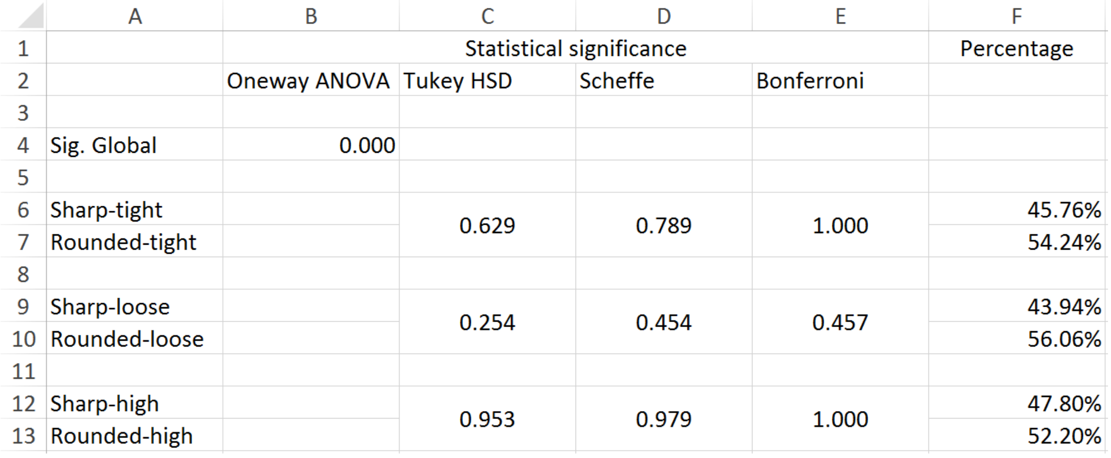


	A	B	C	D	E	F	G	H	I
1									
2		Sharp-	Rounded-		Sharp-	Rounded-		Sharp-	Rounded-
3		tight	tight		loose	loose		high	high
4									
5									
6	Non-	70	81		75	86		63	75
7	prominent	46.36%	53.64%		46.58%	53.42%		45.65%	54.35%
8									
9	Rail-	103	119		93	116		69	75
10	prominent	46.40%	53.60%		44.50%	55.50%		47.92%	52.08%
11									
12	Spot-	93	112		89	109		79	68
13	prominent	45.37%	54.63%		44.95%	55.05%		53.74%	46.26%

Table 3. Preference based on aesthetic judgements for the first viewed sequence among contour features and element complexity transformation levels.

5.7.4.1.2. Second Sequence Analysis

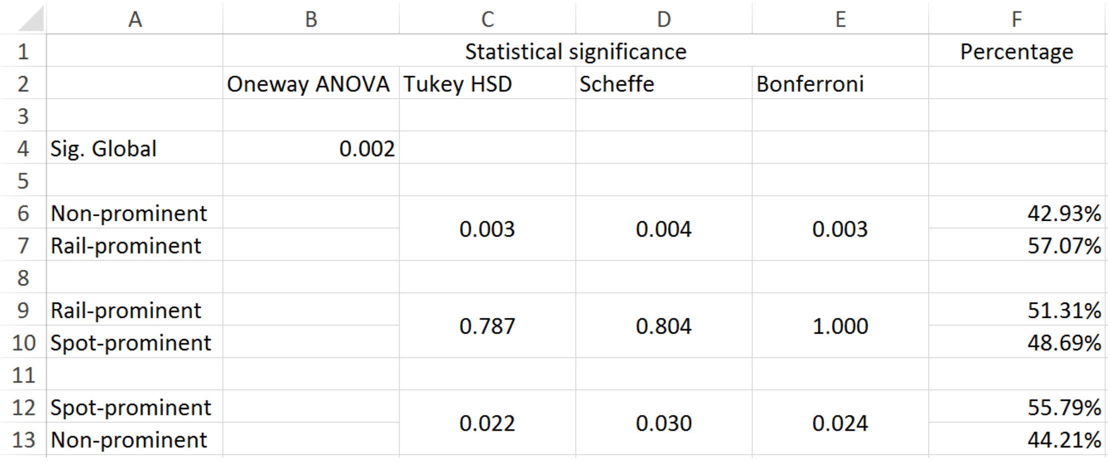
The results achieved on the second cycle of SI presentation are consistent with those of the first sequence. Participants have showed to like slightly more rounded feature SI than their sharp correspondent counterparts, however without rejecting null hypothesis ‘H1a’ and ‘H2a’ (Table 4).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.629	0.789	1.000	45.76%
7	Rounded-tight					54.24%
8						
9	Sharp-loose		0.254	0.454	0.457	43.94%
10	Rounded-loose					56.06%
11						
12	Sharp-high		0.953	0.979	1.000	47.80%
13	Rounded-high					52.20%

Table 4. Preference based on aesthetic judgements and result significance for the second viewed sequence among contour features transformation levels.

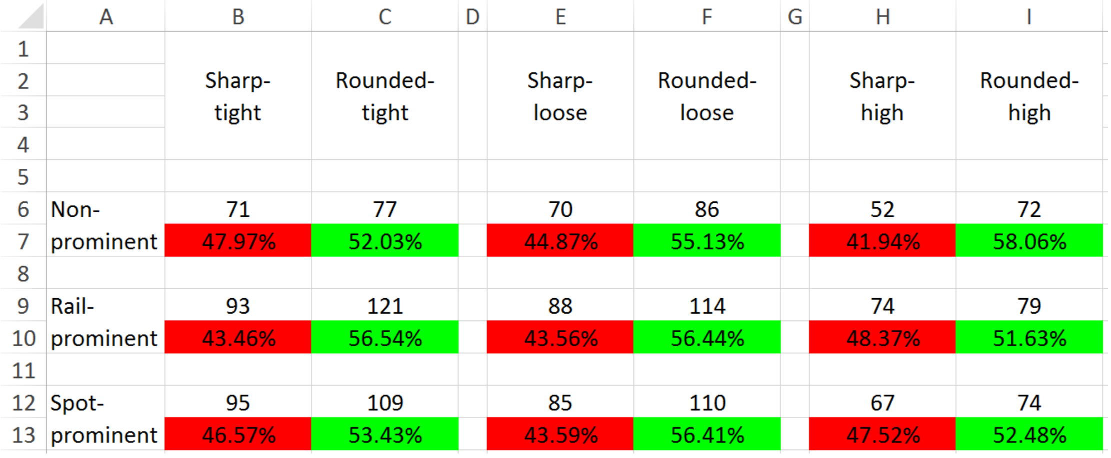
On the other hand, participants have liked ‘rail’ and ‘spot-prominent’ SI more than ‘non-prominent’ SI, once again contrarily to previous expectations and raised hypothesis ‘H3a’ and without SSD that could lead to a rejection of null hypothesis ‘H4a’ (Table 5).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.002				
5						
6	Non-prominent		0.003	0.004	0.003	42.93%
7	Rail-prominent					57.07%
8						
9	Rail-prominent		0.787	0.804	1.000	51.31%
10	Spot-prominent					48.69%
11						
12	Spot-prominent		0.022	0.030	0.024	55.79%
13	Non-prominent					44.21%

Table 5. Preference based on aesthetic judgements and result significance for the second viewed sequence among element complexity transformation levels.

Similarly to what happened in the first viewed sequence, even though relevant SDD towards the null hypotheses were not found, participants liked more ‘rounded’ SI stimuli over their ‘sharp’ counterpart versions, even in the case of the ‘spot-prominent’ ‘high’ stimuli, although with weak differences (Table 6).



	A	B	C	D	E	F	G	H	I
1									
2		Sharp-tight	Rounded-tight		Sharp-loose	Rounded-loose		Sharp-high	Rounded-high
3									
4									
5									
6	Non-prominent	71	77		70	86		52	72
7		47.97%	52.03%		44.87%	55.13%		41.94%	58.06%
8									
9	Rail-prominent	93	121		88	114		74	79
10		43.46%	56.54%		43.56%	56.44%		48.37%	51.63%
11									
12	Spot-prominent	95	109		85	110		67	74
13		46.57%	53.43%		43.59%	56.41%		47.52%	52.48%

Table 6. Preference based on aesthetic judgements for the second viewed sequence among contour features and element complexity transformation levels.

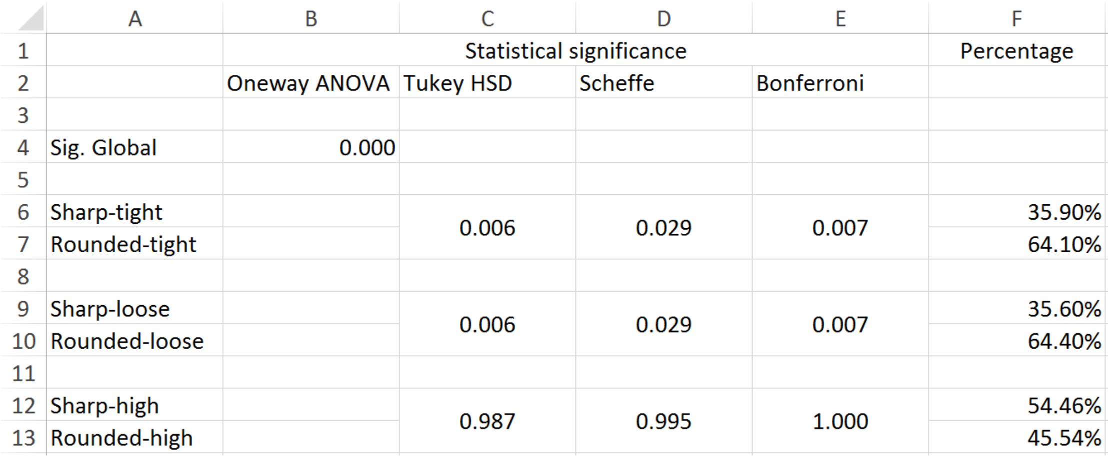
5.7.4.2. Consistent-Response Analysis

Since the analysis on the general sample results didn’t reveal strong evidences against the null hypotheses within contour features transformation levels (hypotheses ‘H1a’ and ‘H2a’), a second analysis, referred to as “consistent-response analysis”, was carried considering only the test-subjects that reported a coherent choice between ‘tight’ and ‘loose’ SI in at least one of the element complexity transformation groups or between ‘tight’ or ‘loose’ SI within element complexity transformation groups. The goal of this analysis was to consider only the participants that revealed ability to make a distinction between the direct related SI (‘sharp/rounded-tight’ and ‘sharp/rounded-loose’). To be included in this analysis participants have had to report a preference of at least a 40% difference (a difference of two or more ‘like’ action-responses in the total of five times that each SI has been presented), between two or more of these categories or at least one preference occurrence equal or over to 60% (difference of three or more ‘likes’). Due to the fact that this experiment pointed to an unconscious rather than conscious response from the participant’s this analysis focused on the first sequence’s results. 13 of the total of 32 test-subjects fulfilled these requirements. A single 40% difference (difference of two ‘likes’) and differences of 20% or less (difference of 1 or 0 ‘likes’) in between these groups were considered casual occurrences and led to the participant’s exclusion due to the fact that he/she was not able to make a distinction between the direct related space-images and was considered noise. In this last group were included 19 test-subjects.

5.7.4.2.1. First Sequence Analysis

In the consistent-response analysis, the related preference related between ‘sharp/rounded-tight’ and ‘sharp/rounded-loose’ space-images was significantly more expressive. The average of this preference was 64.1% against 35.9%, for ‘rounded-tight’ and ‘sharp-tight’ space-images, and 64.4% against 35.6%, for ‘rounded-loose’ and ‘sharp-loose’ types, respectively (see Table 7), being the highest value of reported preference 68.18%, reflecting a level of preference more than 2 times higher for ‘rounded-tight’ space-images (45 ‘likes’ against 21 for ‘sharp-tight’) and the lowest, 60.34%, representing a level of preference of 2/3 and 1/3 for ‘rounded-loose’ and ‘sharp-loose’ space-images respectively (see Table 9). All three ANOVA tests show SSD for ‘rounded-tight’ over ‘sharp-tight’ and ‘rounded-loose’ over ‘sharp-loose’ SI (hypothesis ‘H1a’) with p-values of 0.006 for Tukey HSD, 0.028 for Scheffé and 0.007 for Bonferroni, rejecting in this way, and as expected, the null hypothesis (Table 7).

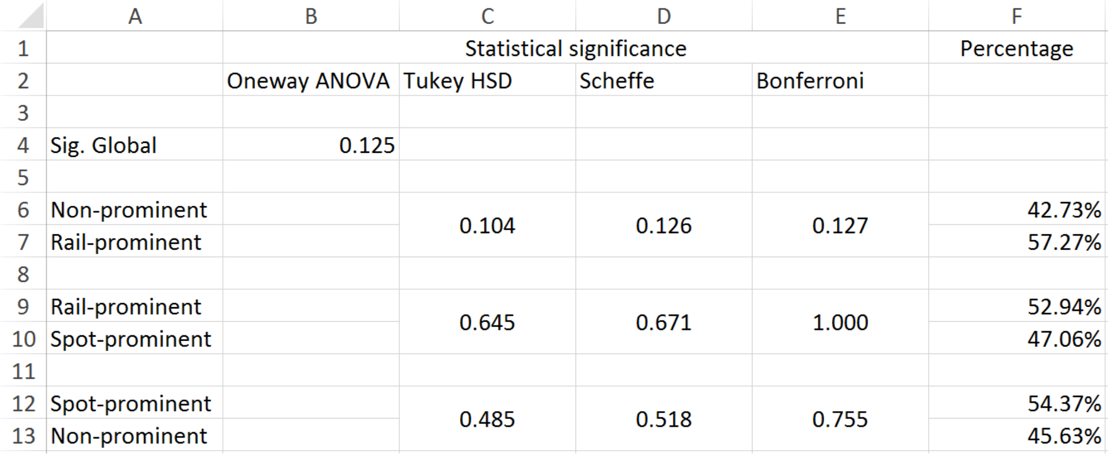
Between ‘sharp/rounded-high’ related images SSD were not found.



	A	B	C	D	E	F
1			Statistical significance			Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.006	0.029	0.007	35.90%
7	Rounded-tight					64.10%
8						
9	Sharp-loose		0.006	0.029	0.007	35.60%
10	Rounded-loose					64.40%
11						
12	Sharp-high		0.987	0.995	1.000	54.46%
13	Rounded-high					45.54%

Table 7. Preference based on aesthetic judgements and result significance for the consistent-response's first viewed sequence among contour features transformation levels.

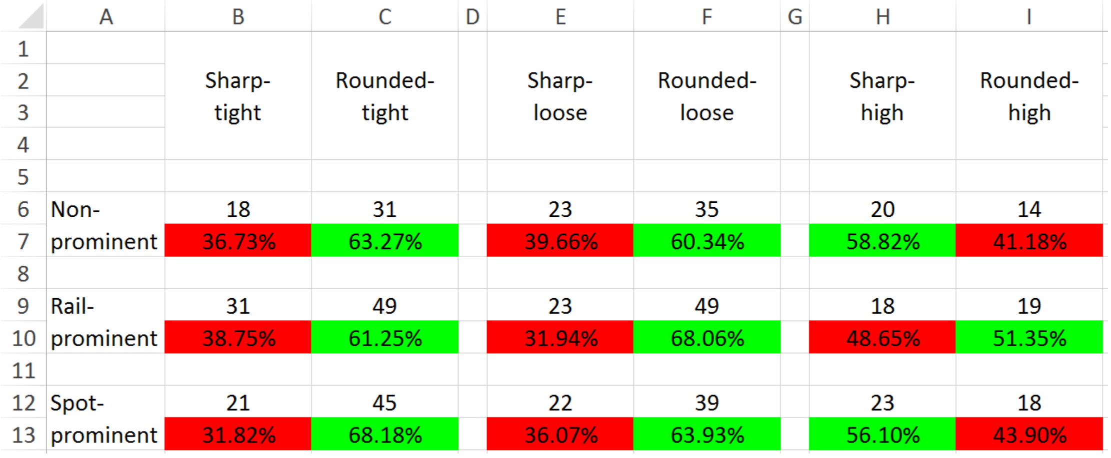
Within the element complexity transformation levels, the 'non-prominent' type was the less preferred, followed by the 'spot-prominent' and lastly, the 'rail-prominent' types, however, without SSD (Table 8).



	A	B	C	D	E	F
1			Statistical significance			Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.125				
5						
6	Non-prominent		0.104	0.126	0.127	42.73%
7	Rail-prominent					57.27%
8						
9	Rail-prominent		0.645	0.671	1.000	52.94%
10	Spot-prominent					47.06%
11						
12	Spot-prominent		0.485	0.518	0.755	54.37%
13	Non-prominent					45.63%

Table 8. Preference based on aesthetic judgements and result significance for the consistent-response's first viewed sequence among element complexity transformation levels.

Table 9 shows the raw data of the participants' 'like' responses towards the presented SI stimuli. According to these results, the participants who fitted the requirements of the consistent-response analysis liked significantly more 'rounded' SI stimuli over their 'sharp' counterparts, with two exceptions, again within the 'high' SI stimuli.

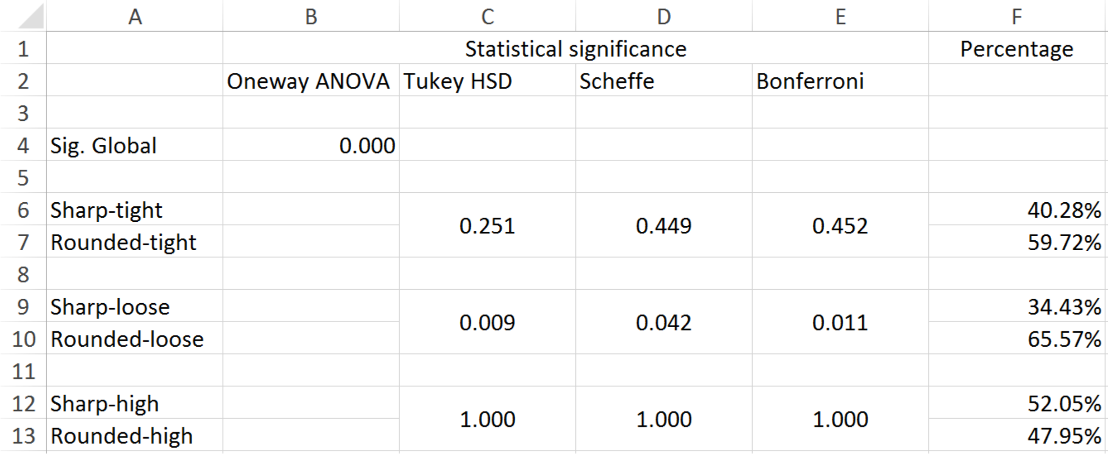


	A	B	C	D	E	F	G	H	I
1									
2		Sharp-	Rounded-		Sharp-	Rounded-		Sharp-	Rounded-
3		tight	tight		loose	loose		high	high
4									
5									
6	Non-	18	31		23	35		20	14
7	prominent	36.73%	63.27%		39.66%	60.34%		58.82%	41.18%
8									
9	Rail-	31	49		23	49		18	19
10	prominent	38.75%	61.25%		31.94%	68.06%		48.65%	51.35%
11									
12	Spot-	21	45		22	39		23	18
13	prominent	31.82%	68.18%		36.07%	63.93%		56.10%	43.90%

Table 9. Preference based on aesthetic judgements for the consistent-response’s first viewed sequence among contour features and element complexity transformation levels.

5.7.4.2.2. Second Sequence Analysis

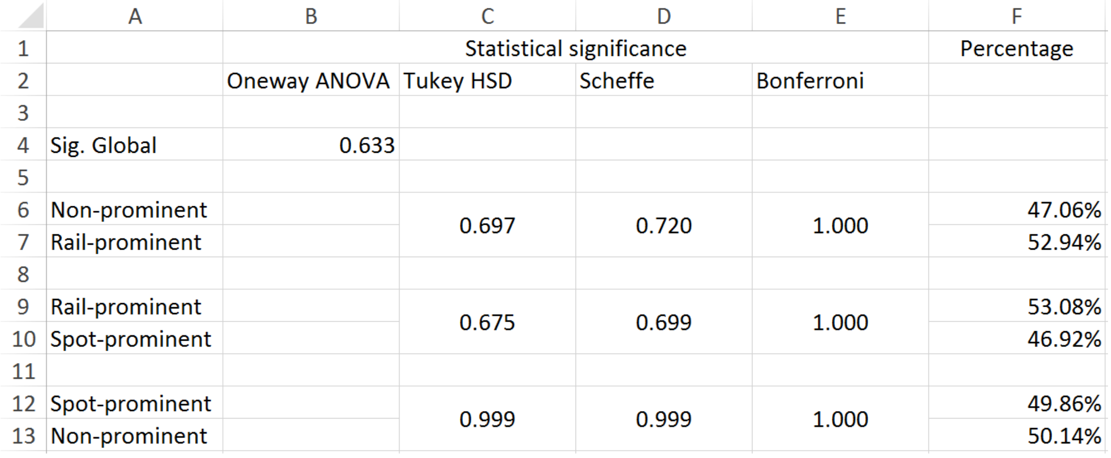
The analyses on the coherent choice’s second sequence’s results showed that participants preferred SI with rounded feature elements to their correspondent sharp versions. However, the analysis of variance on these contour features transformation groups only rejected the null hypothesis ‘H1a’ and between the ‘loose’ SI types (Table 10).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.251	0.449	0.452	40.28%
7	Rounded-tight					59.72%
8						
9	Sharp-loose		0.009	0.042	0.011	34.43%
10	Rounded-loose					65.57%
11						
12	Sharp-high		1.000	1.000	1.000	52.05%
13	Rounded-high					47.95%

Table 10. Preference based on aesthetic judgements and result significance for the consistent-response's second viewed sequence among contour features transformation levels.

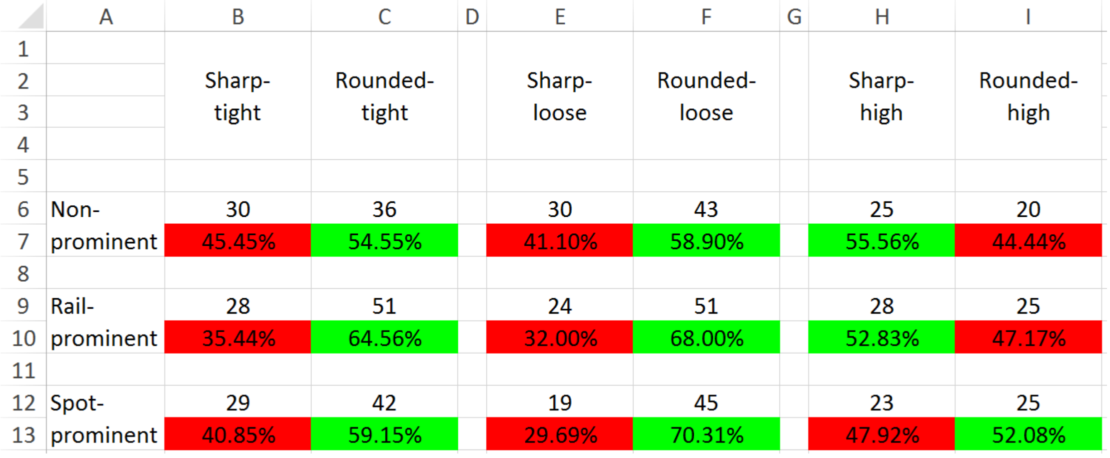
As happened in the previous sequence, we did not find SSD between the element complexity transformation levels of 'non', 'rail' and 'spot-prominent' types (Table 11).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.633				
5						
6	Non-prominent		0.697	0.720	1.000	47.06%
7	Rail-prominent					52.94%
8						
9	Rail-prominent		0.675	0.699	1.000	53.08%
10	Spot-prominent					46.92%
11						
12	Spot-prominent		0.999	0.999	1.000	49.86%
13	Non-prominent					50.14%

Table 11. Preference based on aesthetic judgements and result significance for the consistent-response's second viewed sequence among element complexity transformation levels.

Table 12 shows the number and percentage of liked responses for consistent-response's second viewed sequence.



	A	B	C	D	E	F	G	H	I
1									
2		Sharp-tight	Rounded-tight		Sharp-loose	Rounded-loose		Sharp-high	Rounded-high
3									
4									
5									
6	Non-prominent	30	36		30	43		25	20
7		45.45%	54.55%		41.10%	58.90%		55.56%	44.44%
8									
9	Rail-prominent	28	51		24	51		28	25
10		35.44%	64.56%		32.00%	68.00%		52.83%	47.17%
11									
12	Spot-prominent	29	42		19	45		23	25
13		40.85%	59.15%		29.69%	70.31%		47.92%	52.08%

Table 12. Preference based on aesthetic judgements for the consistent-response's second viewed sequence among contour features and element complexity transformation levels.

5.7.5. Conclusions

The analyses on the general sample results, in which we took into account the responses of all the 32 participants of the study, showed a general preference based on aesthetic judgements, for rounded characteristic elements when in comparison with their correspondent sharp counterparts without, however, strong evidences against the null hypotheses. In light of this conclusion, and given the fact that a deeper result analysis showed that many of the participants have evaluated 'rounded' and 'sharp' direct counterparts in identical or very close ways, we have conducted a second results analysis considering only the participants that were able to make a distinction between 'sharp' and 'rounded-tight' SI and/or 'sharp' and 'rounded-loose' SI, within the same element complexity transformation group, or between 'sharp-tight', 'rounded-tight', 'sharp-loose' or 'rounded-loose', within at least two of the element complexity transformation groups. To be included in this finer analysis, participants had to have reported, as mentioned earlier, a preference of at least a 40% difference (a difference of two or more 'like' action-responses in the total of five times that each SI has been presented), between two or more of these categories or at least one preference occurrence equal or over to 60% (difference of three or more 'likes') within this experiment's first sequence[124].

The results show that participants that made a coherent choice between the groups under consideration, prefer abstract architecture spaces with rounded rather than sharp feature elements, with strong evidences against the null hypothesis 'H1a', with the exception of second sequence's 'sharp-tight' and 'rounded-tight' SI, which, although with a preference for the latter over the former, do not show relevant SSD. Additionally, what was initially interpreted as some participant's lack of attention or sensibility towards the contour features transformation levels, specially reported within the limits of the peripheral city area with virtually imperceptible differentiation values, revealed to be in fact a predominance of attention on either these contour features transformation levels or the element complexity transformation ones. This conclusion is supported by the fact that the general sample analysis shows a preference, with relevant SSD, for some element complexity transformation levels over others (rail and spot-prominent over non-prominent SI – see Tables 2 and 5), results that are not achieved in the second, consistent-choice analysis (see Tables 8 and 11). These results, however, are not consistent with what was previously expected: a preference for 'non-prominent' over 'rail-prominent' SI and, by turn, a preference for the latter over 'spot-prominent' SI. This has probably to do with the fact that this study was set up by an architect used to think and face architecture spaces in their raw form, devoid of additional elements, a reality not shared by most of this study's participants, with the exception of punctual control back office situations. As mentioned before, many of them have reported to be affected by the "strange emptiness" of 'non-prominent' SI when in comparison with the "more composed" 'rail' and 'spot-prominent' SI types.

Additionally, even though participants have reported higher levels of preference for SI with more pronounced rounded feature elements within moderate evolution levels when in comparison with their direct correspondent counterparts, they have not reported to like more rounded extreme evolution SI ('rounded-high') when in comparison with its indirect correspondent counterparts ('sharp-high'). This has

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[124] See section 5.7.4.2., 'Consistent-Response Analysis'.

probably to do with the fact that the latter are more likely to fit within our close every-day experiences and hence a probable target of Zajonc's "mere-exposure" effect (Zajonc 1968). By opposition, complete non-Euclidean SI are likely to fit in the opposed category of "strange" things and hence not as likable as orthogonal, Euclidean SI.

5.8. Experiment 2

5.8.1. Context

Experiment 1 addressed the problem of the preference of architecture space form with distinct geometric features at contour level, through aesthetic judgements. In order to address other potential factors that enable us to better understand the preference for such forms, we designed Experiment 2, addressing approach-avoidance decisions for the same reasons given in context of Experiment 1 (section 5.7.1).

In order to understand our preference towards abstract architecture spaces with distinct geometric characteristics at contour level, which include moderate and extreme geometric levels of evolution that consider mere plan transitions and, in some examples, the whole space surface, Experiment 2 exposes the same SI stimuli that were used in the course of Experiment 1, to this experiment's exact same participants.

Based on the previous achieved results of experimental studies on the general topic of the preference for lines, shapes and forms[125] and the specific one of the preference for interior architecture environment form (Dazir and Read 2012; Vartanian, et al. 2013; van Oel and van de Berkhof 2013), it is expected that participant's associate abstract architecture spaces with prominent sharp edges and vertices with avoidance decisions, meaning that the participants would tend to avoid environments endowed with such characteristics. We also expect that participants will accept and not tend to avoid abstract architecture spaces with curved, rounded plan transitions. However, contrarily to what was expected in Experiment 1, it is uncertain if participants will decide to avoid or approach the sharp-high and rounded-high SI stimuli, independently of their element complexity transformations, due to the fact that such judgements refer to more objective and primitive levels not likely to be influenced by

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[125] For references, see list of variables and sources present in Chapter 4, section 4.5.2., 'Overview and Taxonomy on the Preference for Elements and Interior Architecture Environment Form with Distinct Geometric Characteristics'.

the previously mentioned “mere-exposure” and ‘strangeness’ effects. We expect to clarify such with the outcomes of the next Experiment 2.

The conditions under which this Experiment 2 took place will be described in the next methodology oriented sections.

5.8.2. Methodology

5.8.2.1. Variables

The independent variable of Experiment 2 is, as in Experiment 1, the two-dimensional matrix $x(i,j)$, $1 \leq i \leq 3$ and $1 \leq j \leq 6$, where:

- i: is the geometric element complexity variation;
- j: is the geometric contour features variation.

The dependent variable of Experiment 2 is:

- The approach-avoidance decisions triggered by SI stimuli, captured by a dichotomic ‘enter’ and ‘do not enter’ response pair.

As in Experiment 1, the extraneous (control) variables were:

- The gender of the participants (32), divided in female (18) and male (14) (best effort);
- The age of the participants divided in young adults, with ages from 18 to 40 years old, and middle-aged adults, with ages from 41 to 64 years old (best effort).
- The stimulus exposure time (set to 3.0 seconds).

5.8.2.2. Hypotheses

The hypotheses of Experiment 2 follow the general raised hypotheses of this thesis in order to understand if people find abstract architecture spaces with curved, rounded elements to be more pleasing than architecture spaces with angular, sharp elements. In particular, Experiment 2 addresses this thesis following sub-problem: “The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in approach-avoidance decision”. The experiment envisages demonstrating the following major and minor hypotheses, which are another variant of ‘H1’ to ‘H4’:

Major hypotheses:

H1b. People decide to approach abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts;

H2b. People decide to approach full non-Euclidean abstract architecture spaces, rather than Euclidean-based (fully orthogonal) abstract architecture spaces;

Minor hypotheses:

H3b. People decide to approach abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements.

H4b. People decide to approach abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features.

5.8.2.3. Experiment’s Sample

This study, a part of the within-subject experimental design, counted with the exact same 32 participants of Experiment 1. In this Experiment 2, each participant’s aesthetic judgement corresponded to an approach-avoidance decision. The consideration of the same participants for both experimental stages raised however another question: Experiment 2 could be infected by the answers of Experiment 1. In order to assure that such wouldn't happen we decided that Experiment 2 shouldn't take place in a period of time no less inferior to three months after Experiment 1.

5.8.2.4. Conducting Experiment 2

The layout of Experiment 2 followed, basically, the same layout of Experiment 1 with the exception of the question that we raised during the experiment to participants. In the course of this Experiment 2, participants were asked to answer to the question "Taking into account the presented stimuli, do you decide to enter or not enter the abstract architecture SI?" Participants had to choose one from the two dichotomic response pair: 'enter' ("I chose to enter in the presented abstract architecture SI") or 'do not enter' ("I chose to not enter in the presented abstract architecture SI").

To respond to the question, participants had at their disposal two grey identical buttons, with a diameter of 5 cm, centred over the computer's keyboard and located over the 'd' and 'return' keys, one of which corresponded to the 'enter' answer and the other to the 'do not enter' answer, according to a pre-defined order that will be explained in the next paragraphs. To better assist the participants in their action-responses, a grey horizontal bar with '+' and '-' symbols was added at the bottom of every SI. The side on which appeared such '+' and '-' symbols corresponded to the side where the 'enter' and 'do not enter' action-responses should be made, respectively.

As in Experiment 1, every SI appeared on the computer screen for maximum time span of 3.0 seconds and required, within this period, the participant's action-response. The stimuli's exposition time was limited to seek a more unconscious rather than conscious response from the participants. The SI stimulus exposition time would end whether the presentation software system acknowledged a participant's action-response or the 3.0 seconds period ran out, in which case any action-response after this period would be considered invalid and thus ignored and not suitable for result purposes and analysis, giving place to a transitory image. Such image, which was composed by a centred black 'X' over neutral grey background, intercalated each SI stimulus and, contrarily to these, didn't required a participant's action-response and was presented for a variable time span that went from 1.85 to 2.15 seconds (2.0

seconds minus and plus 150 ms) in order to avoid the possibility that the participant adopted a repetitive rhythm of response, something that could contribute to distract them from their task.

Likewise, all participants of Experiment 2 shared then the same experimental conditions. They viewed each of the 18 SI stimuli for a total five times within each of this study's two sequences of 90 SI, a 'regular' sequence, whose order was randomly calculated at www.random.org, and its corresponding inverse order sequence, the same considered in Experiment 1, which can be found in in 'Appendix C'.

To ensure neutral bias in the action-response process, participants were divided into the same four groups of eight test-subjects of Experiment 1 according to the order that the space-images were presented (first 'regular' then 'inverted' or first 'inverted' then 'regular') and the location of the action-response buttons ('enter' on the right side and 'do not enter' on the left side or 'do not enter' on the right side and 'enter' on the left side).

Each group saw the presented stimuli in the opposed order from that which was followed in the course of Experiment 1 (first 'regular' then 'inverted' or first 'inverted' then 'regular' according to each case), and answered to the raised question through the two response buttons, which had also attributed the opposed response type from that which was used in Experiment 1 (positive/'enter' on the right side and negative/'do not enter' on the left side or negative/'do not enter' on the right side and positive/'enter' on the left side according to each case) (Figure 41).

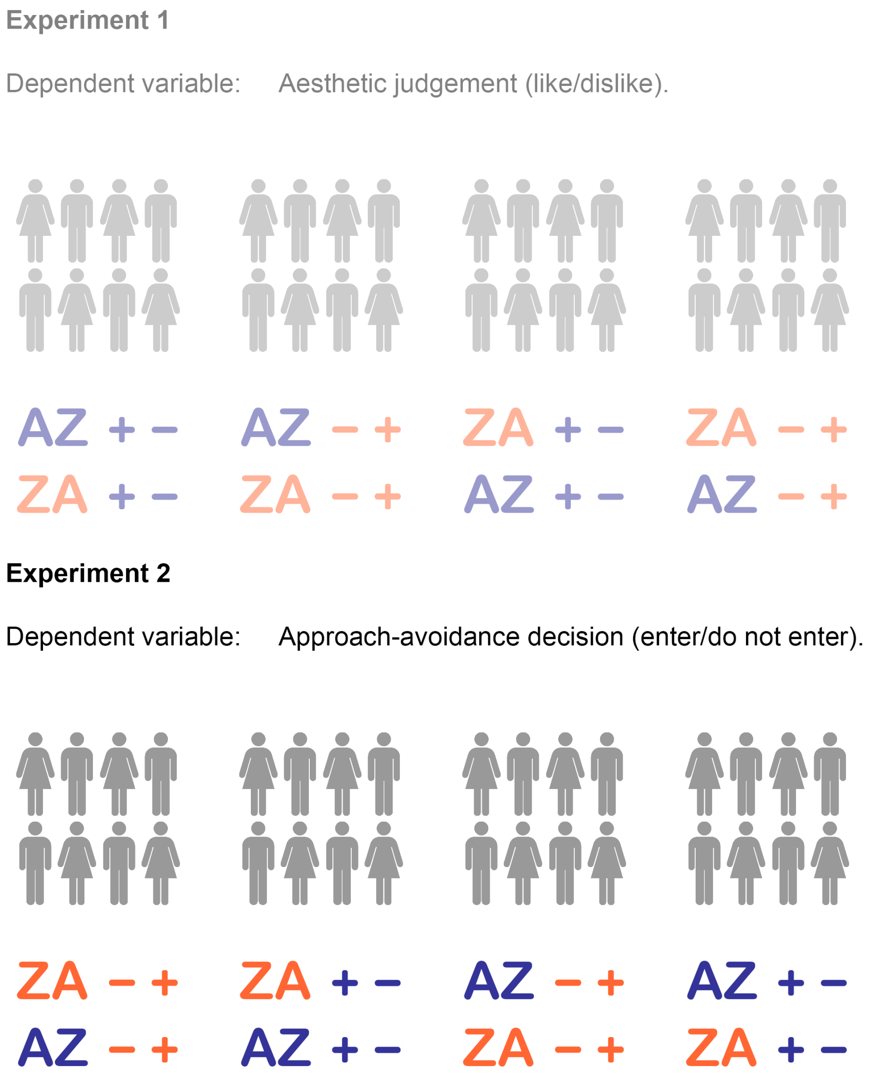


Figure 41. Experiment 2 detailed design in contrast to Experiment 1 detailed design.

Group A saw first the ‘inverted sequence’ and secondly the ‘regular’ one and responded ‘do not enter’ on the left and ‘enter’ on the right buttons. Group B equally saw the ‘inverted sequence’ first and the ‘regular sequence’ afterwards and responded ‘enter’ on the left and ‘do not enter’ on the right sides. Group C saw primarily to ‘regular sequence’ and then the ‘inverted’ one and responded ‘do not enter’ on the left and ‘enter’ on the right buttons. Finally, group D saw first the ‘regular sequence’ followed by the ‘inverted’ one, as the previous set, and responded ‘enter’ on the left and ‘do not enter’ on the right sides. The sample of participants was divided between two geographic areas: a metropolitan city and a peripheral small city.

To run this experiment we have used PsychoPy, an open source software package oriented to psychological and psychophysical studies, version 1.84.1.

Before the experimental stage took place, participants were informed of the experiment’s essential procedures, in a need-to-know basis, in order to be able to perform the task that they were asked. This ‘Experimental Guide’ can be found in ‘Appendix A’.

5.8.2.5. Pre-test

Following the methodology applied in Experiment 1, the experimental stage of Experiment 2 was also preceded by a standard, neutral pre-test, with the goal to prepare the participants to this decisive experimental phase, whose results would be determinants to the conclusions to be achieved. Since the participants already proofed to understand and be able to follow and control the logic and physical mechanics of the dichotocmic left and right action-responses in the course of Experiment 1, this pre-test was set in order to rekindle such past knowledge and train them to where positive (‘enter’) and negative (‘do not enter’) responses should be made, which in this Experiment 2 were to take place in the opposite side of Experiment’s 1 positive and negative responses, as explained in the previous ‘Conducting Experiment 2’ section.

This pre-test counted with 14 parameters to be evaluated by the participants according to their approach-avoidance decision judgements. Additionally, although the parameters had been previously and carefully chosen to assure neutral bias but also to point to an expected answer, in order to become absolutely clear that the participants were being able to interiorise on which button they should press to respond to their ‘enter’ and the ‘do not enter’ decisions, additional 6 other parameters where added, three ‘enter’ and three ‘do not enter’ expressions to which the participants were asked to answer in accordance: ‘enter’ to the ‘enter’ and ‘do not enter’ to the ‘do not enter’ parameters. To understand if the participants were being able to respond in accordance with their decisions, this pre-test was followed closely by the study’s host without, however, such control was perceived by the participants ensuring in this way any kind of interference in the responses.

The presented parameters followed a fixed list of words of natural and human made tri-dimensional environment structures susceptible of being approached or avoided, included the 'enter' and 'do not enter' expressions and respected the same order of appearance among all the participants. The order of exposition of these parameters was as followed:

- Museum;
- Attic;
- 'Enter';
- Garage;
- Haystack;
- Plane;
- 'Do not enter'
- Oven;
- Cave;
- Nightclub;
- Prison;
- 'Do not enter'
- 'Enter'
- Basement;
- 'Enter'
- Hospital;
- 'Do not enter'
- Living-room;
- Public-Lavatory;
- Well.

All the parameters were directly parameterised in the used PsychoPy software, displayed in white colour over neutral grey background, in Arial font type, with a scale value of 0.1 and located in the position (0,0). Similarly to what would happen in the experimental stage, the parameters were presented for a maximum time span of 3.0 seconds or until the occurrence of a participant's action-response and were interspersed by neutral grey images with a centred black 'X', which were displayed for a variable time that went from 1.85 to 2.15 seconds (2.0 seconds minus and plus 150 ms).

5.8.2.6. Technical Specifications

The technical specifications of Experiment 2 were the same used in Experiment 1 (see section 5.7.2.6).

5.8.3. Experiment Walkthrough

This Experiment 2 walkthrough is very similar to the one of Experiment 1, listed in section 5.7.3. The only difference lays on the fact that Experiment 1's was oriented by 'like/dislike' aesthetic judgments and Experiment 2's by 'enter/do not enter' approach-avoidance decisions.

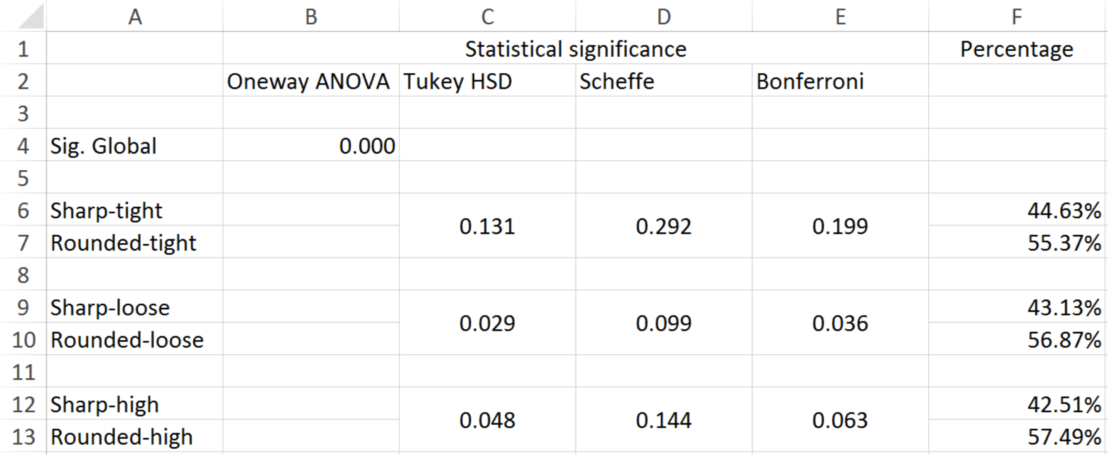
5.8.4. Results

5.8.4.1. General Sample Analysis

As expected, general sample result analysis shows a preference based in approach-avoidance decisions for rounded rather than sharp feature SI. Contrarily to this same sample's results on aesthetic judgements, relevant SSD were found, showing strong evidence against null hypotheses in more than half of the conducted Post-Hoc Tests. Participants have also shown to prefer rounded SI with extreme levels of geometry evolutions, in most cases with also relevant SSD. As to the element complexity transformation groups, participants confirmed their preference for 'rail' and 'spot-prominent' rather than 'non-prominent' SI. Although such preference was not predictable in an initial study's phase, these results were expected after the ones achieved in previous Experiment 1.

5.8.4.1.1. First Sequence Analysis

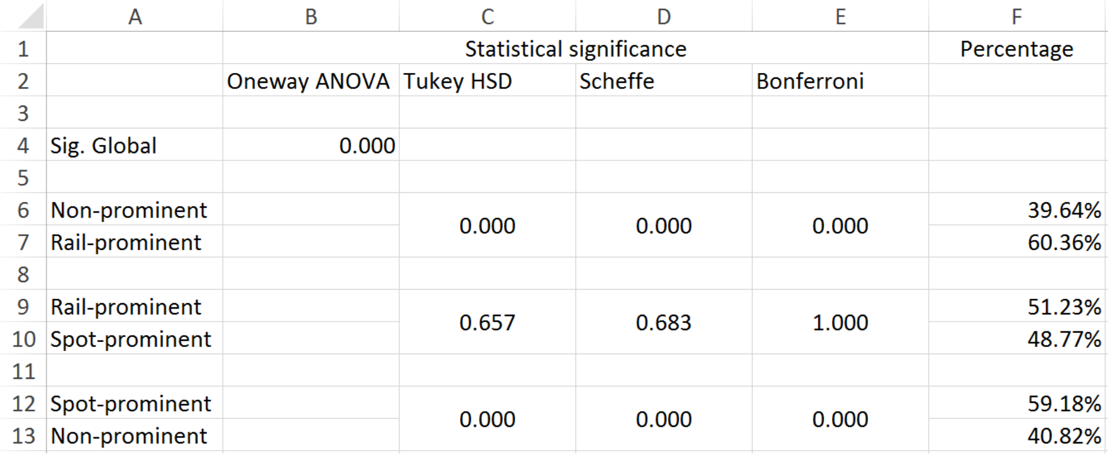
The analysis on the first presented sequence of SI stimuli shows a preference for rounded rather than sharp feature abstract architecture spaces with emphasis on the direct related ‘sharp’/’rounded-loose’ SI and the indirect related ‘sharp’/’rounded-high’ SI. These results show relevant SSD for Tukey HSD Post-Hoc Test among ‘loose’ and ‘high’ SI types and for Bonferroni Post-Hoc test between ‘loose’ SI ones (p-values ≤ 0.05) (Table 13).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.131	0.292	0.199	44.63%
7	Rounded-tight					55.37%
8						
9	Sharp-loose		0.029	0.099	0.036	43.13%
10	Rounded-loose					56.87%
11						
12	Sharp-high		0.048	0.144	0.063	42.51%
13	Rounded-high					57.49%

Table 13. Preference based on approach-avoidance decisions and result significance for the first viewed sequence among contour features transformation levels.

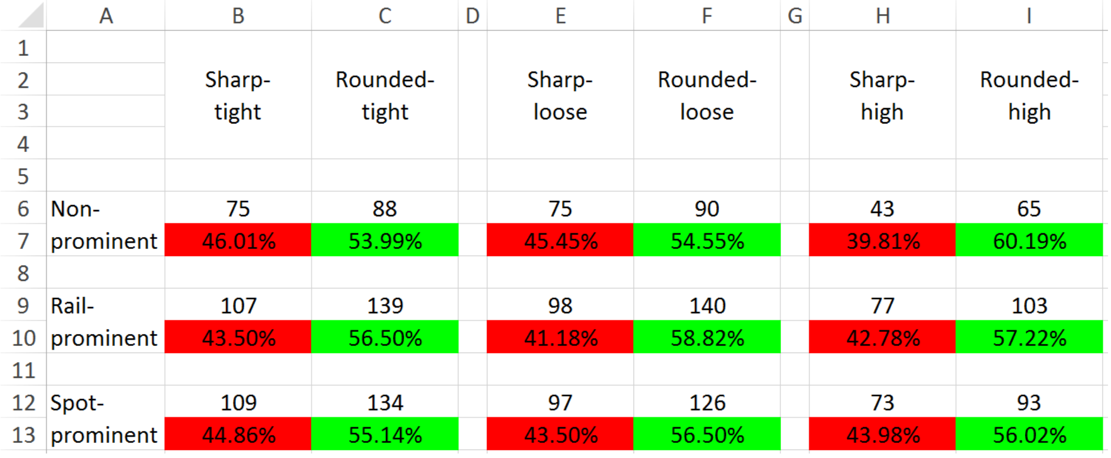
On the other hand, participants also reported a clear preference for ‘rail’ and ‘spot-prominent’ SI over ‘non-prominent’ ones (p-value = 0,000) (Table 14).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Non-prominent		0.000	0.000	0.000	39.64%
7	Rail-prominent					60.36%
8						
9	Rail-prominent		0.657	0.683	1.000	51.23%
10	Spot-prominent					48.77%
11						
12	Spot-prominent		0.000	0.000	0.000	59.18%
13	Non-prominent					40.82%

Table 14. Preference based on approach-avoidance decisions and result significance for the first viewed sequence among element complexity transformation levels.

Table 15 shows the number and percentages of the participants' 'enter' responses for the first viewed sequence.

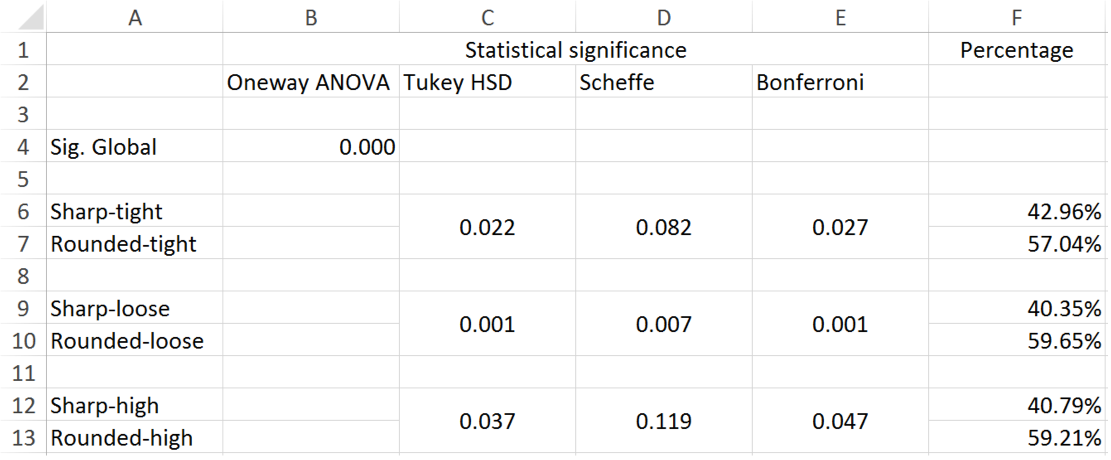


	A	B	C	D	E	F	G	H	I
1									
2		Sharp-tight	Rounded-tight		Sharp-loose	Rounded-loose		Sharp-high	Rounded-high
3									
4									
5									
6	Non-	75	88		75	90		43	65
7	prominent	46.01%	53.99%		45.45%	54.55%		39.81%	60.19%
8									
9	Rail-	107	139		98	140		77	103
10	prominent	43.50%	56.50%		41.18%	58.82%		42.78%	57.22%
11									
12	Spot-	109	134		97	126		73	93
13	prominent	44.86%	55.14%		43.50%	56.50%		43.98%	56.02%

Table 15. Preference based on approach-avoidance decisions for the first viewed sequence among contour features and element complexity transformation levels.

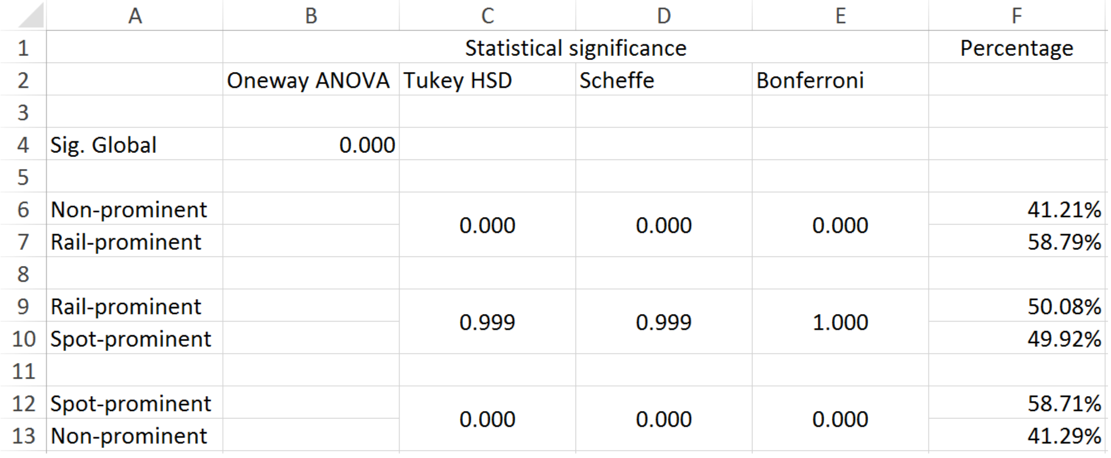
5.8.4.1.2. Second Sequence Analysis

The analyses on the second sequence's results support the ones of the first sequence with, however, more expressive values. Participants have showed to prefer rounded feature SI rather than their sharp correspondent counterparts with relevant SSD that show strong evidence against null hypothesis 'H1b' and 'H2b' in both Tukey HSD and Bonferroni Post-Hoc Tests for all three ‘tight’, ‘loose’ and ‘high’ SI type variations. Hypotheses ‘H3b’ and ‘H4b’ were once again not demonstrated (Tables 16 and 17).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.022	0.082	0.027	42.96%
7	Rounded-tight					57.04%
8						
9	Sharp-loose		0.001	0.007	0.001	40.35%
10	Rounded-loose					59.65%
11						
12	Sharp-high		0.037	0.119	0.047	40.79%
13	Rounded-high					59.21%

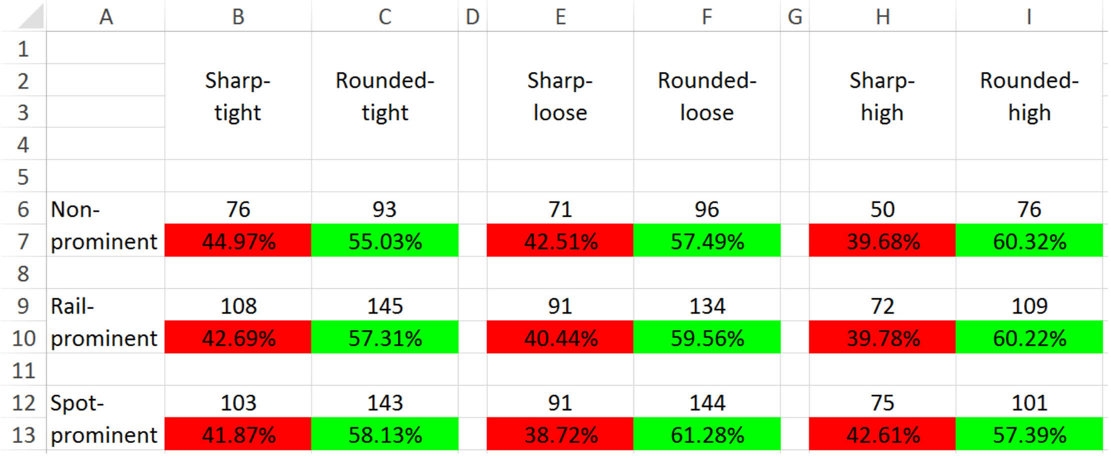
Table 16. Preference based on approach-avoidance decisions and result significance for the second viewed sequence among contour features transformation levels.



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Non-prominent		0.000	0.000	0.000	41.21%
7	Rail-prominent					58.79%
8						
9	Rail-prominent		0.999	0.999	1.000	50.08%
10	Spot-prominent					49.92%
11						
12	Spot-prominent		0.000	0.000	0.000	58.71%
13	Non-prominent					41.29%

Table 17. Preference based on approach-avoidance decisions and result significance for the second viewed sequence among element complexity transformation levels.

Table 18 shows the number and percentages of the participants’ ‘enter’ responses for the second viewed sequence.



	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	76	93	71	96	50	76
	44.97%	55.03%	42.51%	57.49%	39.68%	60.32%
Rail-prominent	108	145	91	134	72	109
	42.69%	57.31%	40.44%	59.56%	39.78%	60.22%
Spot-prominent	103	143	91	144	75	101
	41.87%	58.13%	38.72%	61.28%	42.61%	57.39%

Table 18. Preference based on approach-avoidance decisions for the second viewed sequence among contour features and element complexity transformation levels.

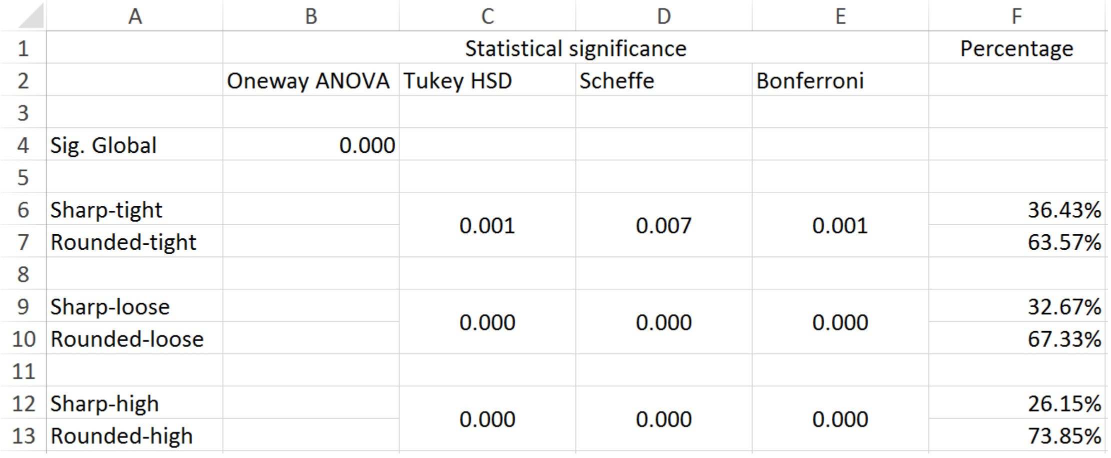
5.8.4.2. Consistent-Response's Analysis

Although this Experiment 2's general sample analysis showed higher preference levels (based on approach-avoidance decisions) than those registered in Experiment 1's same analysis (aesthetic judgement), revealing strong evidences against null hypotheses 'H1b' and 'H2b', we have conducted a second result analysis considering only the participants that reported a consistent-response between 'tight' and 'loose' SI in at least one of the element complexity transformation groups or between 'tight' or 'loose' SI within element complexity transformation groups, as happened in the previous experiment. To be included in this analysis participants had to have reported a preference of at least a 40% difference (a difference of two or more 'like' action-responses in the total of five times that each SI has been presented) between two or more of these categories or at least one preference occurrence equal or over to 60% (difference of three or more 'likes'). Due to the same reason pointed in Experiment 1, since this experiment pointed to an unconscious rather than conscious response from the participant's this analysis focused on the first sequence's results. In this case, 16 of the total of 32 test-subjects fulfilled these requirements and were included in this group.

Results show to be significantly more expressive than the ones achieved in both this Experiment 2's general sample analysis and Experiment 1's consistent-response one.

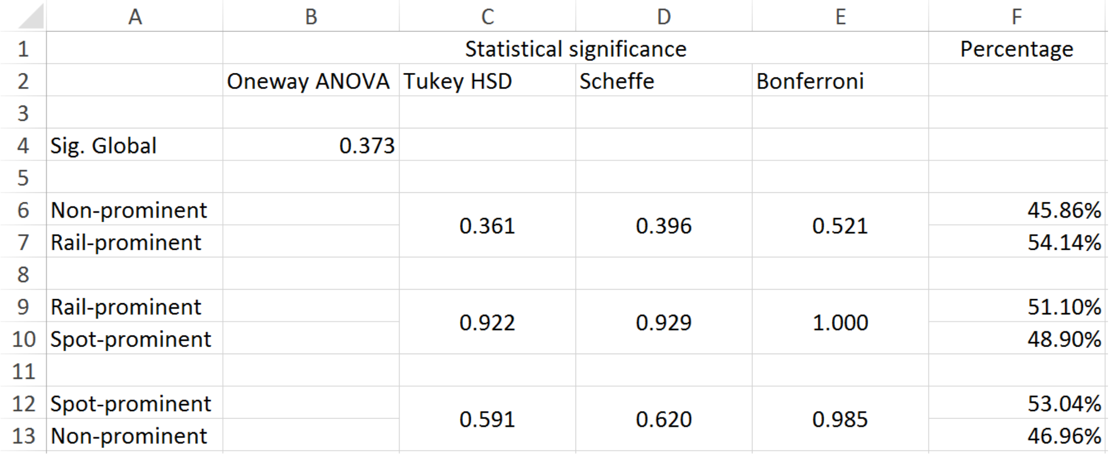
5.8.4.2.1. First Sequence Analysis

The analysis on the results of the first sequence of the coherent-choice-response shows high levels of preference for SI with rounded features when in comparison with their sharp correspondent counterparts. ANOVA on these results shows strong evidences against null hypotheses ‘H1b’ and ‘H2b’ in all three Post-Hoc Test methods, demonstrating in this way both of these two hypotheses. As expected after the results on Experiment 1, the preference for element complexity transformation groups repeated previous result analysis not proving hypotheses ‘H3b’ and ‘H4b’ and, more important to the discussion on these results, not showing strong evidences against neither of such null hypotheses (Tables 19 and 20).



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.001	0.007	0.001	36.43%
7	Rounded-tight					63.57%
8						
9	Sharp-loose		0.000	0.000	0.000	32.67%
10	Rounded-loose					67.33%
11						
12	Sharp-high		0.000	0.000	0.000	26.15%
13	Rounded-high					73.85%

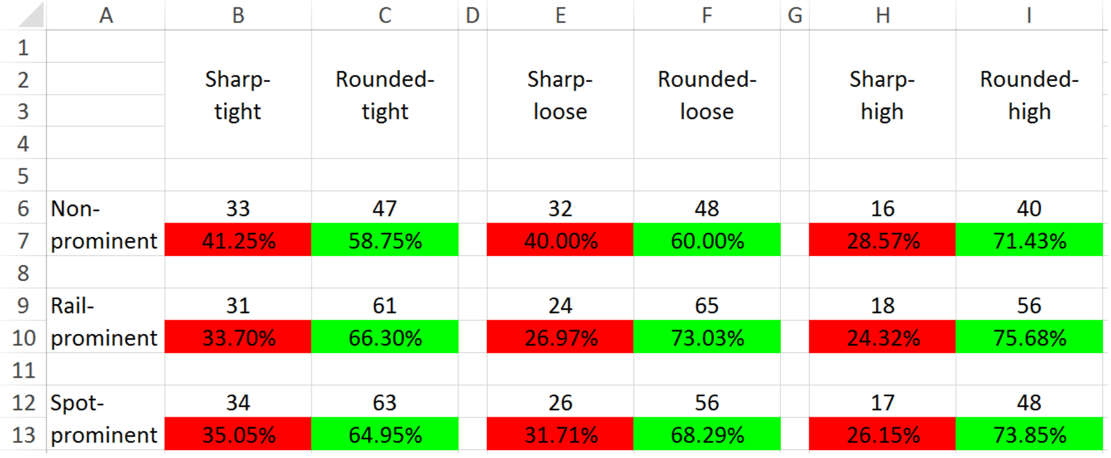
Table 19. Preference based on approach-avoidance decisions and result significance for the consistent-response’s first viewed sequence among contour features transformation levels.



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.373				
5						
6	Non-prominent		0.361	0.396	0.521	45.86%
7	Rail-prominent					54.14%
8						
9	Rail-prominent		0.922	0.929	1.000	51.10%
10	Spot-prominent					48.90%
11						
12	Spot-prominent		0.591	0.620	0.985	53.04%
13	Non-prominent					46.96%

Table 20. Preference based on approach-avoidance decisions and result significance for the consistent-response's first viewed sequence among element complexity transformation levels.

As expected, the raw data of the number and percentage of the participants' 'enter' responses to the presented SI stimuli show that they have opted to approach the 'rounded' SI stimuli significantly more than their 'sharp' counterpart versions within all the stimuli universe (Table 21).

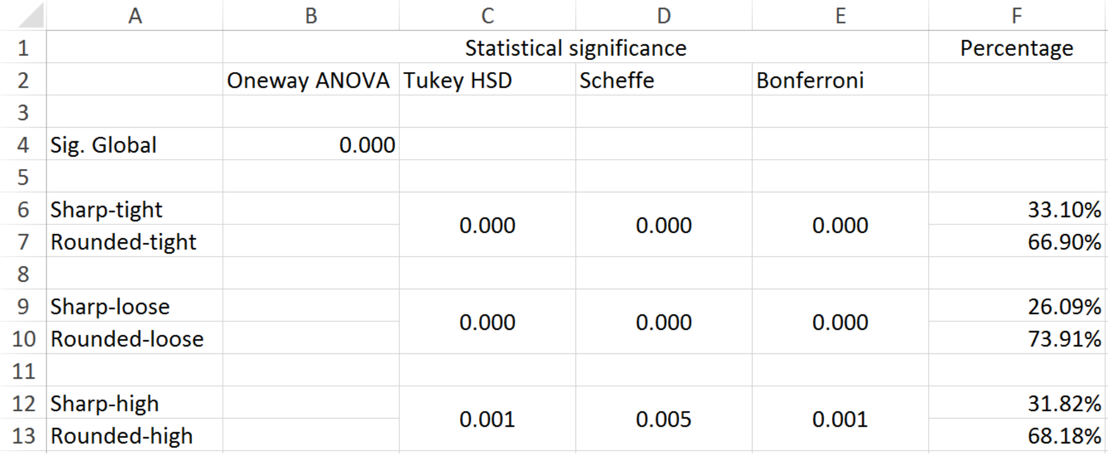


	A	B	C	D	E	F	G	H	I
1									
2		Sharp-tight	Rounded-tight		Sharp-loose	Rounded-loose		Sharp-high	Rounded-high
3									
4									
5									
6	Non-prominent	33	47		32	48		16	40
7		41.25%	58.75%		40.00%	60.00%		28.57%	71.43%
8									
9	Rail-prominent	31	61		24	65		18	56
10		33.70%	66.30%		26.97%	73.03%		24.32%	75.68%
11									
12	Spot-prominent	34	63		26	56		17	48
13		35.05%	64.95%		31.71%	68.29%		26.15%	73.85%

Table 21. Preference based on approach-avoidance decisions for the consistent-response's first viewed sequence among contour features and element complexity transformation levels.

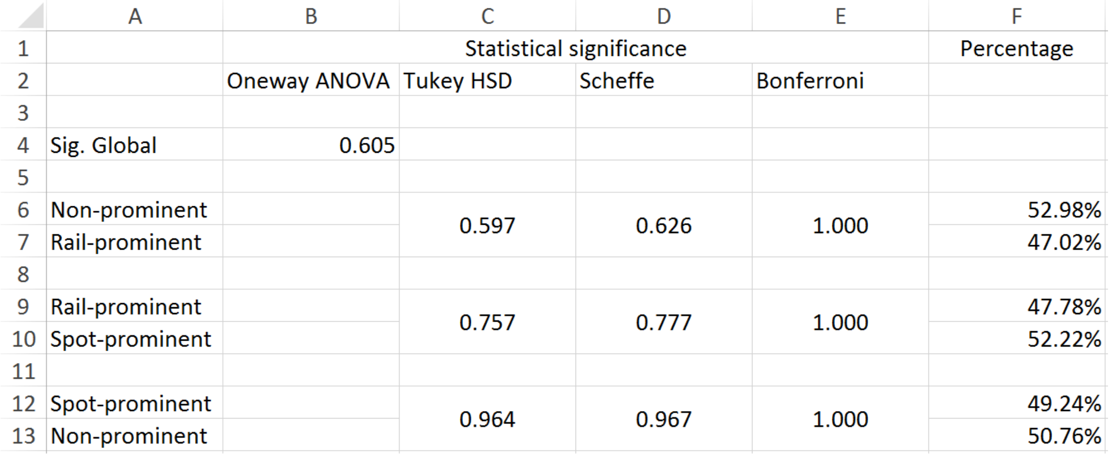
5.8.4.2.2. Second Sequence Analysis

The analysis on the consistent-responses' second sequence is in every way consistent with the one of previous 'First Sequence Analysis' section (Tables 22, 23 and 24).



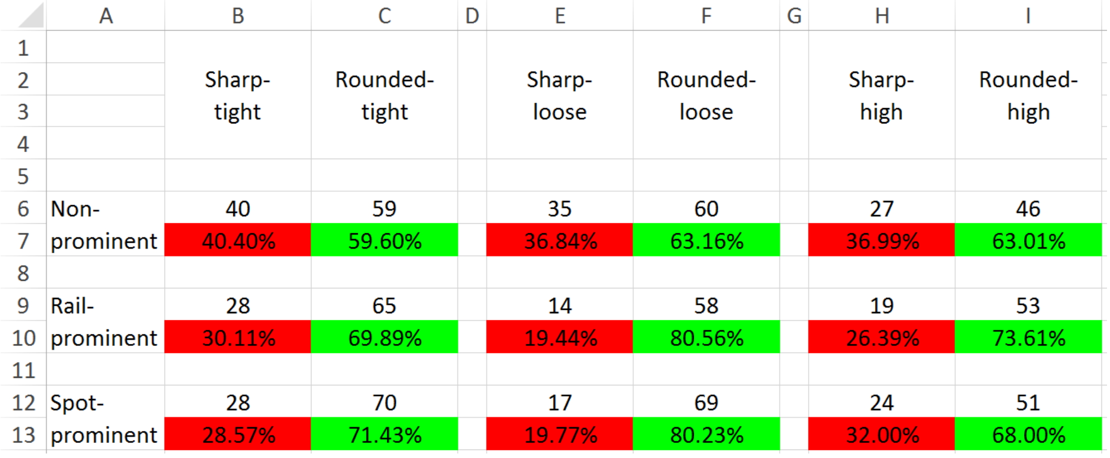
	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.000				
5						
6	Sharp-tight		0.000	0.000	0.000	33.10%
7	Rounded-tight					66.90%
8						
9	Sharp-loose		0.000	0.000	0.000	26.09%
10	Rounded-loose					73.91%
11						
12	Sharp-high		0.001	0.005	0.001	31.82%
13	Rounded-high					68.18%

Table 22. Preference based on approach-avoidance decisions and result significance for the consistent-response's second viewed sequence among contour features transformation levels.



	A	B	C	D	E	F
1		Statistical significance				Percentage
2		Oneway ANOVA	Tukey HSD	Scheffe	Bonferroni	
3						
4	Sig. Global	0.605				
5						
6	Non-prominent		0.597	0.626	1.000	52.98%
7	Rail-prominent					47.02%
8						
9	Rail-prominent		0.757	0.777	1.000	47.78%
10	Spot-prominent					52.22%
11						
12	Spot-prominent		0.964	0.967	1.000	49.24%
13	Non-prominent					50.76%

Table 23. Preference based on approach-avoidance decisions and result significance for the consistent-response's second viewed sequence among element complexity transformation levels.



	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	40	59	35	60	27	46
	40.40%	59.60%	36.84%	63.16%	36.99%	63.01%
Rail-prominent	28	65	14	58	19	53
	30.11%	69.89%	19.44%	80.56%	26.39%	73.61%
Spot-prominent	28	70	17	69	24	51
	28.57%	71.43%	19.77%	80.23%	32.00%	68.00%

Table 24. Preference based on approach-avoidance decisions for the consistent-response's second viewed sequence among contour features and element complexity transformation levels.

5.8.5. Conclusions

The analysis on Experiment 2's results shows that based on approach-avoidance decisions participants have shown to prefer abstract architecture spaces with rounded characteristic elements when in comparison with their correspondent sharp counterparts. Contrarily to what happened in Experiment 1, where it was under evaluation the participants level of preference for the SI stimuli based on aesthetic judgements, the analysis of general sample's results showed strong evidence against null hypothesis 'H1b' (people decide to approach abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts) in most of the Post-Hoc conducted tests and the same level of evidence against null hypothesis 'H2b' (people decide to approach full non-Euclidean abstract architecture spaces environments, rather than Euclidean-based (fully orthogonal) abstract architecture spaces) in half of these tests. Although with results contrary to what was initially expected, the analysis on the element complexity transformation groups have also shown relevant SSD without, however, verifying the previously raised hypotheses 'H3b' and 'H4b' (people decide to approach abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements and people decide to approach abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features).

The consistent-response analysis, the one that focused only on the participants that make a coherent choice between ‘sharp’ and ‘rounded-tight’ SI and/or ‘sharp’ and ‘rounded-loose’ SI within the same element complexity transformation group or between ‘sharp-tight’, ‘rounded-tight’, ‘sharp-loose’ or ‘rounded-loose’ within at least two of the element complexity transformation groups, showed an overall strong evidence against null hypothesis ‘H1b’, clearly demonstrating this hypothesis. Interestingly, this analysis also showed distinct strong evidence against null hypothesis ‘H2b’, something that didn’t occur in the aesthetic judgement run.

In fact, these results gain a new interest level when compared with those achieved in Experiment 1. Contrarily to what happened in such prior experiment, where participants didn’t like more full non-Euclidean abstract architecture spaces over their orthogonal, Euclidean counterparts, in Experiment 2 ‘rounded-high’ were preferred over their ‘sharp-high’ counterparts in the general sample analysis (even with relevant SSD values in some of the conducted Post-Hoc tests) and clearly preferred in the consistent-response analysis. These results point to the fact that even though people may not find ‘rounded-high’ SI to be beautiful, they clearly prefer them when an approach (or an avoidance in opposition) to these spaces is considered, meaning that they find them to be less harmful then their ‘sharp-high’ correspondent counterpart versions. These are considered to be interesting achieved results.

Also, in the case of the participant’s aesthetic judgement having been influenced by Zajonc’s reported “mere-exposure” effect (Zajonc 1968), such didn’t happen in the approach-avoidance decision run.

On the other hand, contrarily to what occurred in the general sample’s analysis, strong evidences against null hypotheses ‘H3b’ and ‘H4b’ where not found, confirming the previous raised possibility that, when viewing and evaluated the stimuli, participants focused either on the contour features or element complexity transformation levels not showing to be able to evaluate both at the same time.

Apart from relevant, as stated, these results are considered to be interesting especially when the results of both Experiment 1 and 2 are compared.

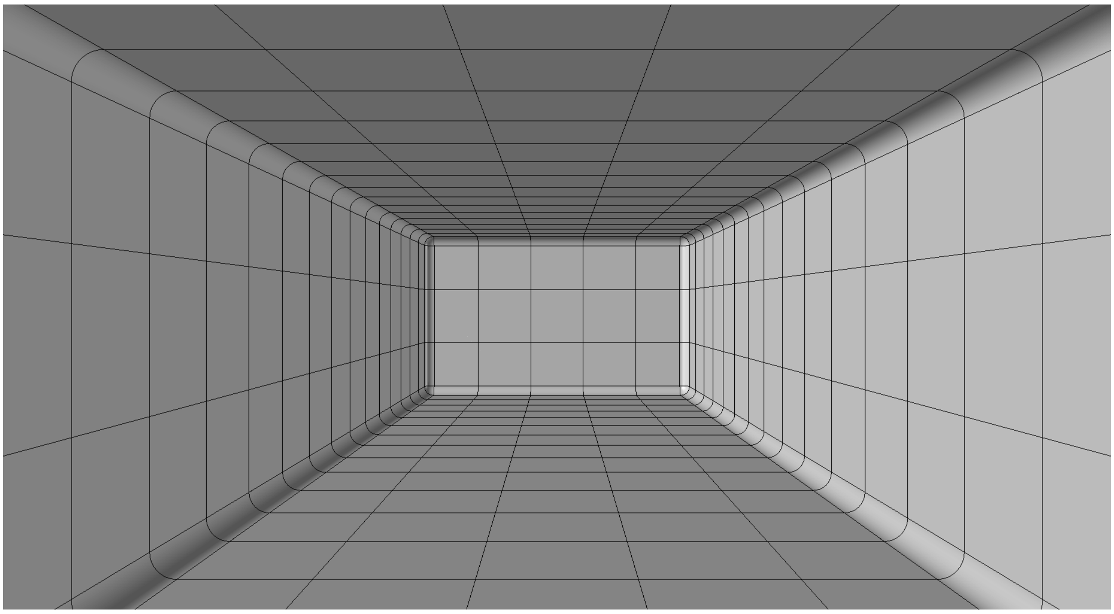
5.9. Self-questionnaire

After the completion of Experiment 2, the last of this study's two experiments, all participants were asked to fill in a 'Conscious Response Self-Questionnaire'. As the name suggests, contrarily to Experiments 1 and 2, which sought unconscious rather than conscious responses from the participants in respect to the presented SI stimuli, this self-questionnaire aimed to the conscious participants' response towards the same stimuli. This 'Conscious Response Self-Questionnaire' was presented to the participants, as pointed, only after the conclusion of last Experiment 2 in order to assure that it didn't influence the participants answers during the experimental force-choice response stages.

5.9.1. Description / Structure

This self-questionnaire was divided in three sections:

1. A first section which counted with general test questions about previous held Experiments 1 and 2 and asked for the participant's free response without access to the 18 SI stimuli. This section aimed to understand the level of consciousness of the participants during the referred experimental stages;
2. A second section where all SI stimuli were presented individually to the participants. In this section participants were asked to evaluate each of the SI according to the ratings of a 7-point Likert scale (1 – like less; 7 – like more) as shown in 'Figure 42';



Like less						Like more
1	2	3	4	5	6	7

Image 42. Example of one of the SI stimuli presented to evaluation through a 7-point Likert scale.

3. A third and last section where direct and indirect correspondent SI stimuli were presented two-by-two (figures 43 and 44). In this section, the participants were asked to answer to 2 questions in which they were forced to choose one of the two SI, firstly according to an aesthetic judgement (‘Which of the presented SI do you like more?’) and secondly according to an approach-avoidance decision (‘If you would have to enter in one of the SI, in which of them would decide to do it?’) evaluation.

All questionnaires were printed in paper and filled with an ink pen.

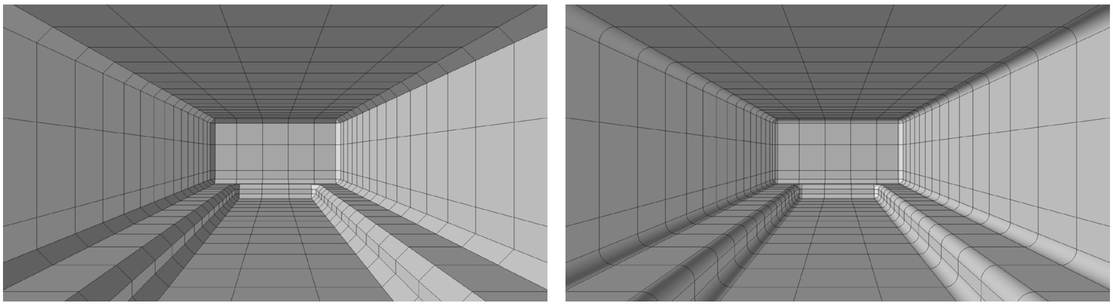


Image 43. Example of two direct correspondent SI.

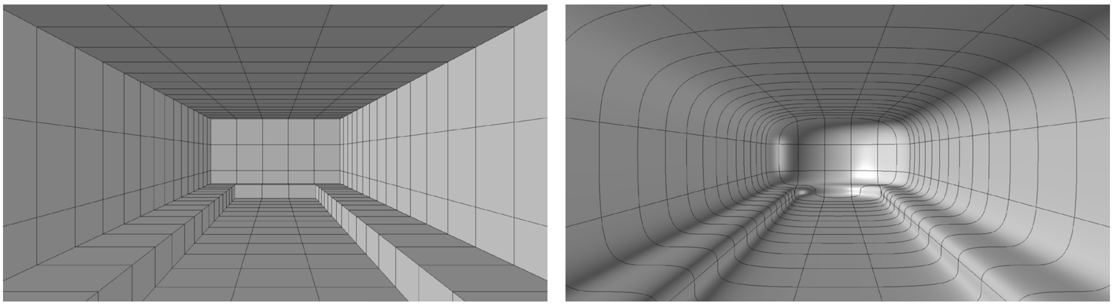


Image 44. Example of two indirect correspondent SI.

5.9.2. Results

5.9.2.1. Section One of the 'Conscious Response Self-Questionnaire'

The results of the first section of the 'Conscious Response Self-Questionnaire' show that, after Experiment 2, the participants had a basic, general idea on the experiments in which they have participated. However, as expected, they were not able to develop full comprehension and control over these experiments, suggesting that their responses to the presented SI Stimuli of Experiments 1 and 2 were rather taken based on quick impressions than on fully conscious cognition processes.

When asked if they found any differences among the experiments' presented SI stimuli, only 12 out of the 32 participants were able to identify both of the core variables that characterized these stimuli, the environments' rectilinear or curvilinear surface transition and the presence of non-prominent (neither positive edges nor vertices), rail-prominent (positive edges) and spot-prominent (positive edges and vertices) elements or derived transitions. Moreover, 16 out of 32 participants were able to identify at least one of these variables, in most cases the rectilinear and curvilinear surface transitions. Moreover, some participants identified such differences with benches (7/32), light (3/32), depth (2/32) and spaciousness (1/32).

On the other hand, when the participants were asked about the distribution of the SI Stimuli's sample, if there were presented more rectilinear based SI, more curvilinear based SI or a balance between both, 11 out of 32 answered 'rectilinear', 4 out of 32 answered 'curvilinear' and 17 out of 32 answered 'balanced'.

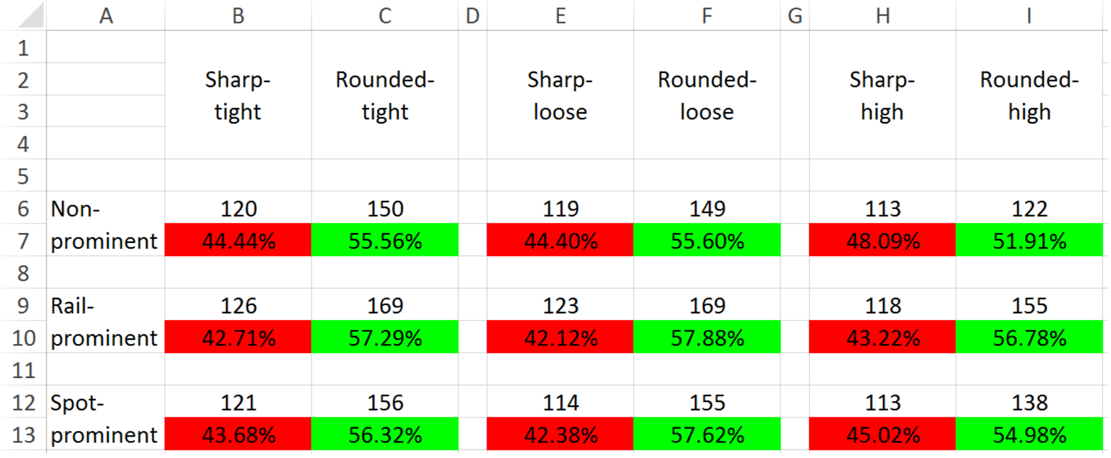
Lastly, when inquired how many original SI stimuli were presented during the experimental stages (not taking in consideration the number times that each SI was repeated), the answers of the participants varied from 4 to 30 original SI, with an average of 13, a median of 12 and a mode of 10 original SI, far from the actual 18.

These results show that, although the participants had some idea about the experiments in which they were involved, their level of awareness and control over Experiments 1 and 2 was rather low than high, suggesting, as said before, that their responses to the presented SI stimuli were rather based on quick impressions than on fully conscious cognitive processes.

5.9.2.2. Section Two of the 'Conscious Response Self-Questionnaire'

In this section, all the participants were then asked to evaluate each SI stimuli individually, according to a 7-point Likert scale, where '1' stood for 'like less' and '7' for 'like more'.

The following Table 25 shows the sum and percentage of all the participants' ratings to all the SI.

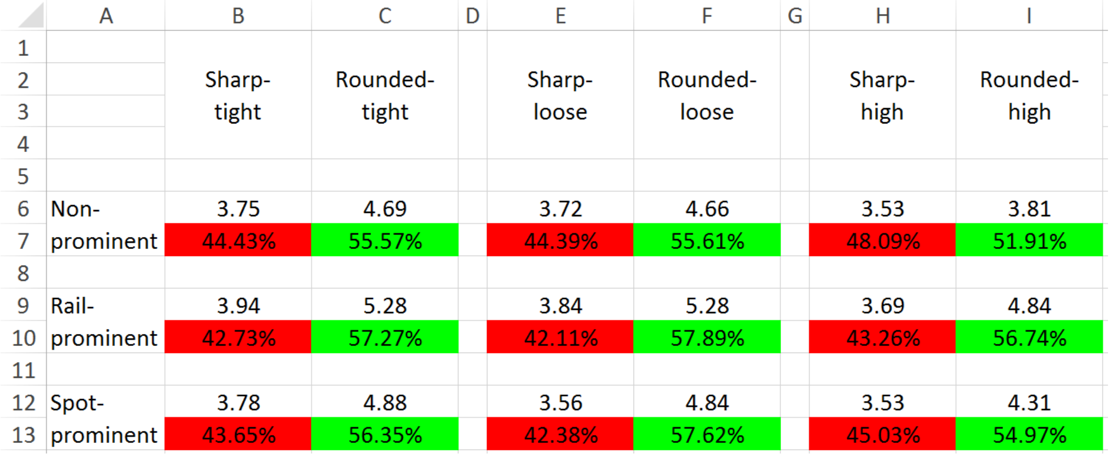


	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	120	150	119	149	113	122
	🟥 44.44%	🟩 55.56%	🟥 44.40%	🟩 55.60%	🟥 48.09%	🟩 51.91%
Rail-prominent	126	169	123	169	118	155
	🟥 42.71%	🟩 57.29%	🟥 42.12%	🟩 57.88%	🟥 43.22%	🟩 56.78%
Spot-prominent	121	156	114	155	113	138
	🟥 43.68%	🟩 56.32%	🟥 42.38%	🟩 57.62%	🟥 45.02%	🟩 54.98%

Table 25. Total number of ratings of the SI stimuli' evaluation on the 7-point Likert scale.

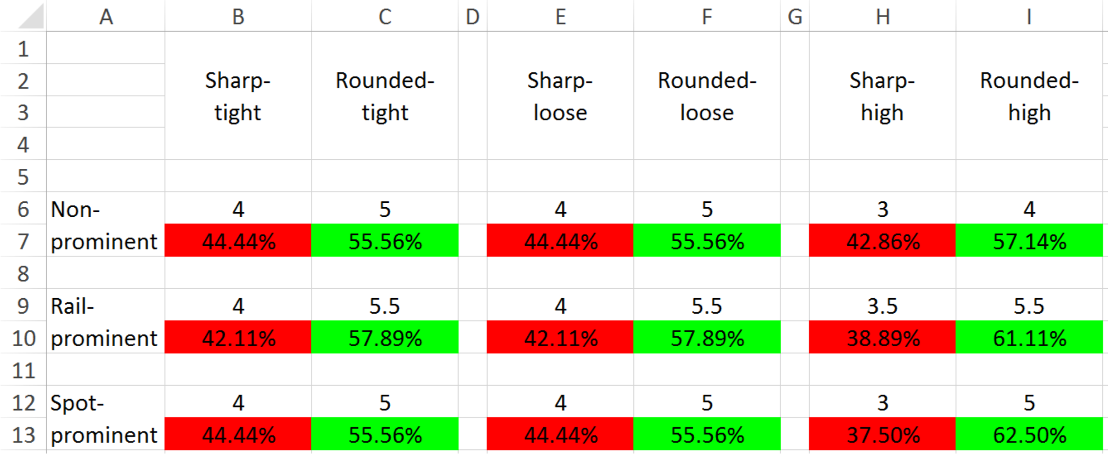
As we can see, although all rounded SI were rated more than their sharp correspondent SI, the results among the contour features transformation levels are not that expressive. The results on the element complexity transformation levels follow the previous ones and are also not expressive.

The following Tables 26, 27 and 28 show these ratings average, median and mode, respectively. While the ratings' average values don't add much to the previous analysis, it is interesting to notice that the median and mode values on the correspondent 'sharp-high' and 'rounded-high' SI show that most participants preferred the full non-Euclidean SI to their correspondent Euclidean, full-orthogonal ones.



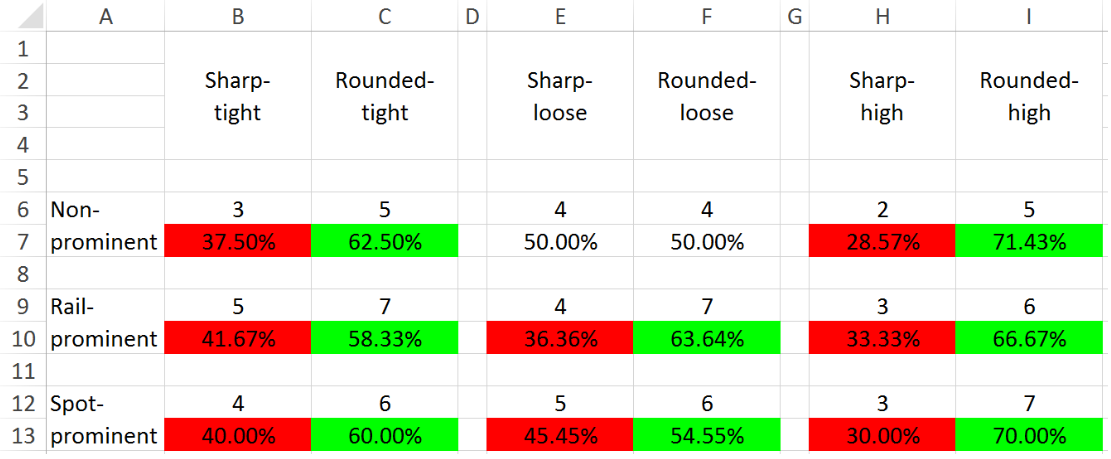
	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	3.75	4.69	3.72	4.66	3.53	3.81
	🟥 44.43%	🟩 55.57%	🟥 44.39%	🟩 55.61%	🟥 48.09%	🟩 51.91%
Rail-prominent	3.94	5.28	3.84	5.28	3.69	4.84
	🟥 42.73%	🟩 57.27%	🟥 42.11%	🟩 57.89%	🟥 43.26%	🟩 56.74%
Spot-prominent	3.78	4.88	3.56	4.84	3.53	4.31
	🟥 43.65%	🟩 56.35%	🟥 42.38%	🟩 57.62%	🟥 45.03%	🟩 54.97%

Table 26. Ratings' average of the SI stimuli's evaluation on the 7-point Likert scale.



	A	B	C	D	E	F	G	H	I
1									
2		Sharp-	Rounded-		Sharp-	Rounded-		Sharp-	Rounded-
3		tight	tight		loose	loose		high	high
4									
5									
6	Non-	4	5		4	5		3	4
7	prominent	44.44%	55.56%		44.44%	55.56%		42.86%	57.14%
8									
9	Rail-	4	5.5		4	5.5		3.5	5.5
10	prominent	42.11%	57.89%		42.11%	57.89%		38.89%	61.11%
11									
12	Spot-	4	5		4	5		3	5
13	prominent	44.44%	55.56%		44.44%	55.56%		37.50%	62.50%

Table 27. Ratings' median of the SI stimuli's evaluation on a 7-point Likert scale.



	A	B	C	D	E	F	G	H	I
1									
2		Sharp-	Rounded-		Sharp-	Rounded-		Sharp-	Rounded-
3		tight	tight		loose	loose		high	high
4									
5									
6	Non-	3	5		4	4		2	5
7	prominent	37.50%	62.50%		50.00%	50.00%		28.57%	71.43%
8									
9	Rail-	5	7		4	7		3	6
10	prominent	41.67%	58.33%		36.36%	63.64%		33.33%	66.67%
11									
12	Spot-	4	6		5	6		3	7
13	prominent	40.00%	60.00%		45.45%	54.55%		30.00%	70.00%

Table 28. Ratings' mode on the SI stimuli's evaluation on a 7-point Likert scale.

5.9.2.3. Section Three of the 'Conscious Response Self-Questionnaire'

In the last section of this 'Conscious Response Self-Questionnaire' all participants were asked to answer two questions, one according to the aesthetic judgements ('Which of the presented SI do you like more?') and another to approach-avoidance decision ('If you would have to enter in one of the SI, in which of them would decide to do it?'). In each of these questions they were forced to choose one of the two correspondent SI. While the aesthetics judgement questions was framed by

Experiment 1 hypotheses[126], the approach-avoidance decisions questions were framed by Experiment 2 hypotheses[127]. Furthermore, while the analyses of variance tests on the results of Experiments 1 and 2 took in consideration all the 18 SI stimuli since they were presented equally as part of a whole, the ANOVA tests on the results of the participants' answers to the above questions laid exclusively on the two correspondent SI. However, as before, the significance level, alpha, was set to 0.05.

As expected, the results of this evaluation exercise proved to be far more expressive than those of Experiments 1 and 2 and that described in the previous second section of this 'Conscious Response Self-Questionnaire'.

Aesthetic judgment (I like more SI 'x')

When participants had to choose which of the correspondent SI they liked more between the 'sharp-tight' and 'rounded-tight' SI, they have exponentially opted for the round versions, with ratio of at least 4-to-1 (80.00%). The same applied when they had to choose between the 'sharp-loose' and 'rounded-loose' SI, case in which they have also exponentially opted for the rounded versions, with ratio of 6-to-1 (non-prominent), 7-to-1 (rail-prominent) and even 10-to-1 in the case of the 'spot-prominent' versions (Table 29). The ANOVA tests on these scenarios showed strong evidence against null hypothesis 'H1a' with p-values inferior to the significance level (Table 30). However, although overall the participants have liked more 'rounded-high', non-Euclidean SI than their correspondent 'sharp-high', Euclidean-orthogonal SI, the ANOVA tests on these stimuli did not show SSD since the p-values were higher than the alpha, denoting weak evidence against null hypothesis 'H2a'. On the other hand, the presence of prominent elements didn't seem to affect the results, not pointing to the verification of 'H3a' and 'H4a'.

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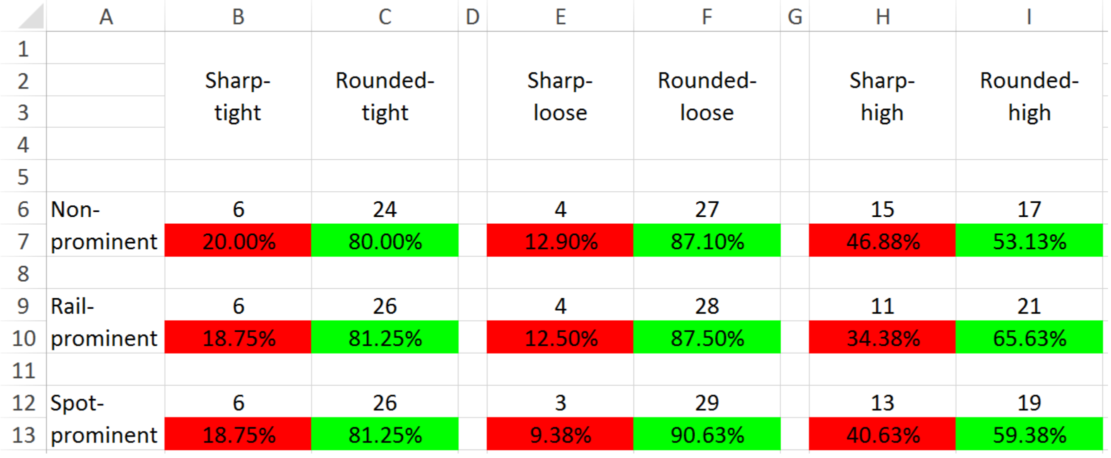
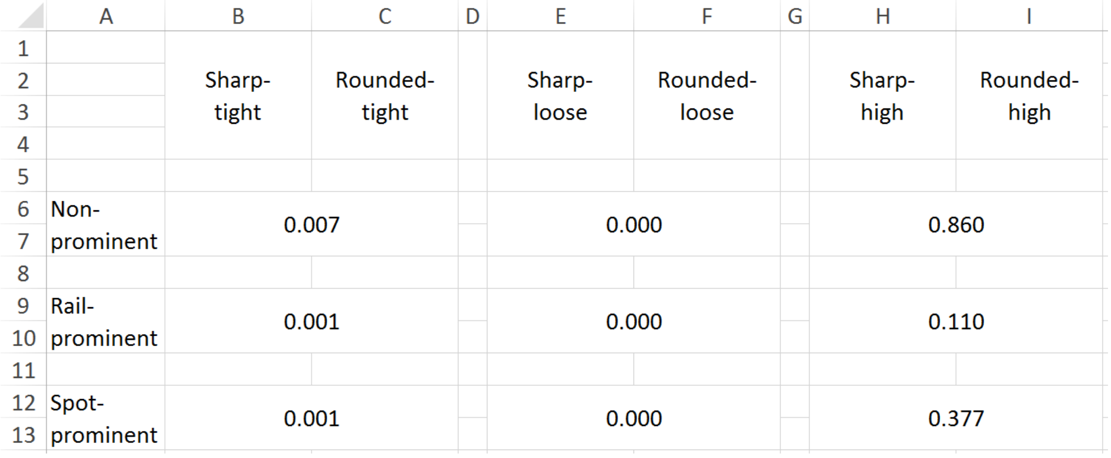
[126] See section 5.7.2.2. 'Hypotheses' of Experiment 1.

[127] See section 5.8.2.2. 'Hypotheses' of Experiment 2.



	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	6	24	4	27	15	17
	20.00%	80.00%	12.90%	87.10%	46.88%	53.13%
Rail-prominent	6	26	4	28	11	21
	18.75%	81.25%	12.50%	87.50%	34.38%	65.63%
Spot-prominent	6	26	3	29	13	19
	18.75%	81.25%	9.38%	90.63%	40.63%	59.38%

Table 29. Preference based on aesthetic judgements for the self-questionnaire among contour features and element complexity transformation levels.

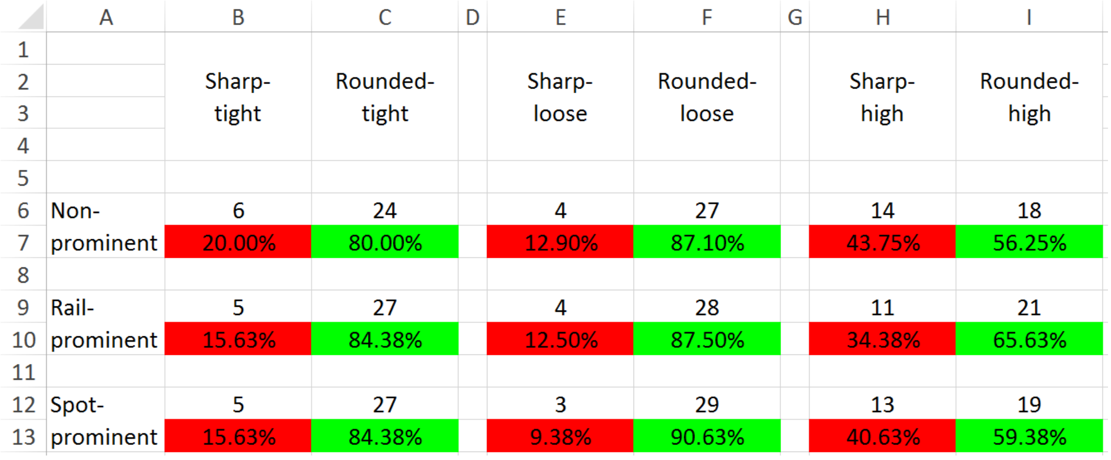


	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	0.007		0.000		0.860	
Rail-prominent	0.001		0.000		0.110	
Spot-prominent	0.001		0.000		0.377	

Table 30. Preference based on aesthetic judgements and result significance for the self-questionnaire among contour features and element complexity transformation levels.

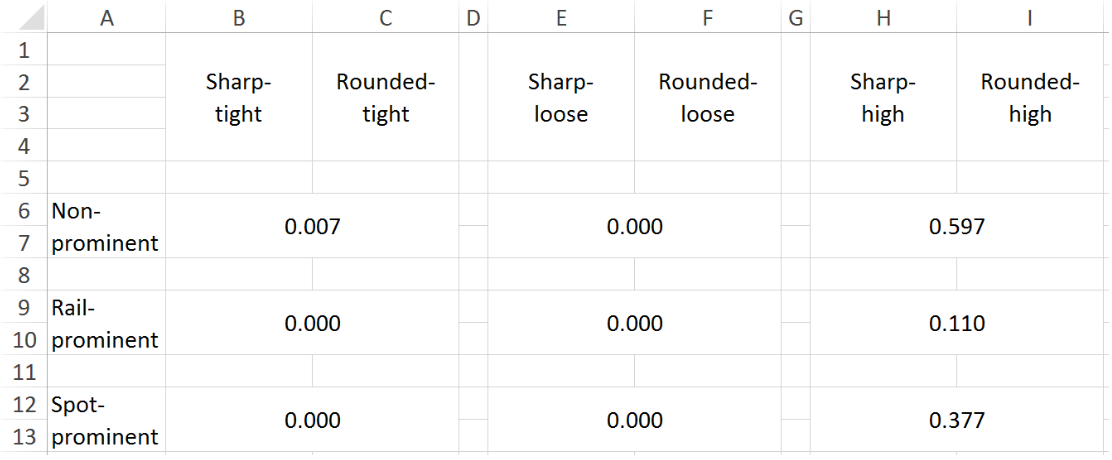
Approach-avoidance decision (I decide to enter in SI ‘x’)

The results on the approach-avoidance run of this conscious response self-questionnaire are very similar to those previous analyzed aesthetic judgment one. Overall the participants have decided to enter exponentially more in the ‘rounded-tight’ and ‘rounded-loose’ than in their sharp direct correspondent counterparts (Table 31). The ANOVA tests on the ‘sharp-tight’/’rounded-tight’ and ‘sharp-loose’/’rounded-loose’ correspondents demonstrate that the participants chose to enter more in the rounded SI than in their counterpart versions with SSD, p-values $\leq \alpha$, showing strong evidence against null hypothesis ‘H1b’ (Table 32). As also verified in the results of the aesthetic judgement oriented questions, although the participants have decided to enter more in non-Euclidean architecture SI than in their full orthogonal correspondent versions, the ANOVA test don’t show SSD that support evidence against null hypothesis ‘H2b’. The presence of prominent elements didn’t show once again to affect the results, not pointing thus to the verification of ‘H3b’ and ‘H4b’.



	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	6	24	4	27	14	18
	20.00%	80.00%	12.90%	87.10%	43.75%	56.25%
Rail-prominent	5	27	4	28	11	21
	15.63%	84.38%	12.50%	87.50%	34.38%	65.63%
Spot-prominent	5	27	3	29	13	19
	15.63%	84.38%	9.38%	90.63%	40.63%	59.38%

Table 31. Preference based on approach-avoidance decisions for the self-questionnaire among contour features and element complexity transformation levels.



	Sharp-tight	Rounded-tight	Sharp-loose	Rounded-loose	Sharp-high	Rounded-high
Non-prominent	0.007		0.000		0.597	
Rail-prominent	0.000		0.000		0.110	
Spot-prominent	0.000		0.000		0.377	

Table 32. Preference based on approach-avoidance decisions and result significance for the self-questionnaire among contour features and element complexity transformation levels.

5.9.3. Conclusions

Overall, the results of this conscious response self-questionnaire support and give strength to the results achieved in both Experiment 1 and 2 of this experimental study on the preference for abstract architecture spaces with distinct geometric characteristics at contour level. The participants have shown to prefer curved, rounded architecture SI with moderate levels of evolution rather than their angular, sharp correspondent versions with SSD, verifying in this way this documents and study hypothesis ‘H1’. On another hand, although they also shown to prefer more curved, rounded architecture SI with extreme, full non-Euclidean levels of evolution to their full orthogonal correspondent counterpart versions, the results do not show SSD and thus weak evidences against null hypothesis ‘H2’. As to hypotheses ‘H3’ and ‘H4’, these results also support those achieved in Experiment 1 and 2, in which these hypotheses were not verified.

Chapter 6

6. Discussion, Conclusions and Future Work

Abstract. This chapter closes the thesis. We will address the conclusions of the developed work and present, based on the achieved results, explainable answers to the raised research question, which directly addressed the thesis main problem and hypotheses. This chapter includes also considerations on the developed work and the candidate's thoughts about related activities to be developed in a near future.

6.1. Discussion and Conclusions

This thesis aimed at achieving better understanding and creating new knowledge on the general topic of the preference for form, particularly on the preference for architecture space form. We studied if humans show different levels of the preference for curved, rounded abstract architecture spaces over angular, sharp abstract architecture ones, and the reasons that could lead to such preference.

The analysis of the prior state-of-the-art showed us that the understanding of the thesis problem could be divided in two: (i) the preference for form and architecture space form based in aesthetic judgments and (ii) the preference for form and architecture space form based in approach-avoidance decisions. While, aligned with the literature survey, we hypothesised that the former may be influenced by our empirical and rational experiences and manifest mainly in a conscious level, we hypothesised that the latter is associated with instinct and unconscious behaviours and performances, based on probable primeval, settled and innate knowledge stored in certain regions of the human brain, which project us to approach curved, rounded feature elements – perceived as pleasant – while avoiding angular, sharp feature elements for the threat that they may convey to the integrity of our bodies, well-being and survival conditions – thus perceived as dangerous and unpleasant.

Some of the discourse of this thesis was dedicated to understanding and identifying historic reasons and core key events that have contributed directly to the definition and structure of the western civilization's thought, namely in Chapter 2 and the additional material of 'Appendix G'. We covered the identification of ground concepts, mostly based on mathematics, that allowed us to frame our thinking activity and subsequent behaviour and performance; the evolution of the methods of science, through which we attempt to unveil the truth about things and create knowledge; and the evolution of methods, techniques, tools and technologies (mainly on graphic representation and production), through which we managed to contribute to the development of this same knowledge. All these realities influenced directly not only what we know, as in knowledge, but in a more intrinsic way, what we are, as in thought.

Among such ground concepts, we could find order, unity, balance, scale, symmetry or proportion, which started to be an object of careful, justified attention by the western civilizations, particularly by the ancient classic period (we have tracked references as far as the Old Testament's Pentateuch). We could also find fundamental principles of control, harmony or stability in several periods of our history. These concepts, well represented in mathematics and geometry, have shaped the way we look at things and ultimately contributed to who we are. Thales' mathematical proof and Aristotle's deduction logic method of reasoning based on the syllogism, are some of the examples of the influence exercised by mathematics on our reasoning and scientific thought. Later experimental study methodologies based on experimentation (Galilei) and descriptive statistics measures, such as mean, median, mode (Fechner), or variance (Fisher), to point a few, have allowed us to strengthen this link between mathematics and thought and to look at subjective, individual based information in a more objective way, as if it belonged to an impartial 'ideal observer' (Taliaferro 2011, loc.349/2086, Radcliffe 1994).

On the other hand, the representation of our thought through graphic languages and techniques have, in turn, enhanced our ability to improve such thought either at an inner level, as a thinking tool, or at an outer one, as when the communication of an idea is considered. On the spectrum of production methods, techniques, tools and technologies that we have being able to develop and achieve, have allowed us to orient the way we use to face and think, optimizing or restraining its results (as in the Industrial Revolution's standardization vs. the Digital Revolution's open range production systems), contributing to the shape of our identity.

The Industrial Revolution with its standardization, based on prototype and mass production techniques and social-economic context factors, contributed to restrain the range of forms that we produced, notably in the domain of architecture and construction, conducting to an excess of orthogonal, Euclidean structures and spaces, which still today dominates our urban landscapes.

In turn, the Digital Revolution with its ground-breaking achievement to fabricate single, complex forms at a sustainable economic cost (close to the standardized, mass production ones), together with its innovative technologies of representation, visualization and production, unleashed a whole new universe of possible forms, not only in the domain of architecture and construction, but also in product design, among which we include curved, non-Euclidean forms, which until recently only belonged to a restrict conceptualization domain.

In our opinion, these two technology trends are here to stay, shaping the way we think, behave and perform.

In this way the path that we have built along our history has directly contributed to the definition and characterization of how we think, behave and perform, influencing our aesthetic and beauty concepts. Ultimately, by being part of our history and consciously or unconsciously present in each of us, such events and their direct results have been able to affect our preference based on familiarization effects, well described thru Zajonc's "mere-exposure" effect (Zajonc 1968)[128].

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[128] Within the framework of Chapter 2 and the additional material of 'Appendix G', we don´t claim to have created ground knowledge. The addressed history of rational man, is well and vastly documented. We can however say that, within the context of the aesthetics and the preference for shapes and form and architecture space form, without discovering ground knowledge, we have been able to identify significant associations that ultimately brought us closer to understand the bases of our 'subjective' notions of beauty. However subjective these notions may be, they may not be as entirely subjective as some made us think, namely Hume. It seems also clear that, through our education process, we were driven to think in a 'proper' given way, according to the path that our ancestors have left written in the pages of history and beauty may, then, not only reside in the 'eye of the beholder' but enclosure ground, key concepts and events shared by most

In Chapter 3, we followed the evolution of beauty and aesthetic notions, from ancient times to Modern Era, going through specific references and the works of Hogarth, Fechner and Gordon, which have launched the solid grounds and research methodology that would be followed by future works on aesthetics and preference.

In Chapter 4, we have focused on the state-of-the-art of the preference for lines, shapes and forms, including architecture space form, with distinct geometric characteristics at contour level, through a series of qualitative and quantitative research methodology experimental studies, which aimed to understand if we tend to prefer some elements, with specific geometric features, over others, and the reasons why we do so.

Along such literature review we have been able to identify and point aesthetic judgements and approach-avoidance decisions as decisive factors that influence preference, ultimately linking them with subjective and objective-based human knowledge 'datasets', respectively. Aside from these we have also identified and listed a series of other variables to keep under attention while conduction experimental studies on preference. For these reasons, the information gathered in this Chapter was of crucial importance for the design of the conducted experimental study, which was described in Chapter 5.

In Chapter 5, we have addressed the design and description of the conducted experimental study on the preference for abstract architecture spaces with different characteristics, aimed at validating the thesis hypotheses. For clarification purposes, we re-state them here:

Our research question was expressed in the following form:

- "Do people find architecture spaces with curved, rounded elements to be more pleasing than architecture spaces with angular, sharp elements?"

This research question highlighted the problem addressed in this thesis:

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of the western civilization, among which may be included the ones previously described, that may ultimately lead towards positive aesthetic judgements.

- "The problem of understanding the preference for form, namely the preference for architecture spaces form, with distinct geometric characteristics".

From this initial major problem, we derived two sub-problems:

- "The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in aesthetic judgements";
- "The sub-problem of understanding the preference for form, namely the preference for architecture space form, based in approach-avoidance decisions".

In order to answer the research question, that addressed such problem and sub-problems, we have raised four hypotheses, two major and two minor ones:

Major hypotheses:

H1. People prefer abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts;
H2. People prefer full non-Euclidean-based abstract architecture spaces, rather than Euclidean-based (fully orthogonal) abstract architecture spaces.

Minor hypotheses:

H3. People prefer abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements;
H4. People prefer abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features.

The demonstration of these hypotheses was subsequently addressed through the development of the mentioned study, encompassing two experiments, designed to better understand the topic of the preference for form, namely considering a novel approach for the design of experimental architectural spaces: (i) architecture spaces in their abstract, close-to-essence form and (ii) with moderate and extreme geometric levels of evolution at contour level.

Results of Experiment 1, the aesthetic judgement run, have demonstrated with statistical significance, that participants liked more abstract architecture spaces with curved, rounded feature elements when in comparison with their angular, sharp correspondent counterparts, especially for moderate rather than extreme levels of evolution at contour level, notably when participants were able to distinguish rounded and sharp direct correspondent, contour features transformations. In such cases, which framed hypothesis 'H1a' ("people like more abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts"), most results show SSD - statistically significant differences (ANOVA Post Hoc tests p-values inferior or equal to 0.05), expressing strong evidences against the null hypothesis. These results were more expressive within 'loose' rather than 'tight' stimuli, demonstrating that participants were more sensible to more moderately pronounced rounded planar transitions. On the other hand, participants haven't shown to like more one kind of extreme space evolution over the other (fully orthogonal vs non-Euclidean SI), therefore not demonstrating hypothesis 'H2a' ("people like more non-Euclidean abstract architecture spaces, rather than Euclidean-based (fully orthogonal) abstract architecture spaces"). Hypotheses 'H3a' ("people like more abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements"), and 'H4a' ("people like more abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features), were equally not proved. Such may have happened due to the fact that, as reported, participants have been more negatively affected by the emptiness of architecture spaces with non-prominent elements rather than the presence of prominent edges and vertices, something that may be explained by the fact that most participants weren't familiarized with abstract architecture space representations[129].

Results of Experiment 2, the approach-avoidance decision run, were mostly consistent with the ones of Experiment 1, although with higher levels of expression. Participants decided to approach more abstract architecture spaces with curved, rounded elements

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[129] These results express the consistent-response's results. See previous Chapter 5, section 5.7.4.2.

rather than their direct or indirect correspondent counterparts. Hypotheses 'H1b' ("people decide to approach abstract architecture spaces with curved, rounded elements, rather than their angular, sharp correspondent counterparts") and 'H2b' ("people decide to approach full non-Euclidean abstract architecture spaces, rather than Euclidean-based (fully orthogonal) abstract architecture spaces"), where demonstrated with SSD, in at least half of the ANOVA Post Hoc conducted tests, in the general sample analysis. These results were however significantly more expressive in the consistent-response analysis. Regarding hypothesis 'H1b', participants have decided "to approach" abstract architecture spaces with curved, rounded elements rather than their angular, sharp correspondent counterparts, with SSD in all of the conducted Post Hoc tests, showing strong evidences against the null hypothesis. Interestingly, contrarily to what was observed in Experiment 1, where results "didn't show" that participants "liked more" non-Euclidean abstract architecture spaces, to their fully orthogonal, Euclidean indirect correspondent counterparts, in this approach-avoidance decision run, and considering hypothesis 'H2b', participants have "decided to approach" non-Euclidean abstract architecture spaces environments significantly more than fully orthogonal, Euclidean spaces, with SSD in all conducted ANOVA Post Hoc tests. These results are very interesting especially when in contrast with those of Experiment 1, due to the fact that, although non-Euclidean abstract architecture spaces were "not liked" significantly more than their indirect correspondent counterparts (in Experiment 1), participants have "decide to approach" them significantly more than fully orthogonal, Euclidean abstract architecture spaces (in Experiment 2). They point to the hypothesis that although not considered more beautiful, non-Euclidean abstract architecture spaces are in fact perceived as safer or less harmful and preferred, within this approach-avoidance decision judgement. On the other hand, hypothesis 'H3b' ("people decide to approach abstract architecture spaces with non-prominent elements, rather than those equipped with prominent elements") and 'H4b' ("people decide to approach abstract architecture spaces with prominent edges or derived features, rather than those equipped with prominent edges and vertices or derived features") were once again not verified[130], for the same reasons, previously pointed for hypothesis 'H3a' and 'H4a'.

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[130] These results express the consistent-response analysis results. See previous Chapter 5, section

Both Experiments 1 and 2 were designed to elicit the participants' unconscious rather than conscious response, as an answer to the presented SI stimuli. In order to also obtain the participant's conscious response of such stimuli, the participants were asked to answer a 'Conscious Response Self-Questionnaire' centred on the same SI stimuli presented in Experiments 1 and 2, and immediately after the conclusion of these experiments. The results of such questionnaire's responses are consistent with the preference for curved, rounded abstract architecture spaces over their correspondent counterparts in their moderate evolution levels, demonstrating hypothesis 'H1', with SSD.

However, although participants have also shown to prefer fully non-Euclidean architecture spaces to their fully orthogonal counterpart version, the results of 'Conscious Response Self-Questionnaire' did not show SSD, and for this reason we cannot state that hypothesis 'H2' has been verified.

Regarding hypotheses 'H3' and 'H4', the preference for abstract architecture spaces with non-prominent over rail-prominent feature elements and, by turn, over spot-prominent feature elements, the results of this Conscious Response Self-Questionnaire, point in the direction of the conclusions extracted from Experiments 1 and 2, which did not verified neither 'H3' nor 'H4'.

In more detail, overall, major 'H1' was verified with SSD ($\alpha \leq 0.05$) in 9 out of 12 ANOVA tests of the aesthetic judgement Experiment 1 run - consistent-response (verified), in 12/12 ANOVA tests of the approach-avoidance decision Experiment 2 run - consistent-response (verified), in 6/6 ANOVA tests of the aesthetic judgement of the Self-Questionnaire (verified) and in 6/6 ANOVA tests of the approach-avoidance decision of the Self-Questionnaire (verified). Major 'H2' was verified with SSD ($\alpha \leq 0.05$) in 0 out of 6 ANOVA tests of the aesthetic judgement Experiment 1 run - consistent-response (not verified), in 6/6 of the approach-avoidance decision Experiment 2 run - consistent-response (verified), and in 0/3 of the aesthetic judgement (not verified) and 0/3 of the approach-avoidance of the Self-Questionnaire (not verified). We then consider major 'H1' to be verified and major 'H2' to be only

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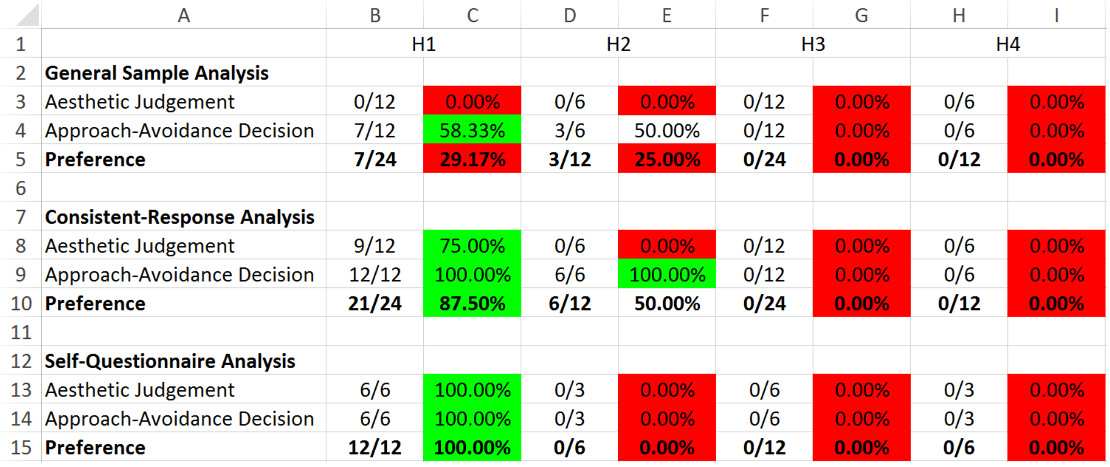
5.8.4.2.

partially verified, notably in the approach-avoidance objective experiment. Minor ‘H3’ and minor ‘H4’ were not verified in both experiment runs and self-questionnaires (see Table 33).



	A	B	C	D	E	F	G	H	I
1		H1		H2		H3		H4	
2	**General Sample Analysis**								
3	Aesthetic Judgement	0/12	0.00%	0/6	0.00%	0/12	0.00%	0/6	0.00%
4	Approach-Avoidance Decision	7/12	58.33%	3/6	50.00%	0/12	0.00%	0/6	0.00%
5	**Preference**	**7/24**	**29.17%**	**3/12**	**25.00%**	**0/24**	**0.00%**	**0/12**	**0.00%**
6									
7	**Consistent-Response Analysis**								
8	Aesthetic Judgement	9/12	75.00%	0/6	0.00%	0/12	0.00%	0/6	0.00%
9	Approach-Avoidance Decision	12/12	100.00%	6/6	100.00%	0/12	0.00%	0/6	0.00%
10	**Preference**	**21/24**	**87.50%**	**6/12**	**50.00%**	**0/24**	**0.00%**	**0/12**	**0.00%**
11									
12	**Self-Questionnaire Analysis**								
13	Aesthetic Judgement	6/6	100.00%	0/3	0.00%	0/6	0.00%	0/3	0.00%
14	Approach-Avoidance Decision	6/6	100.00%	0/3	0.00%	0/6	0.00%	0/3	0.00%
15	**Preference**	**12/12**	**100.00%**	**0/6**	**0.00%**	**0/12**	**0.00%**	**0/6**	**0.00%**

Table 33. Number of ANOVA Post-Hoc Tests (out of the number of total conducted ANOVA Post-Hoc Tests) in which each hypothesis was validated.

With respect to the results of table 33, we **have demonstrated** that **participants prefer** abstract **architecture spaces** with **curved, rounded** feature **elements**, rather than their angular, sharp correspondent counterparts. In detail, disaggregating this level of preference into its two identified sub-levels of aesthetic judgement and approach-avoidance decisions, **participants** have shown to **like** more abstract **architecture spaces** with **curved, rounded features** rather than their angular, sharp correspondent counterparts, with **moderate** rather than extreme levels of evolution, and have **decided to approach** abstract **architecture spaces** with **curved, rounded features** rather than their angular, sharp correspondent counterparts, with **either moderate** or **extreme** level of evolution variations.

On the contrary, we have **not verified** that **participants prefer** abstract **architecture spaces** with **non-prominent elements**, rather than those equipped with prominent elements, and **abstract architecture spaces** with **prominent edges or derived features**, rather than those equipped with **prominent edges and vertices or derived features**, possible due to base configuration reasons.

We consider these results, together with their context, as being novel and significant and therefore interesting, and should be a target of further attention in a near future.

Moreover, such results are aligned and support those found in the literature on the topic of the preference for elements, namely lines, shapes and forms[131], and the more particular one of the preference for architecture space form[132], according to which people tend to prefer curved, rounded elements over angular, sharp ones, either when an aesthetic judgement (like/dislike[133]; beautiful/not beautiful[134]) or an approach-avoidance decision (like/dislike[135]; enter/exit[136]; attractive/not attractive[137]) is considered. Additionally, although the consideration of abstract, close-to-essential architecture space stimuli pointed to the control of the experimental study's independent variable, its results still point to strong presence and interference of familiarity and "mere-exposure" (Zajonc 1968) and, in the opposite scope, 'strangeness', confirming Zajonc's achievements.

These results are pertinent to both theoretical and practical sides of the field of architecture, in the way that, today, we have access to further work and knowledge on the topic of preference for architecture space form. Within the open range of potentialities that the Digital Revolution, namely the one that we have identified as the 'Second Digital Revolution', is able to bring to the present and future of the production of free from and architecture space form, such knowledge is able to reach those who dedicate themselves to architecture thinking and construction and help them to develop architecture spaces that may be closer to the reality of our aesthetic

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[131] Leder & Carbon 2005; Bar & Neta 2006; Bar & Neta 2007; Silvia & Barona 2009; Carbon 2010; Leder, et al. 2011; Jakesch & Carbon 2011; Westerman, et al. 2012; Bertamini, et al. 2015; Palumbo & Bertamini 2015; Velasco, et al. 2016; Cotter at al. 2017; Blazhenkova & Kumar 2017.

[132] Dazir & Read 2012; Vartanian, et al. 2013; van Oel & van de Berkhof 2013.

[133] Silvia & Barona 2009 [scale]; Carbon 2010 [scale] Leder, et al. 2011; Jakesch & Carbon 2011; Vartanian, et al. 2013 [liking]; Bertamini, et al. 2015; Palumbo & Bertamini 2016.

[134] Vartanian, et al. 2013.

[135] Bar & Neta 2006; Bar & Neta 2007.

[136] Vartanian, et al. 2013.

[137] Leder & Carbon 2005; van Oel & van de Berkhof 2013; Palumbo & Bertamini 2015; Bertamini 2015.

judgements and approach-avoidance decisions, possibly bringing us closer to better architecture spaces.

6.2. Considerations on the Developed Work

This thesis comes in line with the author’s previous developed work and professional interests.

His architecture background began in the School of Architecture of Oporto (FAUP), an institution known for its rational approach on architecture. Before finishing his degree in Architecture, Miguel Carreiro has collaborated with Roberto Collovà and Josep Llinàs architecture studios in Palermo and Barcelona, respectively, a professional international experience that has strengthen his view and position towards architecture and the search for ‘good’, quality architecture spaces. His thirst for this relatively long-standing search led him afterwards to develop an one hundred pages graduate thesis on the perception of three distinct, ground spaces based on their geometry characteristics and performance abilities: (i) a first considered steady space characterized by basic orthogonal, Euclidean relationships in which late-stage perceptions easily correspond to the expectations that are raised in an initial phase of the space’s perception and experience, due to the existing bond between its geometric relationships and our western civilization identity; (ii) a second space characterized by more complex geometric relationships that surpass basic orthogonal, Euclidean ones in which late-stage perceptions do not necessarily concretise early-stage raised expectations and the whole space’s comprehension may actual depend on a multi-level travel through its geometry limits; and (iii) a third, unsteady space characterized by either simple or complex geometric relationships able, however, to change and perform in both space and time dimensions in which early-stage expectations are difficult to build and even more difficult or impossible to be verified in a late-stage of the perceptive experience, as it is the case of the whole space’s comprehension.

The journey that conducted to this thesis, in the context of the author’s search for what was to be considered ‘good’, quality architecture spaces, continued with his collaboration with the team of Cloud9/Enric Ruiz Geli architecture studio, where he was familiarised with and developed Euclidean and non-Euclidean complex geometry architecture.

It is within this context, that he showed interest in developing a Ph.D. thesis on the geometry of architecture spaces. The idea was to strengthen and complement the previously achieved knowledge on architecture and the geometry of architecture spaces gained within academic and professional, practice and theoretical developed activities. A Ph.D. proposal was sought and submitted to the Scientific Committee of the Ph.D. Program of Architecture of Contemporary Metropolitan Territories of ISCTE-IUL. This proposal would address the understanding of the core and historic reasons that influence our orientation and preference for some spaces with given geometric characteristics over others – framework that became clear to be necessary and essential to the proper comprehension of these topics during the development of the referred degree thesis – and understand the level of subjective preference of humans towards distinct geometric spaces – including Euclidean and non-Euclidean geometries – taking advantage of state-of-the-art technologies. Initially, the proposal addressed the development of an interactive architecture immersive visualization system, which would include 3D environment creation functionalities and biometric data collection, such as heart rate (HR), electro-dermal response (EDR), electroencephalography (EEG) – appropriate for the human perception of such environments and for the measurement of the impact that such spaces with distinct geometric features had on people. The candidate has attended and got approval curricular units of the courses of Computer Engineering and Telecommunication and Computer Engineering and the master of Telecommunication and Computer Engineering at ISCTE-IUL, essential to accomplish the proposed goals. Additionally, he has joined the ISTAR-IUL Research Unit (former ADETTI-IUL), a multidisciplinary team under the supervision of Professor Miguel Sales Dias, one of this thesis' coordinators. Over the period of two years, he has integrated a multidisciplinary team responsible for the development of two pilot experimental studies on the perception of architecture spaces geometry and of indoor safety elements using, immersive virtual reality biometric data collection technologies, available at the ISTAR-IUL lab (e.g. Pocket CAVE, heart-beat rate and electro-dermal response).

On 1st of August of 2014 the doctorate candidate meat with Professors and thesis' coordinators Miguel Sales Dias and Elisabete Raposo Freire in the ISCTE-IUL facilities with the purpose to do a state-of-play on this thesis' past and future research and work. After highlighting the ambition and pertinence of the original proposed thesis topics, the candidate's personal dedication, developed work and recognized achievements, these coordinators have pointed the inherent difficulties of a project with such scale, including its dependency to skilled third parties, and advised the candidate to reformulate it according to the standard format of a Ph.D. thesis. It was agreed however that the core intentions of the original thesis proposal would be given continuity, maintaining its integrity. Following these recommendations, the candidate proposed to still develop a study on key events of the western civilization history, that influence the preference for form, namely its aesthetic judgements, and address the preference of people for Euclidean and non-Euclidean geometry based architecture spaces, launching a series of hypotheses that could be demonstrated through an experimental study using test-subjects, focusing on abstract architecture space form, and considering aesthetic judgements and approach-avoidance decisions and moderate and extreme geometric levels of evolution. As said, such experimental study was initially thought also to consider (i) interactive space morphing software for the presentation of the stimuli, (ii) immersive visualization technology for the perception of such stimuli and (iii) biometric sensing or brain scanning technology for the quantitative measure of such stimuli's impact on the experiments' participants. Despite of the dedication employed in following these intentions, in long-term they were discarded. The first due to its dependency to specialized third parties, despite of the candidate's efforts and recognized achieved results in that field, the second due to the difficulties that were found in the process of aligning the indispensable psychophysical experiment software to run the experimental study with the available immersive, 3D visualization technology, and the third, due to the fact that, according to the state-of-the-art analysis, EEG and particularly, fMRI, were the options that would make sense considering and neither of the student's research units met such technology requirements. Under these conditionings, the candidate, together with the two mentioned Professors, have reformulated the thesis experimental protocol and thesis structure, to the present document, which was acknowledged as a valid and pertinent Ph.D. thesis project.

6.3. Future Work

The international scientific community's recognition of the late achievements on experimental studies on the topics of the preference for form, and the more recent preference for architecture space form, demonstrate, the scientific pertinence and interest of such research topic and debate. Following the work developed within this thesis, in a near future the author has the will to continue the same line of research, in the expectation to contribute towards the creation of even further knowledge on the preference for form, namely the preference for forms of Euclidean and non-Euclidean geometric natures, moderate and extreme geometric levels of evolution and forms with different levels of prominent elements (non-prominent, edge-prominent and spot-prominent). He plans to achieve this goal by taking into account the knowledge acquired and achieved from the developed experimental studies, including its identified limitations, namely:

- To study the collected participants response reaction time (the time that each participant takes to respond to the stimuli after such stimuli appears to his/her senses, until the participant's answer takes place or the predefined time for the stimuli exposure runs out), interpret these results and draw conclusions;
- The consideration of studying the dependent variables of study of both considered experiment runs, aesthetic judgement and approach-avoidance decisions, in a mathematical dependent way, in order to be able to extract higher level information and conclusions on the general topic of the preference for abstract architecture space form.
- The close control of the gender and age extraneous control variables, which should be as balanced as possible, to assure that neither gender or age uneven variations interfere with the results;
- The consideration of a more expressive participant sample, to strengthen the results validation and statistical significance;
- Include in the Conscious Response Self-Questionnaire's Section Two, an approach-avoidance decision evaluation and, in this same questionnaire's Section Three, separate both aesthetic judgement and approach-avoidance decision's questions, asking the former first, in a row, and only then the latter, also in a row, so that the influence of some in others can be decreased towards neutral bias.

- The consideration of abstract, raw space representations, which may be applied to test-subjects with education on Architecture but avoided to others that don't share such background, to minimise the creation of undesirable noise in the interpretation of the stimuli and;
- The consideration of multiple levels of relevant information (e.g. – in the context of this thesis experiments – combined contour and element transformation levels), which may conduct the experiment's participants to consider some over others and ensure that participants focus on and evaluate the whole parameters under study;
- The consideration, as previously expected, of immersive visual technology for the stimuli presentation. In case of technical limitations, at least the presentation of stereoscopic SI;
- The consideration, as previously expected, of biometric sensing technology, with special focus on the possibility of using fMRI or at least EEG technology;

At last, there are some pertinent problems, questions or hypothesis that may, and we believe should, be raised and considered in order to better understand the apparent logic on how external phenomena work interferes with perception and ultimately defines behavior.

For one hand, in the particular case of the perception of curved-based elements, the raised pleasant sensations and feelings may not be exclusively directly connected with the perception of such featured objects in the sense that, due to the fact that they may not actually directly contribute to anything good[138], the awareness of the presence of such geometric features 'should' not elicit pleasure just by itself. In their universe, curved-based elements can either be made of a mixture of curved and sharp lines, shapes and forms or completely composed by rounded elements. In the case of mixed-based elements it may happen that, due to the priority of protection and survival over pleasure and well-being, the presence of sharp elements superimposes the presence of the other curved elements, raising sensations and feelings more closed to survival than

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[138] With the exception of smoothness, a variable that we have grouped with the density property of objects and may *per se* give rise to pleasant sensations.

to the other. However, as pointed, when fully curved elements are perceived, it may happen that the sensation of pleasure is simply a side effect of something that is not perceived as potential threatening or dangerous and thus interpreted as pleasant.

On the other hand, considering now the ‘baby schema’ effect, we might raise the question whether infant human and animal faces and body proportions induce the reported effects (e.g. cuteness and care-taking), because they are perceived and interpreted as pleasant, or, on other way, they are perceived and interpreted as pleasant because they elicit such effects, in a universe that goes far beyond this subject and may, for all that matters, belong to basic evolutionary-response mechanisms and behavior (Carbon 2010). As said, these are however mere questions and hypothesis that, yet with no scientific grounds, we believe should be raised in order to better understand and considered the universe of possible causes and implications of these effects.

The whole knowledge that the candidate achieved within this work is to be considered in his future work.

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Appendices

Appendix A

Experimental Study's Research Protocol

This document includes the experimental study's:

Free Informed Consent

Participation Criteria Verification List

Experiment Guide

Conscious Response Self-Questionnaire

Research Protocol

Experimental Study on Abstract Architecture Spaces with Distinct Geometric Features

This document is headed to the Ethic Committee of ISCTE-IUL as part of the process of the Research Authorization Application, for the psychophysical experimental study on abstract architecture spaces with distinct geometric features, in order to request its opinion and ultimately its permission for the study's continuance.

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Architecture of Contemporary Metropolitan Territories

A Psychophysical Experience on Contour of Abstract Architectural Spaces

1. Introduction

As a field that seeks knowledge about beauty and taste, aesthetics have been under the scope of thinkers since at least the Greek Classical Period. Disciplines such as philosophy and natural and social sciences have made efforts to unveil and push forward the understanding of these concepts.

In this Classic Period, beauty was an open topic of debate. Its understanding and the places where it dwells were active subjects of this time's reference studies and dialogue methodology so commonly employed to control, analyze and expand knowledge. And it was often associated with perfection. It is to be found in apparent discrepant fields that could go from mathematics to the youth's spirit and physical bodies, the elders' sober character or the excellence of the divine. From Pythagoras, to Socrates, Plato, Aristotle and Plotinus that order, proportion, symmetry, good and virtue and unity were some of the main ideas that have ever since been associated with the concept of the beautiful.

As it was to predict, along time it either kept some common basis as it have changed considerably according to individual perspectives and the philosophy of thought that attempted to understand and set a clearer subjective view over what it was believed to be more objective reality.

In the Medieval Era, Augustine of Hippo looks at beauty as form, order, proportion and unity of a God, Father of all Christians. And in the 13th century, Thomas of Aquino proposes that the experience of beauty is closer to the intellect than to the senses, contributing, by doing so, to mark a difference in the theological view over this matter, from an esoteric, ethereal point of view to a more rational, acceptable one[1].

Latter, in the Age of the Enlightenment, the empiricist David Hume would suggest that "beauty may be in the eye of the beholder" although "it is important that the beholder actually sees and experiences the art or natural object (a candidate to be judged beautiful)."[2] Somewhere between both Aquino's and Hume's core theories, Immanuel Kant would claim that "beauty consists of a harmonious correspondence between experience and the intellect"[3].

However, the way we used to examine *real matter of fact*[4] would change considerably in the late 19th century when, in the "Vorschule der Aesthetik" from 1876, Gustav Fechner tries to understand subjective judgments through methods of extreme ranks[5]. He later introduces the notion of the "median into the formal analysis of data" and jumps into the field of experimental aesthetics and elaborates on the pleasing condition of aesthetic objects[6]. At this point the study of aesthetics begins to stand apart from subjective reasoning to getting closer to a more objective evaluation.

Future work on the 20th century would perform experimental studies on angularity (Lundholm, 1921) and curvature (Poffenberger et al.) and on subjective preferences on lines, forms, colours and shapes (Gordon, 1909; Valentine, 1962).

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[1] Kul-Want & Piero, 2012, Introducing Aesthetics, loc. 226/1333

[2] Taliaferro, C., 2011, Aesthetics: A Beginner's Guide, loc. 338/2086

[3] Kul-Want & Piero, 2012, Introducing Aesthetics, loc. 362/1333

[4] Hume, D., 1757. On the Standard of Taste

[5] Heidelberger, M. in https://www.encyclopediaofmath.org/index.php/Fechner,_Gustav_Theodor

[6] ibidem

Giving continuity to Fechner's work, with the arrival of the Digital Revolution that took place in the second half of the 20th century, a set of innovative tools become available to measure beauty at a completely different level. More than ever the study of subjects in general was closer to an objective and quantitative point of view rather than a more subjective, fallible and less accurate one[7]. Techniques like low and high space frequency (Bar et al., 2007) and biosensing technologies such as hearth beat, electrodermal response and electroencephalography opened a whole new era on the definition, perception and evaluation of beauty and aesthetics.

Among modern researches on angularity and curvature are studies on car interior design (Leder et al. 2005), real objects and meaningless patterns (Bar et al. 2006, 2007), symmetrical and asymmetrical abstract geometric forms (Silvia et al. 2009), level of curvature evolution through time (Carbon, 2010), realistic architecture environments with decorative elements (Vartanian et al. 2013) and virtual reality architectural spaces with distinctive high level geometric natures (Shemesh et al. 2015). Balance (Locker et al., 2002), contrast (Specht, 2007), colour (Polzella et al., 2005) and geometric orientation (Miller, 2007) are other studies developed under these new techniques and technologies with the aim to better understand the way that we perceive and evaluate form either in a conscious or unconscious state.

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[7] *All sentiment is right; because sentiment has a reference to nothing beyond itself, and is always real, wherever a man is conscious of it. But all determinations of the understanding are not right; because they have a reference to something beyond themselves, to wit, real matter of fact; and are not always conformable to that standard. in* Of the Standard of Taste, 1757.

2. Goals

The goal of this study is understand and create knowledge on the hypothesis that humans show a higher preference for curved, rounded elements rather than angular, sharp ones. To identify, in a quantitative level, the way that abstract architecture spaces with different geometric contour natures and distinctive characteristics elements are perceived and the grade of this preference. In order to do so, there will be considered spaces composed by plans, curved surfaces and both elements arranged together. The evaluation of the case studies is to be done according to the basic aesthetic judgment and the approach/avoid decisions that they trigger. This study also aims to verify the existence of a statistical significant correlation between the collected answers on the perceived beauty sensation and the attractive judgement on the represented spaces. Ultimately and based on these results, it aims to propose a significant and effective improvement in the process of architecture design.

3. Methodology

The experience to be held is integrated in the authors PhD thesis. In order to collect the necessary data to perform an analysis and evaluation of the spaces in consideration it will count with 60 (sixty) test subjects. As stated above, during experience time the subjects in test will be asked to response to aesthetic judgements and approach/avoidance decisions through 2 (two) groups of questions based on dichotonic pairs. The represented architecture space images to be answered upon have differentiation elements at a contour and prominence levels. The test-subject responses are to be collected at two moments with the use of two distinctive methodology: First at the experience's instant through unconscious target subject action and later, at the end of the experience's second phase thru a conscious self-questionnaire.

3.1. Research Hypothesis

This study has two research questions. The primary research question is:

1. Do people find architectural space environments with curved, rounded elements to be more pleasing than architectural space environments with angular, sharp elements?

The secondary research question takes ground either the primary hypothesis is verified or not. The secondary research question is:

2. What is the quantitative level of this preference?

3.2. Study's Sample

This study will count with 60 (sixty) voluntary persons. These test-subjects will be selected according to the following criteria:

1. Adult persons from both genre, distributed in a balanced way;
2. Young Adults and adults aged between 18 (eighteen) and 65 (sixty-five) years old;
3. Be a native Portuguese speaker or be fluent in this language;
4. Have good eyesight or corrected eyesight through the use of spectacles or contact lens;
5. Have a good cognitive ability;
6. Neither to be educated nor have education in the architecture fields.

Being voluntaries, the participants of this study will not receive any financial incentive. All inclusion and exclusion criteria will be verified though direct observation and through a question/answer standard procedure. Additionally, all participants will be previously informed of the study's general but not revealing goals and will be asked to sign an Informed Consent Form (appendix 1).

3.3. Variables of the study

This study will consider 3 (three) kinds of variables: Moderating, independent and depended. These variables are as followed:

1. Moderating variables:
    a. Gender:
        i. Male;
        ii. Female;

2. Independent variables:
    a. Architectural spaces composed by:
        i. Rectilinear surface transitions;
        ii. Curvilinear surface transitions;
    b. Architectural spaces composed by:
        i. Non-prominent edges and vertices or derived transitions;
        ii. Non-prominent edges and vertices and prominent edges or derived transitions;
        iii. Non-prominent edges and vertices and prominent edges and vertices or derived transitions;

3. Dependent variables
    a. Perceived beauty sensation:
        i. Like (beauty);
        ii. Dislike (ugly);
    b. Indented action over the space:

        i. Enter (approach);
        ii. Exit (avoid);
    c. Action/response time

3.4. Design Description

The experience to be held is set upon the group of represented space images to be evaluated by the test-subjects through response action.

To each showed images, subjects will be asked to answers to the stand-alone scenario that they have to choose one from the two available answer options. Questions are divided in two groups and are based on dichotonic pairs. The sixty test subjects under analysis will answer to the first and later to the second of the following questions:

The aesthetic judgment that you feel is closer to:

1. Like – I like the presented architecture space image;
2. Dislike – I dislike the presented space image;

The action based on an approach/avoidance decision that you take is closer to:

1. Enter/approach – I choose to enter the presented space image
2. Exit/move away – I choose to exit the presented space image.

The experience is divided in two segments:

1. The first segment is composed by a set of represented space images showed in a case-by-case basis. In this segment, the test subjects are asked to evaluate the represented spaces image-by-image. Each of the 18 (eighteen) base represented space images are showed a total 5 (five) times making up a total of 90 images to be shown.

2. The second segment repeats the layout of the former (segment) but changes the requested analysis from a like/dislike to an enter/exit decision response-action. The same 18 (eighteen) space-images from the first segment will be evaluated 5 (five) times performing the same total of 90 space-images to be presented.

The second sequence is to take place with the same sixty test-subjects sample from the first sequence. Due to the repetition of the tested sample, to avoid any kind of infection from between sequences, each test-subject is to perform this stage no less than 30 (thirty) days apart from the date they have performed the first sequence. Each sequence is to take a maximum of 15 minutes time span.

In order to avoid possible side effect leading options or latency at the subject's response time namely, the use of technology that requires the use of both right and left hands or colours (e.g. green and red for the dichotonic choices) something that could lead to unconscious but nevertheless factual sample infection, the responses in this study are to be made through the use of a joystick. Choice determination should be made with the use of one single hand and by the movement of the stick to the right or to the left from centre position. To do so, at the bottom of each image to be presented there will be a 'minus' and 'plus' simbols, coloured with neutral grey to avoid bias but, at the same time, to assist the test-subjects in their choices. The '+' sing will indicate the side where a like/enter response-action is required and the '-' symbol the side where the dislike/exit response –action shall be made.

3.4.1. Procedure

Each individual study begins when the first image appears on the computer's screen. Images remains in the computer screen for a time span between 0 (zero) and of 3.000 (three thousand) milliseconds, disappearing and giving place to the next image when a test subject's action is detected or when the maximum response time is reached. In the event of this last scenario, the subject's evaluation is aborted for that image-case. The following image replaces the previous one thru a fade in/fade out technique and the cycle repeats itself.

The order in which the represented spaces images are presented was randomly generated through the algorithm Random Sequence Generator found at www.random.org.

3.4.2. Retrospective experience

After the second sequence has taken place and due to the fact that there is no other sequence to be tested, the subjects will be asked to answer a conscience retrospective questionnaire. The aim of this survey is to understand at a higher level if the given answers by the test subjects had a ground and conscious base. This questionnaire can be found in this document in the appendix 4.

3.5. Local and Date for Data Collection

This study experience is to taken in the ISCTE-IUL ground. Tests are to take place during the last trimester of 2016.

4. Description of the architecture spaces

The architecture spaces images that integrate the study are its main object. In this experience are these spaces that are under evaluation since it is upon them that the test subjects will take the necessary decisions to classify the preference on their distinctive elements. In order to assure that, at response time, are these elements and only these elements that are under consideration it was decided that the spaces should be as abstract and close to each other as possible. By doing so, it is guaranteed that no other variable, susceptible of distracting from the study's main purpose and infect the sample, is included.

The base space to be considered is a simple rational orthogonal space. It is comprised of 5 (five) plans: 2 (two) horizontal plans, a ground level and a ceiling, and 3 (three) vertical plans: 2 (two) side walls and a background one, perpendicular to the line of sight of the observer. All the plans share a 90° angle relationship between each other and their intersections are negative, non-prominent edges. They define its length, width and height, its ethereal emptiness or *space*.

This base space is built upon a matrix of 10 (ten) units of length per 5 (five) units of width and 3 (three) units of height. These last two measures (5X3) are Fibonacci numbers and were specially chosen to ensure the perfect or neutral proportion that the golden section is known to enclose. This choice was made in order to, once more, avoid the inclusion of undesired variables, such as unbalanced or disproportionate relations that could be able to interfere with the neutral intended course of this study. The image of the frontal plan of the designed spaces is then a close representation of the golden rectangle. As to the length of this space, it was chosen so it could fulfil the needed field of depth to contain the distinguish elements that will mark the difference between all the spaces to be considered. All these other spaces are direct, close transfigurations from this original, base one.

This study counts with a total of 18 (eighteen) spaces. These spaces are divided in 2 (two) transformation groups: 6 (six) levels of **contour and geometric** evolution and 3 (three) levels of comprised **element complexity**.

- **Contour and geometric** changes embrace low feature transformations, as the name states, at a contour and geometric levels.
    1. Stage one of this transformation group comprises a 90° angle at plan intersection (space type 1);

2. Stage two comprises a 45° angle plan chamfer at plan intersection (space type 2);
3. Stage three comprises a rounded surface with a radius of 10cm at plan intersection (space type 3);
4. Stage four comprises a 45° angle plan chamfer at plan intersection (space type 4);
5. Stage five comprises a rounded surface with a radius of 20cm at plan intersection (space type 5);
6. Stage six comprises a complete transformation from a Euclidian to a non-Euclidian geometric nature at plan intersection. At this level contour embraces the totality of the space surface (space type 6).

- **Element complexity** considers high feature transformations.
    a. Stage one of this transformation group comprises negative, non-prominent edges or rounded surfaces (space type a);
    b. Stage two comprises negative, non-prominent and positive, prominent **edges** or rounded surfaces (space type b);
    c. Stage three, comprises negative, non-prominent and positive, prominent **edges and vertices** or rounded surfaces (space type c).

If the **element complexity** transformation stages aim to understand and create knowledge on the hypothesis that humans show a higher preference for curved, rounded elements rather than angular, sharp ones, the **contour and geometric** transformation stages aim to the quantification of this level of preference.

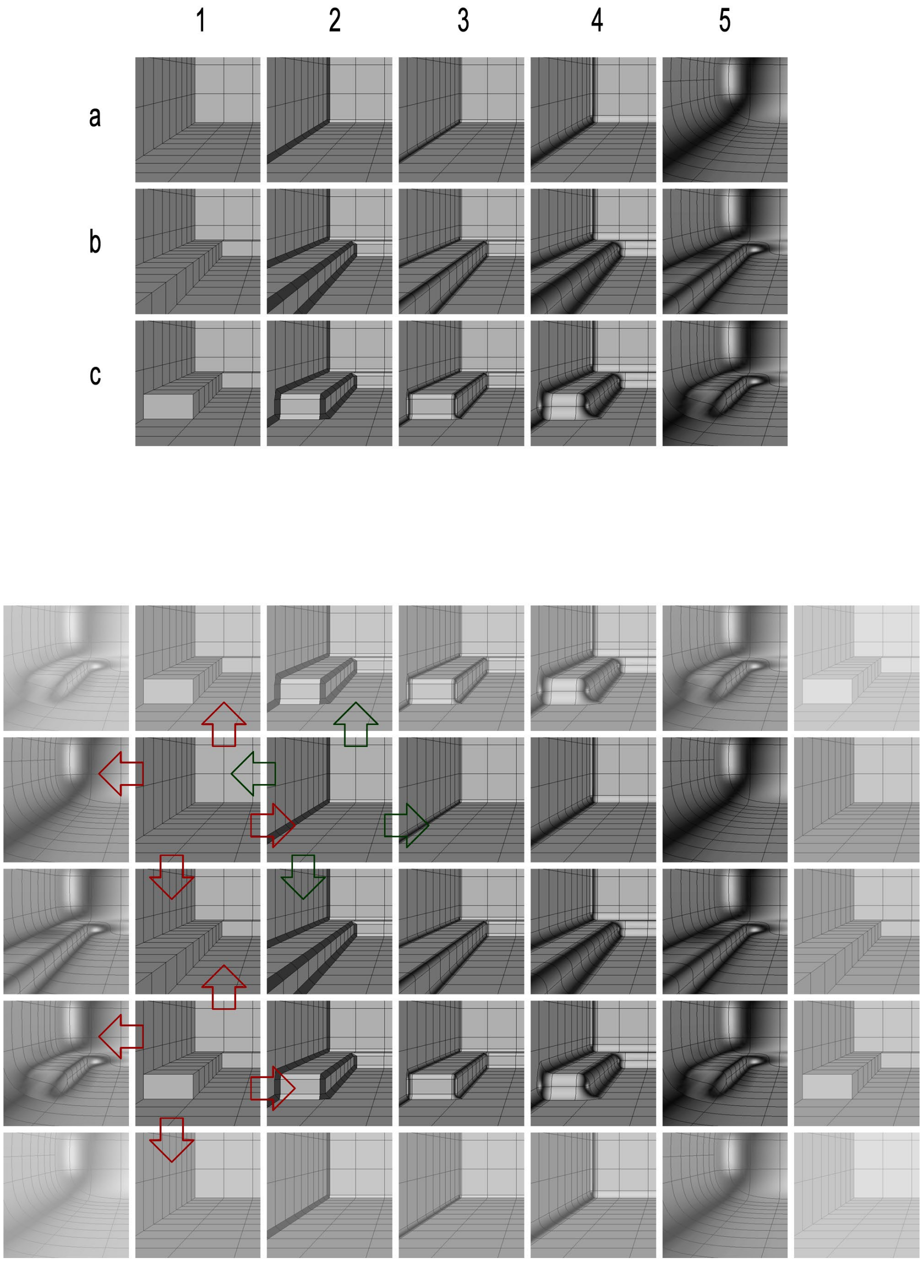

Figure 1 – Contour and geometric and element complexity transformation levels. (illustrative image)

5. Technical specifications

For this study there will be used a laptop computer for the display of the images to be evaluated. The specification of this component are: One desktop Computer Intel® Core™ i7-4700HQ CPU @ 2.40GHz 2.40GHz processor with 16.0 GB installed memory (RAM), 64-bit Operating System, x64-based processor and an Intel® HD Graphics 4600 and a nVIDIA® GeForce GTX 850M Graphic Card;

6. Conclusion

The results of this study aims to create new knowledge on how humans perceive angular and curvilinear contour environments. From the experience-test to be conducted we expect to better understand the level of human preference for angular and rounded architecture spaces, the rate of this preference and if this choices share a relative or otherwise absolute ground. The ultimate goal is to verify the existence of a statistical significant correlation between the collected answers on the perceived beauty sensation and the attractive judgement in order to propose, thru the main author's PhD thesis, a reflection on the way architecture spaces are presently thought and an improvement of the general process of architecture planning.

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Architecture of Contemporary Metropolitan Territories

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8. Appendices

Anexo 1

Termo de Consentimento Livre e Informado

Nome do estudo: Estudo Experimental sobre Espaços Abstractos de Arquitectura com Diferentes Características Geométricas.

Investigador responsável: Miguel Carreiro

Coordenadores do projeto: Professores Paulo Tormenta Pinto, Miguel Sales Dias e Elisabete Raposo Freire

Objetivo do Estudo

O objetivo desta investigação é avaliar o espaço arquitetónico.

Condições do Estudo

O tempo previsto de duração do estudo é de cerca de **15 minutos.** A sua participação representa um importante contributo, não só para o estudo em curso, mas também para o desenvolvimento do conhecimento na área da Arquitetura e da Psicologia. Durante o período da experiência-teste estará presencialmente acompanhado pelo responsável do estudo.

Voluntariado

Este sistema tem um carácter voluntário. O participante tem a possibilidade, por motivos éticos, de negar a participação ou de se retirar do estudo, a qualquer momento, sempre que assim o entender.

Confidencialidade, Privacidade e Anonimato

De acordo com as normas da Comissão de Proteção de Dados, os dados recolhidos são anónimos e a sua eventual publicação só poderá ter lugar em Revistas da especialidade.

Tendo tomado conhecimento sobre a informação disponível do estudo, declaro aceitar participar.

___/___/2017 ____

Anexo 2

Lista de Verificação dos Critérios de Participação

1. Género (marque com um "X" a sua resposta) ☐ Masculino ☐ Feminino

2. Data de nascimento (dd/mm/aa) ____ / ____ / ____

3. Qual é a sua **ocupação**? ____

4. Qual a sua **escolaridade**? (marque com um "X" no grau que frequenta atualmente. No caso de já não estudar, indique o seu último grau)

☐ Educação primária
☐ Preparatório
☐ 9º ano
☐ Ensino secundário (12º ano)
☐ Bacharelato
☐ Licenciatura
☐ Mestrado
☐ Doutoramento
☐ Outra ____

5. Qual a sua mão dominante? (marque com um "X" a sua resposta)

☐ Esquerda (canhoto) ☐ Direita (destro) ☐ Ambos (ambidestro)

CRITÉRIOS	SIM	NÃO
1. Tem entre 18 e 65 anos?		
2. Domina a língua Portuguesa, falada e escrita?		
3. Tem visão (acuidade visual) normal?		
4. Em caso de ter respondido 'NÃO' à questão anterior, tem a visão corrigida por meio de óculos ou lentes graduadas?		
5. Tem problemas de audição?		
6. Sofre de vertigens?		
7. Em caso de ter respondido 'SIM' à questão anterior, tem por hábito o uso de um computador?		

Anexo 3

Guião Experimental

“Bom dia/ boa tarde:

1- APRESENTAÇÃO: O meu nome é Miguel Carreiro. Antes de mais, agradeço a sua disponibilidade para participar neste estudo que se enquadra no âmbito da minha tese de doutoramento.

2 – OBJETIVO: Neste estudo estamos interessados na sua opinião sobre o espaço de arquitetura. Para tal, pedimos-lhe que avalie as imagens que lhe serão apresentadas de acordo com a sensação de estética/ abordagem que estas lhe transmitem.

3 – PREENCHIMENTO DO TERMO DE CONSENTIMENTO INFORMADO: Peço agora que leia com atenção este termo de consentimento livre e informado e, se concordar em participar no estudo, o assine no final. Uma das cópias é para si e a outra é para nós. Se tiver qualquer dúvida estamos à sua disposição para esclarecê-la.

4 – DESENHO DA EXPERIÊNCIA-TESTE: A experiência é constituída por 3 momentos diferentes: Um pré-teste, que tem por objetivo prepará-lo(a) para a experiência em si e dois momentos de experiência

5 – PRÉ-TESTE: Para que se sinta mais confortável, vamos primeiro fazer um pré-teste para melhor se enquadrar no desenho da experiência-teste. Este pré-teste é constituído por uma série de imagens que estão divididos em dois grupos: Uma imagem cinzenta com uma cruz no centro e parâmetros que se vão alterando ao longo da experiência. São estes parâmetros que lhe pedimos para avaliar durante este pré-teste. Pedimos-lhe que responda se gosta/entra ou não gosta/ não entra nos parâmetros apresentados. Em caso de indecisão, deve escolher a resposta que mais de

aproxima da sua convicção: Se gosta/entra mais ou menos nos exemplos que lhe são apresentados.

6 – BOTÕES DE RESPOSTA: Sobre o teclado do computador através do qual realizará a experiência, estão dois botões cinzentos, um posicionado à esquerda e outro à direita. É através destes botões que avaliará os cenários que lhe serão apresentados. Um dos botões corresponde à resposta gosto/entro e o outro à resposta não gosto/ não entro. Para melhor se orientar, sempre que for apresentado um parâmetro que requer a sua avaliação, aparecerá no fundo do ecrã um 'mais' e um 'menos'. O lado em que aparece o símbolo '+' corresponde ao lado em que deve pressionar o botão cinzento para a resposta gosto/entro e o lado em que aparece o símbolo '-' corresponde ao lado em que deve pressionar o botão cinzento para a resposta não gosto/não entro. Cada parâmetro será apresentado por um período máximo de 3 segundos. A sua resposta a estes parâmetros deve portanto ter lugar dentro deste período de exposição. Caso tal não aconteça e a imagem mudar sem que tenha dado qualquer resposta, não se preocupe. Foque-se no próximo parâmetro e tente responder dentro dos 3 segundos destinados à sua exposição.

O pré-teste dura aproximadamente 1 minuto.

Caso sinta qualquer algum desconforto, por favor avise-nos para procedermos à interrupção da experiência. Sinta-se à vontade para desistir a qualquer momento.

Vamos experimentar?

7 – PRÉ-TESTE. (Pedir aos participantes para avaliarem os parâmetros apresentados).

Sente-se bem?

(O cenário da experiência-teste carrega-se automaticamente)

8 – EXPERIENCIA 1: Vamos agora começar a primeira experiência-teste com o ambiente que estamos a avaliar. À semelhança do pré-teste, deve avaliar as imagens

que lhe serão apresentadas através dos dois botões cinzentos. Para melhor o orientar, no fundo do ecrã e por cima de cada um dos botões cinzentos, também estarão presentes os símbolos '+' e '-' em cada uma das imagens que deverá avaliar. À imagem do que aconteceu no pré-teste, cada imagem será apresentada por um período máximo de 3 segundos. A sua resposta a estes parâmetros deve portanto ter lugar dentro deste período de exposição. Caso tal não aconteça e a imagem mudar sem que tenha dado qualquer resposta, não se preocupe. Foque-se no próximo parâmetro e tente responder dentro dos 3 segundos destinados à sua exposição.

Durante o decurso da experiência-teste, estarei atrás de si em silêncio e não poderei falar consigo, a não ser que queira parar por algum motivo. Quando a experiência chegar ao fim, a simulação encerrar-se-á automaticamente.

A experiência-teste 1 dura aproximadamente 6 minutos.

Caso sinta qualquer desconforto, por favor avise-nos para procedermos à interrupção da experiência. Sinta-se à vontade para desistir a qualquer momento.

Tem alguma dúvida? Podemos começar?

(O cenário da experiência-teste carrega-se automaticamente)

9 – EXPERIÊNCIA-TESTE 1. (Pedir aos participantes para avaliarem as imagens apresentadas).

10 – INTERVALO

Sente-se bem?

11 – EXPERIENCIA 2: Vamos agora dar lugar à segunda experiência-teste com o ambiente que estamos a avaliar. À semelhança da experiência-teste 1, deve avaliar as imagens que lhe serão apresentadas através dos dois botões cinzentos. Para melhor o orientar, terá igualmente à sua disposição no fundo do ecrã e por cima de cada um dos

botões cinzentos, os símbolos '+' e '-' em cada uma das imagens que deverá avaliar. À imagem do que aconteceu no pré-teste e na experiência-teste 1, cada imagem será apresentada por um período máximo de 3 segundos. A sua resposta a estes parâmetros deve portanto ter lugar dentro deste período de exposição. Caso tal não aconteça e a imagem mudar sem que tenha dado qualquer resposta, não se preocupe. Foque-se no próximo parâmetro e tente responder dentro dos 3 segundos destinados à sua exposição.

Durante o decurso da experiência-teste, estarei atrás de si em silêncio e não poderei falar consigo, a não ser que queira parar por algum motivo. Quando a experiência chegar ao fim, a simulação encerrar-se-á automaticamente.

A experiência-teste 2 dura aproximadamente 6 minutos.

Caso sinta qualquer desconforto, por favor avise-nos para procedermos à interrupção da experiência. Sinta-se à vontade para desistir a qualquer momento.

Tem alguma dúvida? Podemos começar?

(O cenário da experiência-teste carrega-se automaticamente)

12 – TÉRMINO: Sente-se bem?

13 – QUESTIONÀRIO DE RESPOSTA CONCIENTE: (A apresentar apenas no final do segundo ciclo de experiências). O estudo está quase a terminar. Pedimos-lhe apenas que responda a um breve questionário.

Muito obrigado pela sua participação.

Anexo 4

Questionário de resposta consciente

Durante a experiência-teste foram apresentados espaços-imagem que foram por si avaliados.

1. Na sua opinião, existe alguma diferença entre os espaços-imagem apresentados? (marque com um 'X' a sua resposta)

   ☐ Sim ☐ Não

1.1. No caso de ter respondido 'Sim' à questão anterior, consegue especificar em que consiste(m) esta(s) diferença(s)?

____

2. Gostou particularmente de algum tipo dos espaços-imagem apresentados? (marque com um 'X' a sua resposta)

   ☐ Sim ☐ Não

2.1. No caso de ter respondido 'Sim' à questão anterior, consegue especificar qual?

____

3. Não gostou particularmente de algum tipo dos espaços-imagem apresentados? (marque com um 'X' a sua resposta)

   ☐ Sim ☐ Não

3.1. No caso de ter respondido 'Sim' à questão anterior, consegue especificar qual?

____

4. Entraria particularmente de algum tipo dos espaços-imagem apresentados? (marque com um 'X' a sua resposta)

☐ Sim ☐ Não

4.1. No caso de ter respondido 'Sim' à questão anterior, consegue especificar qual?

____

5. Não entraria particularmente de algum tipo dos espaços-imagem apresentados? (marque com um 'X' a sua resposta)

☐ Sim ☐ Não

5.1. No caso de ter respondido 'Sim' à questão anterior, consegue especificar qual?

____

6. Da totalidade dos espaços-imagem apresentados, alguns têm contornos retilíneos e outros, contornos curvilíneos. Na sua opinião, existem mais espaços-imagem com contornos retilíneos, mais espaços-imagem com contornos curvilíneos ou considera que a amostra está dividida de forma equilibrada? (marque com um 'X' a sua resposta)

☐ Retilíneos ☐ Curvilíneos ☐ Amostra equilibrada

7. Durante a experiência-teste, cada espaço-imagem foi apresentado mais do que uma vez. Sem contar com o número de repetições, consegue precisar quantos espaços-imagem originais foram apresentados?

____

8. Ao longo do tempo que durou a experiência-teste teve a consciência de mudar a sua opinião face a algum, ou algum tipo, dos espaços-imagem? (marque com um 'X' a sua resposta)

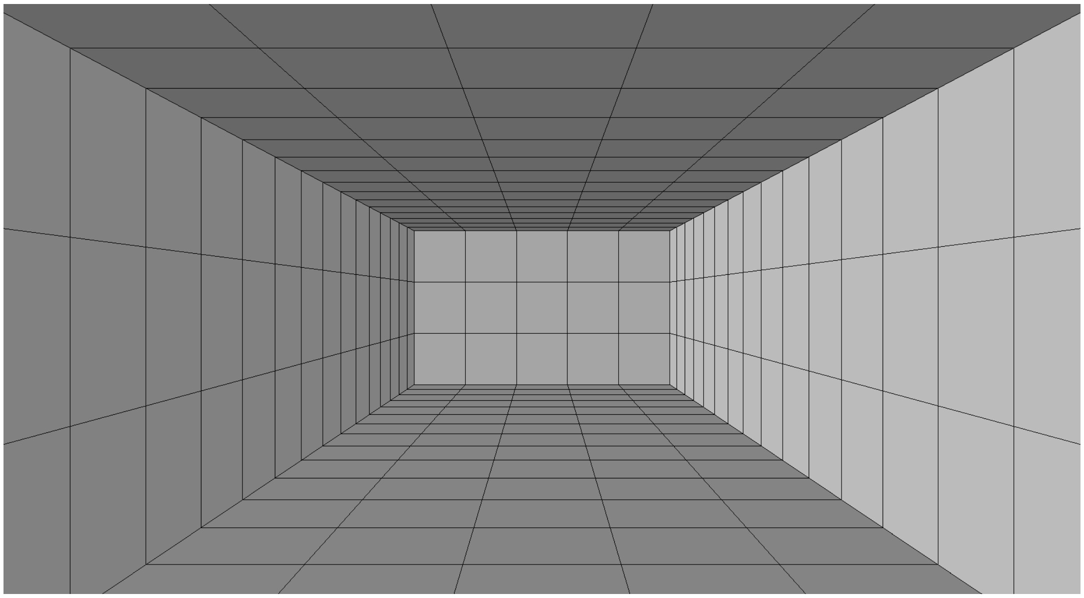
☐ Sim ☐ Não

8.1. No caso de ter respondido 'Sim' à questão anterior, consegue especificar em relação a qual ou a que tipo de espaços-imagem?

De 'não gosto' para 'gosto': ____

De 'gosto' para 'não gosto': ____

9. Por favor avalie os espaços-imagem que se seguem de acordo com a opção que achar mais correta. Marque a sua resposta com um 'X'. (1 = gosto pouco; 7 = gosto muito)



Gosto pouco						**Gosto muito**
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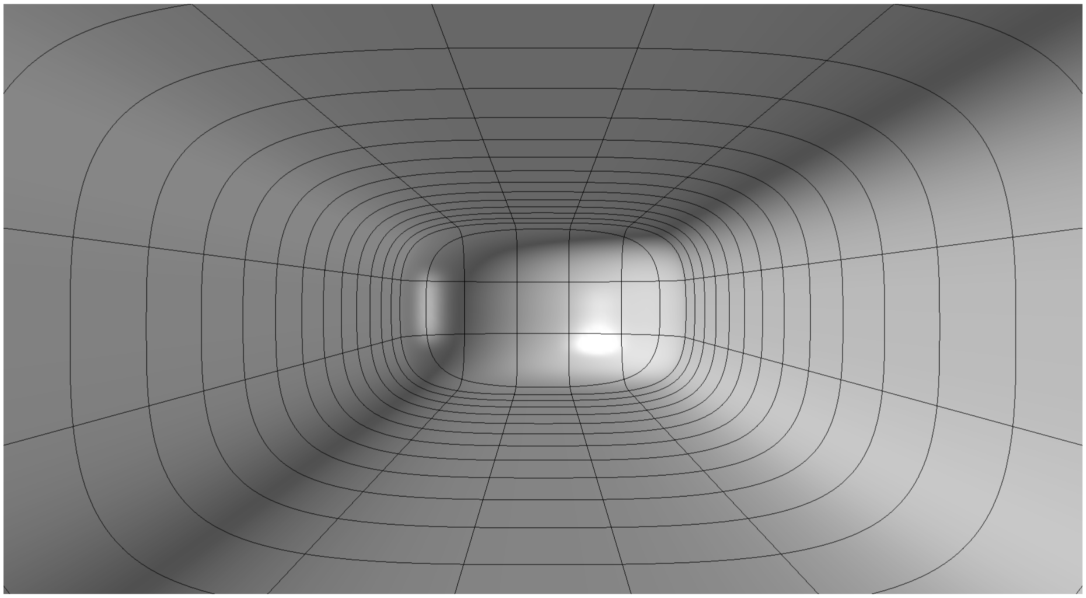

Gosto pouco						**Gosto muito**
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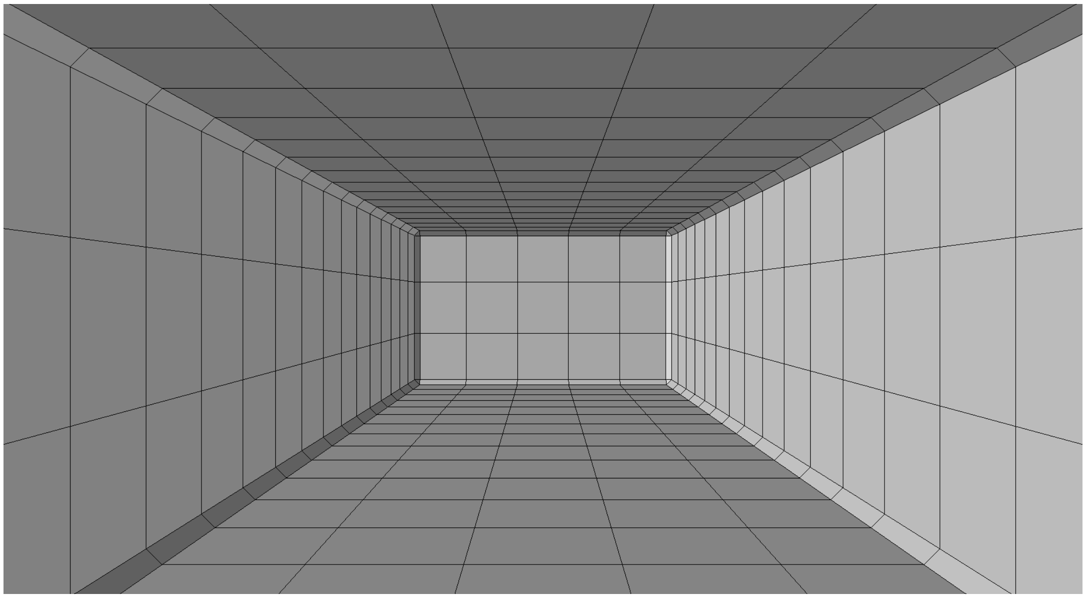

Gosto pouco						**Gosto muito**
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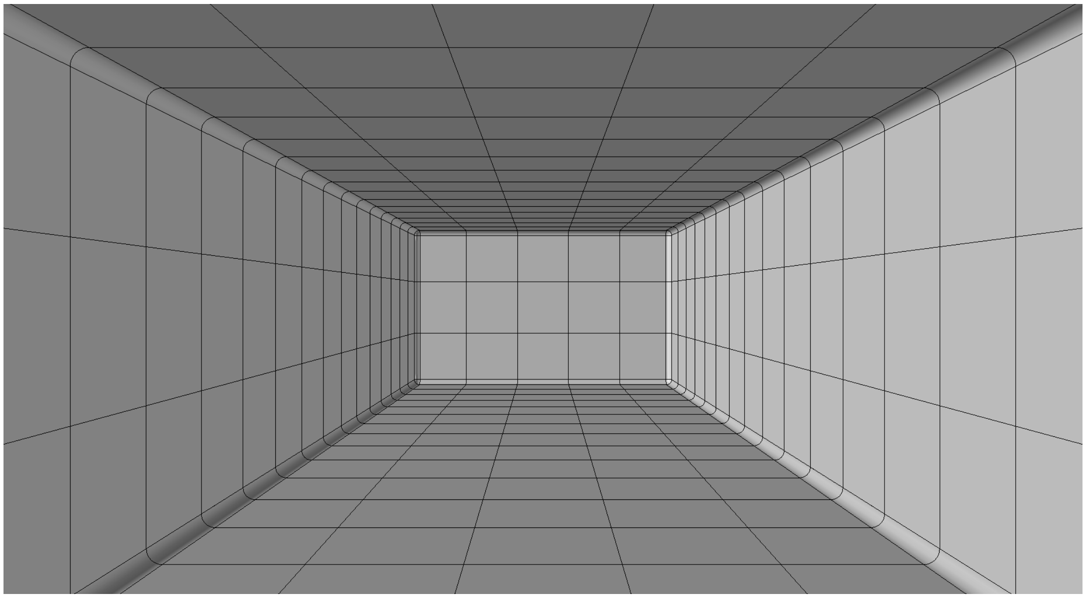

Gosto pouco						**Gosto muito**
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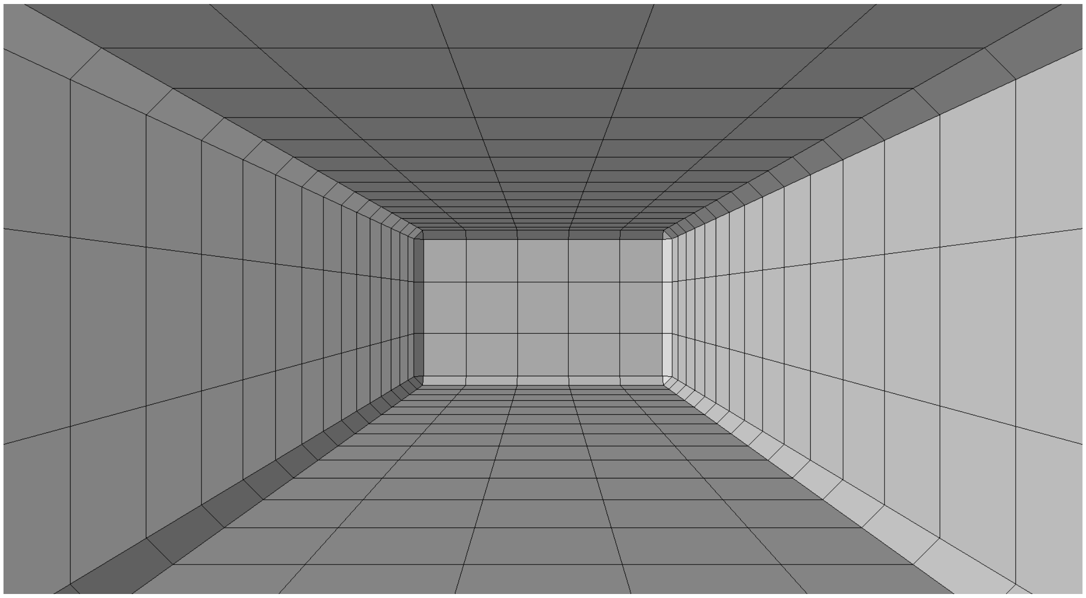

Gosto pouco						**Gosto muito**
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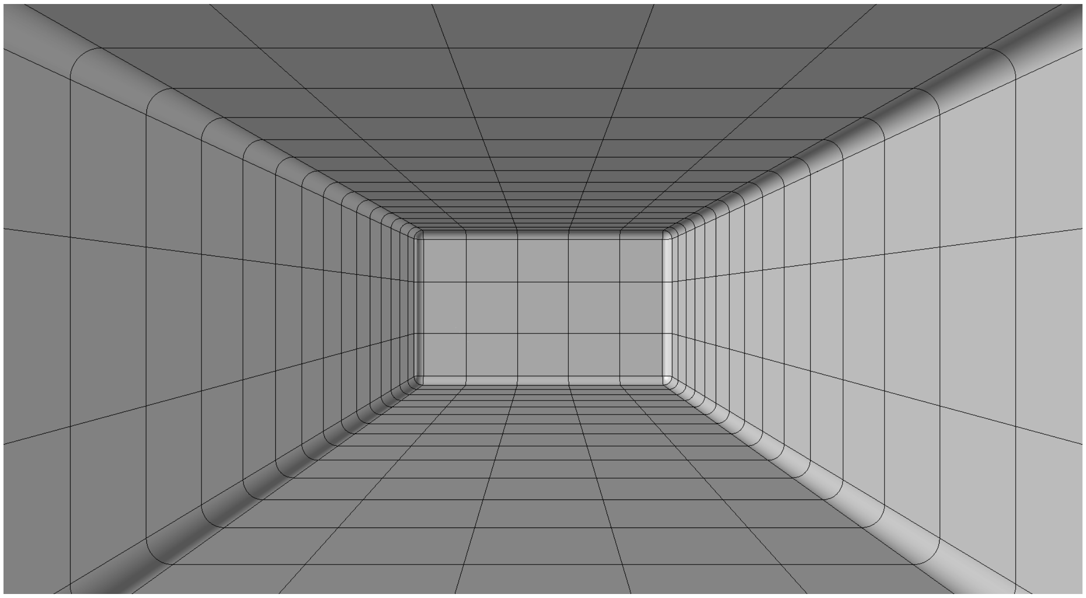

Gosto pouco						**Gosto muito**
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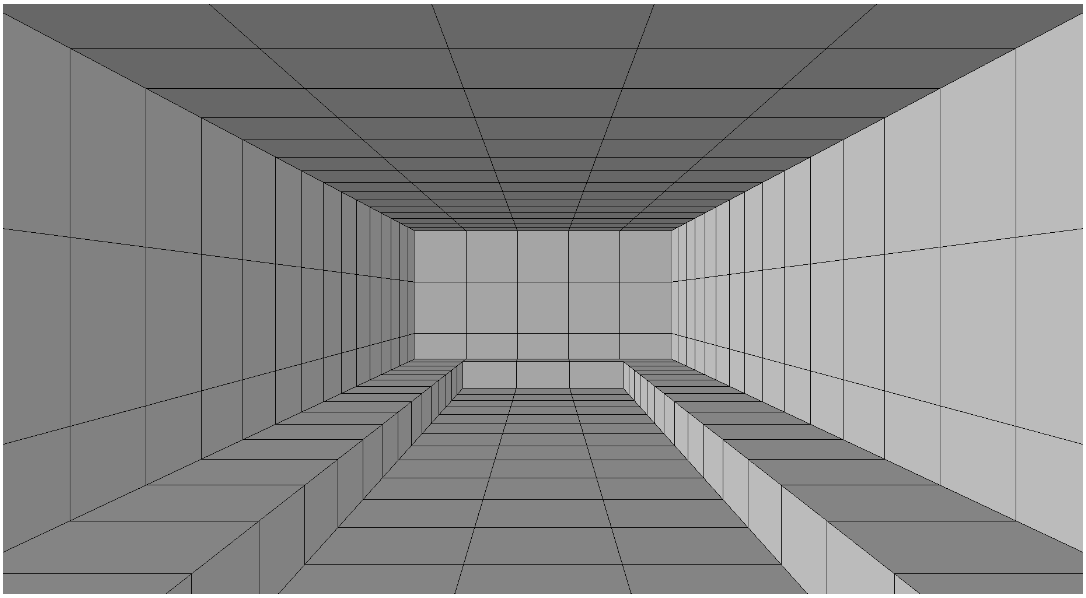

Gosto pouco						**Gosto muito**
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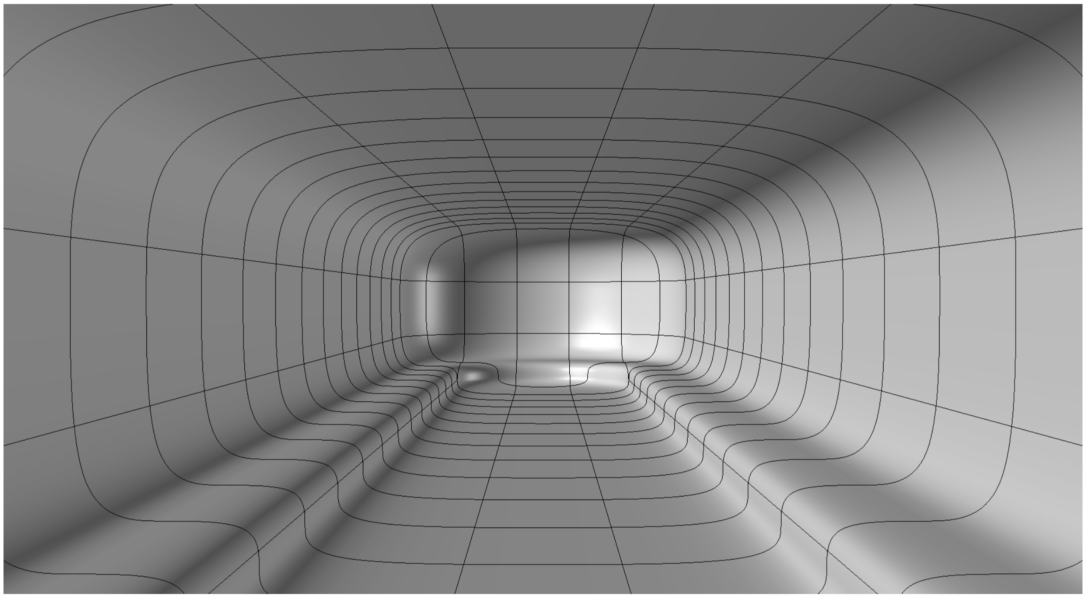

Gosto pouco						**Gosto muito**
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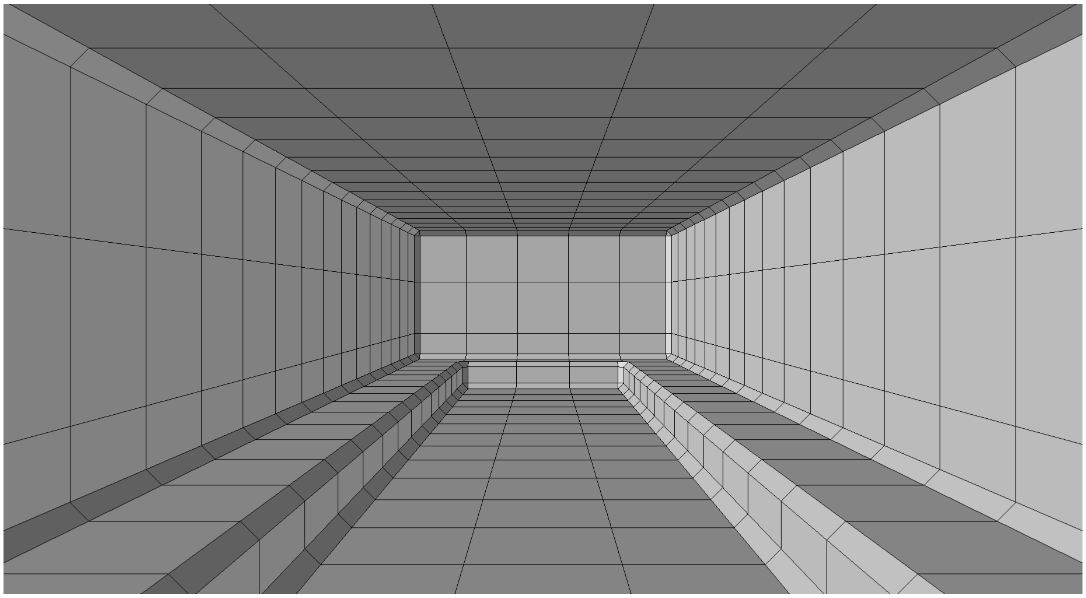

Gosto pouco						**Gosto muito**
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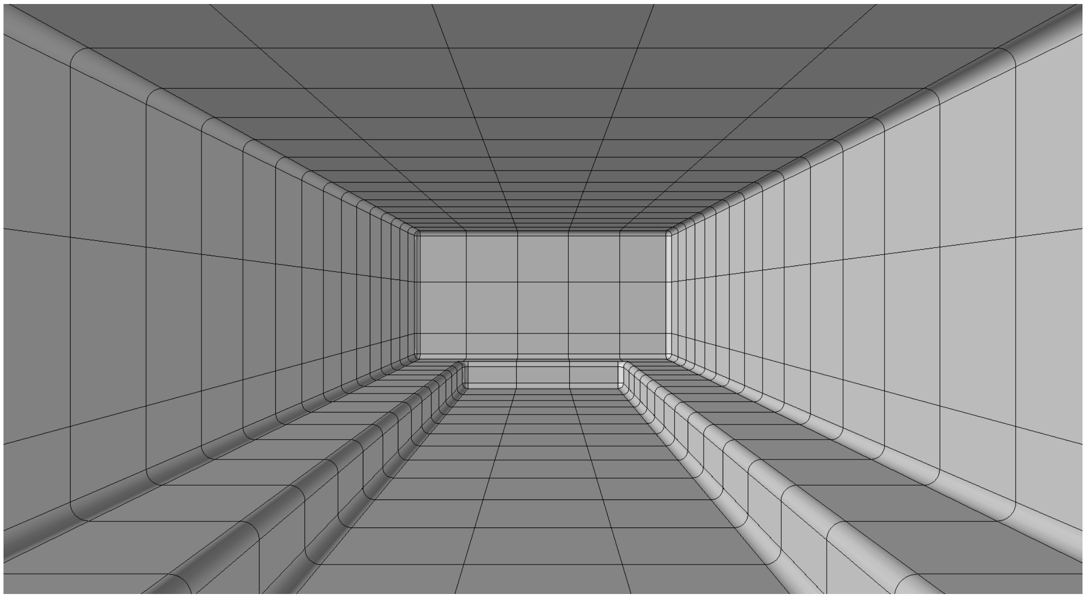

Gosto pouco						**Gosto muito**
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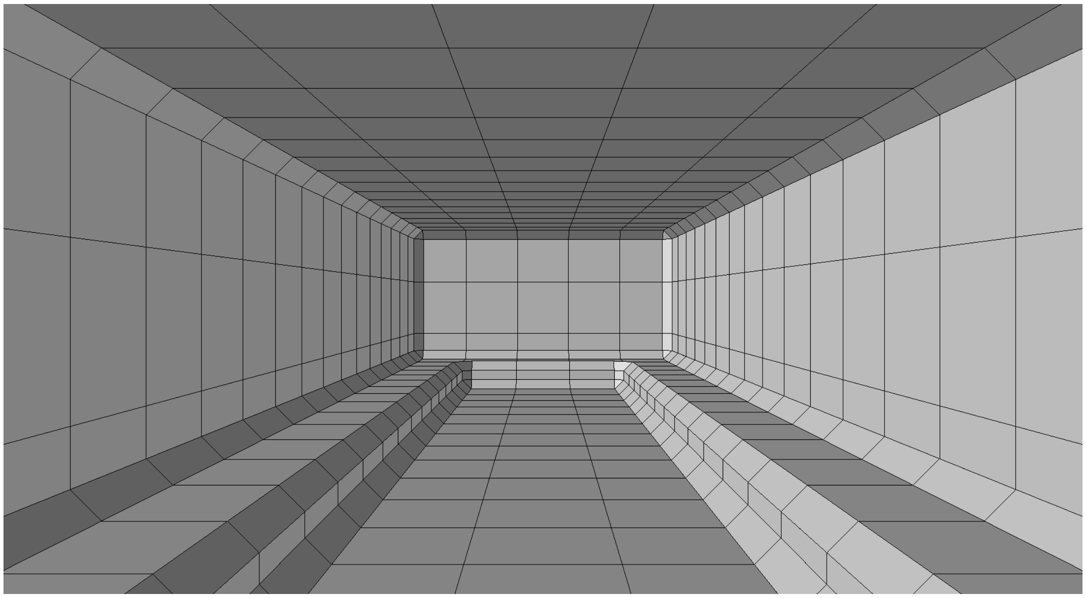

Gosto pouco						**Gosto muito**
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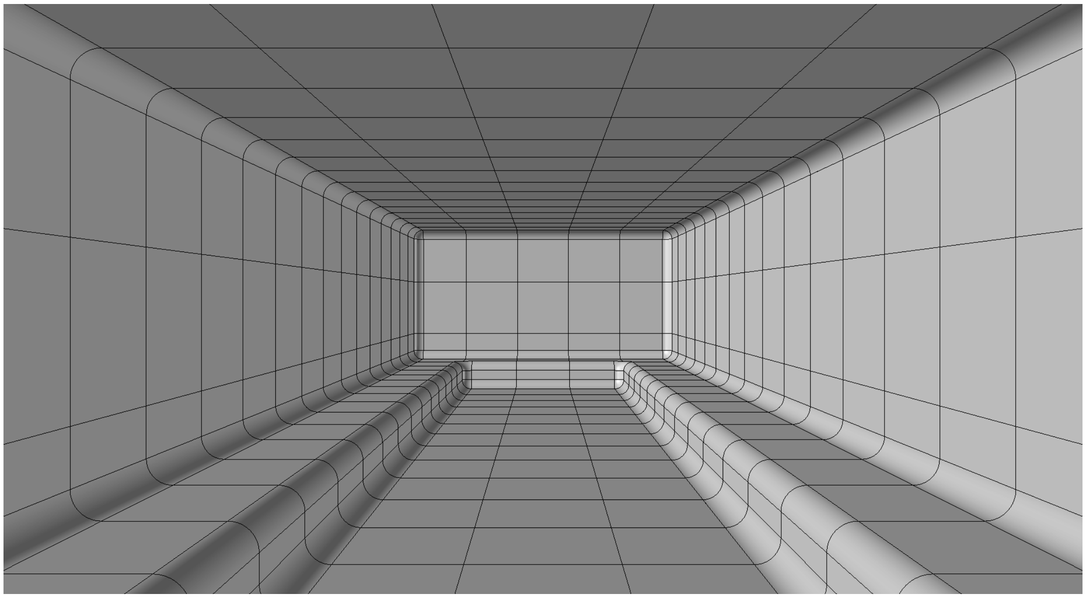
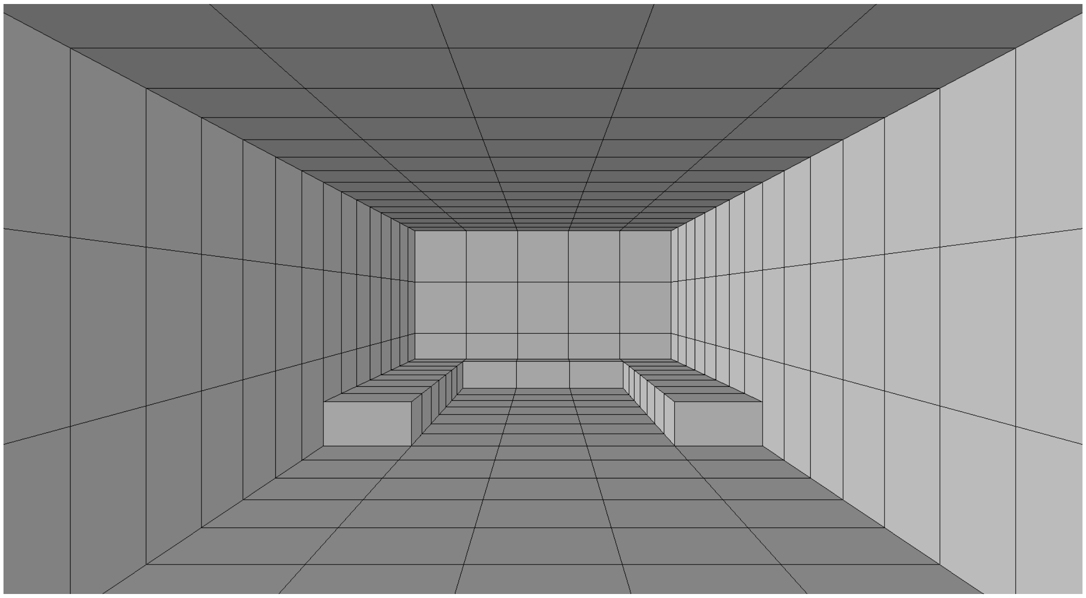
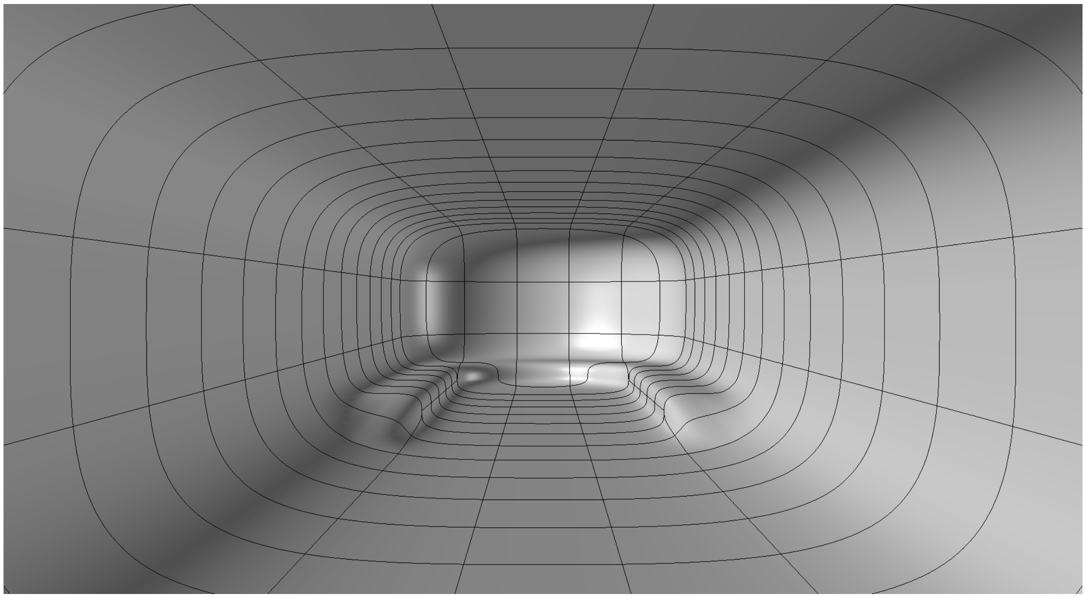


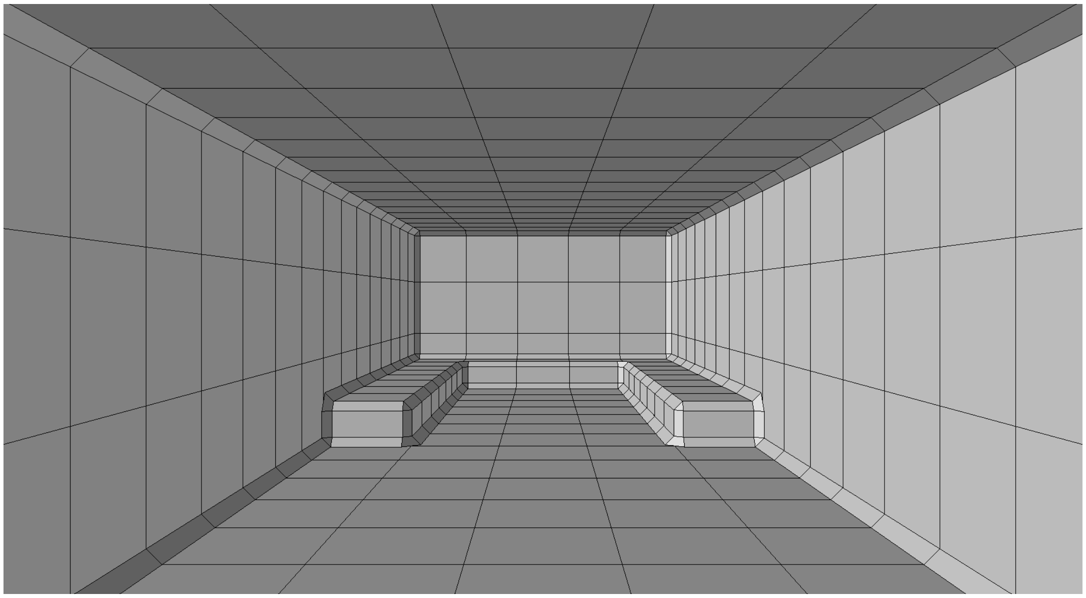
Gosto pouco						**Gosto muito**
1	2	3	4	5	6	7



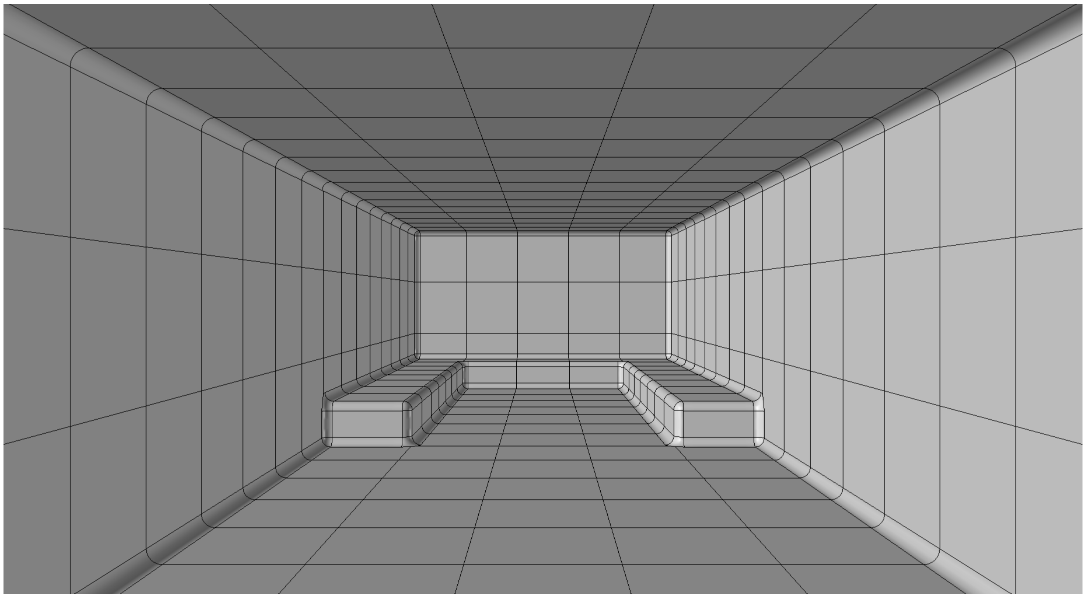
Gosto pouco						**Gosto muito**
1	2	3	4	5	6	7



Gosto pouco						**Gosto muito**
1	2	3	4	5	6	7



Gosto pouco						**Gosto muito**
1	2	3	4	5	6	7



Gosto pouco						**Gosto muito**
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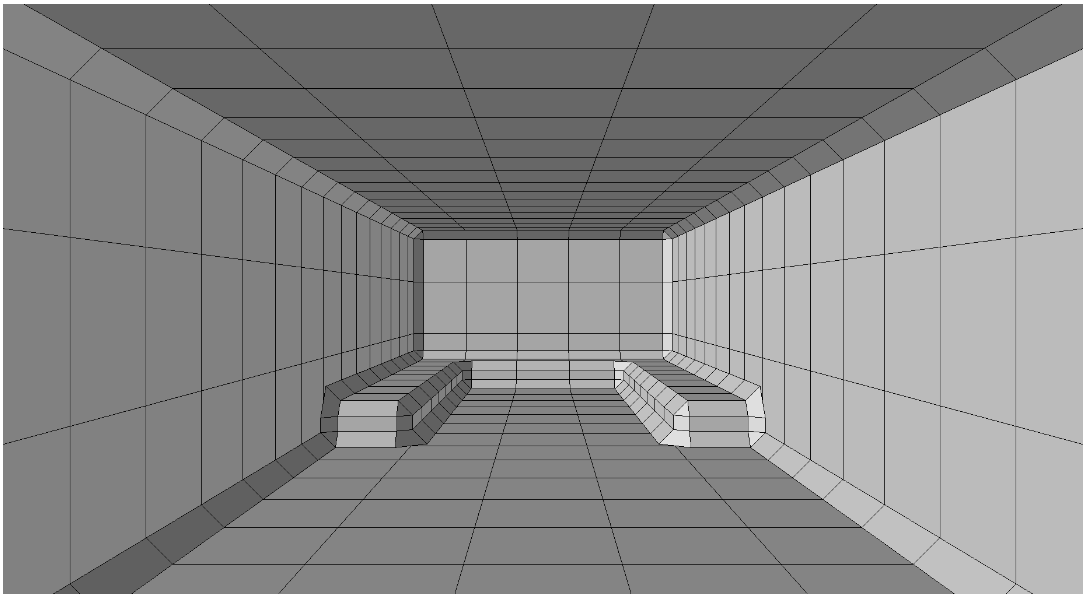
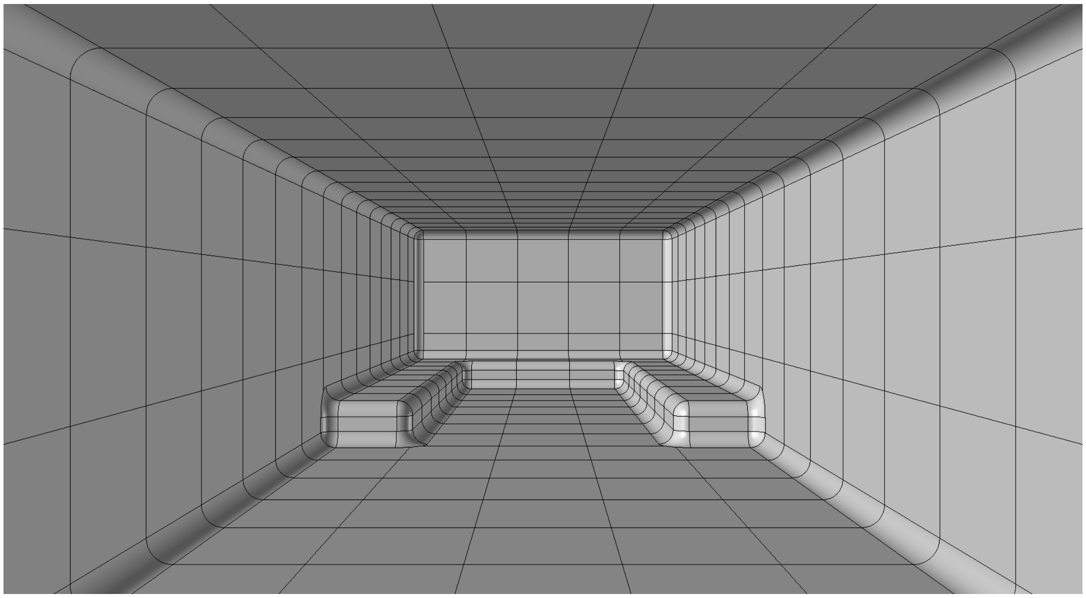


Gosto pouco						**Gosto muito**
1	2	3	4	5	6	7



Gosto pouco						**Gosto muito**
1	2	3	4	5	6	7

10.1. Por favor observe os espaços-imagem da página 7.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.2. Por favor observe os espaços-imagem da página 8.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.3. Por favor observe os espaços-imagem da página 9.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.4. Por favor observe os espaços-imagem da página 10.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.5. Por favor observe os espaços-imagem da página 11.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.6. Por favor observe os espaços-imagem da página 12.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.7. Por favor observe os espaços-imagem da página 13.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.8. Por favor observe os espaços-imagem da página 14.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

10.9. Por favor observe os espaços-imagem da página 15.

Qual deles gosta mais?

____

Se tivesse de entrar em algum deles, em qual deles optaria fazê-lo?

____

Appendix B

ISCTE-IUL’s Ethic Committee stand over the experimental study’s Research Protocol

ISCTE IUL
Instituto Universitário de Lisboa

COMISSÃO DE ÉTICA

PARECER FINAL

11/2016

Projeto: "A Psychophysical Experience on Contour of Abstract Architectural Spaces "

O Projeto " *A Psychophysical Experience on Contour of Abstract Architectural Spaces* ", submetido pelo investigador Miguel Carreiro, foi analisado pela Comissão de Ética na reunião de 06 de Dezembro de 2016.

A Comissão de Ética, no âmbito das suas competências, entende que o projeto apresentado pelo Doutor Miguel Baptista Tavares Carreiro satisfaz os requisitos éticos exigidos em projetos de investigação científica desta natureza, tendo merecido a concordância da Comissão de Ética. Esta não pode, todavia, deixar de fazer notar que a submissão de projetos de investigação à Comissão de Ética não constitui uma mera formalidade administrativa, mas uma exigência ética e legal incontornável, que deve preceder o início do trabalho de investigação, o que, no caso vertente, não terá sido respeitado, uma vez que, segundo a respetiva sinopse, os procedimentos experimentais encontram-se previstos para o último trimestre de 2016.

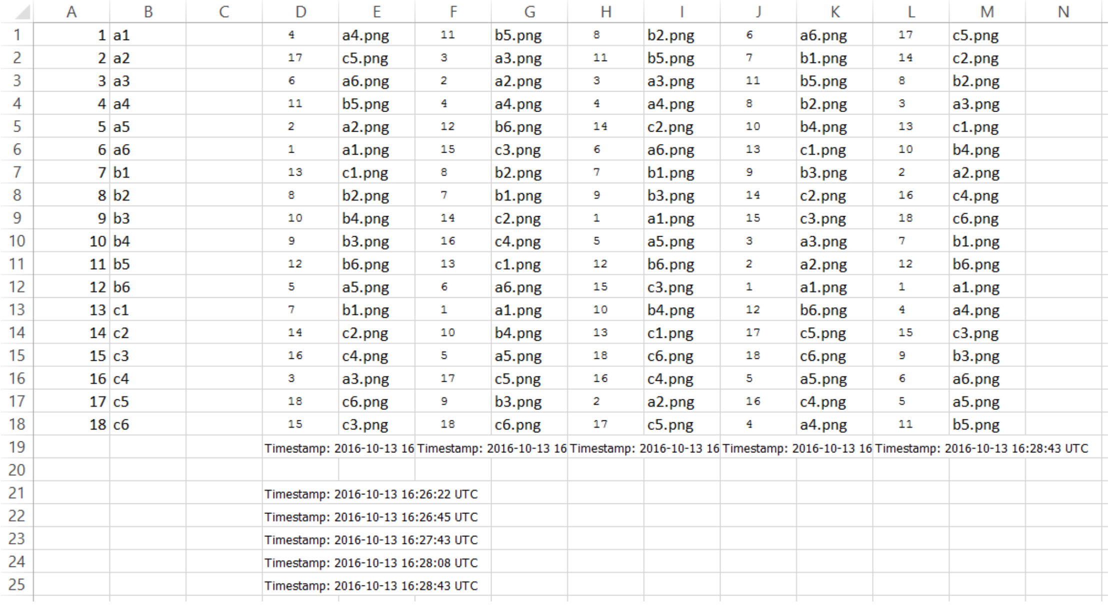
O Presidente da Comissão, *Prof. Doutor Jorge Costa Santos*

O Vogal, *Prof. Doutor Manuel Pita*

Manuel Pita

Appendix C

Order of the experimental study’s stimuli



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
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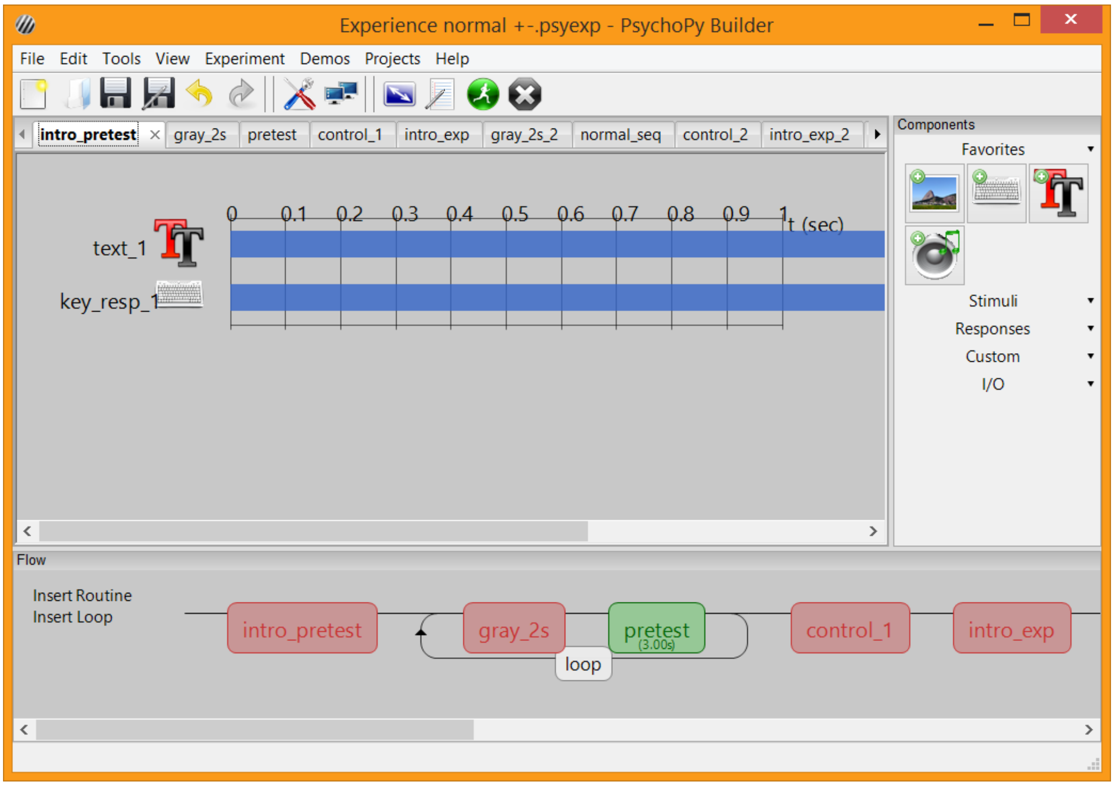
2	2	a2		17	c5.png	3	a3.png	11	b5.png	7	b1.png	14	c2.png	
3	3	a3		6	a6.png	2	a2.png	3	a3.png	11	b5.png	8	b2.png	
4	4	a4		11	b5.png	4	a4.png	4	a4.png	8	b2.png	3	a3.png	
5	5	a5		2	a2.png	12	b6.png	14	c2.png	10	b4.png	13	c1.png	
6	6	a6		1	a1.png	15	c3.png	6	a6.png	13	c1.png	10	b4.png	
7	7	b1		13	c1.png	8	b2.png	7	b1.png	9	b3.png	2	a2.png	
8	8	b2		8	b2.png	7	b1.png	9	b3.png	14	c2.png	16	c4.png	
9	9	b3		10	b4.png	14	c2.png	1	a1.png	15	c3.png	18	c6.png	
10	10	b4		9	b3.png	16	c4.png	5	a5.png	3	a3.png	7	b1.png	
11	11	b5		12	b6.png	13	c1.png	12	b6.png	2	a2.png	12	b6.png	
12	12	b6		5	a5.png	6	a6.png	15	c3.png	1	a1.png	1	a1.png	
13	13	c1		7	b1.png	1	a1.png	10	b4.png	12	b6.png	4	a4.png	
14	14	c2		14	c2.png	10	b4.png	13	c1.png	17	c5.png	15	c3.png	
15	15	c3		16	c4.png	5	a5.png	18	c6.png	18	c6.png	9	b3.png	
16	16	c4		3	a3.png	17	c5.png	16	c4.png	5	a5.png	6	a6.png	
17	17	c5		18	c6.png	9	b3.png	2	a2.png	16	c4.png	5	a5.png	
18	18	c6		15	c3.png	18	c6.png	17	c5.png	4	a4.png	11	b5.png	
19				Timestamp: 2016-10-13 16		Timestamp: 2016-10-13 16		Timestamp: 2016-10-13 16		Timestamp: 2016-10-13 16		Timestamp: 2016-10-13 16:28:43 UTC		
20														
21				Timestamp: 2016-10-13 16:26:22 UTC										
22				Timestamp: 2016-10-13 16:26:45 UTC										
23				Timestamp: 2016-10-13 16:27:43 UTC										
24				Timestamp: 2016-10-13 16:28:08 UTC										
25				Timestamp: 2016-10-13 16:28:43 UTC										

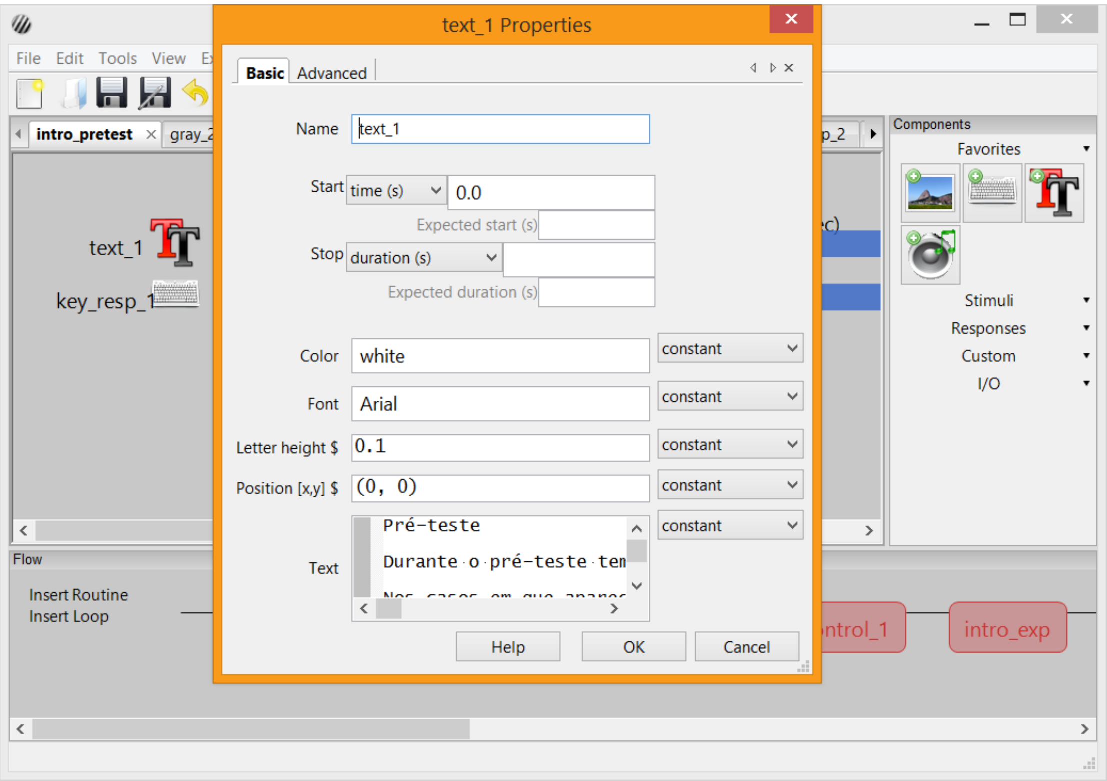
Screenshot I. Experiences’ stimuli order found at www.random.org in 2016-10-13.

Appendix D

Experimental study’s PsychoPy unfolded design



Screenshot I. Introduction pre-test. Layout.



Name: text_1

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Color: white — constant

Font: Arial — constant

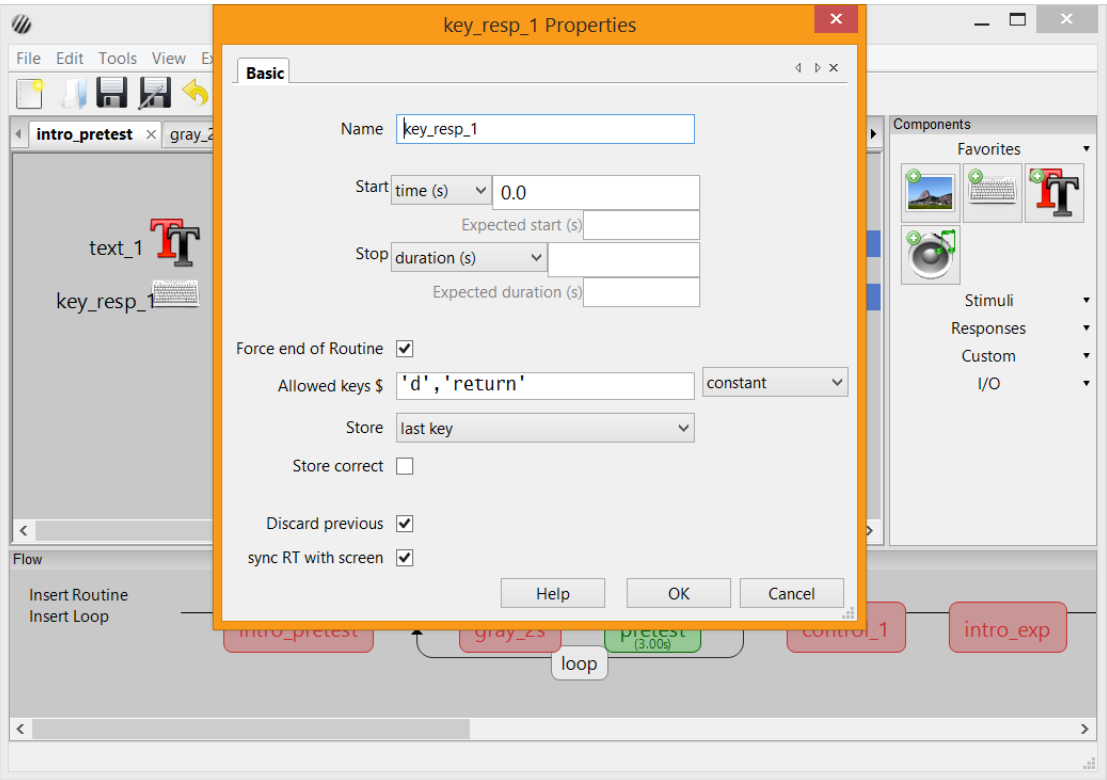
Letter height $: 0.1 — constant

Position [x,y] $: (0, 0) — constant

Text: — constant

```
Pré-teste
Durante o pré-teste tem
```

Screenshot II. Introduction pre-test. Text properties.



Name: key_resp_1

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Force end of Routine ☑

Allowed keys $: 'd','return' — constant

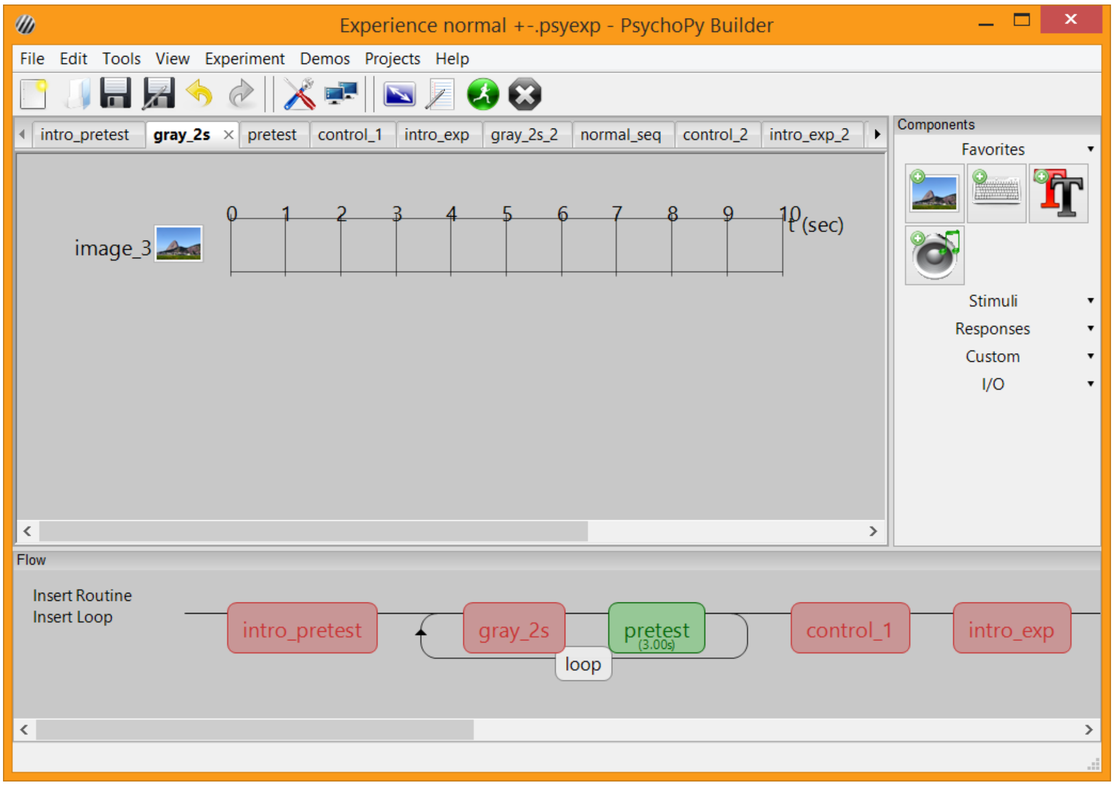
Store: last key

Store correct ☐

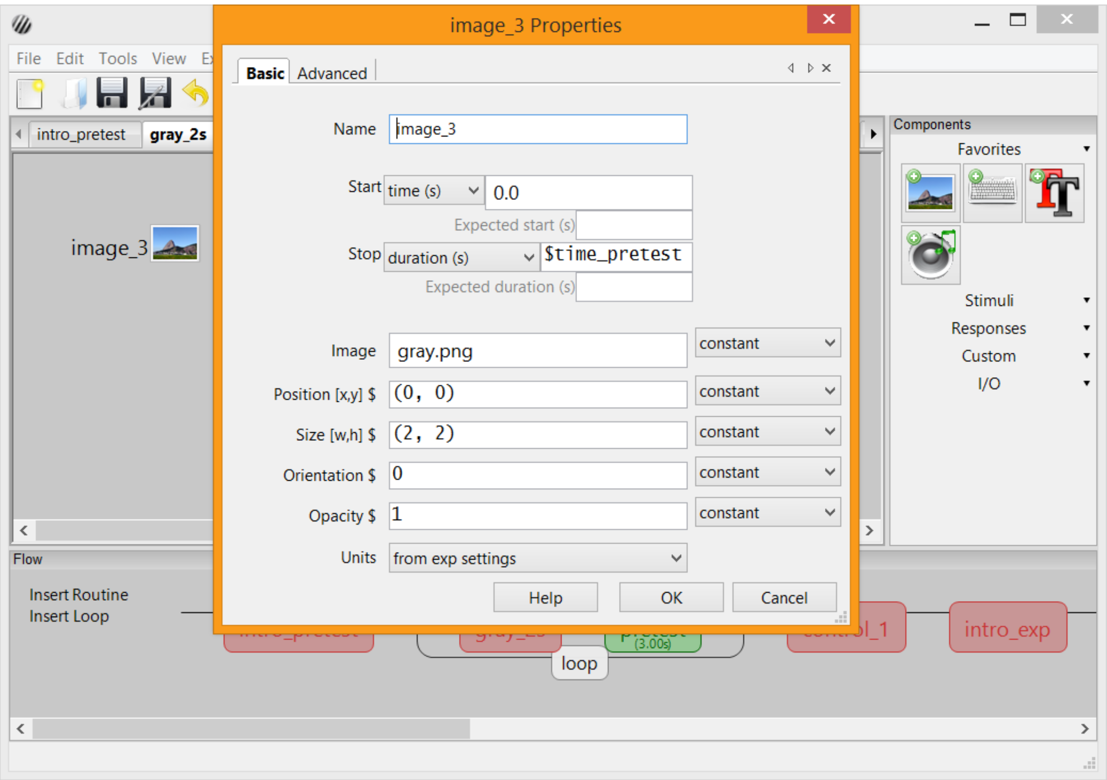
Discard previous ☑

sync RT with screen ☑

Screenshot III. Introduction pre-test. Keyboard response properties.



Screenshot IV. Pre-test. Transitory image. Layout.



Name image_3

Start time (s) 0.0

Expected start (s)

Stop duration (s) $time_pretest

Expected duration (s)

Image gray.png constant

Position [x,y] $ (0, 0) constant

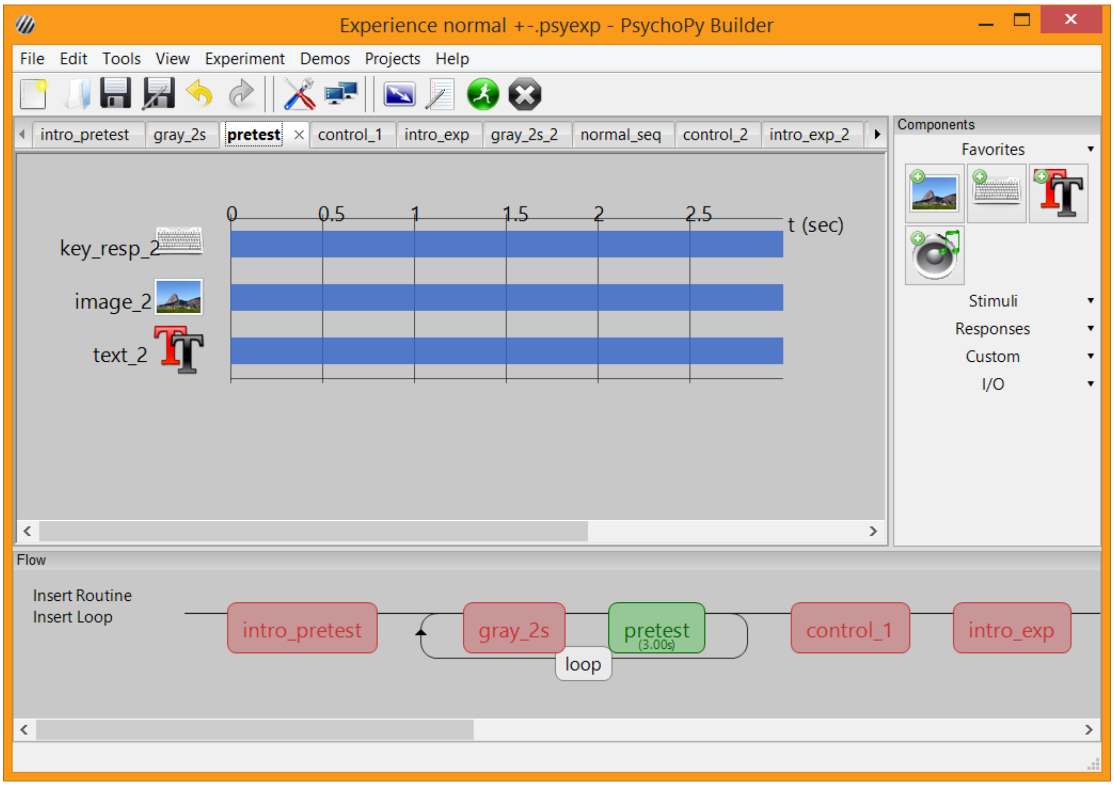
Size [w,h] $ (2, 2) constant

Orientation $ 0 constant

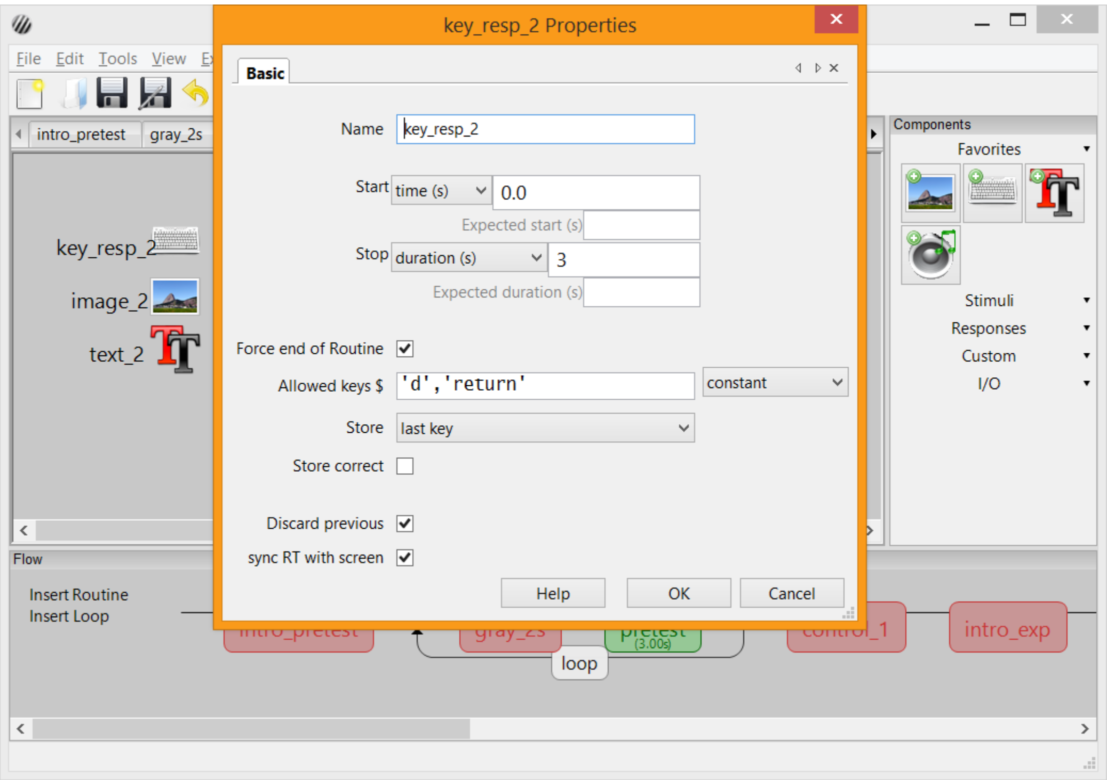
Opacity $ 1 constant

Units from exp settings

Screenshot V. Pre-test. Transitory image. Image properties.



Screenshot VI. Pre-test. Layout.



key_resp_2 Properties

Name key_resp_2

Start time (s) 0.0

Expected start (s)

Stop duration (s) 3

Expected duration (s)

Force end of Routine ☑

Allowed keys $ 'd','return' constant

Store last key

Store correct ☐

Discard previous ☑

sync RT with screen ☑

Screenshot VII. Pre-test. Keyboard response properties.

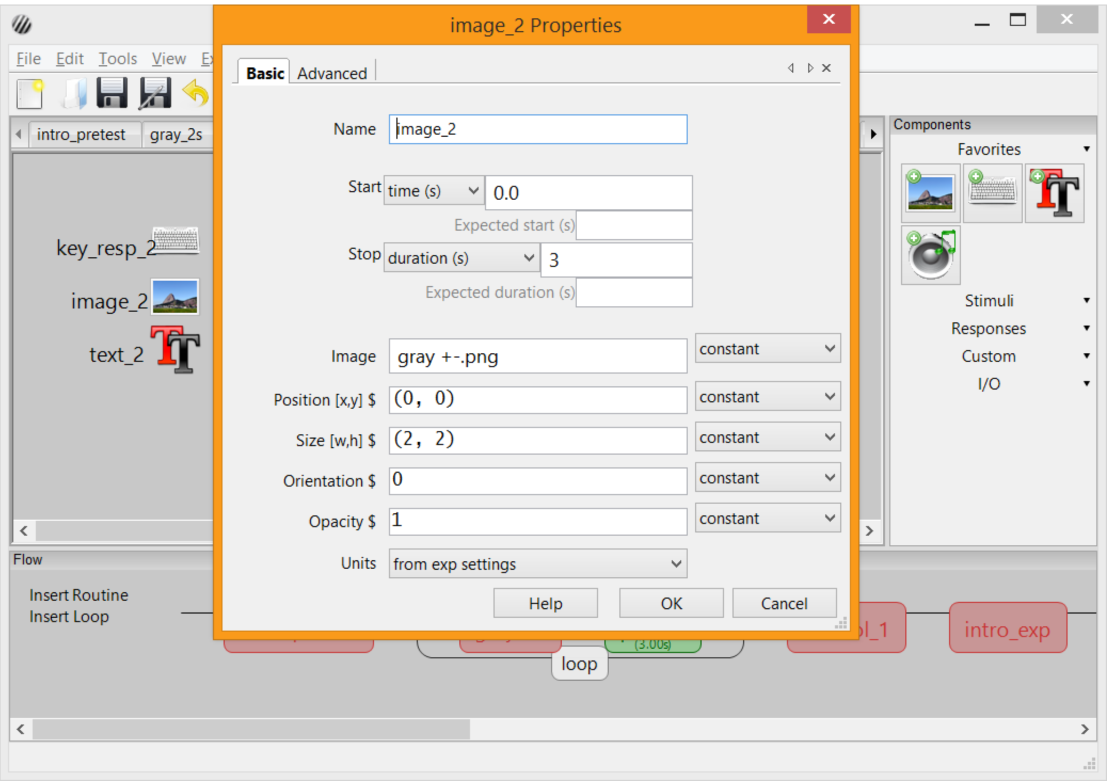


image_2 Properties

Name image_2

Start time (s) 0.0

Expected start (s)

Stop duration (s) 3

Expected duration (s)

Image gray +-.png constant

Position [x,y] $ (0, 0) constant

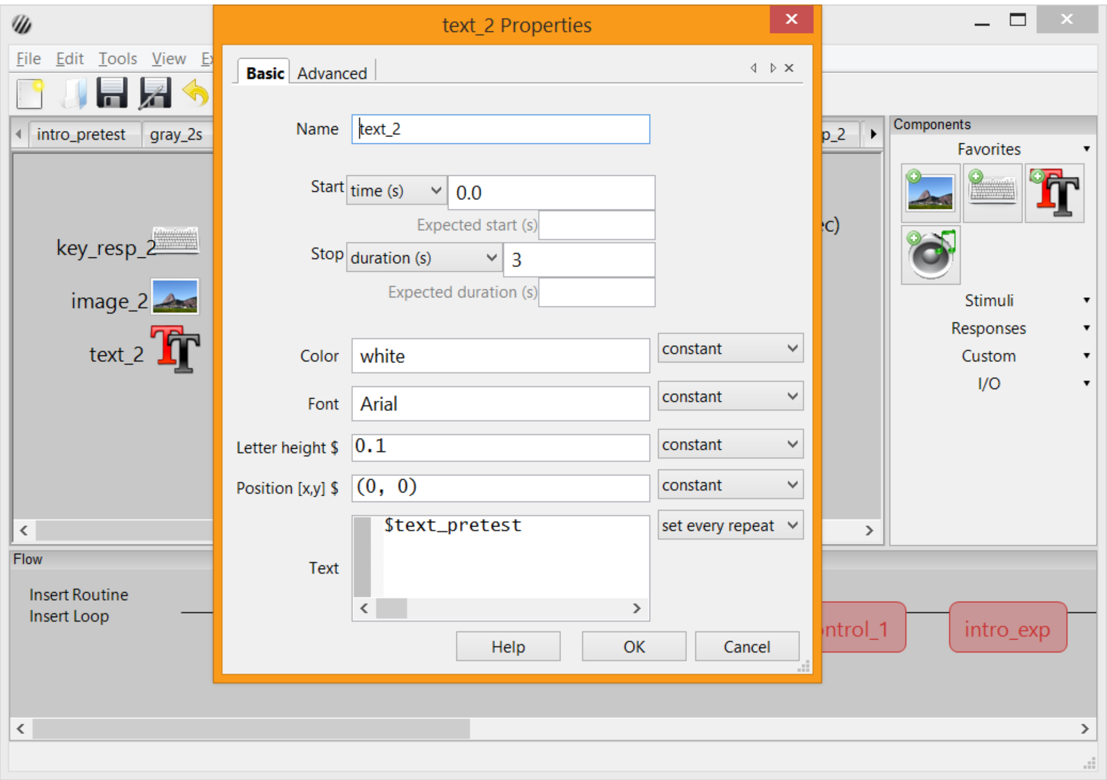
Size [w,h] $ (2, 2) constant

Orientation $ 0 constant

Opacity $ 1 constant

Units from exp settings

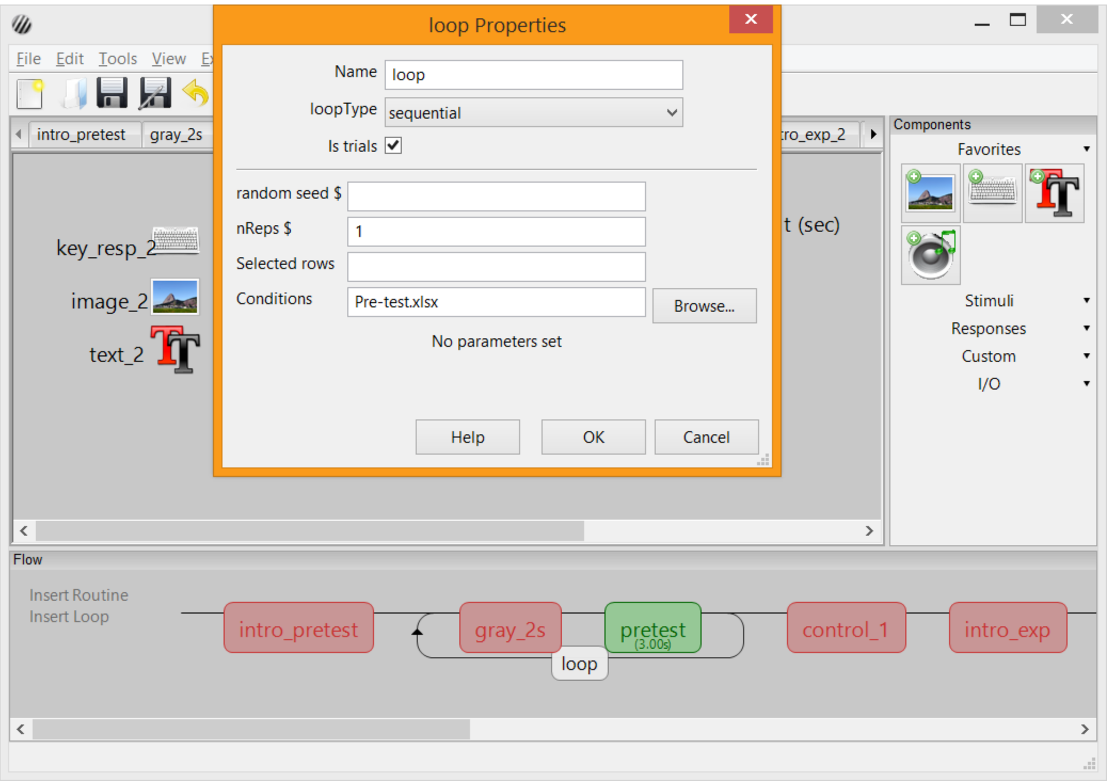
Screenshot VIII. Pre-test. Image properties.



text_2 Properties

Name: text_2
Start: time (s) 0.0
Expected start (s):
Stop: duration (s) 3
Expected duration (s):
Color: white — constant
Font: Arial — constant
Letter height $: 0.1 — constant
Position [x,y] $: (0, 0) — constant
Text: $text_pretest — set every repeat

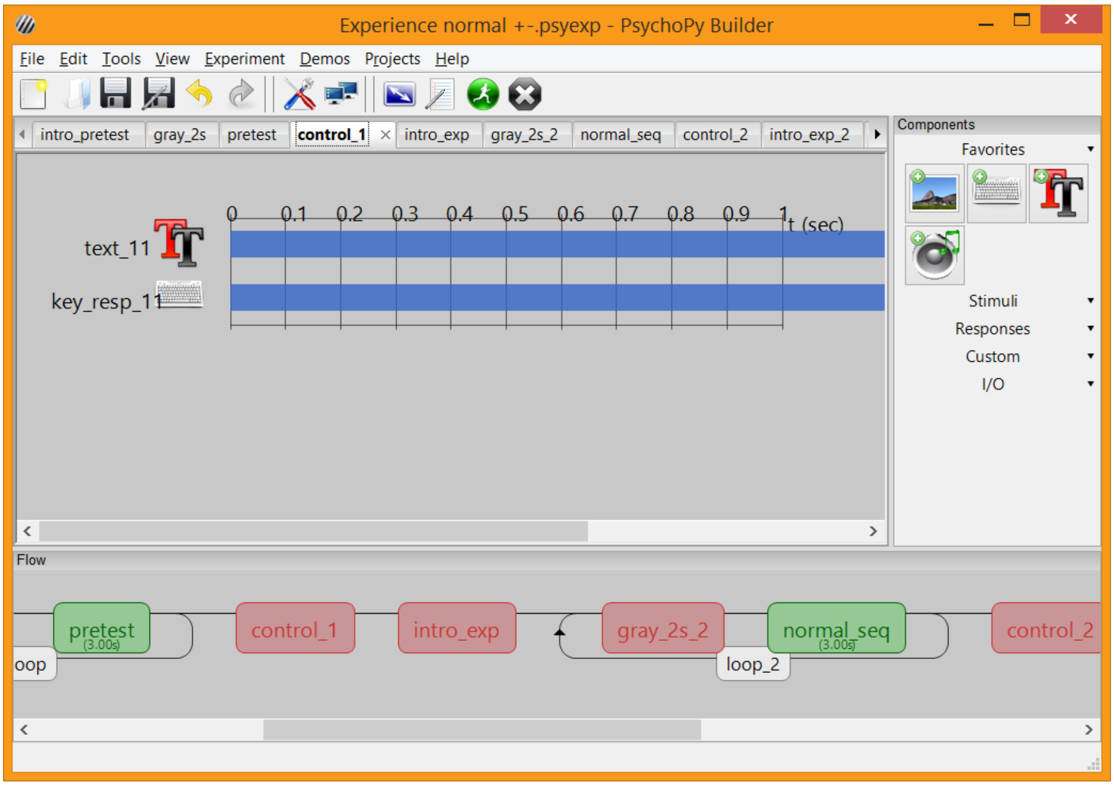
Screenshot IX. Pre-test. Text properties.



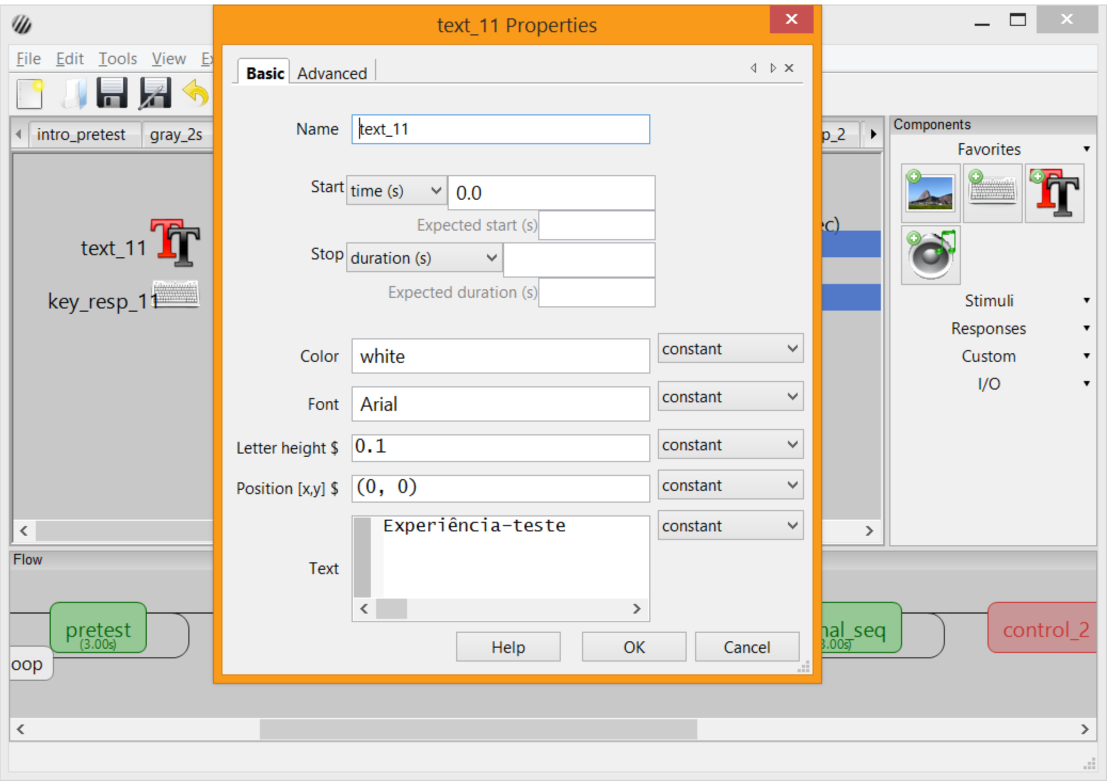
loop Properties

Name: loop
loopType: sequential
Is trials: ☑
random seed $:
nReps $: 1
Selected rows:
Conditions: Pre-test.xlsx
No parameters set

Screenshot X. Pre-test. Loop properties.



Screenshot XI. Control 1. Layout.



Name: text_11

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Color: white — constant

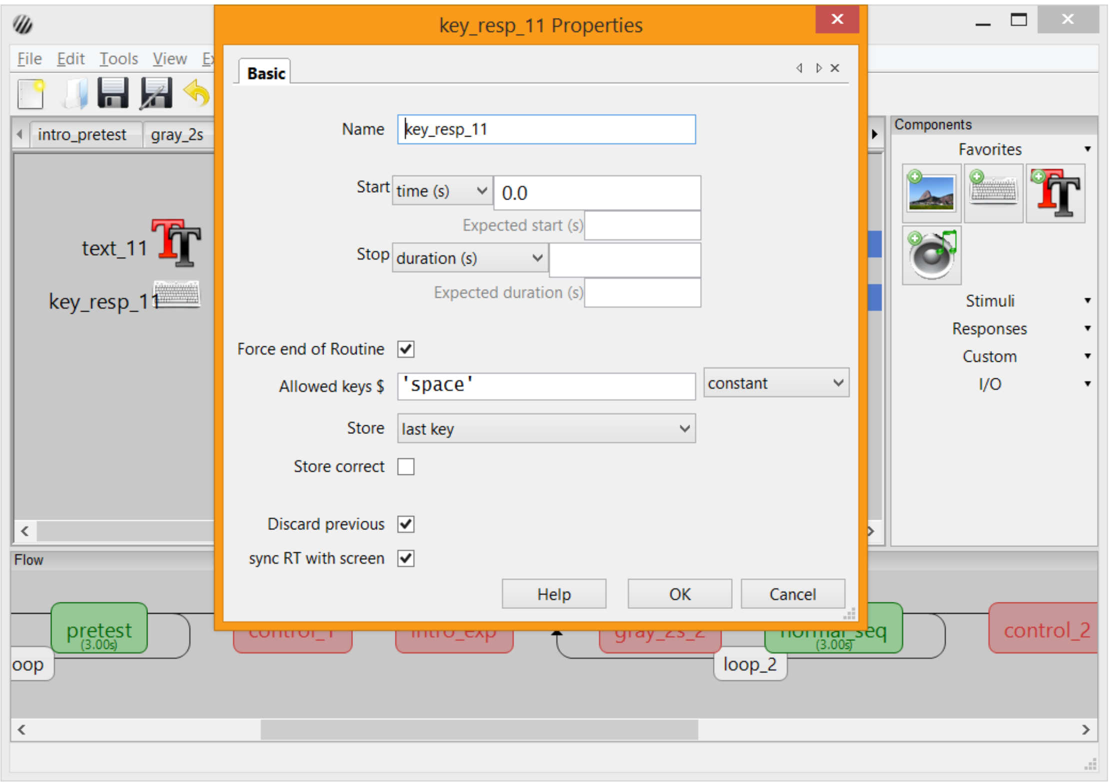
Font: Arial — constant

Letter height $: 0.1 — constant

Position [x,y] $: (0, 0) — constant

Text: Experiência-teste — constant

Screenshot XII. Control 1. Text properties.



Name key_resp_11

Start time (s) 0.0

Expected start (s)

Stop duration (s)

Expected duration (s)

Force end of Routine ☑

Allowed keys $ 'space' constant

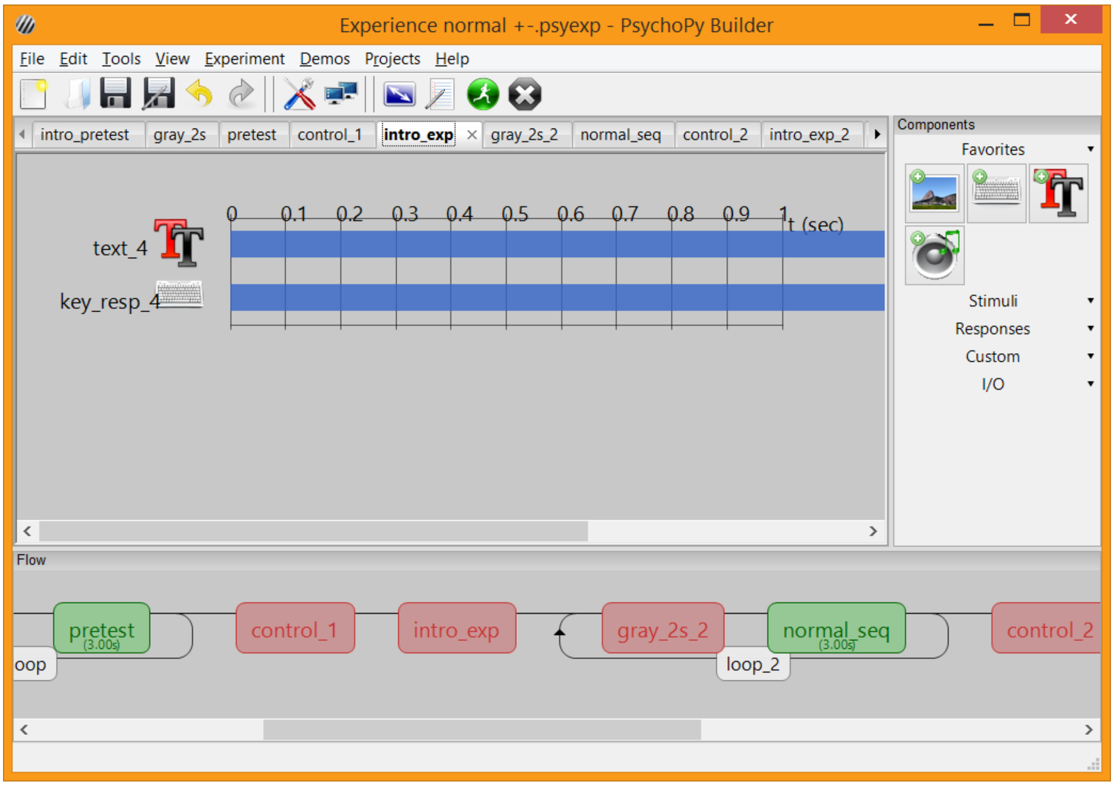
Store last key

Store correct ☐

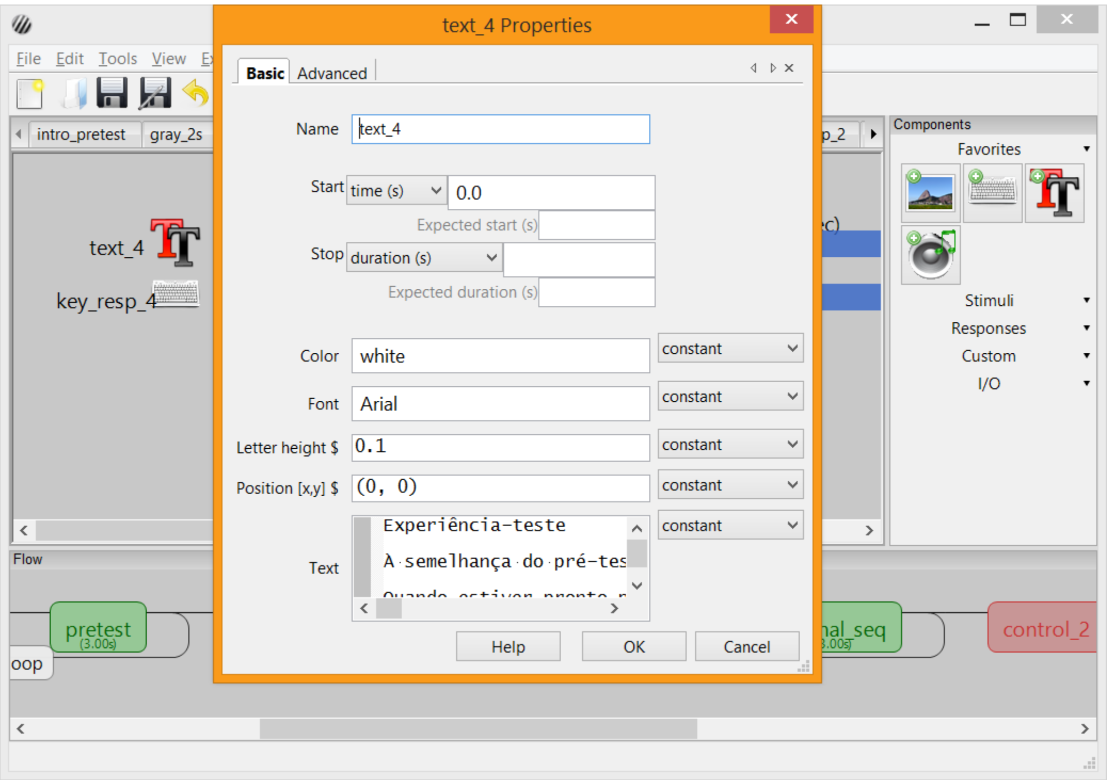
Discard previous ☑

sync RT with screen ☑

Screenshot XIII. Control 1. Keyboard response properties.



Screenshot XIV. Introduction to the experiment's 1st sequence (regular). Layout.



text_4 Properties

Name: text_4

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Color: white — constant

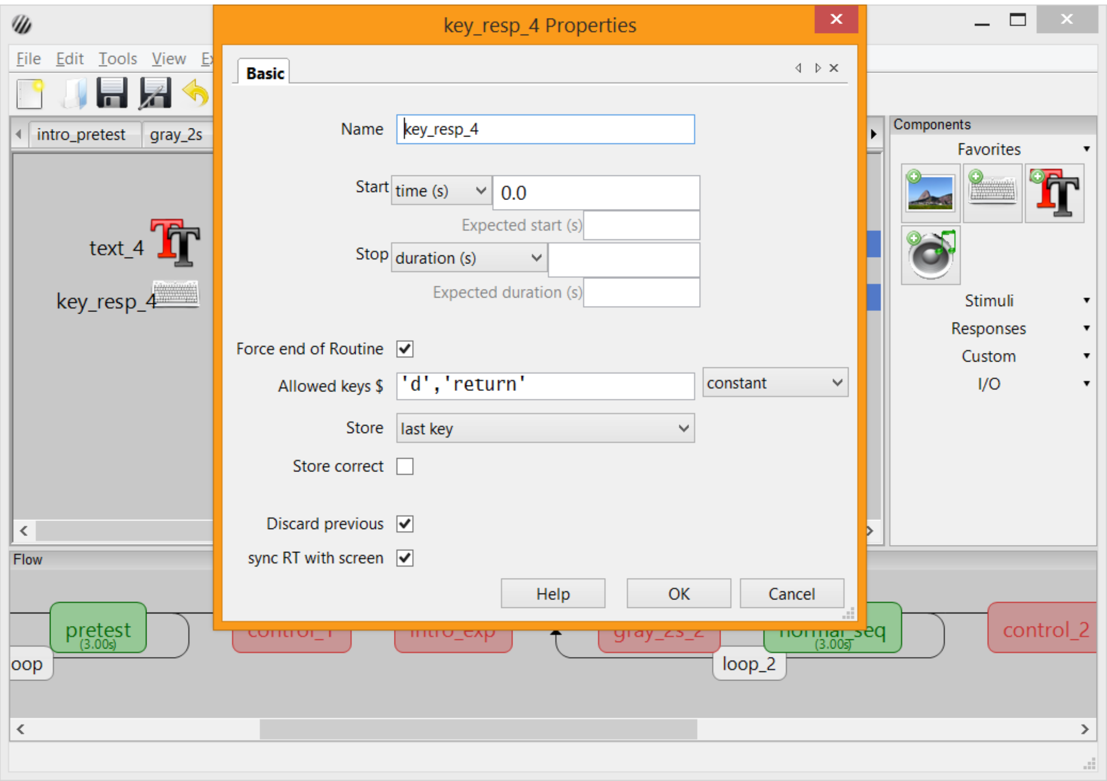
Font: Arial — constant

Letter height $: 0.1 — constant

Position [x,y] $: (0, 0) — constant

Text: Experiência-teste / À semelhança do pré-tes — constant

Screenshot XV. Introduction to the experiment’s 1st sequence (regular). Text properties.



key_resp_4 Properties

Name: key_resp_4

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Force end of Routine ☑

Allowed keys $: 'd','return' — constant

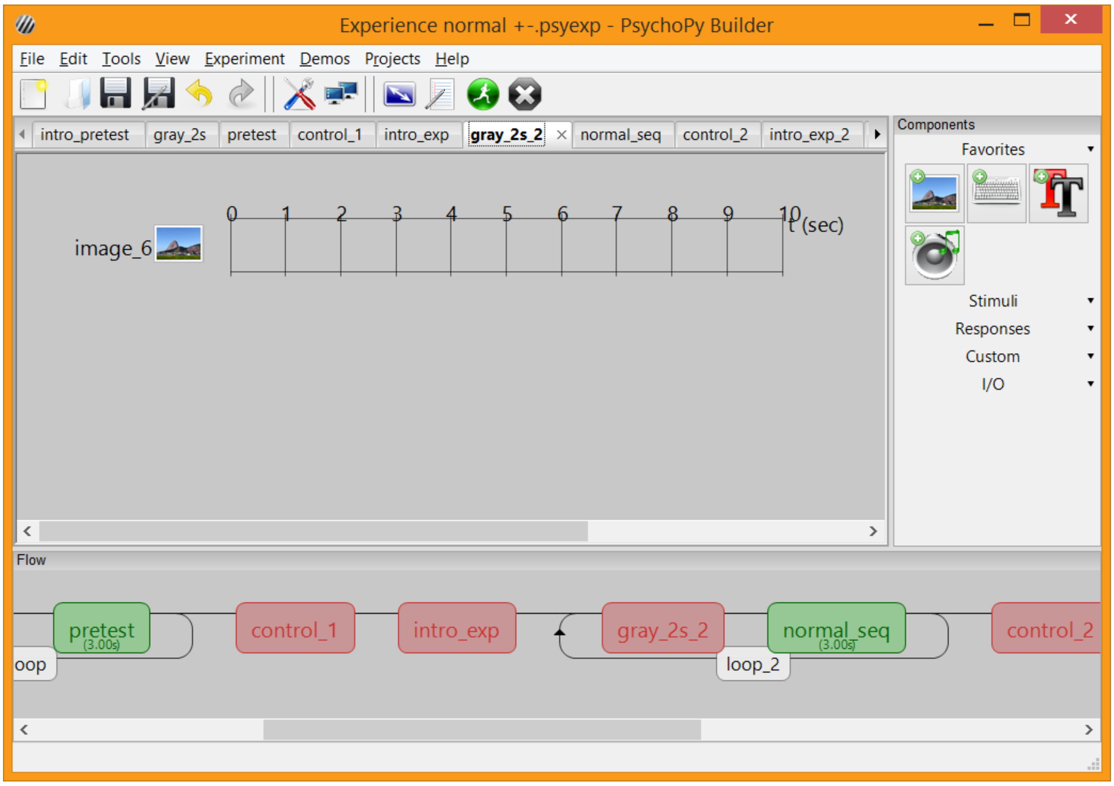
Store: last key

Store correct ☐

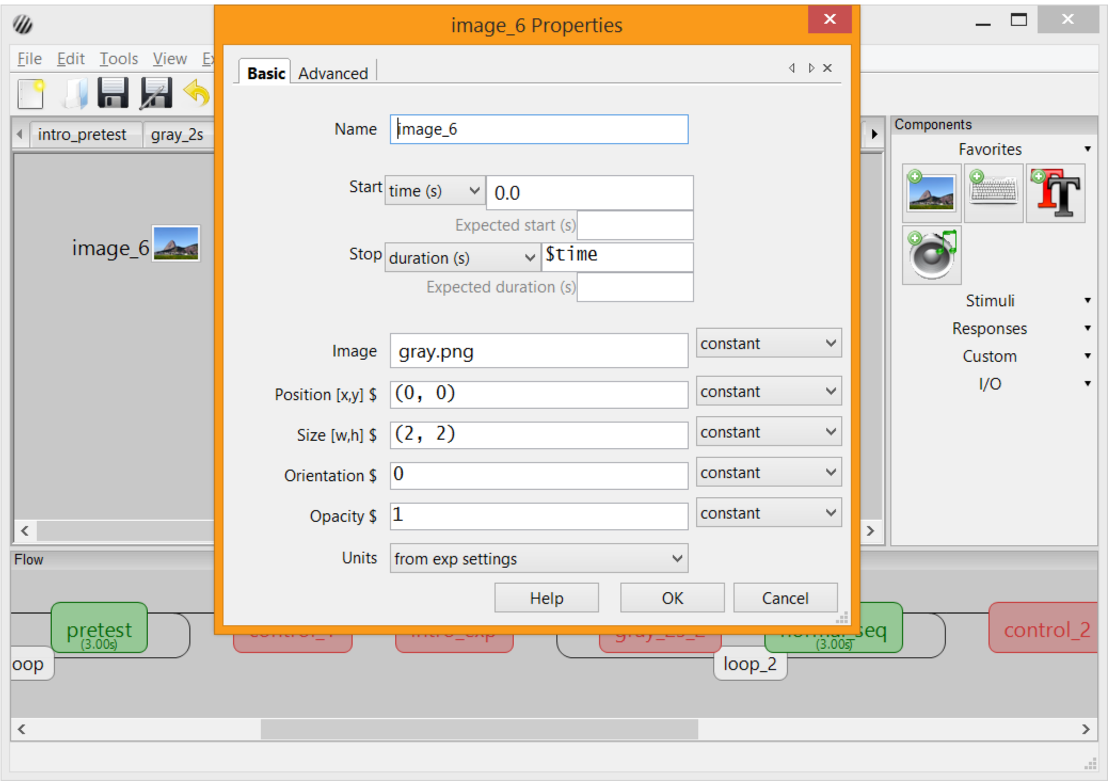
Discard previous ☑

sync RT with screen ☑

Screenshot XVI. Introduction to the experiment’s 1st sequence (regular). Keyboard response properties.



Screenshot XVII. Experiment's 1st sequence (regular). Transitory Image. Layout.



Name: image_6

Start: time (s) 0.0

Expected start (s)

Stop: duration (s) $time

Expected duration (s)

Image: gray.png constant

Position [x,y] $: (0, 0) constant

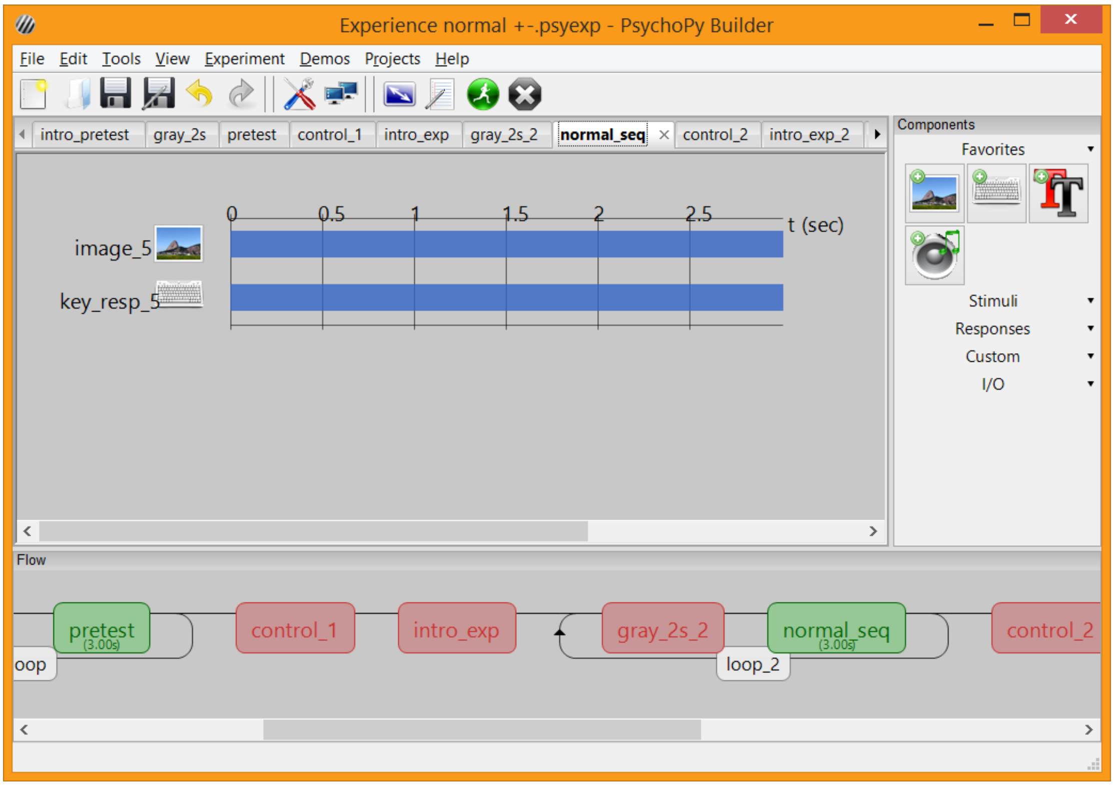
Size [w,h] $: (2, 2) constant

Orientation $: 0 constant

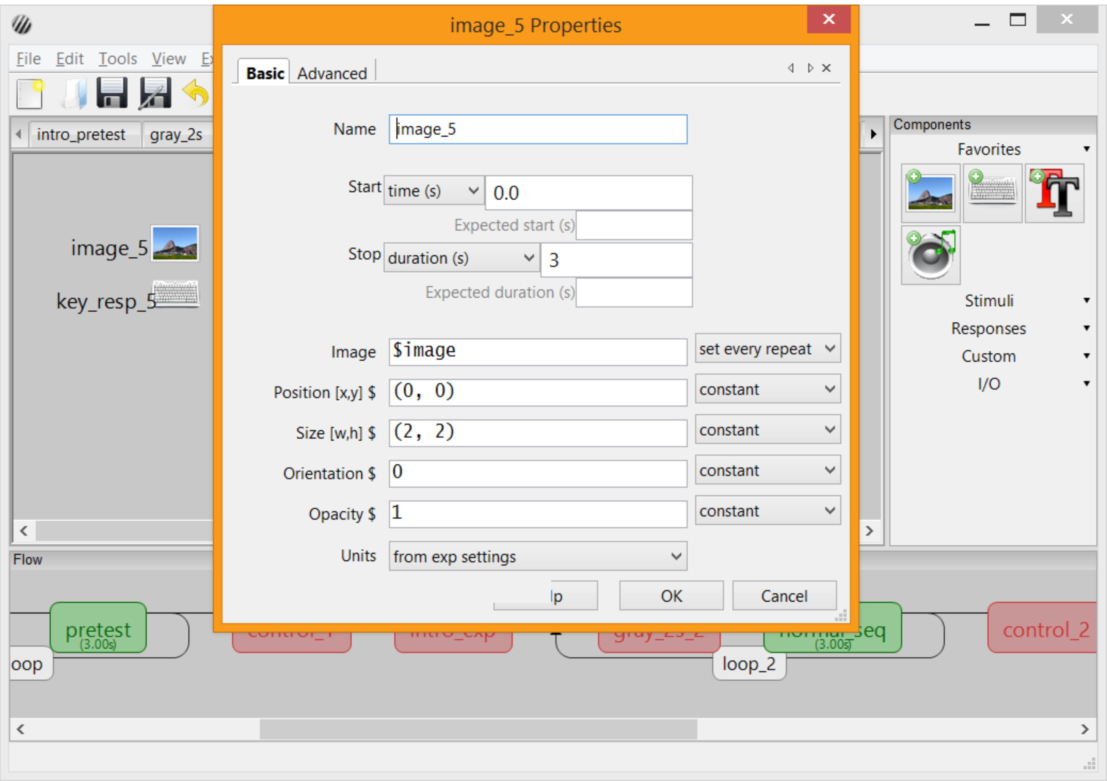
Opacity $: 1 constant

Units: from exp settings

Screenshot XVIII. Experiment's 1st sequence (regular). Transitory image. Image properties.



Screenshot IXX. Experiment’s 1st sequence (regular). Layout.



Name: image_5

Start: time (s) 0.0

Expected start (s):

Stop: duration (s) 3

Expected duration (s):

Image: $image — set every repeat

Position [x,y] $: (0, 0) — constant

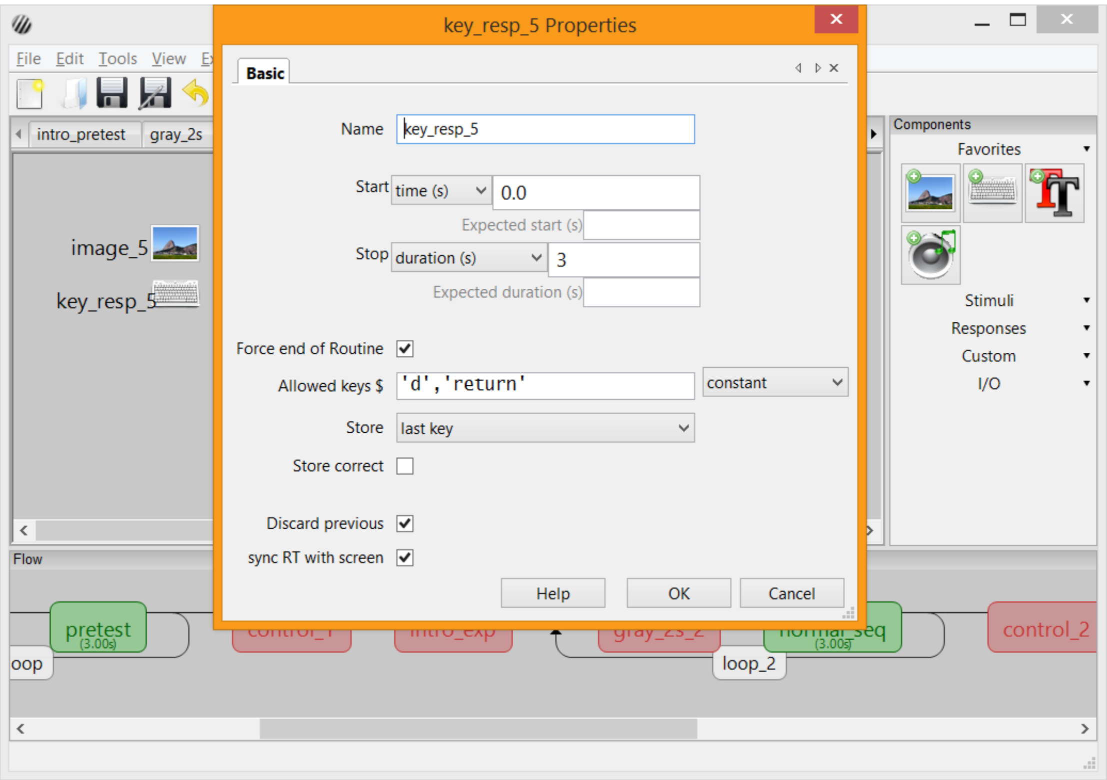
Size [w,h] $: (2, 2) — constant

Orientation $: 0 — constant

Opacity $: 1 — constant

Units: from exp settings

Screenshot XX. Experiment’s 1st sequence (regular). Image properties.


key_resp_5 Properties

Basic

Name: key_resp_5

Start: time (s) 0.0

Expected start (s):

Stop: duration (s) 3

Expected duration (s):

Force end of Routine ☑

Allowed keys $: 'd','return' (constant)

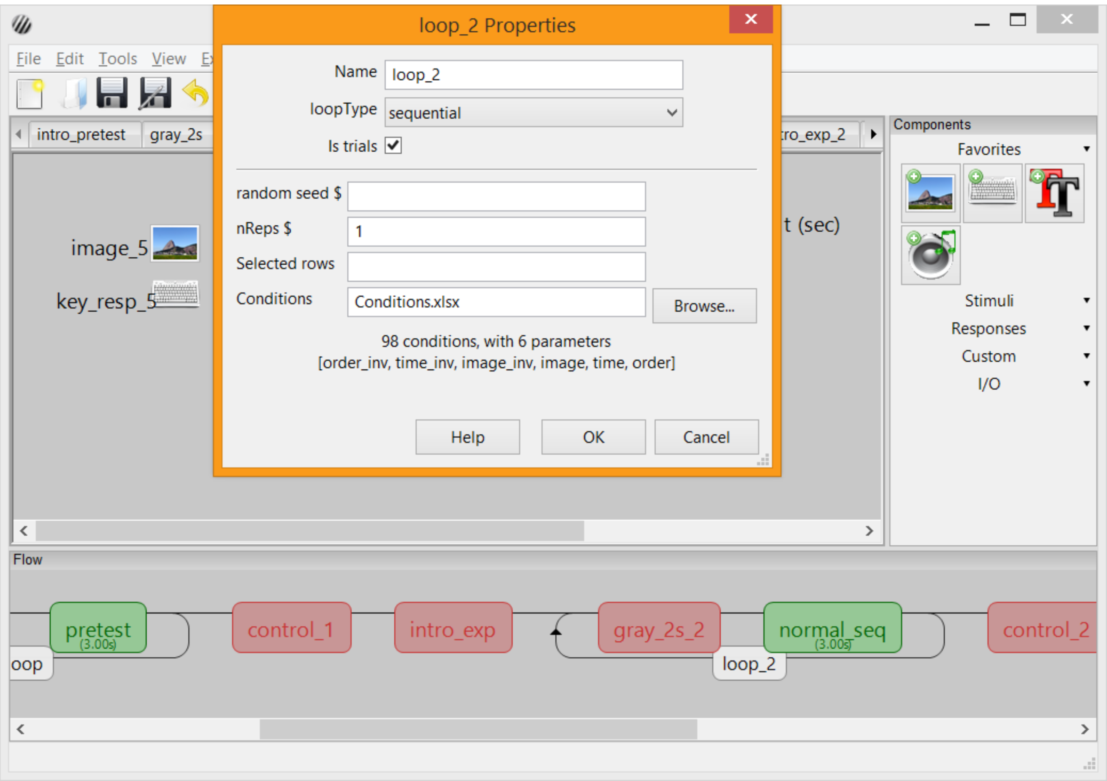
Store: last key

Store correct ☐

Discard previous ☑

sync RT with screen ☑

Screenshot XXI. Experiment’s 1st sequence (regular). Keyboard response properties.


loop_2 Properties

Name: loop_2

loopType: sequential

Is trials ☑

random seed $:

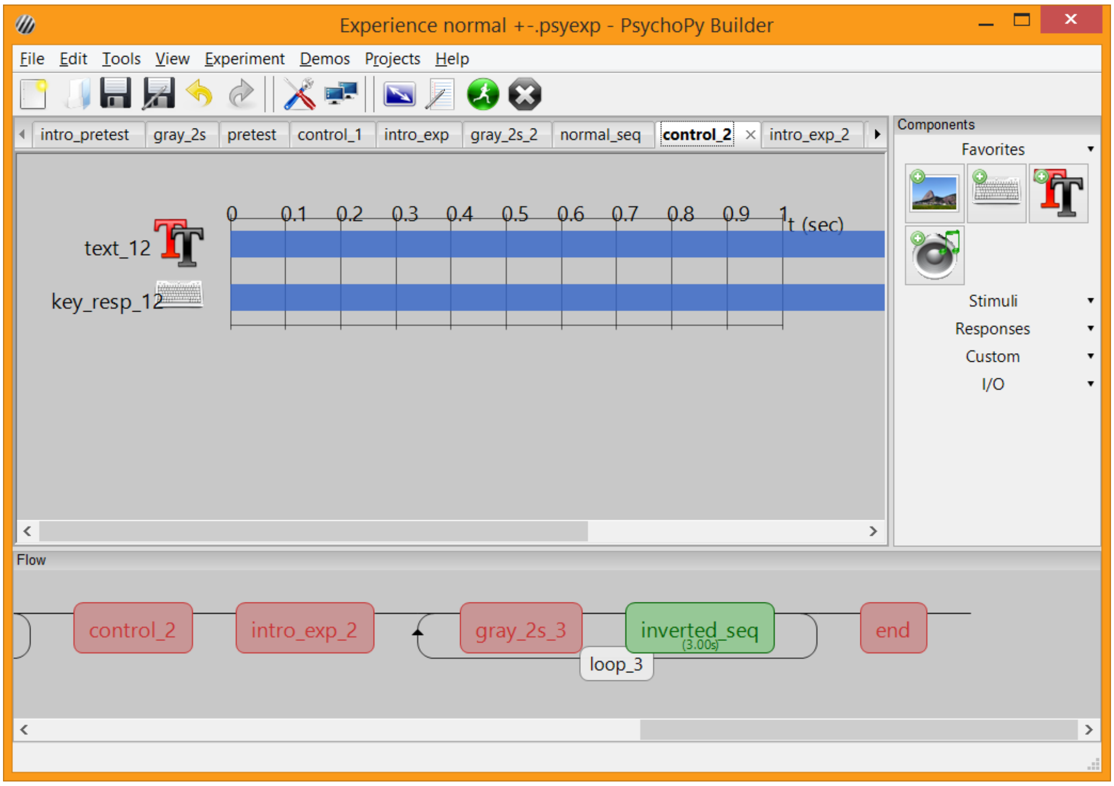
nReps $: 1

Selected rows:

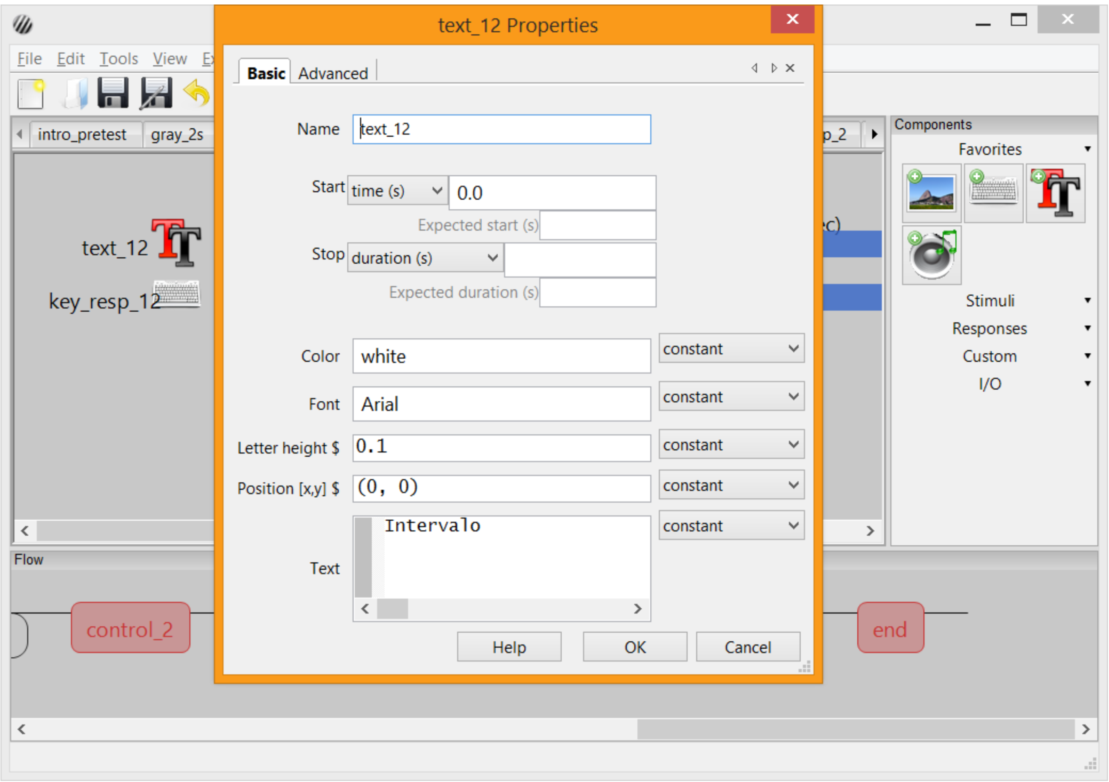
Conditions: Conditions.xlsx

98 conditions, with 6 parameters
[order_inv, time_inv, image_inv, image, time, order]

Screenshot XXII. Experiment’s 1st sequence (regular). Loop properties.



Screenshot XXIII. Control 2. Layout.



Name: text_12

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Color: white, constant

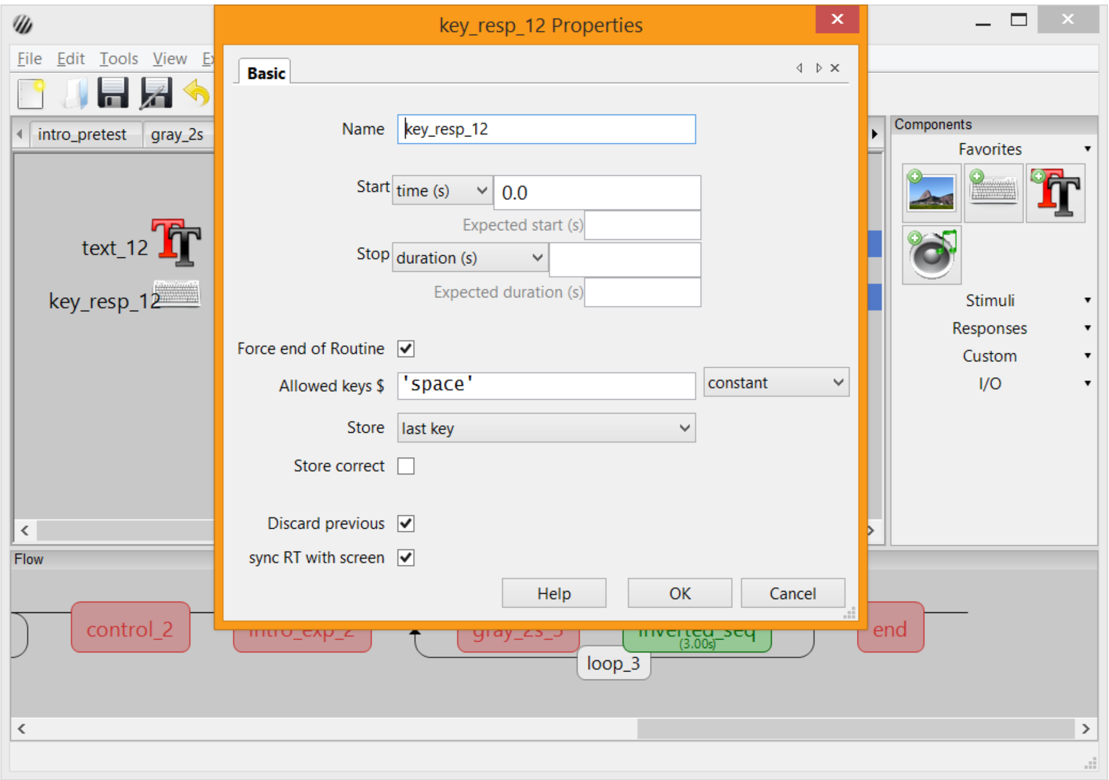
Font: Arial, constant

Letter height $: 0.1, constant

Position [x,y] $: (0, 0), constant

Text: Intervalo, constant

Screenshot XXIV. Control 2. Text properties.



key_resp_12 Properties

Basic

Name: key_resp_12

Start: time (s) 0.0

Expected start (s):

Stop: duration (s)

Expected duration (s):

Force end of Routine ☑

Allowed keys $ 'space' constant

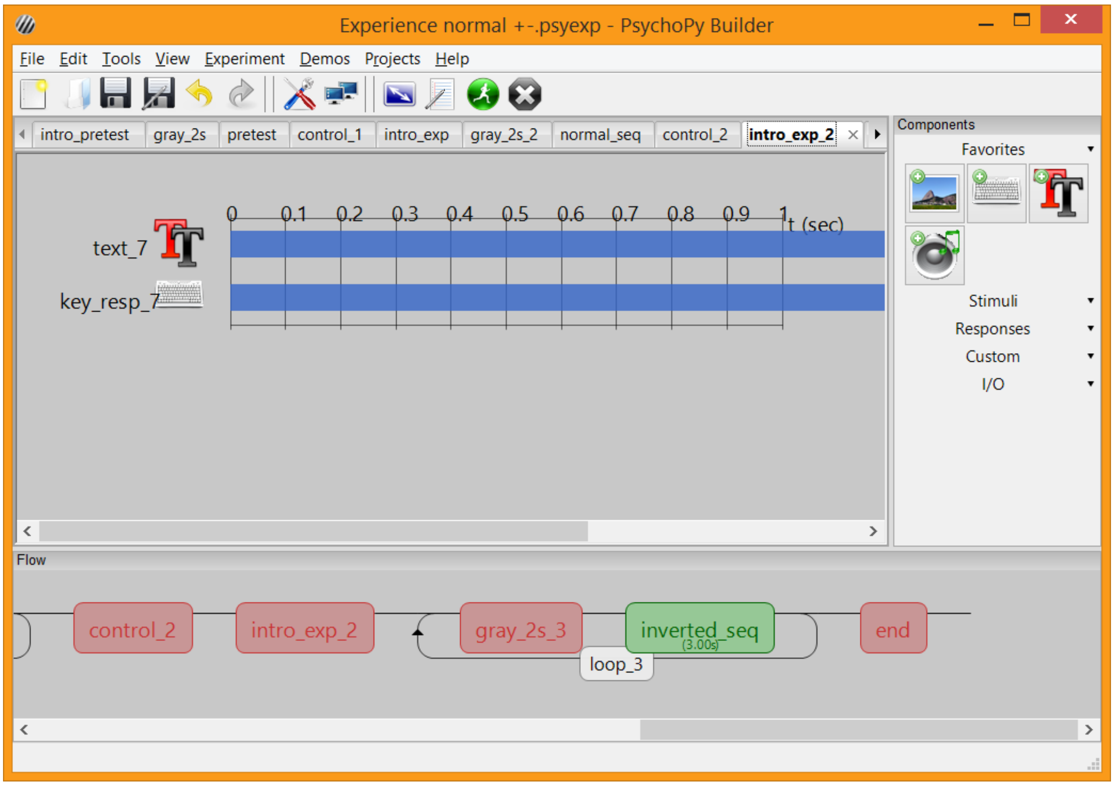
Store: last key

Store correct ☐

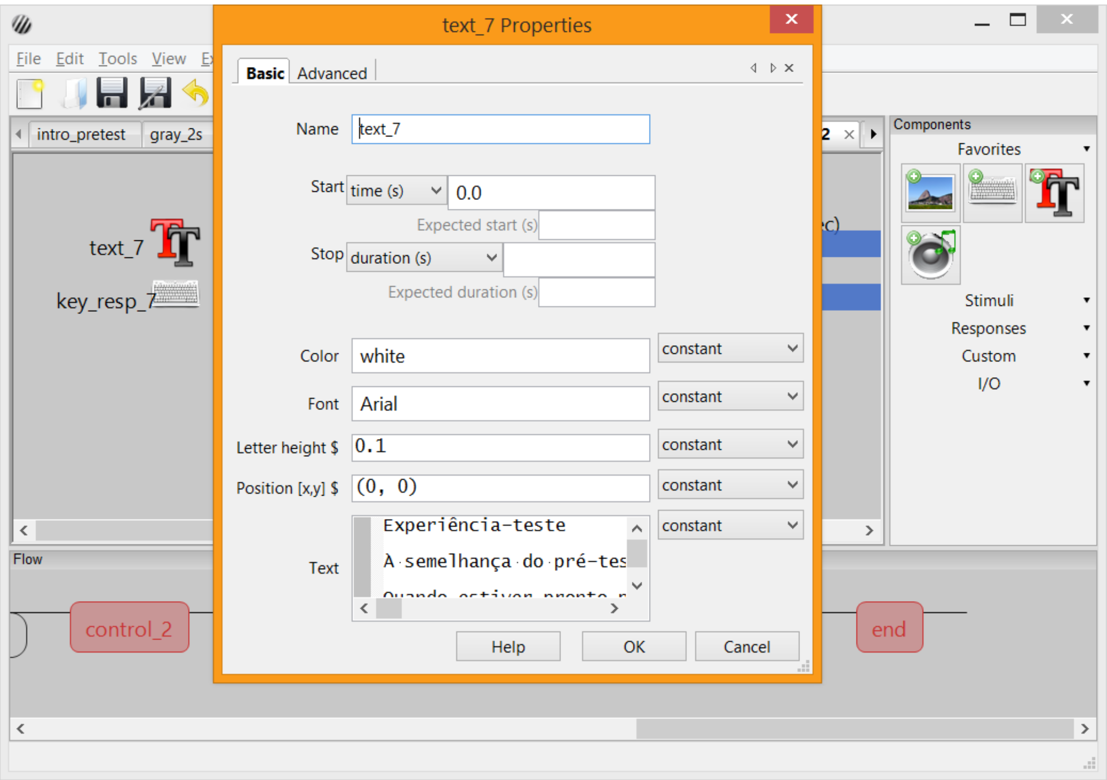
Discard previous ☑

sync RT with screen ☑

Screenshot XXV. Control 2. Keyboard response properties.



Screenshot XVI. Introduction to the experiment’s 2st sequence (inverted). Layout.



text_7 Properties

Name: text_7

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Color: white — constant

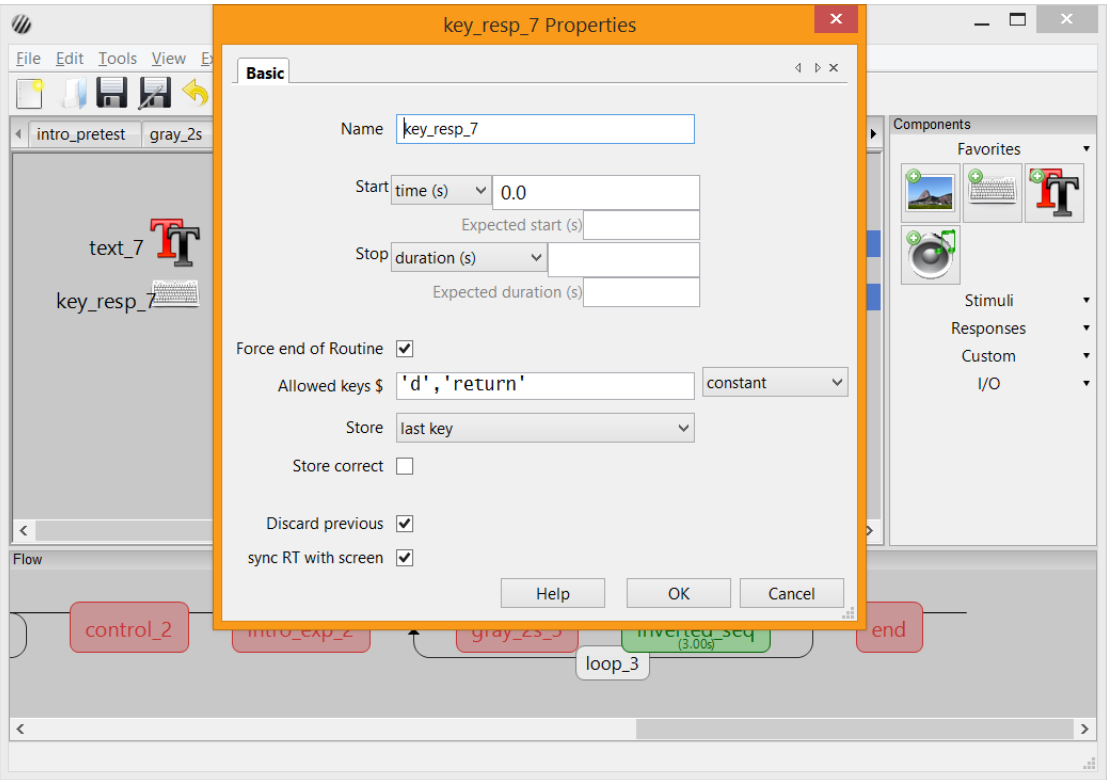
Font: Arial — constant

Letter height $: 0.1 — constant

Position [x,y] $: (0, 0) — constant

Text: Experiência-teste
A semelhança do pré-tes — constant

Screenshot XVII. Introduction to the experiment's 2st sequence (inverted). Text properties.



key_resp_7 Properties

Name: key_resp_7

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Force end of Routine ☑

Allowed keys $: 'd','return' — constant

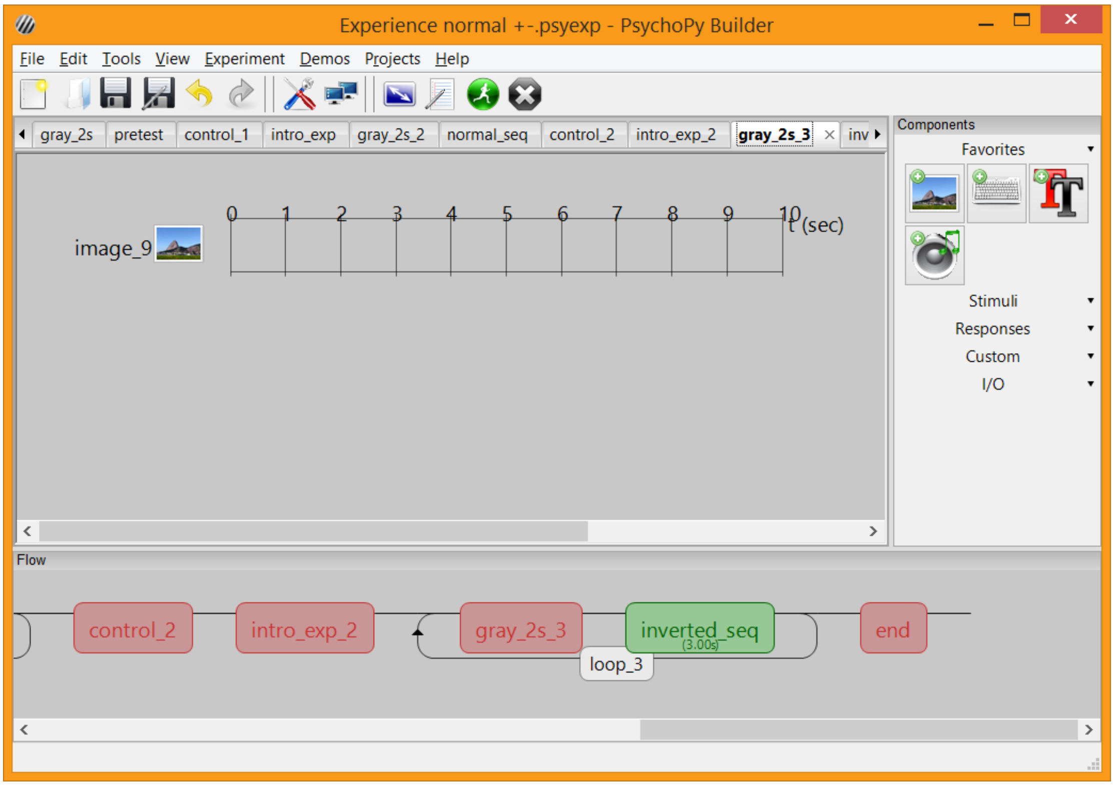
Store: last key

Store correct ☐

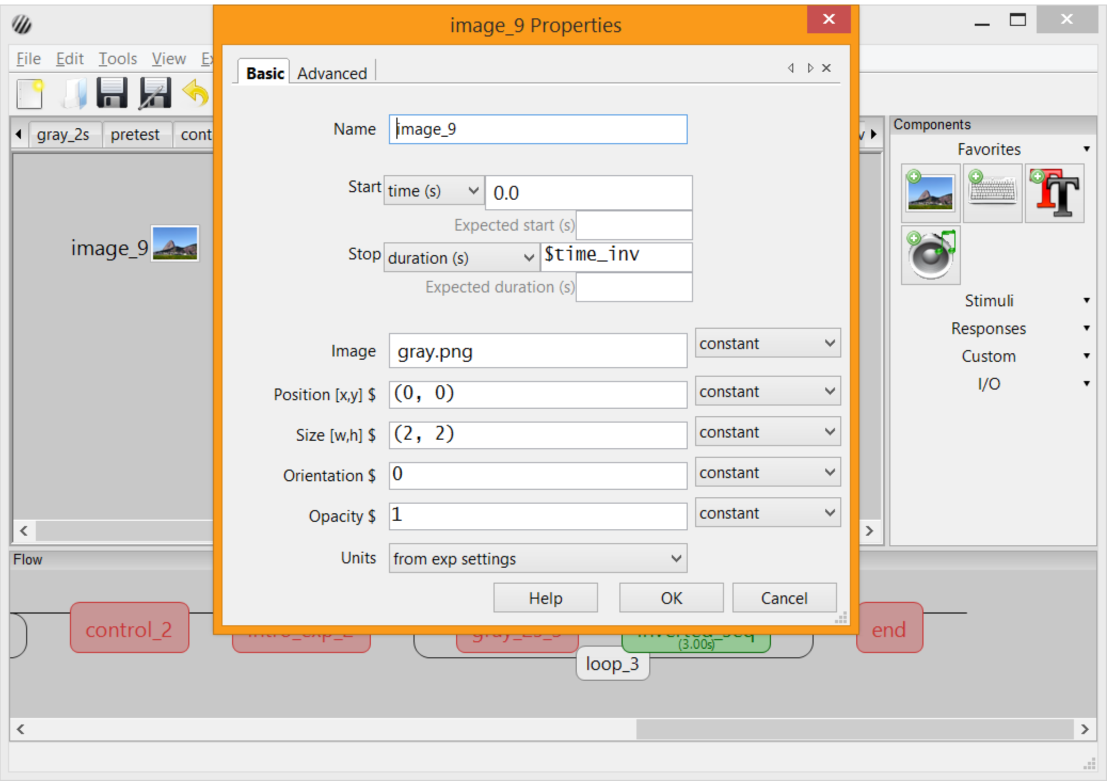
Discard previous ☑

sync RT with screen ☑

Screenshot XVIII. Introduction to the experiment's 2st sequence (inverted). Keyboard response properties.



Screenshot IXXX. Experiment's 2st sequence (inverted). Transitory image. Image properties.



Name: image_9

Start: time (s) 0.0

Expected start (s)

Stop: duration (s) $time_inv

Expected duration (s)

Image: gray.png constant

Position [x,y] $: (0, 0) constant

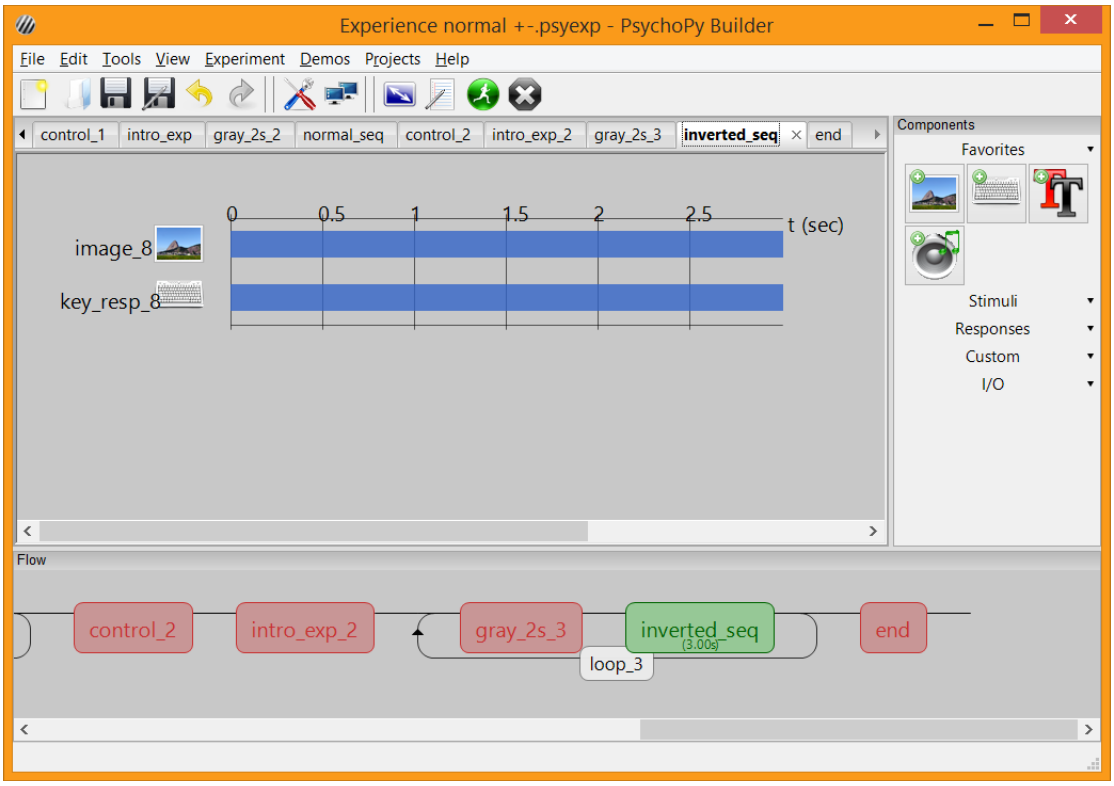
Size [w,h] $: (2, 2) constant

Orientation $: 0 constant

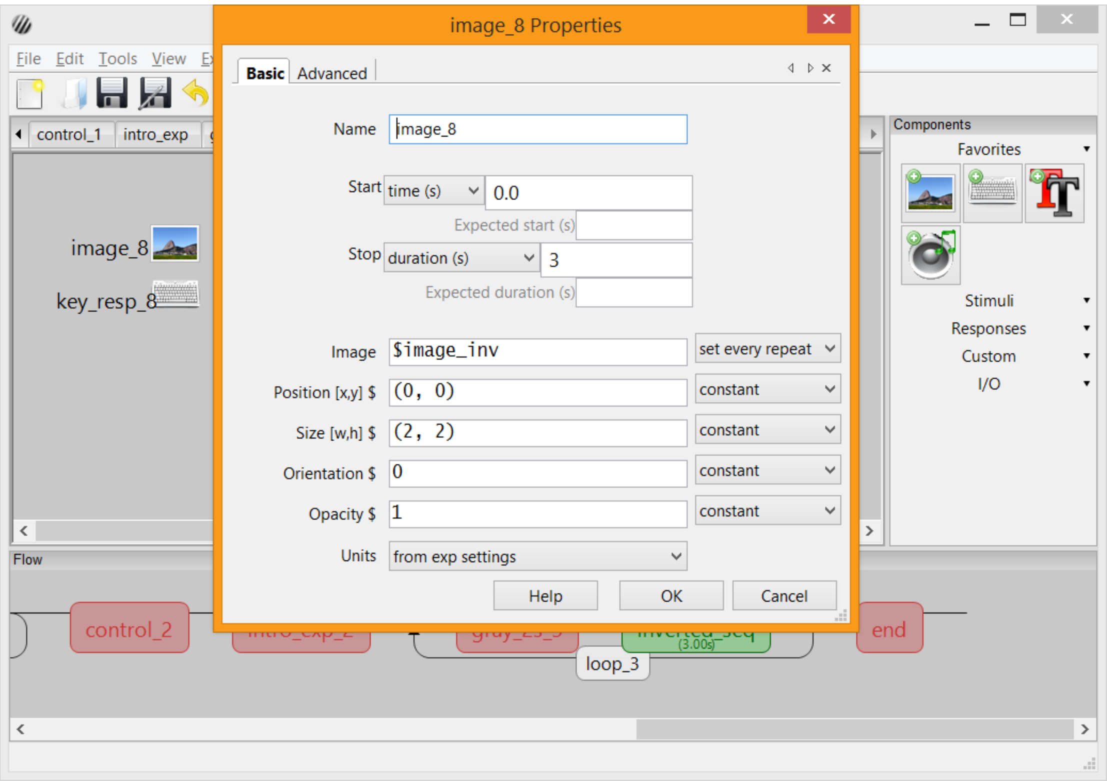
Opacity $: 1 constant

Units: from exp settings

Screenshot XXX. Experiment's 2st sequence (inverted). Transitory image. Text properties.



Screenshot XXXI. Experiment's 2st sequence (inverted). Layout.



Name: image_8

Start: time (s) 0.0

Expected start (s)

Stop: duration (s) 3

Expected duration (s)

Image: $image_inv — set every repeat

Position [x,y] $: (0, 0) — constant

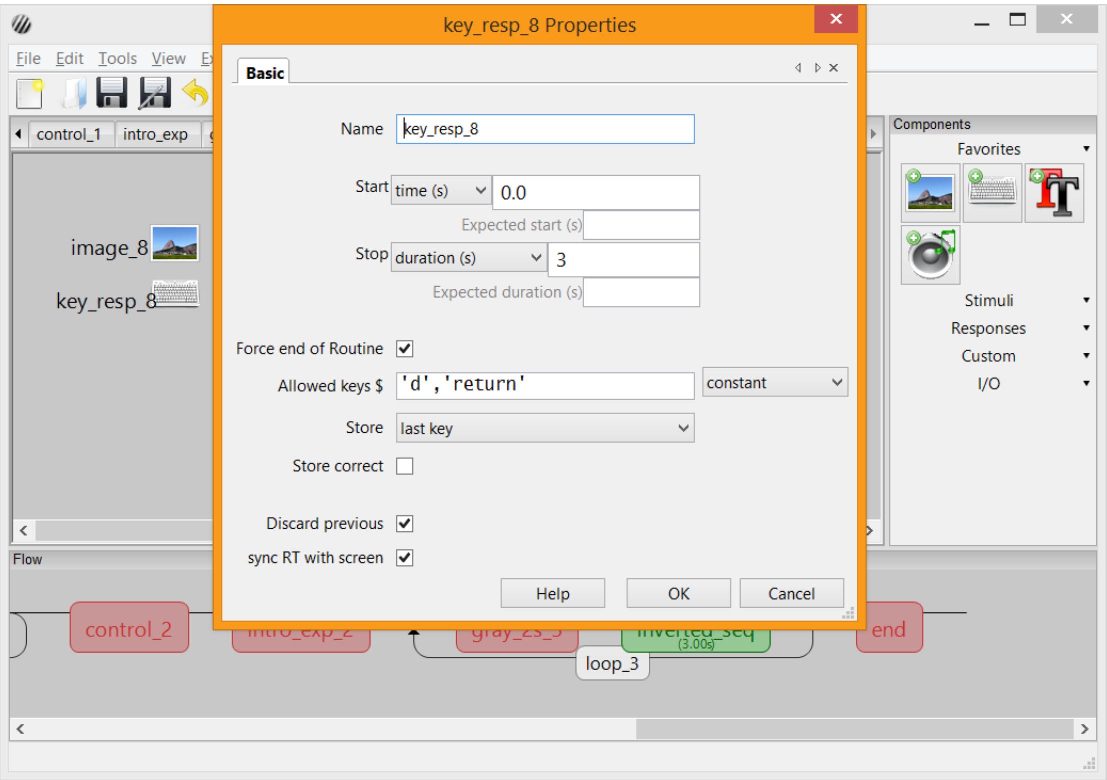
Size [w,h] $: (2, 2) — constant

Orientation $: 0 — constant

Opacity $: 1 — constant

Units: from exp settings

Screenshot XXXII. Experiment's 2st sequence (inverted). Image properties.



Name: key_resp_8

Start: time (s) 0.0

Expected start (s):

Stop: duration (s) 3

Expected duration (s):

Force end of Routine ☑

Allowed keys $ 'd','return' constant

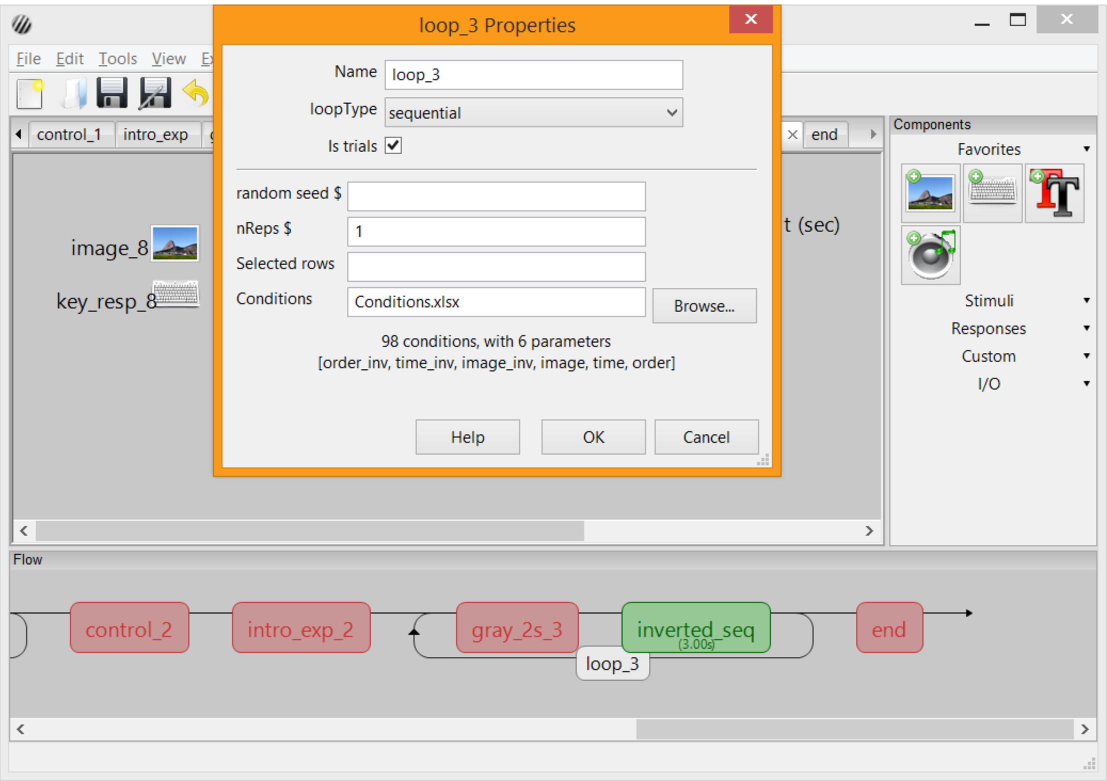
Store: last key

Store correct ☐

Discard previous ☑

sync RT with screen ☑

Screenshot XXXIII. Experiment’s 2st sequence (inverted). Keyboard response properties.



Name: loop_3

loopType: sequential

Is trials ☑

random seed $:

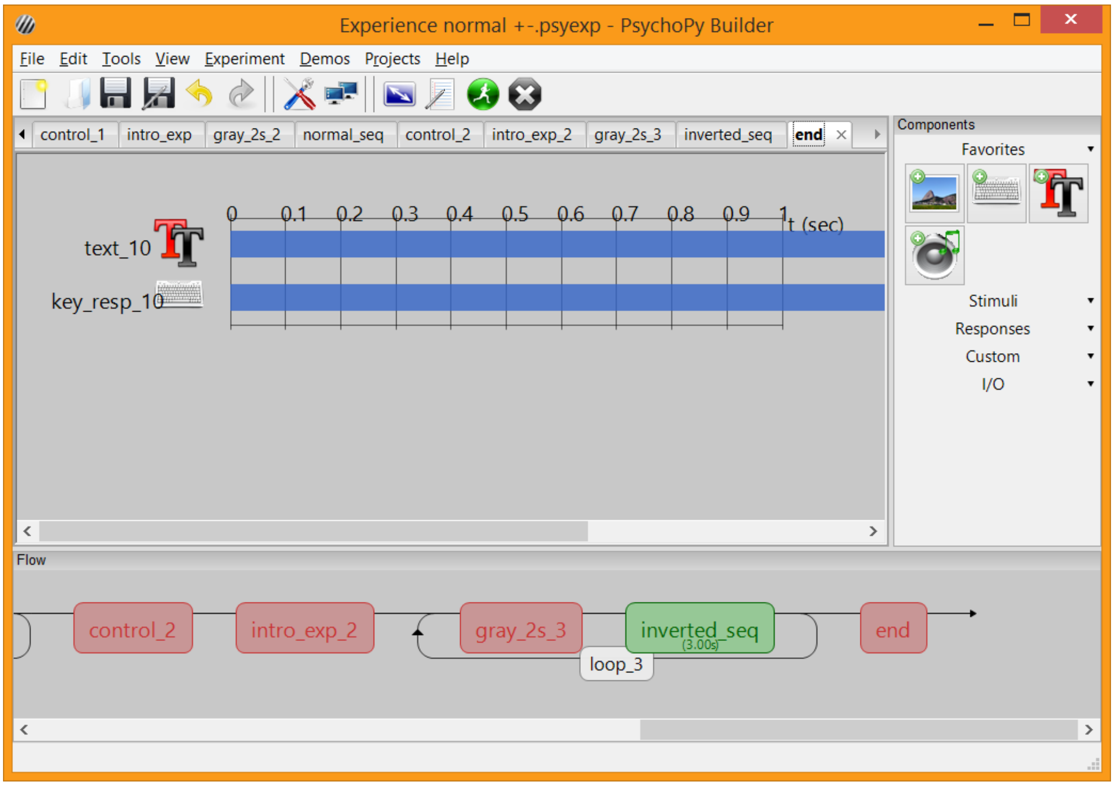
nReps $: 1

Selected rows:

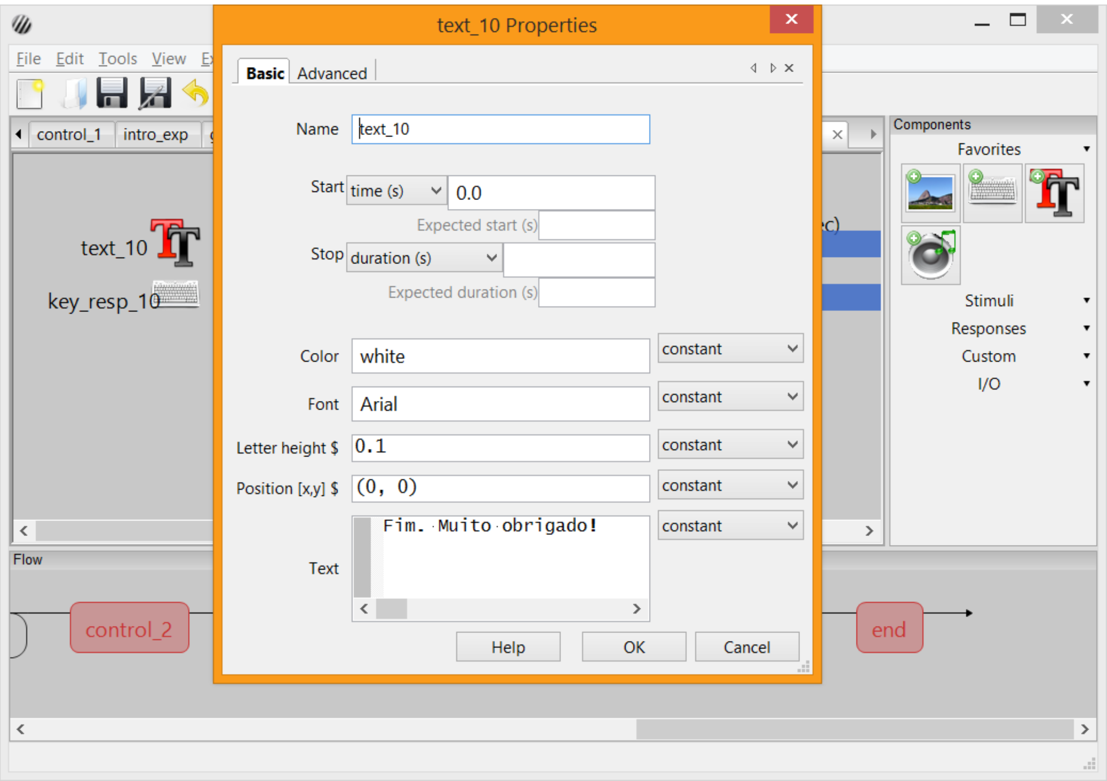
Conditions: Conditions.xlsx

98 conditions, with 6 parameters
[order_inv, time_inv, image_inv, image, time, order]

Screenshot XXXIV. Experiment’s 2st sequence (inverted). Loop properties.



Screenshot XXXV. End. Layout.



text_10 Properties

Name: text_10

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Color: white — constant

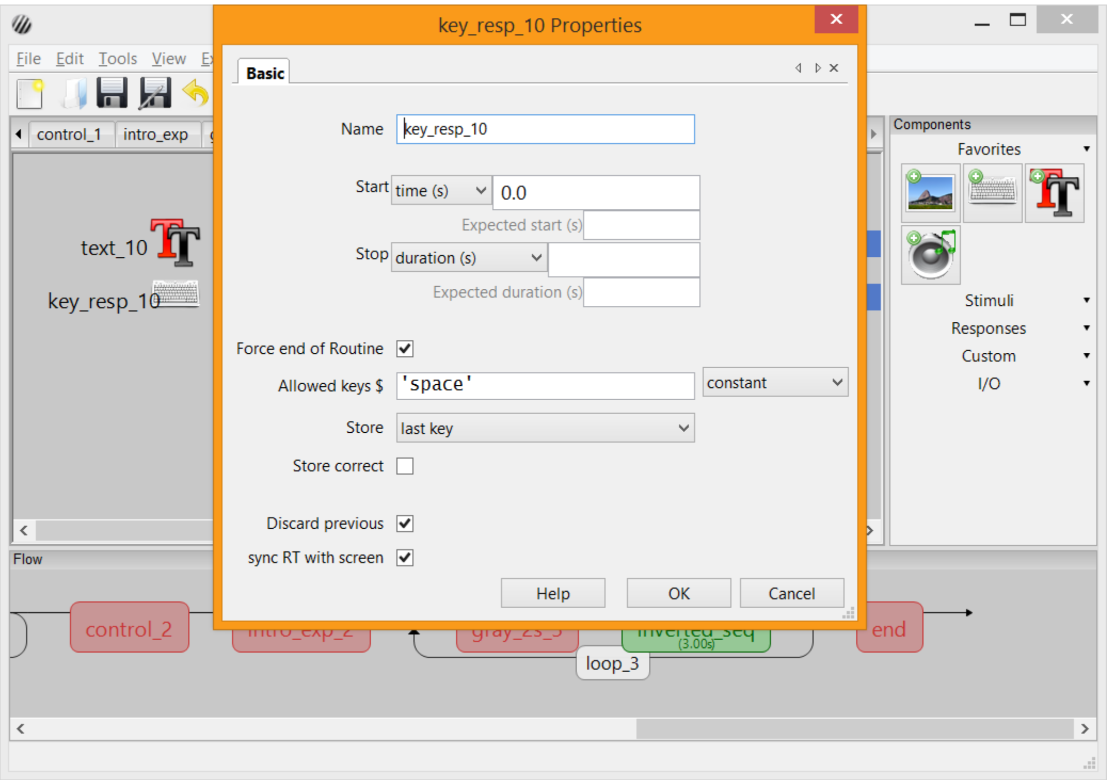
Font: Arial — constant

Letter height $: 0.1 — constant

Position [x,y] $: (0, 0) — constant

Text: Fim. Muito obrigado! — constant

Screenshot XXXVI. End. Text properties.



key_resp_10 Properties

Name: key_resp_10

Start: time (s) 0.0

Expected start (s)

Stop: duration (s)

Expected duration (s)

Force end of Routine ☑

Allowed keys $ 'space' constant

Store: last key

Store correct ☐

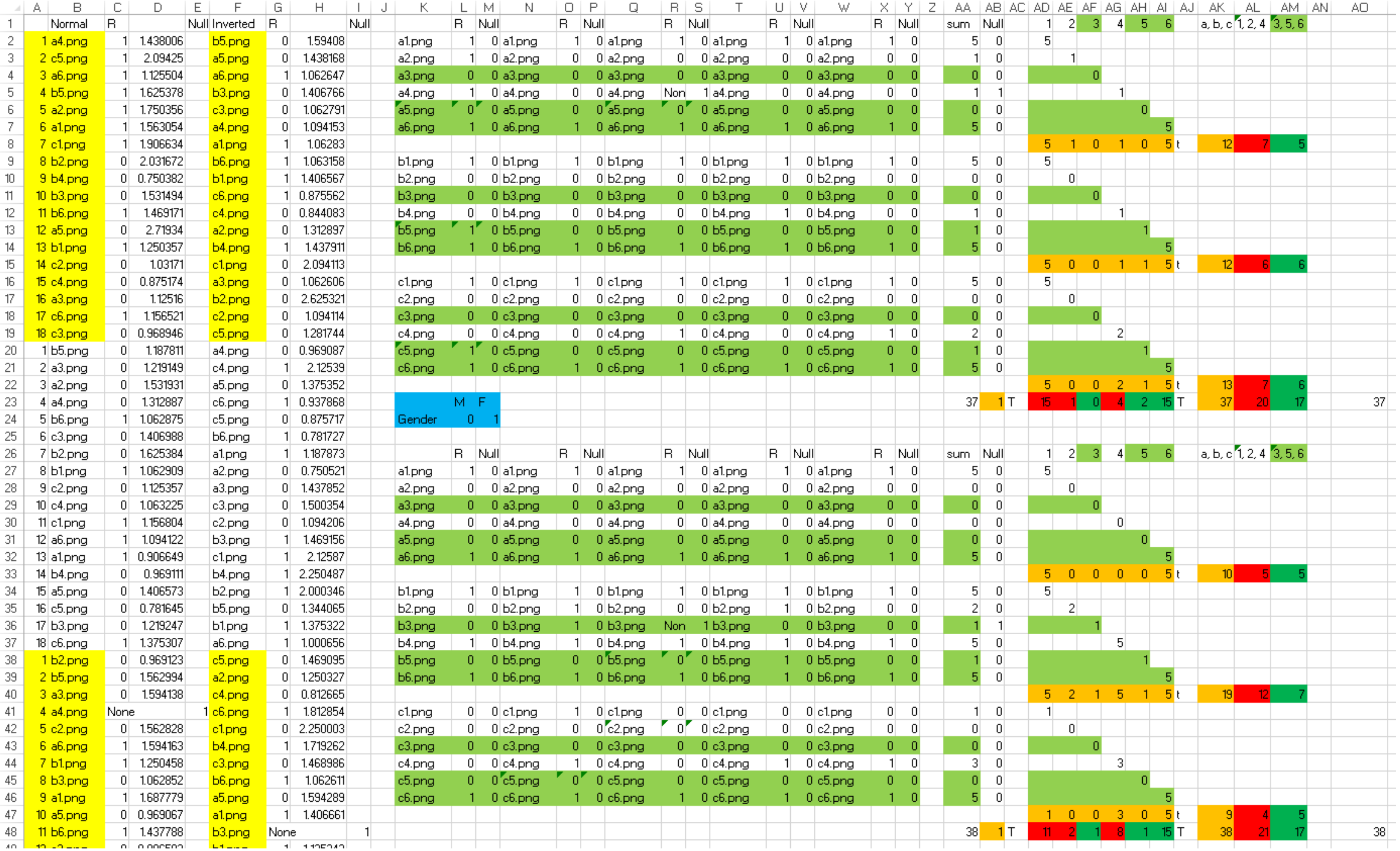
Discard previous ☑

sync RT with screen ☑

Screenshot XXXVII. End. Keyboard response properties.

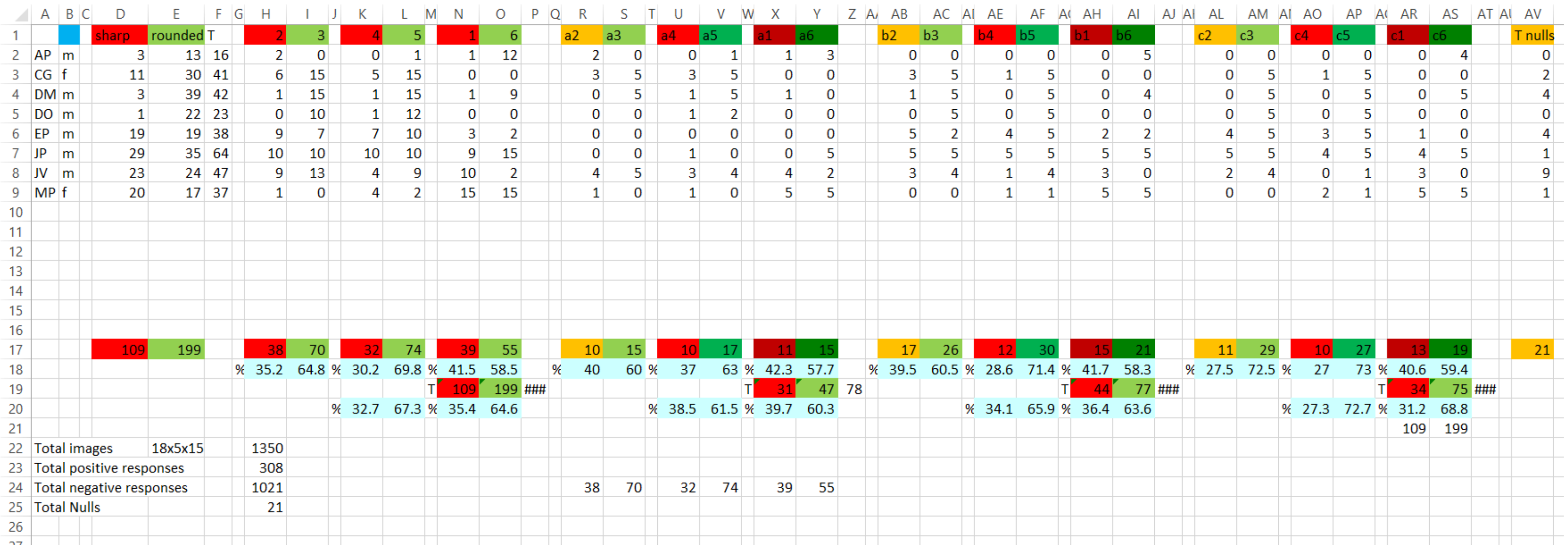
Appendix E

Experimental study’s results analyses sample



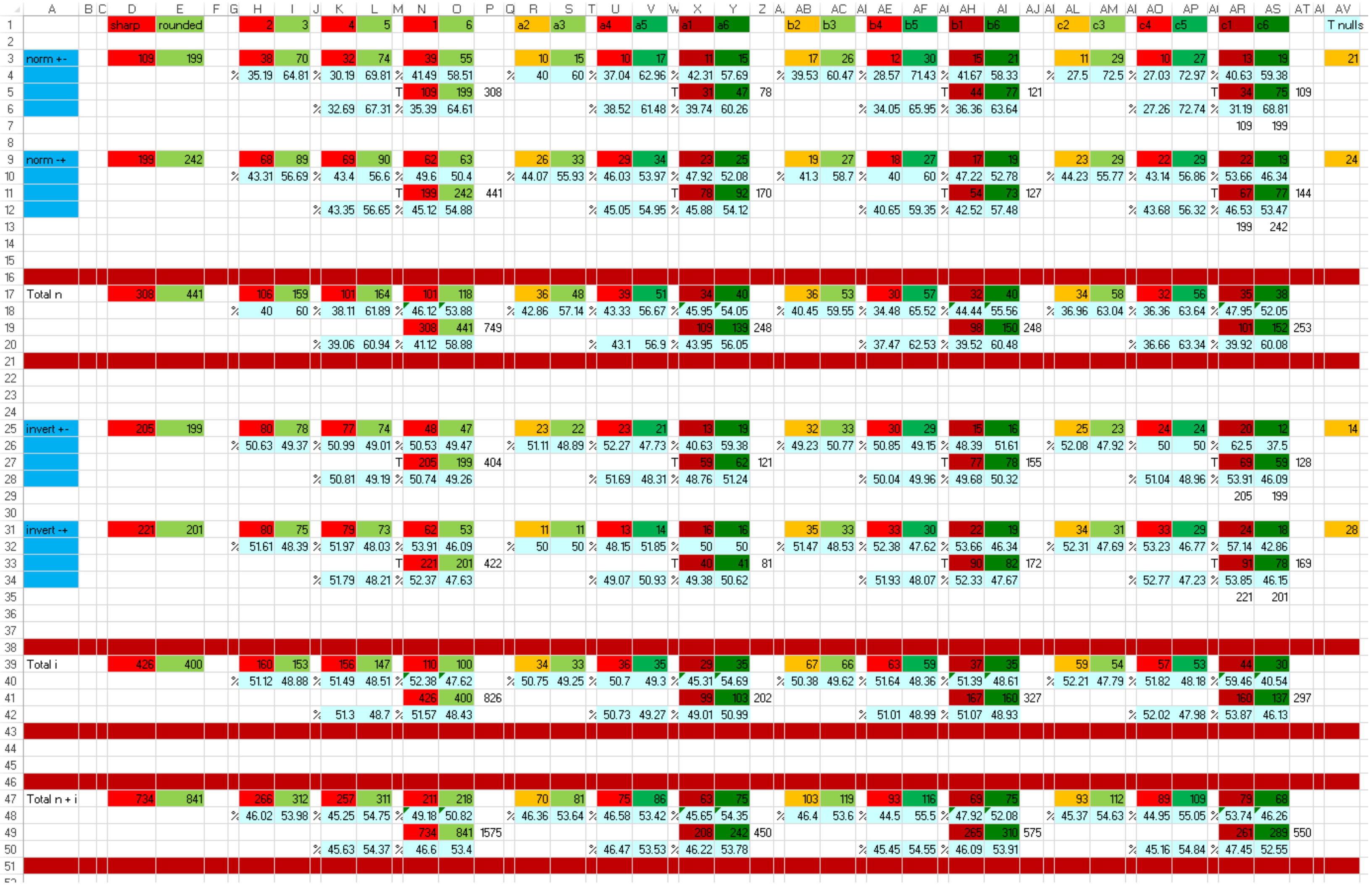
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1		Normal	R		Null	Inverted	R		Null			R	Null		R	Null		R	Null		R	Null		R	Null		sum	Null		1	2	3	4	5	6		a, b, c	1, 2, 4	3, 5, 6		
2	1	a4.png	1	1.438006		b5.png	0	1.59408			a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0		5	0		5											
3	2	c5.png	1	2.09425		a5.png	0	1.438168			a2.png	1	0	a2.png	0	0	a2.png	0	0	a2.png	0	0	a2.png	0	0		1	0			1										
4	3	a6.png	1	1.125504		a6.png	1	1.062647			a3.png	0	0	a3.png	0	0	a3.png	0	0	a3.png	0	0	a3.png	0	0		0	0				0									
5	4	b5.png	1	1.625378		b3.png	0	1.406766			a4.png	1	0	a4.png	0	0	a4.png	Non	1	a4.png	0	0	a4.png	0	0		1	1					1								
6	5	a2.png	1	1.750356		c3.png	0	1.062791			a5.png	0	0	a5.png	0	0	a5.png	0	0	a5.png	0	0	a5.png	0	0		0	0						0							
7	6	a1.png	1	1.563054		a4.png	0	1.094153			a6.png	1	0	a6.png	1	0	a6.png	1	0	a6.png	1	0	a6.png	1	0		5	0							5						
8	7	c1.png	1	1.906634		a1.png	1	1.06283																						5	1	0	1	0	5	t	12	7	5		
9	8	b2.png	0	2.031672		b6.png	1	1.063158			b1.png	1	0	b1.png	1	0	b1.png	1	0	b1.png	1	0	b1.png	1	0		5	0		5											
10	9	b4.png	0	0.750382		b1.png	1	1.406567			b2.png	0	0	b2.png	0	0	b2.png	0	0	b2.png	0	0	b2.png	0	0		0	0			0										
11	10	b3.png	0	1.531494		c6.png	1	0.875562			b3.png	0	0	b3.png	0	0	b3.png	0	0	b3.png	0	0	b3.png	0	0		0	0				0									
12	11	b6.png	1	1.469171		c4.png	0	0.844083			b4.png	0	0	b4.png	0	0	b4.png	0	0	b4.png	1	0	b4.png	0	0		1	0					1								
13	12	a5.png	0	2.71934		a2.png	0	1.312897			b5.png	1	0	b5.png	0	0	b5.png	0	0	b5.png	0	0	b5.png	0	0		1	0						1							
14	13	b1.png	1	1.250357		b4.png	1	1.437911			b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0		5	0							5						
15	14	c2.png	0	1.03171		c1.png	0	2.094113																						5	0	0	1	1	5	t	12	6	6		
16	15	c4.png	0	0.875174		a3.png	0	1.062606			c1.png	1	0	c1.png	1	0	c1.png	1	0	c1.png	1	0	c1.png	1	0		5	0		5											
17	16	a3.png	0	1.12516		b2.png	0	2.625321			c2.png	0	0	c2.png	0	0	c2.png	0	0	c2.png	0	0	c2.png	0	0		0	0			0										
18	17	c6.png	1	1.156521		c2.png	0	1.094114			c3.png	0	0	c3.png	0	0	c3.png	0	0	c3.png	0	0	c3.png	0	0		0	0				0									
19	18	c3.png	0	0.968946		c5.png	0	1.281744			c4.png	0	0	c4.png	0	0	c4.png	1	0	c4.png	0	0	c4.png	1	0		2	0					2								
20	1	b5.png	0	1.187811		a4.png	0	0.969087			c5.png	1	0	c5.png	0	0	c5.png	0	0	c5.png	0	0	c5.png	0	0		1	0						1							
21	2	a3.png	0	1.219149		c4.png	1	2.12539			c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0		5	0							5						
22	3	a2.png	0	1.531931		a5.png	0	1.375352																						5	0	0	2	1	5	t	13	7	6		
23	4	a4.png	0	1.312887		c6.png	1	0.937868				M	F														37	1	T	15	1	0	4	2	15	T	37	20	17		37
24	5	b6.png	1	1.062875		c5.png	0	0.875717			Gender	0	1																												
25	6	c3.png	0	1.406988		b6.png	1	0.781727																																	
26	7	b2.png	0	1.625384		a1.png	1	1.187873				R	Null		R	Null		R	Null		R	Null		R	Null		sum	Null		1	2	3	4	5	6		a, b, c	1, 2, 4	3, 5, 6		
27	8	b1.png	1	1.062909		a2.png	0	0.750521			a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0		5	0		5											
28	9	c2.png	0	1.125357		a3.png	0	1.437852			a2.png	0	0	a2.png	0	0	a2.png	0	0	a2.png	0	0	a2.png	0	0		0	0			0										
29	10	c4.png	0	1.063225		c3.png	0	1.500354			a3.png	0	0	a3.png	0	0	a3.png	0	0	a3.png	0	0	a3.png	0	0		0	0				0									
30	11	c1.png	1	1.156804		c2.png	0	1.094206			a4.png	0	0	a4.png	0	0	a4.png	0	0	a4.png	0	0	a4.png	0	0		0	0					0								
31	12	a6.png	1	1.094122		b3.png	1	1.469156			a5.png	0	0	a5.png	0	0	a5.png	0	0	a5.png	0	0	a5.png	0	0		0	0						0							
32	13	a1.png	1	0.906649		c1.png	1	2.12587			a6.png	1	0	a6.png	1	0	a6.png	1	0	a6.png	1	0	a6.png	1	0		5	0							5						
33	14	b4.png	0	0.969111		b4.png	1	2.250487																						5	0	0	0	0	5	t	10	5	5		
34	15	a5.png	0	1.406573		b2.png	1	2.000346			b1.png	1	0	b1.png	1	0	b1.png	1	0	b1.png	1	0	b1.png	1	0		5	0		5											
35	16	c5.png	0	0.781645		b5.png	0	1.344065			b2.png	0	0	b2.png	1	0	b2.png	0	0	b2.png	1	0	b2.png	0	0		2	0			2										
36	17	b3.png	0	1.219247		b1.png	1	1.375322			b3.png	0	0	b3.png	1	0	b3.png	Non	1	b3.png	0	0	b3.png	0	0		1	1				1									
37	18	c6.png	1	1.375307		a6.png	1	1.000656			b4.png	1	0	b4.png	1	0	b4.png	1	0	b4.png	1	0	b4.png	1	0		5	0					5								
38	1	b2.png	0	0.969123		c5.png	0	1.469095			b5.png	0	0	b5.png	0	0	b5.png	0	0	b5.png	1	0	b5.png	0	0		1	0						1							
39	2	b5.png	0	1.562994		a2.png	0	1.250327			b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0		5	0							5						
40	3	a3.png	0	1.594138		c4.png	0	0.812665																						5	2	1	5	1	5	t	19	12	7		
41	4	a4.png	None		1	c6.png	1	1.812854			c1.png	0	0	c1.png	1	0	c1.png	0	0	c1.png	0	0	c1.png	0	0		1	0		1											
42	5	c2.png	0	1.562828		c1.png	0	2.250003			c2.png	0	0	c2.png	0	0	c2.png	0	0	c2.png	0	0	c2.png	0	0		0	0			0										
43	6	a6.png	1	1.594163		b4.png	1	1.719262			c3.png	0	0	c3.png	0	0	c3.png	0	0	c3.png	0	0	c3.png	0	0		0	0				0									
44	7	b1.png	1	1.250458		c3.png	0	1.468986			c4.png	0	0	c4.png	1	0	c4.png	0	0	c4.png	1	0	c4.png	1	0		3	0					3								
45	8	b3.png	0	1.062852		b6.png	1	1.062611			c5.png	0	0	c5.png	0	0	c5.png	0	0	c5.png	0	0	c5.png	0	0		0	0						0							
46	9	a1.png	1	1.687779		a5.png	0	1.594289			c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0		5	0							5						
47	10	a5.png	0	0.969067		a1.png	1	1.406661																						1	0	0	3	0	5	t	9	4	5		
48	11	b6.png	1	1.437788		b3.png	None		1																		38	1	T	11	2	1	8	1	15	T	38	21	17		38

Screenshot I. Data collection and arrangement for aleatory sample participant MP - Experiment 1 - aesthetic judgement run. This procedure was repeated for all 32 participants.



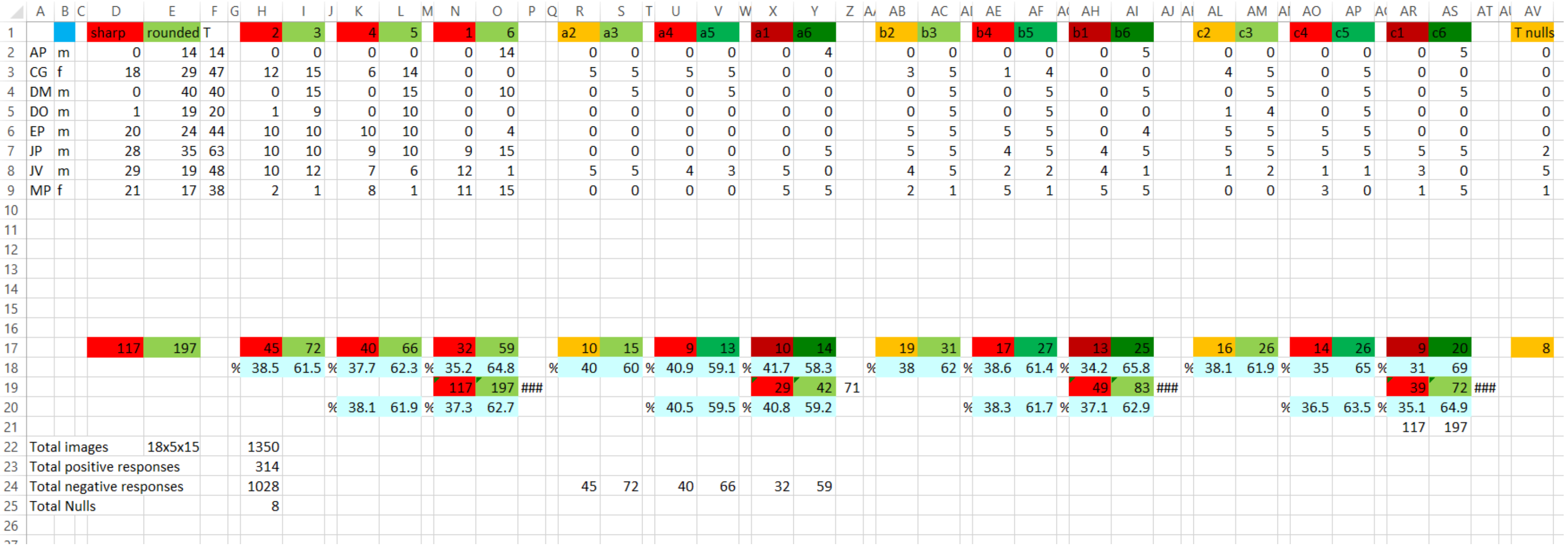
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A/	AB	AC	AI	AE	AF	A(	AH	AI	AJ	AI	AL	AM	AI	AO	AP	A(	AR	AS	AT	AI	AV
1				sharp	rounded	T		2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2	AP	m		3	13	16		2	0		0	1		1	12			2	0		0	1		1	3			0	0		0	0		0	5			0	0		0	0		0	4			0
3	CG	f		11	30	41		6	15		5	15		0	0			3	5		3	5		0	0			3	5		1	5		0	0			0	5		1	5		0	0			2
4	DM	m		3	39	42		1	15		1	15		1	9			0	5		1	5		1	0			1	5		0	5		0	4			0	5		0	5		0	5			4
5	DO	m		1	22	23		0	10		1	12		0	0			0	0		1	2		0	0			0	5		0	5		0	0			0	5		0	5		0	0			0
6	EP	m		19	19	38		9	7		7	10		3	2			0	0		0	0		0	0			5	2		4	5		2	2			4	5		3	5		1	0			4
7	JP	m		29	35	64		10	10		10	10		9	15			0	0		1	0		0	5			5	5		5	5		5	5			5	5		4	5		4	5			1
8	JV	m		23	24	47		9	13		4	9		10	2			4	5		3	4		4	2			3	4		1	4		3	0			2	4		0	1		3	0			9
9	MP	f		20	17	37		1	0		4	2		15	15			1	0		1	0		5	5			0	0		1	1		5	5			0	0		2	1		5	5			1
10																																																
11																																																
12																																																
13																																																
14																																																
15																																																
16																																																
17				109	199			38	70		32	74		39	55			10	15		10	17		11	15			17	26		12	30		15	21			11	29		10	27		13	19			21
18							%	35.2	64.8	%	30.2	69.8	%	41.5	58.5		%	40	60	%	37	63	%	42.3	57.7		%	39.5	60.5	%	28.6	71.4	%	41.7	58.3		%	27.5	72.5	%	27	73	%	40.6	59.4			
19													T	109	199	###							T	31	47	78							T	44	77	###							T	34	75	###		
20										%	32.7	67.3	%	35.4	64.6					%	38.5	61.5	%	39.7	60.3					%	34.1	65.9	%	36.4	63.6					%	27.3	72.7	%	31.2	68.8			
21																																												109	199			
22	Total images				18x5x15			1350																																								
23	Total positive responses							308																																								
24	Total negative responses							1021										38	70		32	74		39	55																							
25	Total Nulls							21																																								
26																																																

Screenshot II. General data arrangement from all participants of group A - Experiment 1 - aesthetics judgement run, 1st sequence. This analysis was repeated for all 4 groups.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			109	199			38	70		32	74		39	55			10	15		10	17		11	15			17	26		12	30		15	21			11	29		10	27		13	19			21
4							%	35.19	64.81	%	30.19	69.81	%	41.49	58.51		%	40	60	%	37.04	62.96	%	42.31	57.69		%	39.53	60.47	%	28.57	71.43	%	41.67	58.33		%	27.5	72.5	%	27.03	72.97	%	40.63	59.38			
5													T	109	199	308							T	31	47	78							T	44	77	121							T	34	75	109		
6										%	32.69	67.31	%	35.39	64.61					%	38.52	61.48	%	39.74	60.26					%	34.05	65.95	%	36.36	63.64					%	27.26	72.74	%	31.19	68.81			
7																																												109	199			
8																																																
9	norm -+			199	242			68	89		69	90		62	63			26	33		29	34		23	25			19	27		18	27		17	19			23	29		22	29		22	19			24
10							%	43.31	56.69	%	43.4	56.6	%	49.6	50.4		%	44.07	55.93	%	46.03	53.97	%	47.92	52.08		%	41.3	58.7	%	40	60	%	47.22	52.78		%	44.23	55.77	%	43.14	56.86	%	53.66	46.34			
11													T	199	242	441							T	78	92	170							T	54	73	127							T	67	77	144		
12										%	43.35	56.65	%	45.12	54.88					%	45.05	54.95	%	45.88	54.12					%	40.65	59.35	%	42.52	57.48					%	43.68	56.32	%	46.53	53.47			
13																																												199	242			
14																																																
15																																																
16																																																
17	Total n			308	441			106	159		101	164		101	118			36	48		39	51		34	40			36	53		30	57		32	40			34	58		32	56		35	38			
18							%	40	60	%	38.11	61.89	%	46.12	53.88		%	42.86	57.14	%	43.33	56.67	%	45.95	54.05		%	40.45	59.55	%	34.48	65.52	%	44.44	55.56		%	36.96	63.04	%	36.36	63.64	%	47.95	52.05			
19														308	441	749								109	139	248								98	150	248								101	152	253		
20										%	39.06	60.94	%	41.12	58.88					%	43.1	56.9	%	43.95	56.05					%	37.47	62.53	%	39.52	60.48					%	36.66	63.34	%	39.92	60.08			
21																																																
22																																																
23																																																
24																																																
25	invert +-			205	199			80	78		77	74		48	47			23	22		23	21		13	19			32	33		30	29		15	16			25	23		24	24		20	12			14
26							%	50.63	49.37	%	50.99	49.01	%	50.53	49.47		%	51.11	48.89	%	52.27	47.73	%	40.63	59.38		%	49.23	50.77	%	50.85	49.15	%	48.39	51.61		%	52.08	47.92	%	50	50	%	62.5	37.5			
27													T	205	199	404							T	59	62	121							T	77	78	155							T	69	59	128		
28										%	50.81	49.19	%	50.74	49.26					%	51.69	48.31	%	48.76	51.24					%	50.04	49.96	%	49.68	50.32					%	51.04	48.96	%	53.91	46.09			
29																																												205	199			
30																																																
31	invert -+			221	201			80	75		79	73		62	53			11	11		13	14		16	16			35	33		33	30		22	19			34	31		33	29		24	18			28
32							%	51.61	48.39	%	51.97	48.03	%	53.91	46.09		%	50	50	%	48.15	51.85	%	50	50		%	51.47	48.53	%	52.38	47.62	%	53.66	46.34		%	52.31	47.69	%	53.23	46.77	%	57.14	42.86			
33													T	221	201	422							T	40	41	81							T	90	82	172							T	91	78	169		
34										%	51.79	48.21	%	52.37	47.63					%	49.07	50.93	%	49.38	50.62					%	51.93	48.07	%	52.33	47.67					%	52.77	47.23	%	53.85	46.15			
35																																												221	201			
36																																																
37																																																
38																																																
39	Total i			426	400			160	153		156	147		110	100			34	33		36	35		29	35			67	66		63	59		37	35			59	54		57	53		44	30			
40							%	51.12	48.88	%	51.49	48.51	%	52.38	47.62		%	50.75	49.25	%	50.7	49.3	%	45.31	54.69		%	50.38	49.62	%	51.64	48.36	%	51.39	48.61		%	52.21	47.79	%	51.82	48.18	%	59.46	40.54			
41														426	400	826								99	103	202								167	160	327								160	137	297		
42										%	51.3	48.7	%	51.57	48.43					%	50.73	49.27	%	49.01	50.99					%	51.01	48.99	%	51.07	48.93					%	52.02	47.98	%	53.87	46.13			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			734	841			266	312		257	311		211	218			70	81		75	86		63	75			103	119		93	116		69	75			93	112		89	109		79	68			
48							%	46.02	53.98	%	45.25	54.75	%	49.18	50.82		%	46.36	53.64	%	46.58	53.42	%	45.65	54.35		%	46.4	53.6	%	44.5	55.5	%	47.92	52.08		%	45.37	54.63	%	44.95	55.05	%	53.74	46.26			
49														734	841	1575								208	242	450								265	310	575								261	289	550		
50										%	45.63	54.37	%	46.6	53.4					%	46.47	53.53	%	46.22	53.78					%	45.45	54.55	%	46.09	53.91					%	45.16	54.84	%	47.45	52.55			
51																																																

Screenshot III. General data arrangement for all groups A B C and D - Experiment 1 - aesthetic judgement run, 1st sequence.

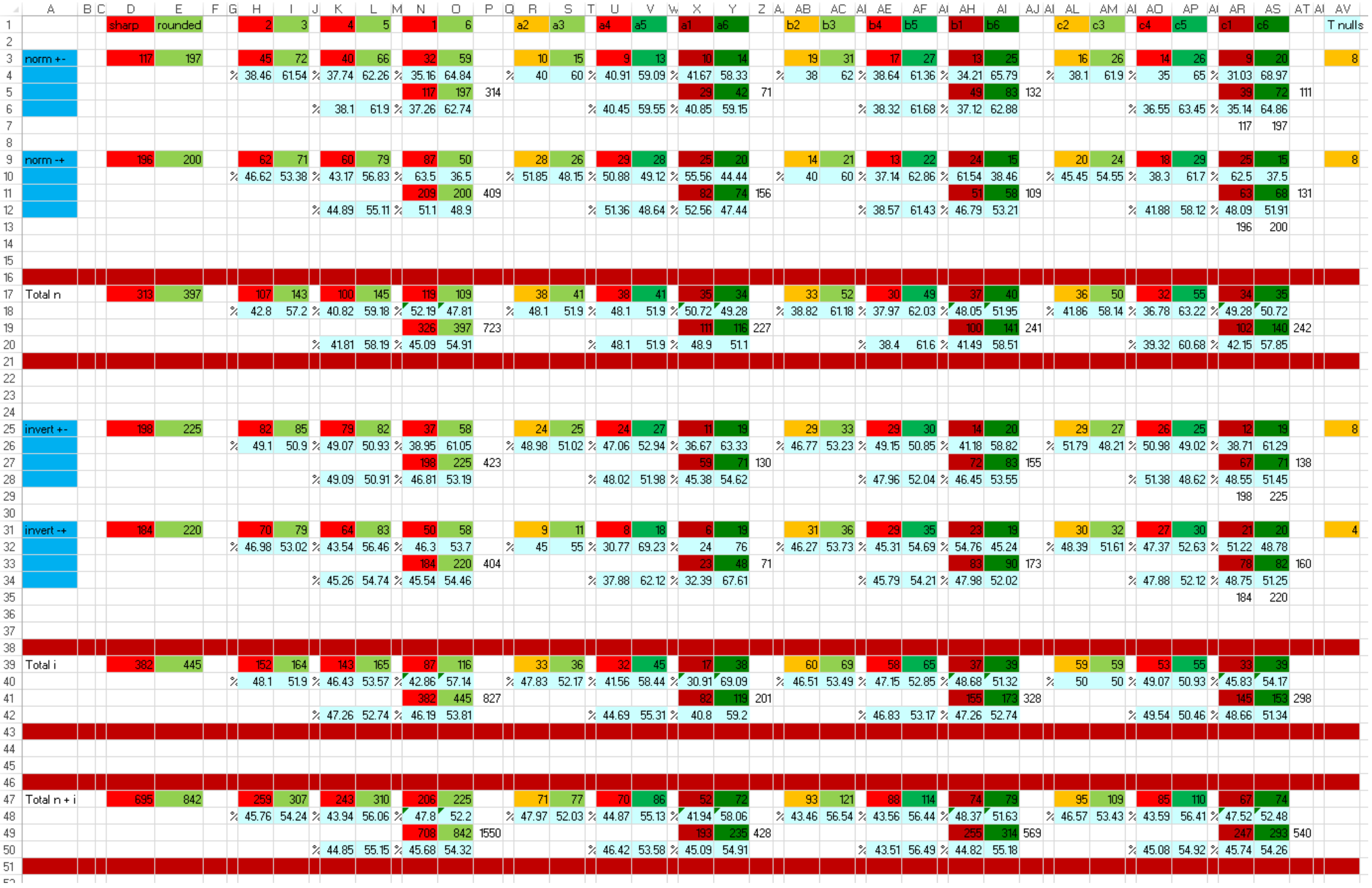


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1		🟦		sharp	rounded	T		2	3		4	5		1	6
2	AP	m		0	14	14		0	0		0	0		0	14
3	CG	f		18	29	47		12	15		6	14		0	0
4	DM	m		0	40	40		0	15		0	15		0	10
5	DO	m		1	19	20		1	9		0	10		0	0
6	EP	m		20	24	44		10	10		10	10		0	4
7	JP	m		28	35	63		10	10		9	10		9	15
8	JV	m		29	19	48		10	12		7	6		12	1
9	MP	f		21	17	38		2	1		8	1		11	15
10															
11															
12															
13															
14															
15															
16															
17				117	197			45	72		40	66		32	59
18							%	38.5	61.5	%	37.7	62.3	%	35.2	64.8
19														117	197
20										%	38.1	61.9	%	37.3	62.7
21															
22	Total images				18x5x15			1350							
23	Total positive responses							314							
24	Total negative responses							1028							
25	Total Nulls							8							
26															

	P	Q	R	S	T	U	V	W	X	Y	Z	A/	AB	AC	AI	AE	AF
1			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5
2			0	0		0	0		0	4			0	0		0	0
3			5	5		5	5		0	0			3	5		1	4
4			0	5		0	5		0	0			0	5		0	5
5			0	0		0	0		0	0			0	5		0	5
6			0	0		0	0		0	0			5	5		5	5
7			0	0		0	0		0	5			5	5		4	5
8			5	5		4	3		5	0			4	5		2	2
9			0	0		0	0		5	5			2	1		5	1
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17			10	15		9	13		10	14			19	31		17	27
18		%	40	60	%	40.9	59.1	%	41.7	58.3		%	38	62	%	38.6	61.4
19	###								29	42	71						
20					%	40.5	59.5	%	40.8	59.2					%	38.3	61.7
21																	
22																	
23																	
24			45	72		40	66		32	59							
25																	
26																	

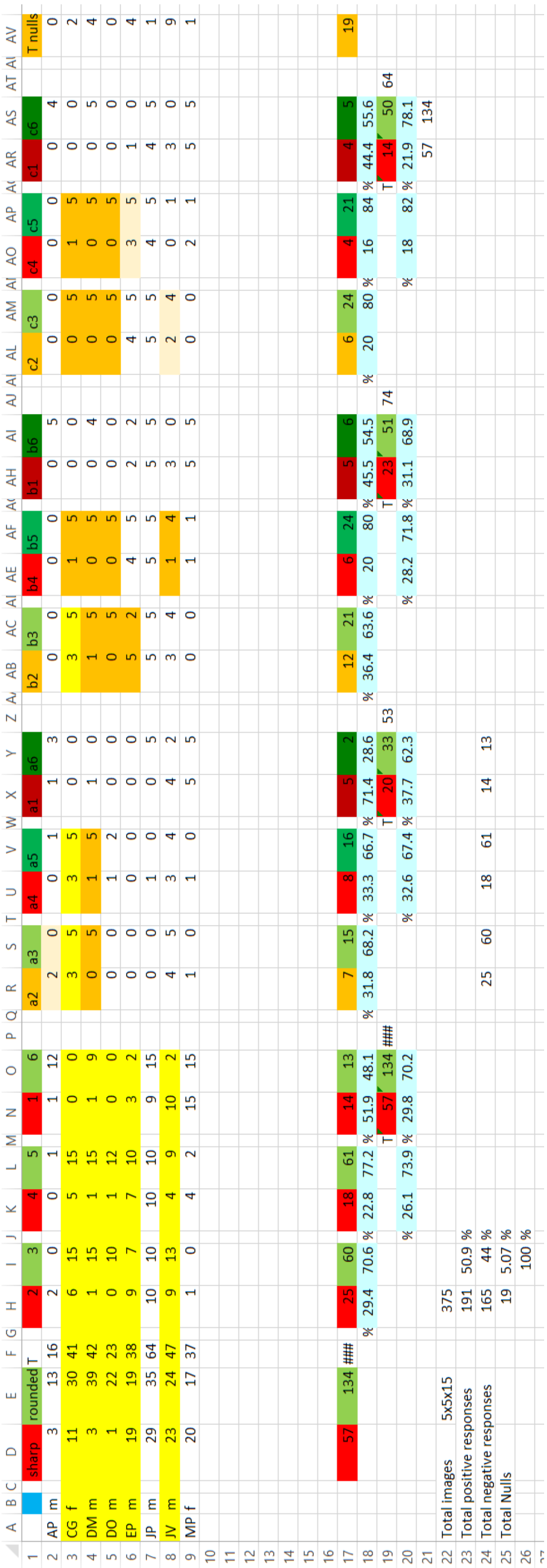
	AC	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AC	AR	AS	AT	AI	AV
1		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2		0	5			0	0		0	0		0	5			0
3		0	0			4	5		0	5		0	0			0
4		0	5			0	5		0	5		0	5			0
5		0	0			1	4		0	5		0	0			0
6		0	4			5	5		5	5		0	0			0
7		4	5			5	5		5	5		5	5			2
8		4	1			1	2		1	1		3	0			5
9		5	5			0	0		3	0		1	5			1
10																
11																
12																
13																
14																
15																
16																
17		13	25			16	26		14	26		9	20			8
18	%	34.2	65.8		%	38.1	61.9	%	35	65	%	31	69			
19		49	83	###								39	72	###		
20	%	37.1	62.9					%	36.5	63.5	%	35.1	64.9			
21												117	197			
22																
23																
24																
25																
26																

Screenshot IV. General data arrangement from all participants of group A - Experiment 1 - aesthetics judgement run, 2nd sequence. This analysis was repeated for all 4 groups.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			117	197			45	72		40	66		32	59			10	15		9	13		10	14			19	31		17	27		13	25			16	26		14	26		9	20			8
4							%	38.46	61.54	%	37.74	62.26	%	35.16	64.84		%	40	60	%	40.91	59.09	%	41.67	58.33		%	38	62	%	38.64	61.36	%	34.21	65.79		%	38.1	61.9	%	35	65	%	31.03	68.97			
5														117	197	314								29	42	71								49	83	132								39	72	111		
6										%	38.1	61.9	%	37.26	62.74					%	40.45	59.55	%	40.85	59.15					%	38.32	61.68	%	37.12	62.88					%	36.55	63.45	%	35.14	64.86			
7																																												117	197			
8																																																
9	norm -+			196	200			62	71		60	79		87	50			28	26		29	28		25	20			14	21		13	22		24	15			20	24		18	29		25	15			8
10							%	46.62	53.38	%	43.17	56.83	%	63.5	36.5		%	51.85	48.15	%	50.88	49.12	%	55.56	44.44		%	40	60	%	37.14	62.86	%	61.54	38.46		%	45.45	54.55	%	38.3	61.7	%	62.5	37.5			
11														209	200	409								82	74	156								51	58	109								63	68	131		
12										%	44.89	55.11	%	51.1	48.9					%	51.36	48.64	%	52.56	47.44					%	38.57	61.43	%	46.79	53.21					%	41.88	58.12	%	48.09	51.91			
13																																												196	200			
14																																																
15																																																
16																																																
17	Total n			313	397			107	143		100	145		119	109			38	41		38	41		35	34			33	52		30	49		37	40			36	50		32	55		34	35			
18							%	42.8	57.2	%	40.82	59.18	%	52.19	47.81		%	48.1	51.9	%	48.1	51.9	%	50.72	49.28		%	38.82	61.18	%	37.97	62.03	%	48.05	51.95		%	41.86	58.14	%	36.78	63.22	%	49.28	50.72			
19														326	397	723								111	116	227								100	141	241								102	140	242		
20										%	41.81	58.19	%	45.09	54.91					%	48.1	51.9	%	48.9	51.1					%	38.4	61.6	%	41.49	58.51					%	39.32	60.68	%	42.15	57.85			
21																																																
22																																																
23																																																
24																																																
25	invert +-			198	225			82	85		79	82		37	58			24	25		24	27		11	19			29	33		29	30		14	20			29	27		26	25		12	19			8
26							%	49.1	50.9	%	49.07	50.93	%	38.95	61.05		%	48.98	51.02	%	47.06	52.94	%	36.67	63.33		%	46.77	53.23	%	49.15	50.85	%	41.18	58.82		%	51.79	48.21	%	50.98	49.02	%	38.71	61.29			
27														198	225	423								59	71	130								72	83	155								67	71	138		
28										%	49.09	50.91	%	46.81	53.19					%	48.02	51.98	%	45.38	54.62					%	47.96	52.04	%	46.45	53.55					%	51.38	48.62	%	48.55	51.45			
29																																												198	225			
30																																																
31	invert -+			184	220			70	79		64	83		50	58			9	11		8	18		6	19			31	36		29	35		23	19			30	32		27	30		21	20			4
32							%	46.98	53.02	%	43.54	56.46	%	46.3	53.7		%	45	55	%	30.77	69.23	%	24	76		%	46.27	53.73	%	45.31	54.69	%	54.76	45.24		%	48.39	51.61	%	47.37	52.63	%	51.22	48.78			
33														184	220	404								23	48	71								83	90	173								78	82	160		
34										%	45.26	54.74	%	45.54	54.46					%	37.88	62.12	%	32.39	67.61					%	45.79	54.21	%	47.98	52.02					%	47.88	52.12	%	48.75	51.25			
35																																												184	220			
36																																																
37																																																
38																																																
39	Total i			382	445			152	164		143	165		87	116			33	36		32	45		17	38			60	69		58	65		37	39			59	59		53	55		33	39			
40							%	48.1	51.9	%	46.43	53.57	%	42.86	57.14		%	47.83	52.17	%	41.56	58.44	%	30.91	69.09		%	46.51	53.49	%	47.15	52.85	%	48.68	51.32		%	50	50	%	49.07	50.93	%	45.83	54.17			
41														382	445	827								82	119	201								155	173	328								145	153	298		
42										%	47.26	52.74	%	46.19	53.81					%	44.69	55.31	%	40.8	59.2					%	46.83	53.17	%	47.26	52.74					%	49.54	50.46	%	48.66	51.34			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			695	842			259	307		243	310		206	225			71	77		70	86		52	72			93	121		88	114		74	79			95	109		85	110		67	74			
48							%	45.76	54.24	%	43.94	56.06	%	47.8	52.2		%	47.97	52.03	%	44.87	55.13	%	41.94	58.06		%	43.46	56.54	%	43.56	56.44	%	48.37	51.63		%	46.57	53.43	%	43.59	56.41	%	47.52	52.48			
49														708	842	1550								193	235	428								255	314	569								247	293	540		
50										%	44.85	55.15	%	45.68	54.32					%	46.42	53.58	%	45.09	54.91					%	43.51	56.49	%	44.82	55.18					%	45.08	54.92	%	45.74	54.26			
51																																																

Screenshot V. General data arrangement for all groups A B C and D - Experiment 1 - aesthetic judgement run, 2nd sequence.

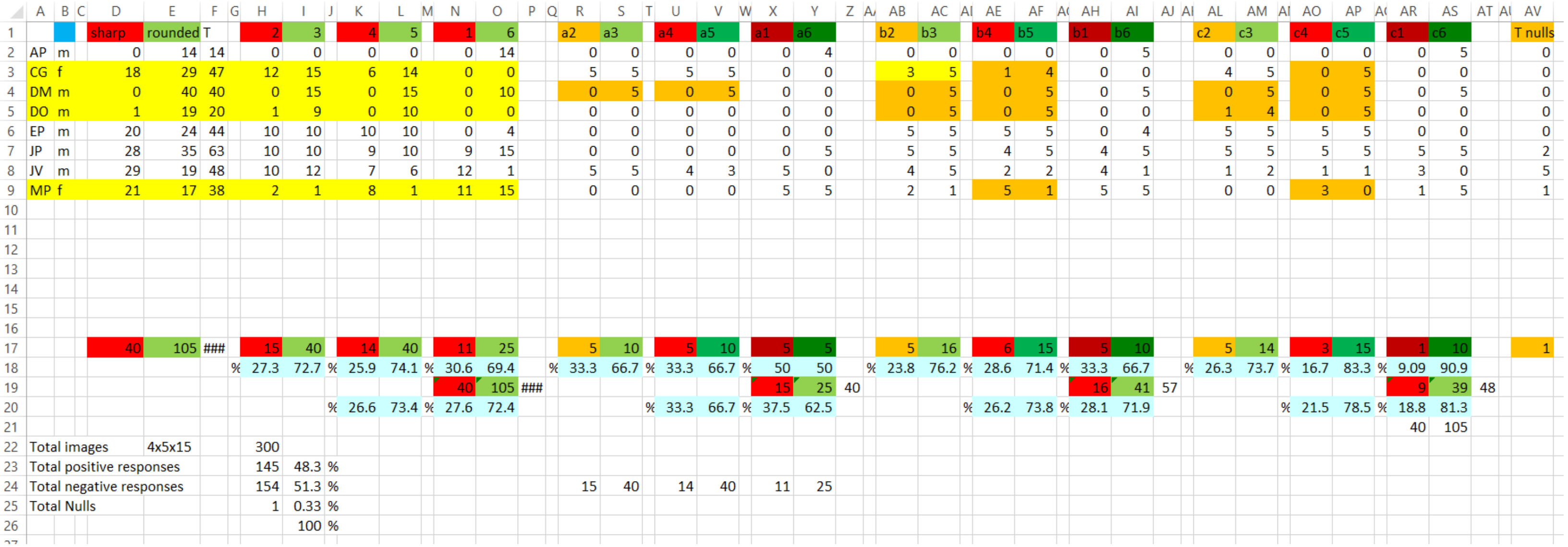


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	AB	AC	AI	AE	AF	A(	AH	AI	AJ	AI	AL	AM	AI	AO	AP	A(	AR	AS	AT	AI	AV
1				sharp	rounded	T		2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2	AP	m		3	13	16		2	0		0	1		1	12			2	0		0	1		1	3			0	0		0	0		0	5			0	0		0	0		0	4			0
3	CG	f		11	30	41		6	15		5	15		0	0			3	5		3	5		0	0			3	5		1	5		0	0			0	5		1	5		0	0			2
4	DM	m		3	39	42		1	15		1	15		1	9			0	5		1	5		1	0			1	5		0	5		0	4			0	5		0	5		0	5			4
5	DO	m		1	22	23		0	10		1	12		0	0			0	0		1	2		0	0			0	5		0	5		0	0			0	5		0	5		0	0			0
6	EP	m		19	19	38		9	7		7	10		3	2			0	0		0	0		0	0			5	2		4	5		2	2			4	5		3	5		1	0			4
7	JP	m		29	35	64		10	10		10	10		9	15			0	0		1	0		0	5			5	5		5	5		5	5			5	5		4	5		4	5			1
8	JV	m		23	24	47		9	13		4	9		10	2			4	5		3	4		4	2			3	4		1	4		3	0			2	4		0	1		3	0			9
9	MP	f		20	17	37		1	0		4	2		15	15			1	0		1	0		5	5			0	0		1	1		5	5			0	0		2	1		5	5			1
10																																																
11																																																
12																																																
13																																																
14																																																
15																																																
16																																																
17				57	134	###		25	60		18	61		14	13			7	15		8	16		5	2			12	21		6	24		5	6			6	24		4	21		4	5			19
18							%	29.4	70.6	%	22.8	77.2	%	51.9	48.1		%	31.8	68.2	%	33.3	66.7	%	71.4	28.6		%	36.4	63.6	%	20	80	%	45.5	54.5		%	20	80	%	16	84	%	44.4	55.6			
19													T	57	134	###							T	20	33	53							T	23	51	74							T	14	50	64		
20										%	26.1	73.9	%	29.8	70.2					%	32.6	67.4	%	37.7	62.3					%	28.2	71.8	%	31.1	68.9					%	18	82	%	21.9	78.1			
21																																												57	134			
22	Total images				5x5x15			375																																								
23	Total positive responses							191	50.9	%																																						
24	Total negative responses							165	44	%								25	60		18	61		14	13																							
25	Total Nulls							19	5.07	%																																						
26									100	%																																						

Screenshot VI. Consistent response data arrangement from all participants of group A - Experiment 1 - aesthetics judgement run, 1st sequence. This analysis was repeated for all 4 groups.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			57	134			25	60		18	61		14	13			7	15		8	16		5	2			12	21		6	24		5	6			6	24		4	21		4	5			19
4							%	29.41	70.59	%	22.78	77.22	%	51.85	48.15		%	31.82	68.18	%	33.33	66.67	%	71.43	28.57		%	36.36	63.64	%	20	80	%	45.45	54.55		%	20	80	%	16	84	%	44.44	55.56			
5													T	57	134	191							T	20	33	53							T	23	51	74							T	14	50	64		
6										%	26.1	73.9	%	29.84	70.16					%	32.58	67.42	%	37.74	62.26					%	28.18	71.82	%	31.08	68.92					%	18	82	%	21.88	78.13			
7																																												57	134			
8																																																
9	norm -+			74	112			25	43		24	42		25	27			8	13		9	14		10	9			9	16		8	14		6	9			8	14		7	14		9	9			19
10							%	36.76	63.24	%	36.36	63.64	%	48.08	51.92		%	38.1	61.9	%	39.13	60.87	%	52.63	47.37		%	36	64	%	36.36	63.64	%	40	60		%	36.36	63.64	%	33.33	66.67	%	50	50			
11													T	74	112	186							T	27	36	63							T	23	39	62							T	24	37	61		
12										%	36.56	63.44	%	39.78	60.22					%	38.61	61.39	%	42.86	57.14					%	36.18	63.82	%	37.1	62.9					%	34.85	65.15	%	39.34	60.66			
13																																												74	112			
14																																																
15																																																
16																																																
17	Total n			131	246			50	103		42	103		39	40			15	28		17	30		15	11			21	37		14	38		11	15			14	38		11	35		13	14			
18							%	32.68	67.32	%	28.97	71.03	%	49.37	50.63		%	34.88	65.12	%	36.17	63.83	%	57.69	42.31		%	36.21	63.79	%	26.92	73.08	%	42.31	57.69		%	26.92	73.08	%	23.91	76.09	%	48.15	51.85			
19														131	246	377								47	69	116								46	90	136								38	87	125		
20										%	30.82	69.18	%	34.75	65.25					%	35.53	64.47	%	40.52	59.48					%	31.56	68.44	%	33.82	66.18					%	25.42	74.58	%	30.4	69.6			
21																																																
22																																																
23																																																
24																																																
25	invert +-			20	19	39		6	8		8	9		6	2			0	0		0	1		0	0			3	5		3	5		1	1			3	3		5	3		5	1			5
26							%	42.86	57.14	%	47.06	52.94	%	75	25		%	####	####	%	0	100	%	####	####		%	37.5	62.5	%	37.5	62.5	%	50	50		%	50	50	%	62.5	37.5	%	83.33	16.67			
27													T	20	19	39							T	0	1	1							T	7	11	18							T	13	7	20		
28										%	44.96	55.04	%	51.28	48.72					%	####	####	%	0	100					%	37.5	62.5	%	38.89	61.11					%	56.25	43.75	%	65	35			
29																																												20	19			
30																																																
31	invert -+			48	34			14	14		18	11		16	9			3	3		6	4		5	3			7	7		6	6		6	3			4	4		6	1		5	3			14
32							%	50	50	%	62.07	37.93	%	64	36		%	50	50	%	60	40	%	62.5	37.5		%	50	50	%	50	50	%	66.67	33.33		%	50	50	%	85.71	14.29	%	62.5	37.5			
33													T	48	34	82							T	14	10	24							T	19	16	35							T	15	8	23		
34										%	56.03	43.97	%	58.54	41.46					%	55	45	%	58.33	41.67					%	50	50	%	54.29	45.71					%	67.86	32.14	%	65.22	34.78			
35																																												48	34			
36																																																
37																																																
38																																																
39	Total i			68	53			20	22		26	20		22	11			3	3		6	5		5	3			10	12		9	11		7	4			7	7		11	4		10	4			
40							%	47.62	52.38	%	56.52	43.48	%	66.67	33.33		%	50	50	%	54.55	45.45	%	62.5	37.5		%	45.45	54.55	%	45	55	%	63.64	36.36		%	50	50	%	73.33	26.67	%	71.43	28.57			
41														68	53	121								14	11	25								26	27	53								28	15	43		
42										%	52.07	47.93	%	56.2	43.8					%	52.27	47.73	%	56	44					%	45.23	54.77	%	49.06	50.94					%	61.67	38.33	%	65.12	34.88			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			199	299			70	125		68	123		61	51			18	31		23	35		20	14			31	49		23	49		18	19			21	45		22	39		23	18			
48							%	35.9	64.1	%	35.6	64.4	%	54.46	45.54		%	36.73	63.27	%	39.66	60.34	%	58.82	41.18		%	38.75	61.25	%	31.94	68.06	%	48.65	51.35		%	31.82	68.18	%	36.07	63.93	%	56.1	43.9			
49														199	299	498								61	80	141								72	117	189								66	102	168		
50										%	35.75	64.25	%	39.96	60.04					%	38.19	61.81	%	43.26	56.74					%	35.35	64.65	%	38.1	61.9					%	33.94	66.06	%	39.29	60.71			
51																																																

Screenshot VII. Consistent response data arrangement for all groups A B C and D - Experiment 1 - aesthetic judgement run, 1^{st} sequence.

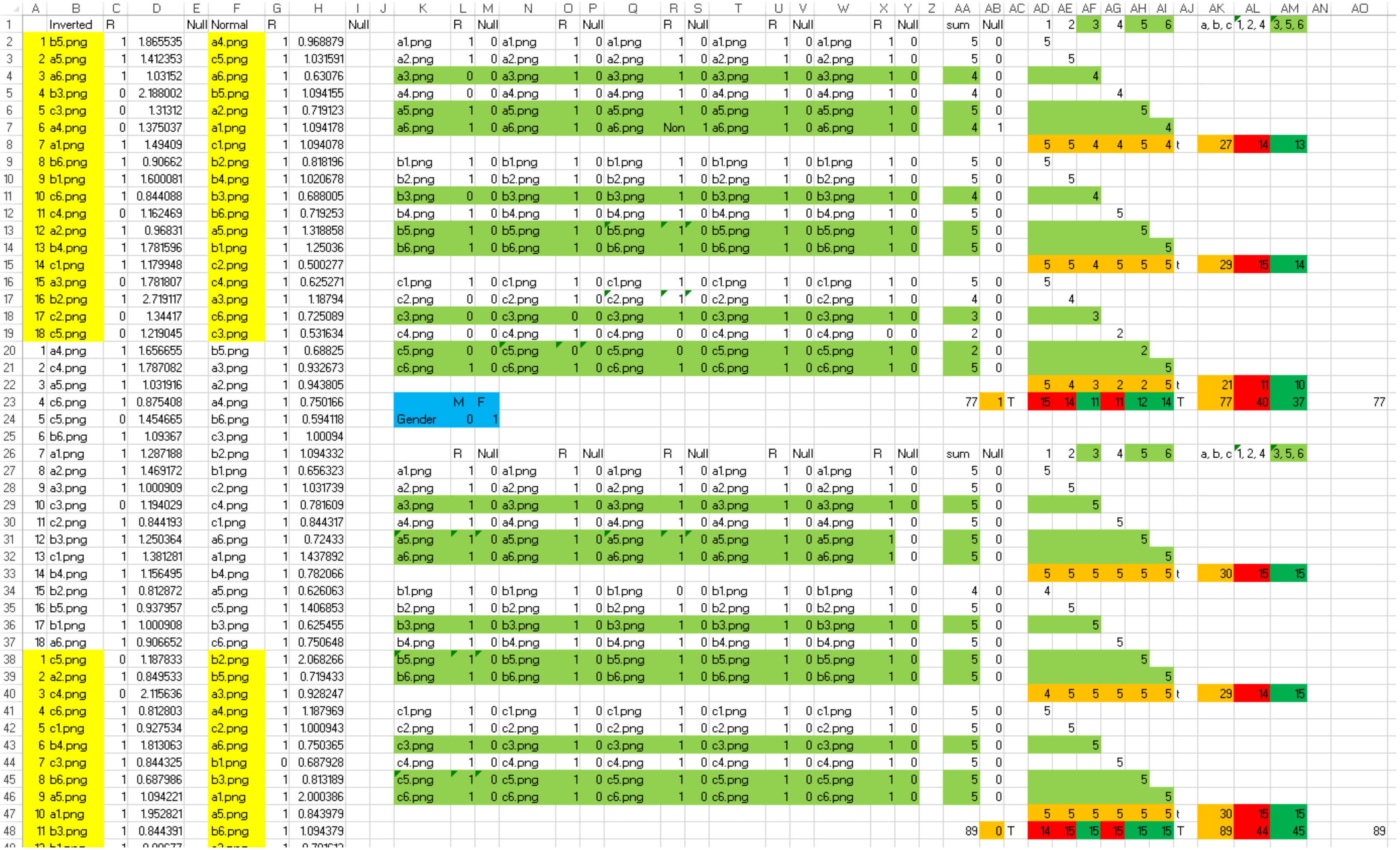


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A/	AB	AC	AI	AE	AF	A(	AH	AI	AJ	AI	AL	AM	AI	AO	AP	A(	AR	AS	AT	AI	AV
1				sharp	rounded	T		2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2	AP	m		0	14	14		0	0		0	0		0	14			0	0		0	0		0	4			0	0		0	0		0	5			0	0		0	0		0	5			0
3	CG	f		18	29	47		12	15		6	14		0	0			5	5		5	5		0	0			3	5		1	4		0	0			4	5		0	5		0	0			0
4	DM	m		0	40	40		0	15		0	15		0	10			0	5		0	5		0	0			0	5		0	5		0	5			0	5		0	5		0	5			0
5	DO	m		1	19	20		1	9		0	10		0	0			0	0		0	0		0	0			0	5		0	5		0	0			1	4		0	5		0	0			0
6	EP	m		20	24	44		10	10		10	10		0	4			0	0		0	0		0	0			5	5		5	5		0	4			5	5		5	5		0	0			0
7	JP	m		28	35	63		10	10		9	10		9	15			0	0		0	0		0	5			5	5		4	5		4	5			5	5		5	5		5	5			2
8	JV	m		29	19	48		10	12		7	6		12	1			5	5		4	3		5	0			4	5		2	2		4	1			1	2		1	1		3	0			5
9	MP	f		21	17	38		2	1		8	1		11	15			0	0		0	0		5	5			2	1		5	1		5	5			0	0		3	0		1	5			1
10																																																
11																																																
12																																																
13																																																
14																																																
15																																																
16																																																
17				40	105	###		15	40		14	40		11	25			5	10		5	10		5	5			5	16		6	15		5	10			5	14		3	15		1	10			1
18							%	27.3	72.7	%	25.9	74.1	%	30.6	69.4		%	33.3	66.7	%	33.3	66.7	%	50	50		%	23.8	76.2	%	28.6	71.4	%	33.3	66.7		%	26.3	73.7	%	16.7	83.3	%	9.09	90.9			
19														40	105	###								15	25	40								16	41	57								9	39	48		
20										%	26.6	73.4	%	27.6	72.4					%	33.3	66.7	%	37.5	62.5					%	26.2	73.8	%	28.1	71.9					%	21.5	78.5	%	18.8	81.3			
21																																												40	105			
22	Total images				4x5x15			300																																								
23	Total positive responses							145	48.3	%																																						
24	Total negative responses							154	51.3	%								15	40		14	40		11	25																							
25	Total Nulls							1	0.33	%																																						
26									100	%																																						

Screenshot VIII. Consistent response data arrangement from all participants of group A - Experiment 1 - aesthetics judgement run, 2nd sequence. This analysis was repeated for all 4 groups.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			40	105	145		15	40		14	40		11	25			5	10		5	10		5	5			5	16		6	15		5	10			5	14		3	15		1	10			1
4							%	27.27	72.73	%	25.93	74.07	%	30.56	69.44		%	33.33	66.67	%	33.33	66.67	%	50	50		%	23.81	76.19	%	28.57	71.43	%	33.33	66.67		%	26.32	73.68	%	16.67	83.33	%	9.091	90.91			
5														40	105	145								15	25	40								16	41	57								9	39	48		
6										%	26.6	73.4	%	27.59	72.41					%	33.33	66.67	%	37.5	62.5					%	26.19	73.81	%	28.07	71.93					%	21.49	78.51	%	18.75	81.25			
7																																												40	105			
8																																																
9	norm -+			92	101	193		32	38		30	48		30	15			13	11		14	13		10	5			9	13		8	16		10	5			10	14		8	19		10	5			7
10							%	45.71	54.29	%	38.46	61.54	%	66.67	33.33		%	54.17	45.83	%	51.85	48.15	%	66.67	33.33		%	40.91	59.09	%	33.33	66.67	%	66.67	33.33		%	41.67	58.33	%	29.63	70.37	%	66.67	33.33			
11														92	101	193								37	29	66								27	34	61								28	38	66		
12										%	42.09	57.91	%	47.67	52.33					%	53.01	46.99	%	56.06	43.94					%	37.12	62.88	%	44.26	55.74					%	35.65	64.35	%	42.42	57.58			
13																																												92	101			
14																																																
15																																																
16																																																
17	Total n			132	206			47	78		44	88		41	40			18	21		19	23		15	10			14	29		14	31		15	15			15	28		11	34		11	15			
18							%	37.6	62.4	%	33.33	66.67	%	50.62	49.38		%	46.15	53.85	%	45.24	54.76	%	60	40		%	32.56	67.44	%	31.11	68.89	%	50	50		%	34.88	65.12	%	24.44	75.56	%	42.31	57.69			
19														132	206	338								52	54	106								43	75	118								37	77	114		
20										%	35.47	64.53	%	39.05	60.95					%	45.7	54.3	%	49.06	50.94					%	31.83	68.17	%	36.44	63.56					%	29.66	70.34	%	32.46	67.54			
21																																																
22																																																
23																																																
24																																																
25	invert +-			41	34	75		15	18		10	14		16	2			6	8		6	8		5	1			4	7		3	5		6	1			5	3		1	1		5	0			6
26							%	45.45	54.55	%	41.67	58.33	%	88.89	11.11		%	42.86	57.14	%	42.86	57.14	%	83.33	16.67		%	36.36	63.64	%	37.5	62.5	%	85.71	14.29		%	62.5	37.5	%	50	50	%	100	0			
27														41	34	75								17	17	34								13	13	26								11	4	15		
28										%	43.56	56.44	%	54.67	45.33					%	42.86	57.14	%	50	50					%	36.93	63.07	%	50	50					%	56.25	43.75	%	73.33	26.67			
29																																												41	34			
30																																																
31	invert -+			63	98	161		25	33		19	37		19	28			6	7		5	12		5	9			10	15		7	15		7	9			9	11		7	10		7	10			3
32							%	43.1	56.9	%	33.93	66.07	%	40.43	59.57		%	46.15	53.85	%	29.41	70.59	%	35.71	64.29		%	40	60	%	31.82	68.18	%	43.75	56.25		%	45	55	%	41.18	58.82	%	41.18	58.82			
33														63	98	161								16	28	44								24	39	63								23	31	54		
34										%	38.52	61.48	%	39.13	60.87					%	37.78	62.22	%	36.36	63.64					%	35.91	64.09	%	38.1	61.9					%	43.09	56.91	%	42.59	57.41			
35																																												63	98			
36																																																
37																																																
38																																																
39	Total i			104	132			40	51		29	51		35	30			12	15		11	20		10	10			14	22		10	20		13	10			14	14		8	11		12	10			
40							%	43.96	56.04	%	36.25	63.75	%	53.85	46.15		%	44.44	55.56	%	35.48	64.52	%	50	50		%	38.89	61.11	%	33.33	66.67	%	56.52	43.48		%	50	50	%	42.11	57.89	%	54.55	45.45			
41														104	132	236								33	45	78								37	52	89								34	35	69		
42										%	40.1	59.9	%	44.07	55.93					%	39.96	60.04	%	42.31	57.69					%	36.11	63.89	%	41.57	58.43					%	46.05	53.95	%	49.28	50.72			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			236	338			87	129		73	139		76	70			30	36		30	43		25	20			28	51		24	51		28	25			29	42		19	45		23	25			
48							%	40.28	59.72	%	34.43	65.57	%	52.05	47.95		%	45.45	54.55	%	41.1	58.9	%	55.56	44.44		%	35.44	64.56	%	32	68	%	52.83	47.17		%	40.85	59.15	%	29.69	70.31	%	47.92	52.08			
49														236	338	574								85	99	184								80	127	207								71	112	183		
50										%	37.36	62.64	%	41.11	58.89					%	43.28	56.72	%	46.2	53.8					%	33.72	66.28	%	38.65	61.35					%	35.27	64.73	%	38.8	61.2			
51																																																

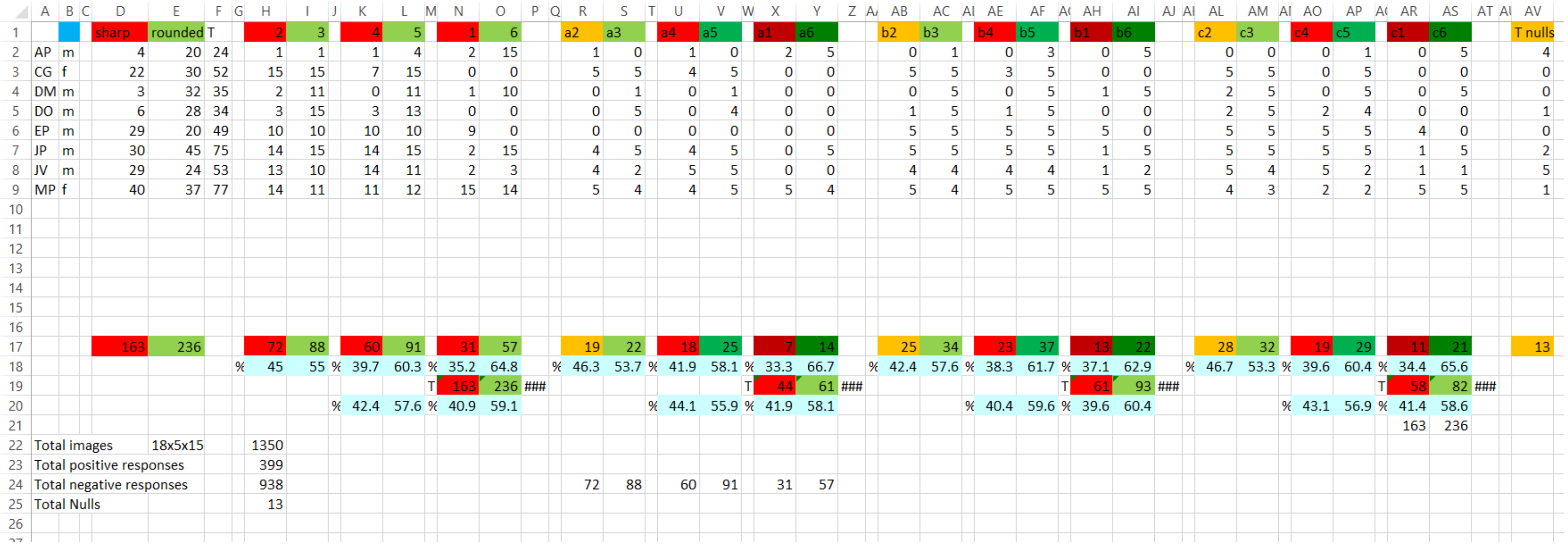
Screenshot IX. Consistent response data arrangement for all groups A B C and D - Experiment 1 - aesthetic judgement run, 2^{nd} sequence.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1		Inverted	R		Null	Normal	R		Null			R	Null		R	Null		R	Null		R	Null		R	Null
2	1	b5.png	1	1.865535		a4.png	1	0.968879			a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0
3	2	a5.png	1	1.412353		c5.png	1	1.031591			a2.png	1	0	a2.png	1	0	a2.png	1	0	a2.png	1	0	a2.png	1	0
4	3	a6.png	1	1.03152		a6.png	1	0.63076			a3.png	0	0	a3.png	1	0	a3.png	1	0	a3.png	1	0	a3.png	1	0
5	4	b3.png	0	2.188002		b5.png	1	1.094155			a4.png	0	0	a4.png	1	0	a4.png	1	0	a4.png	1	0	a4.png	1	0
6	5	c3.png	0	1.31312		a2.png	1	0.719123			a5.png	1	0	a5.png	1	0	a5.png	1	0	a5.png	1	0	a5.png	1	0
7	6	a4.png	0	1.375037		a1.png	1	1.094178			a6.png	1	0	a6.png	1	0	a6.png	Non	1	a6.png	1	0	a6.png	1	0
8	7	a1.png	1	1.49409		c1.png	1	1.094078																	
9	8	b6.png	1	0.90662		b2.png	1	0.818196			b1.png	1	0	b1.png	1	0	b1.png	1	0	b1.png	1	0	b1.png	1	0
10	9	b1.png	1	1.600081		b4.png	1	1.020678			b2.png	1	0	b2.png	1	0	b2.png	1	0	b2.png	1	0	b2.png	1	0
11	10	c6.png	1	0.844088		b3.png	1	0.688005			b3.png	0	0	b3.png	1	0	b3.png	1	0	b3.png	1	0	b3.png	1	0
12	11	c4.png	0	1.162469		b6.png	1	0.719253			b4.png	1	0	b4.png	1	0	b4.png	1	0	b4.png	1	0	b4.png	1	0
13	12	a2.png	1	0.96831		a5.png	1	1.318858			b5.png	1	0	b5.png	1	0	b5.png	1	0	b5.png	1	0	b5.png	1	0
14	13	b4.png	1	1.781596		b1.png	1	1.25036			b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0
15	14	c1.png	1	1.179948		c2.png	1	0.500277																	
16	15	a3.png	0	1.781807		c4.png	1	0.625271			c1.png	1	0	c1.png	1	0	c1.png	1	0	c1.png	1	0	c1.png	1	0
17	16	b2.png	1	2.719117		a3.png	1	1.18794			c2.png	0	0	c2.png	1	0	c2.png	1	0	c2.png	1	0	c2.png	1	0
18	17	c2.png	0	1.34417		c6.png	1	0.725089			c3.png	0	0	c3.png	0	0	c3.png	1	0	c3.png	1	0	c3.png	1	0
19	18	c5.png	0	1.219045		c3.png	1	0.531634			c4.png	0	0	c4.png	1	0	c4.png	0	0	c4.png	1	0	c4.png	0	0
20	1	a4.png	1	1.656655		b5.png	1	0.68825			c5.png	0	0	c5.png	0	0	c5.png	0	0	c5.png	1	0	c5.png	1	0
21	2	c4.png	1	1.787082		a3.png	1	0.932673			c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0
22	3	a5.png	1	1.031916		a2.png	1	0.943805																	
23	4	c6.png	1	0.875408		a4.png	1	0.750166				M	F												
24	5	c5.png	0	1.454665		b6.png	1	0.594118			Gender	0	1												
25	6	b6.png	1	1.09367		c3.png	1	1.00094																	
26	7	a1.png	1	1.287188		b2.png	1	1.094332				R	Null		R	Null		R	Null		R	Null		R	Null
27	8	a2.png	1	1.469172		b1.png	1	0.656323			a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0	a1.png	1	0
28	9	a3.png	1	1.000909		c2.png	1	1.031739			a2.png	1	0	a2.png	1	0	a2.png	1	0	a2.png	1	0	a2.png	1	0
29	10	c3.png	0	1.194029		c4.png	1	0.781609			a3.png	1	0	a3.png	1	0	a3.png	1	0	a3.png	1	0	a3.png	1	0
30	11	c2.png	1	0.844193		c1.png	1	0.844317			a4.png	1	0	a4.png	1	0	a4.png	1	0	a4.png	1	0	a4.png	1	0
31	12	b3.png	1	1.250364		a6.png	1	0.72433			a5.png	1	0	a5.png	1	0	a5.png	1	0	a5.png	1	0	a5.png	1	0
32	13	c1.png	1	1.381281		a1.png	1	1.437892			a6.png	1	0	a6.png	1	0	a6.png	1	0	a6.png	1	0	a6.png	1	0
33	14	b4.png	1	1.156495		b4.png	1	0.782066																	
34	15	b2.png	1	0.812872		a5.png	1	0.626063			b1.png	1	0	b1.png	1	0	b1.png	0	0	b1.png	1	0	b1.png	1	0
35	16	b5.png	1	0.937957		c5.png	1	1.406853			b2.png	1	0	b2.png	1	0	b2.png	1	0	b2.png	1	0	b2.png	1	0
36	17	b1.png	1	1.000908		b3.png	1	0.625455			b3.png	1	0	b3.png	1	0	b3.png	1	0	b3.png	1	0	b3.png	1	0
37	18	a6.png	1	0.906652		c6.png	1	0.750648			b4.png	1	0	b4.png	1	0	b4.png	1	0	b4.png	1	0	b4.png	1	0
38	1	c5.png	0	1.187833		b2.png	1	2.068266			b5.png	1	0	b5.png	1	0	b5.png	1	0	b5.png	1	0	b5.png	1	0
39	2	a2.png	1	0.849533		b5.png	1	0.719433			b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0	b6.png	1	0
40	3	c4.png	0	2.115636		a3.png	1	0.928247																	
41	4	c6.png	1	0.812803		a4.png	1	1.187969			c1.png	1	0	c1.png	1	0	c1.png	1	0	c1.png	1	0	c1.png	1	0
42	5	c1.png	1	0.927534		c2.png	1	1.000943			c2.png	1	0	c2.png	1	0	c2.png	1	0	c2.png	1	0	c2.png	1	0
43	6	b4.png	1	1.813063		a6.png	1	0.750365			c3.png	1	0	c3.png	1	0	c3.png	1	0	c3.png	1	0	c3.png	1	0
44	7	c3.png	1	0.844325		b1.png	0	0.687928			c4.png	1	0	c4.png	1	0	c4.png	1	0	c4.png	1	0	c4.png	1	0
45	8	b6.png	1	0.687986		b3.png	1	0.813189			c5.png	1	0	c5.png	1	0	c5.png	1	0	c5.png	1	0	c5.png	1	0
46	9	a5.png	1	1.094221		a1.png	1	2.000386			c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0	c6.png	1	0
47	10	a1.png	1	1.952821		a5.png	1	0.843979																	
48	11	b3.png	1	0.844391		b6.png	1	1.094379																	

	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1		sum	Null		1	2	3	4	5	6		a, b, c	1, 2, 4	3, 5, 6		
2		5	0		5											
3		5	0			5										
4		4	0				4									
5		4	0					4								
6		5	0						5							
7		4	1							4						
8					5	5	4	4	5	4	t	27	14	13		
9		5	0		5											
10		5	0			5										
11		4	0				4									
12		5	0					5								
13		5	0						5							
14		5	0							5						
15					5	5	4	5	5	5	t	29	15	14		
16		5	0		5											
17		4	0			4										
18		3	0				3									
19		2	0					2								
20		2	0						2							
21		5	0							5						
22					5	4	3	2	2	5	t	21	11	10		
23		77	1	T	15	14	11	11	12	14	T	77	40	37		77
24																
25																
26		sum	Null		1	2	3	4	5	6		a, b, c	1, 2, 4	3, 5, 6		
27		5	0		5											
28		5	0			5										
29		5	0				5									
30		5	0					5								
31		5	0						5							
32		5	0							5						
33					5	5	5	5	5	5	t	30	15	15		
34		4	0		4											
35		5	0			5										
36		5	0				5									
37		5	0					5								
38		5	0						5							
39		5	0							5						
40					4	5	5	5	5	5	t	29	14	15		
41		5	0		5											
42		5	0			5										
43		5	0				5									
44		5	0					5								
45		5	0						5							
46		5	0							5						
47					5	5	5	5	5	5	t	30	15	15		
48		89	0	T	14	15	15	15	15	15	T	89	44	45		89

Screenshot X. Data collection and arrangement for aleatory sample participant MP - Experiment 2 - approach-avoidance decision run. This procedure was repeated for all 32 participants.

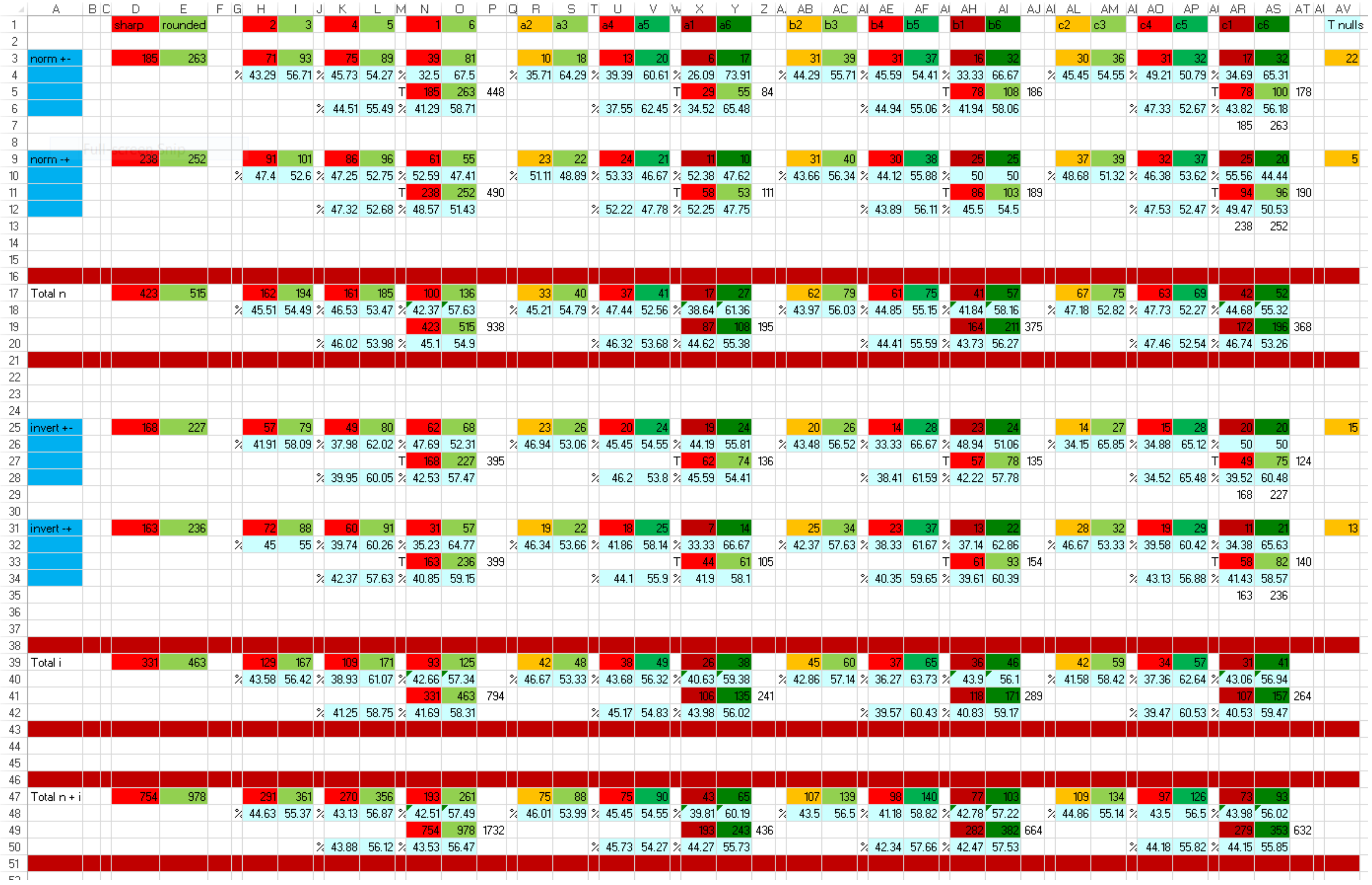


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1		🟦		sharp	rounded	T		2	3		4	5		1	6	
2	AP	m		4	20	24		1	1		1	4		2	15	
3	CG	f		22	30	52		15	15		7	15		0	0	
4	DM	m		3	32	35		2	11		0	11		1	10	
5	DO	m		6	28	34		3	15		3	13		0	0	
6	EP	m		29	20	49		10	10		10	10		9	0	
7	JP	m		30	45	75		14	15		14	15		2	15	
8	JV	m		29	24	53		13	10		14	11		2	3	
9	MP	f		40	37	77		14	11		11	12		15	14	
10																
11																
12																
13																
14																
15																
16																
17				163	236			72	88		60	91		31	57	
18							%	45	55	%	39.7	60.3	%	35.2	64.8	
19													T	163	236	###
20										%	42.4	57.6	%	40.9	59.1	
21																
22	Total images				18x5x15			1350								
23	Total positive responses							399								
24	Total negative responses							938								
25	Total Nulls							13								
26																

	Q	R	S	T	U	V	W	X	Y	Z	A/	AB	AC	AI	AE	AF	A(
1		a2	a3		a4	a5		a1	a6			b2	b3		b4	b5	
2		1	0		1	0		2	5			0	1		0	3	
3		5	5		4	5		0	0			5	5		3	5	
4		0	1		0	1		0	0			0	5		0	5	
5		0	5		0	4		0	0			1	5		1	5	
6		0	0		0	0		0	0			5	5		5	5	
7		4	5		4	5		0	5			5	5		5	5	
8		4	2		5	5		0	0			4	4		4	4	
9		5	4		4	5		5	4			5	4		5	5	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17		19	22		18	25		7	14			25	34		23	37	
18	%	46.3	53.7	%	41.9	58.1	%	33.3	66.7		%	42.4	57.6	%	38.3	61.7	%
19							T	44	61	###							T
20				%	44.1	55.9	%	41.9	58.1					%	40.4	59.6	%
21																	
22																	
23																	
24		72	88		60	91		31	57								
25																	
26																	

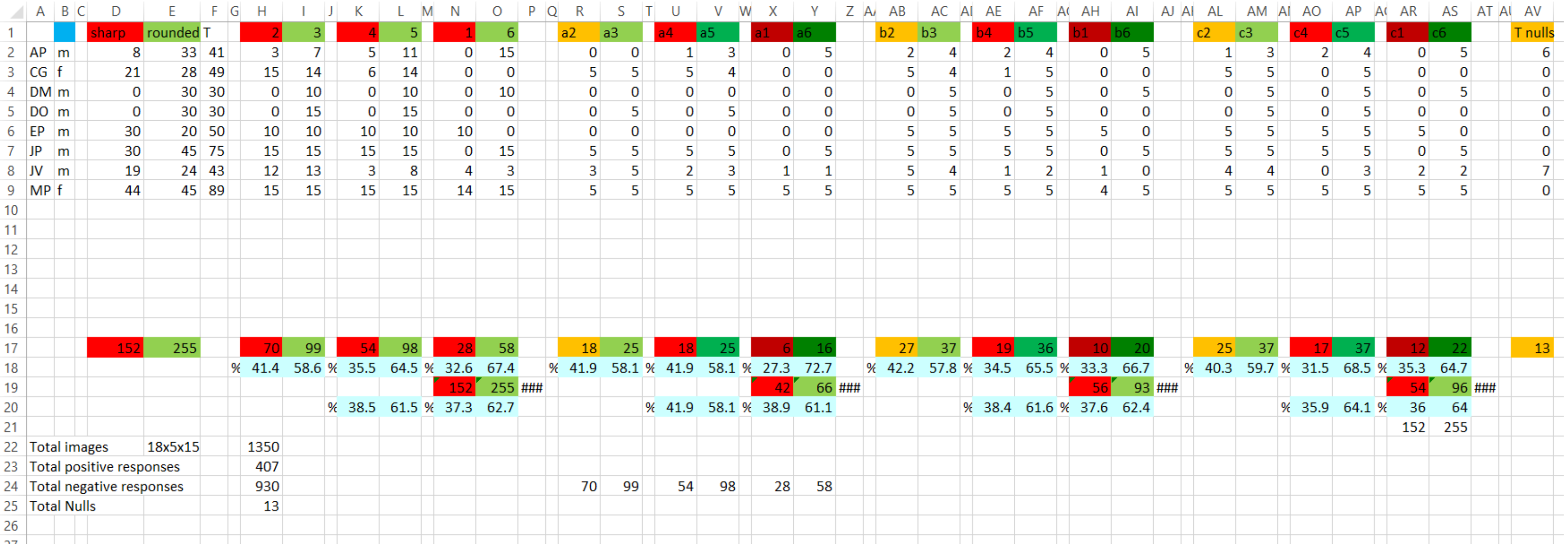
	AH	AI	AJ	AI	AL	AM	AI	AO	AP	A(	AR	AS	AT	AI	AV
1	b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2	0	5			0	0		0	1		0	5			4
3	0	0			5	5		0	5		0	0			0
4	1	5			2	5		0	5		0	5			0
5	0	0			2	5		2	4		0	0			1
6	5	0			5	5		5	5		4	0			0
7	1	5			5	5		5	5		1	5			2
8	1	2			5	4		5	2		1	1			5
9	5	5			4	3		2	2		5	5			1
10															
11															
12															
13															
14															
15															
16															
17	13	22			28	32		19	29		11	21			13
18	37.1	62.9		%	46.7	53.3	%	39.6	60.4	%	34.4	65.6			
19	61	93	###							T	58	82	###		
20	39.6	60.4					%	43.1	56.9	%	41.4	58.6			
21											163	236			
22															
23															
24															
25															
26															

Screenshot XI. General data arrangement from all participants of group A - Experiment 2 - approach-avoidance decision run, 1st sequence. This analysis was repeated for all 4 groups.



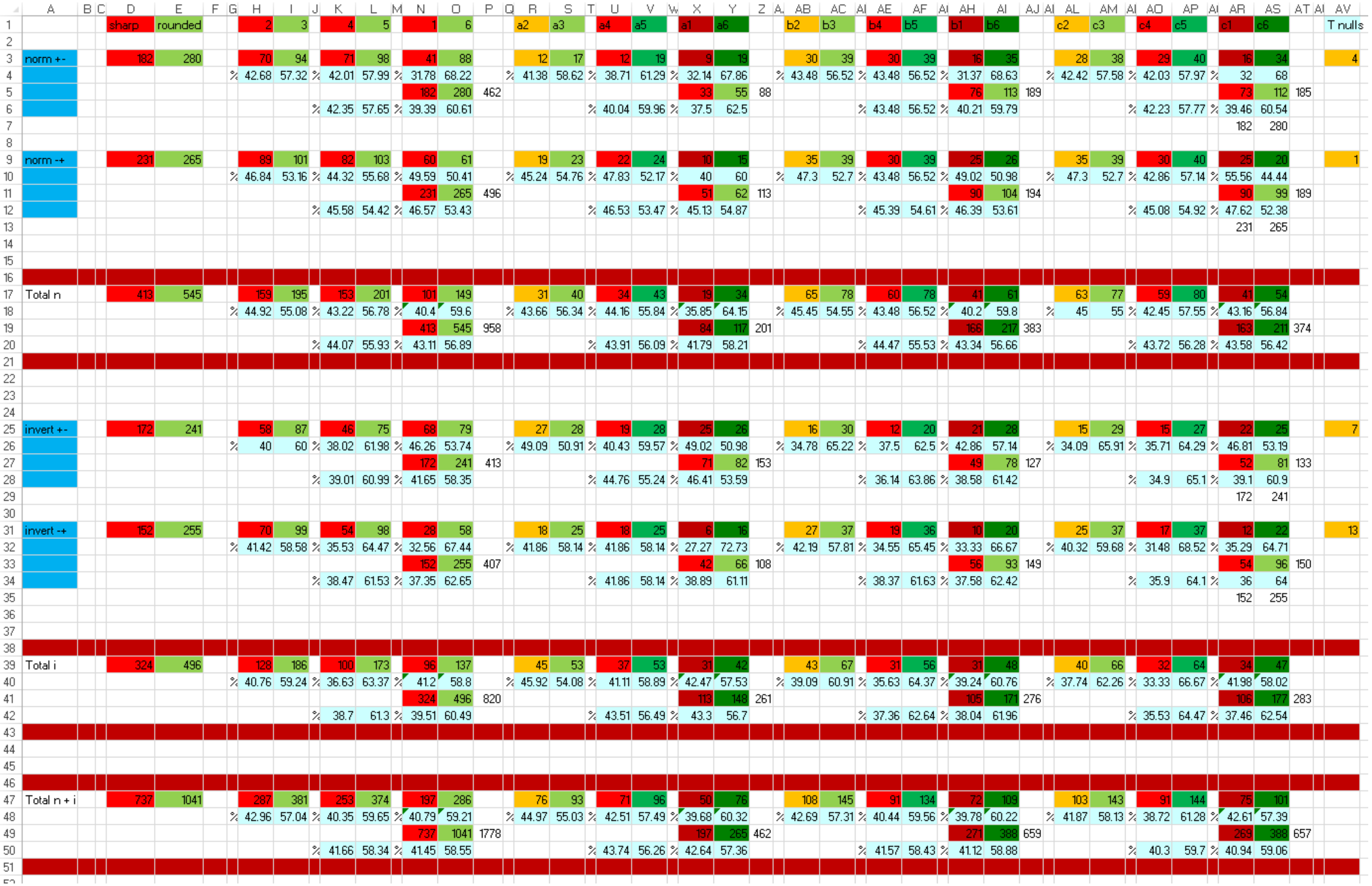
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			185	263			71	93		75	89		39	81			10	18		13	20		6	17			31	39		31	37		16	32			30	36		31	32		17	32			22
4							%	43.29	56.71	%	45.73	54.27	%	32.5	67.5		%	35.71	64.29	%	39.39	60.61	%	26.09	73.91		%	44.29	55.71	%	45.59	54.41	%	33.33	66.67		%	45.45	54.55	%	49.21	50.79	%	34.69	65.31			
5													T	185	263	448							T	29	55	84							T	78	108	186							T	78	100	178		
6										%	44.51	55.49	%	41.29	58.71					%	37.55	62.45	%	34.52	65.48					%	44.94	55.06	%	41.94	58.06					%	47.33	52.67	%	43.82	56.18			
7																																												185	263			
8																																																
9	norm -+			238	252			91	101		86	96		61	55			23	22		24	21		11	10			31	40		30	38		25	25			37	39		32	37		25	20			5
10							%	47.4	52.6	%	47.25	52.75	%	52.59	47.41		%	51.11	48.89	%	53.33	46.67	%	52.38	47.62		%	43.66	56.34	%	44.12	55.88	%	50	50		%	48.68	51.32	%	46.38	53.62	%	55.56	44.44			
11													T	238	252	490							T	58	53	111							T	86	103	189							T	94	96	190		
12										%	47.32	52.68	%	48.57	51.43					%	52.22	47.78	%	52.25	47.75					%	43.89	56.11	%	45.5	54.5					%	47.53	52.47	%	49.47	50.53			
13																																												238	252			
14																																																
15																																																
16																																																
17	Total n			423	515			162	194		161	185		100	136			33	40		37	41		17	27			62	79		61	75		41	57			67	75		63	69		42	52			
18							%	45.51	54.49	%	46.53	53.47	%	42.37	57.63		%	45.21	54.79	%	47.44	52.56	%	38.64	61.36		%	43.97	56.03	%	44.85	55.15	%	41.84	58.16		%	47.18	52.82	%	47.73	52.27	%	44.68	55.32			
19														423	515	938								87	108	195								164	211	375								172	196	368		
20										%	46.02	53.98	%	45.1	54.9					%	46.32	53.68	%	44.62	55.38					%	44.41	55.59	%	43.73	56.27					%	47.46	52.54	%	46.74	53.26			
21																																																
22																																																
23																																																
24																																																
25	invert +-			168	227			57	79		49	80		62	68			23	26		20	24		19	24			20	26		14	28		23	24			14	27		15	28		20	20			15
26							%	41.91	58.09	%	37.98	62.02	%	47.69	52.31		%	46.94	53.06	%	45.45	54.55	%	44.19	55.81		%	43.48	56.52	%	33.33	66.67	%	48.94	51.06		%	34.15	65.85	%	34.88	65.12	%	50	50			
27													T	168	227	395							T	62	74	136							T	57	78	135							T	49	75	124		
28										%	39.95	60.05	%	42.53	57.47					%	46.2	53.8	%	45.59	54.41					%	38.41	61.59	%	42.22	57.78					%	34.52	65.48	%	39.52	60.48			
29																																												168	227			
30																																																
31	invert -+			163	236			72	88		60	91		31	57			19	22		18	25		7	14			25	34		23	37		13	22			28	32		19	29		11	21			13
32							%	45	55	%	39.74	60.26	%	35.23	64.77		%	46.34	53.66	%	41.86	58.14	%	33.33	66.67		%	42.37	57.63	%	38.33	61.67	%	37.14	62.86		%	46.67	53.33	%	39.58	60.42	%	34.38	65.63			
33													T	163	236	399							T	44	61	105							T	61	93	154							T	58	82	140		
34										%	42.37	57.63	%	40.85	59.15					%	44.1	55.9	%	41.9	58.1					%	40.35	59.65	%	39.61	60.39					%	43.13	56.88	%	41.43	58.57			
35																																												163	236			
36																																																
37																																																
38																																																
39	Total i			331	463			129	167		109	171		93	125			42	48		38	49		26	38			45	60		37	65		36	46			42	59		34	57		31	41			
40							%	43.58	56.42	%	38.93	61.07	%	42.66	57.34		%	46.67	53.33	%	43.68	56.32	%	40.63	59.38		%	42.86	57.14	%	36.27	63.73	%	43.9	56.1		%	41.58	58.42	%	37.36	62.64	%	43.06	56.94			
41														331	463	794								106	135	241								118	171	289								107	157	264		
42										%	41.25	58.75	%	41.69	58.31					%	45.17	54.83	%	43.98	56.02					%	39.57	60.43	%	40.83	59.17					%	39.47	60.53	%	40.53	59.47			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			754	978			291	361		270	356		193	261			75	88		75	90		43	65			107	139		98	140		77	103			109	134		97	126		73	93			
48							%	44.63	55.37	%	43.13	56.87	%	42.51	57.49		%	46.01	53.99	%	45.45	54.55	%	39.81	60.19		%	43.5	56.5	%	41.18	58.82	%	42.78	57.22		%	44.86	55.14	%	43.5	56.5	%	43.98	56.02			
49														754	978	1732								193	243	436								282	382	664								279	353	632		
50										%	43.88	56.12	%	43.53	56.47					%	45.73	54.27	%	44.27	55.73					%	42.34	57.66	%	42.47	57.53					%	44.18	55.82	%	44.15	55.85			
51																																																

Screenshot XII. General data arrangement for all groups A B C and D - Experiment 2 - approach-avoidance decision run, 1st sequence.



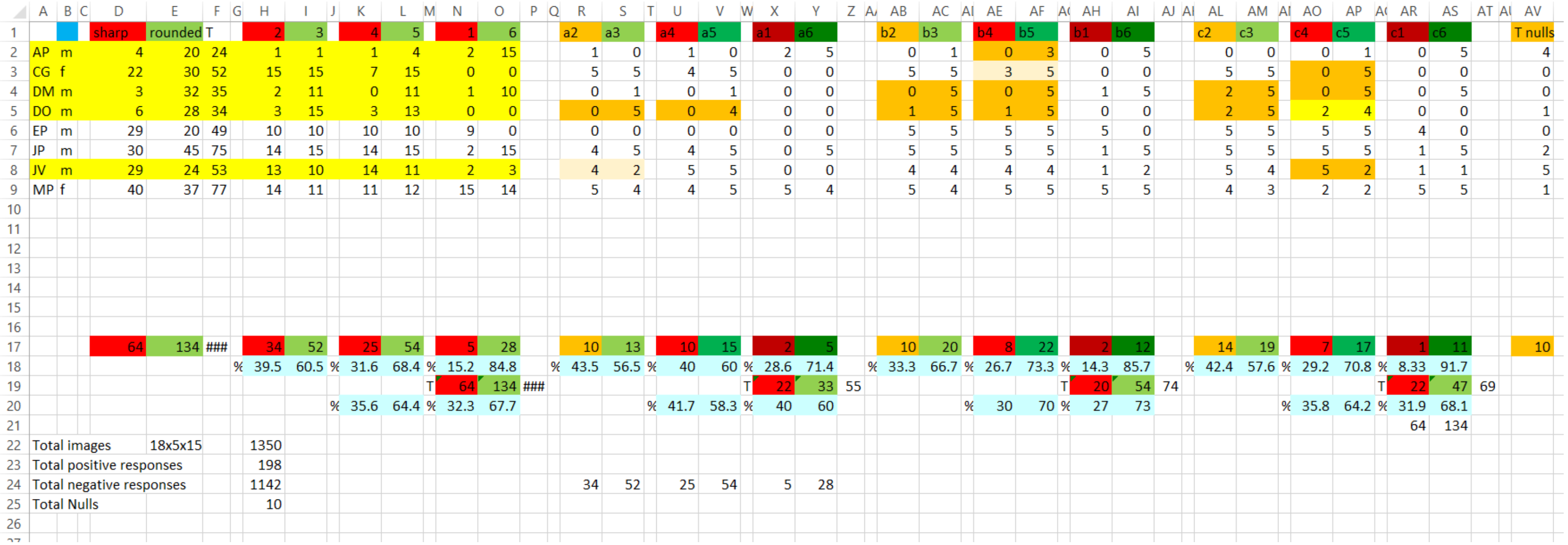
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A/	AB	AC	AI	AE	AF	A(	AH	AI	AJ	AI	AL	AM	AI	AO	AP	A(	AR	AS	AT	AI	AV
1		🟦		sharp	rounded	T		2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2	AP	m		8	33	41		3	7		5	11		0	15			0	0		1	3		0	5			2	4		2	4		0	5			1	3		2	4		0	5			6
3	CG	f		21	28	49		15	14		6	14		0	0			5	5		5	4		0	0			5	4		1	5		0	0			5	5		0	5		0	0			0
4	DM	m		0	30	30		0	10		0	10		0	10			0	0		0	0		0	0			0	5		0	5		0	5			0	5		0	5		0	5			0
5	DO	m		0	30	30		0	15		0	15		0	0			0	5		0	5		0	0			0	5		0	5		0	0			0	5		0	5		0	0			0
6	EP	m		30	20	50		10	10		10	10		10	0			0	0		0	0		0	0			5	5		5	5		5	0			5	5		5	5		5	0			0
7	JP	m		30	45	75		15	15		15	15		0	15			5	5		5	5		0	5			5	5		5	5		0	5			5	5		5	5		0	5			0
8	JV	m		19	24	43		12	13		3	8		4	3			3	5		2	3		1	1			5	4		1	2		1	0			4	4		0	3		2	2			7
9	MP	f		44	45	89		15	15		15	15		14	15			5	5		5	5		5	5			5	5		5	5		4	5			5	5		5	5		5	5			0
10																																																
11																																																
12																																																
13																																																
14																																																
15																																																
16																																																
17				152	255			70	99		54	98		28	58			18	25		18	25		6	16			27	37		19	36		10	20			25	37		17	37		12	22			13
18							%	41.4	58.6	%	35.5	64.5	%	32.6	67.4		%	41.9	58.1	%	41.9	58.1	%	27.3	72.7		%	42.2	57.8	%	34.5	65.5	%	33.3	66.7		%	40.3	59.7	%	31.5	68.5	%	35.3	64.7			
19														152	255	###								42	66	###								56	93	###								54	96	###		
20										%	38.5	61.5	%	37.3	62.7					%	41.9	58.1	%	38.9	61.1					%	38.4	61.6	%	37.6	62.4					%	35.9	64.1	%	36	64			
21																																												152	255			
22	Total images				18x5x15			1350																																								
23	Total positive responses							407																																								
24	Total negative responses							930										70	99		54	98		28	58																							
25	Total Nulls							13																																								
26																																																

Screenshot XIII. General data arrangement from all participants of group A - Experiment 2 - approach-avoidance decision run, 2nd sequence. This analysis was repeated for all 4 groups.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			182	280			70	94		71	98		41	88			12	17		12	19		9	19			30	39		30	39		16	35			28	38		29	40		16	34			4
4							%	42.68	57.32	%	42.01	57.99	%	31.78	68.22		%	41.38	58.62	%	38.71	61.29	%	32.14	67.86		%	43.48	56.52	%	43.48	56.52	%	31.37	68.63		%	42.42	57.58	%	42.03	57.97	%	32	68			
5														182	280	462								33	55	88								76	113	189								73	112	185		
6										%	42.35	57.65	%	39.39	60.61					%	40.04	59.96	%	37.5	62.5					%	43.48	56.52	%	40.21	59.79					%	42.23	57.77	%	39.46	60.54			
7																																												182	280			
8																																																
9	norm -+			231	265			89	101		82	103		60	61			19	23		22	24		10	15			35	39		30	39		25	26			35	39		30	40		25	20			1
10							%	46.84	53.16	%	44.32	55.68	%	49.59	50.41		%	45.24	54.76	%	47.83	52.17	%	40	60		%	47.3	52.7	%	43.48	56.52	%	49.02	50.98		%	47.3	52.7	%	42.86	57.14	%	55.56	44.44			
11														231	265	496								51	62	113								90	104	194								90	99	189		
12										%	45.58	54.42	%	46.57	53.43					%	46.53	53.47	%	45.13	54.87					%	45.39	54.61	%	46.39	53.61					%	45.08	54.92	%	47.62	52.38			
13																																												231	265			
14																																																
15																																																
16																																																
17	Total n			413	545			159	195		153	201		101	149			31	40		34	43		19	34			65	78		60	78		41	61			63	77		59	80		41	54			
18							%	44.92	55.08	%	43.22	56.78	%	40.4	59.6		%	43.66	56.34	%	44.16	55.84	%	35.85	64.15		%	45.45	54.55	%	43.48	56.52	%	40.2	59.8		%	45	55	%	42.45	57.55	%	43.16	56.84			
19														413	545	958								84	117	201								166	217	383								163	211	374		
20										%	44.07	55.93	%	43.11	56.89					%	43.91	56.09	%	41.79	58.21					%	44.47	55.53	%	43.34	56.66					%	43.72	56.28	%	43.58	56.42			
21																																																
22																																																
23																																																
24																																																
25	invert +-			172	241			58	87		46	75		68	79			27	28		19	28		25	26			16	30		12	20		21	28			15	29		15	27		22	25			7
26							%	40	60	%	38.02	61.98	%	46.26	53.74		%	49.09	50.91	%	40.43	59.57	%	49.02	50.98		%	34.78	65.22	%	37.5	62.5	%	42.86	57.14		%	34.09	65.91	%	35.71	64.29	%	46.81	53.19			
27														172	241	413								71	82	153								49	78	127								52	81	133		
28										%	39.01	60.99	%	41.65	58.35					%	44.76	55.24	%	46.41	53.59					%	36.14	63.86	%	38.58	61.42					%	34.9	65.1	%	39.1	60.9			
29																																												172	241			
30																																																
31	invert -+			152	255			70	99		54	98		28	58			18	25		18	25		6	16			27	37		19	36		10	20			25	37		17	37		12	22			13
32							%	41.42	58.58	%	35.53	64.47	%	32.56	67.44		%	41.86	58.14	%	41.86	58.14	%	27.27	72.73		%	42.19	57.81	%	34.55	65.45	%	33.33	66.67		%	40.32	59.68	%	31.48	68.52	%	35.29	64.71			
33														152	255	407								42	66	108								56	93	149								54	96	150		
34										%	38.47	61.53	%	37.35	62.65					%	41.86	58.14	%	38.89	61.11					%	38.37	61.63	%	37.58	62.42					%	35.9	64.1	%	36	64			
35																																												152	255			
36																																																
37																																																
38																																																
39	Total i			324	496			128	186		100	173		96	137			45	53		37	53		31	42			43	67		31	56		31	48			40	66		32	64		34	47			
40							%	40.76	59.24	%	36.63	63.37	%	41.2	58.8		%	45.92	54.08	%	41.11	58.89	%	42.47	57.53		%	39.09	60.91	%	35.63	64.37	%	39.24	60.76		%	37.74	62.26	%	33.33	66.67	%	41.98	58.02			
41														324	496	820								113	148	261								105	171	276								106	177	283		
42										%	38.7	61.3	%	39.51	60.49					%	43.51	56.49	%	43.3	56.7					%	37.36	62.64	%	38.04	61.96					%	35.53	64.47	%	37.46	62.54			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			737	1041			287	381		253	374		197	286			76	93		71	96		50	76			108	145		91	134		72	109			103	143		91	144		75	101			
48							%	42.96	57.04	%	40.35	59.65	%	40.79	59.21		%	44.97	55.03	%	42.51	57.49	%	39.68	60.32		%	42.69	57.31	%	40.44	59.56	%	39.78	60.22		%	41.87	58.13	%	38.72	61.28	%	42.61	57.39			
49														737	1041	1778								197	265	462								271	388	659								269	388	657		
50										%	41.66	58.34	%	41.45	58.55					%	43.74	56.26	%	42.64	57.36					%	41.57	58.43	%	41.12	58.88					%	40.3	59.7	%	40.94	59.06			
51																																																

Screenshot XIV. General data arrangement for all groups A B C and D - Experiment 2 - approach-avoidance decision run, 2nd sequence.

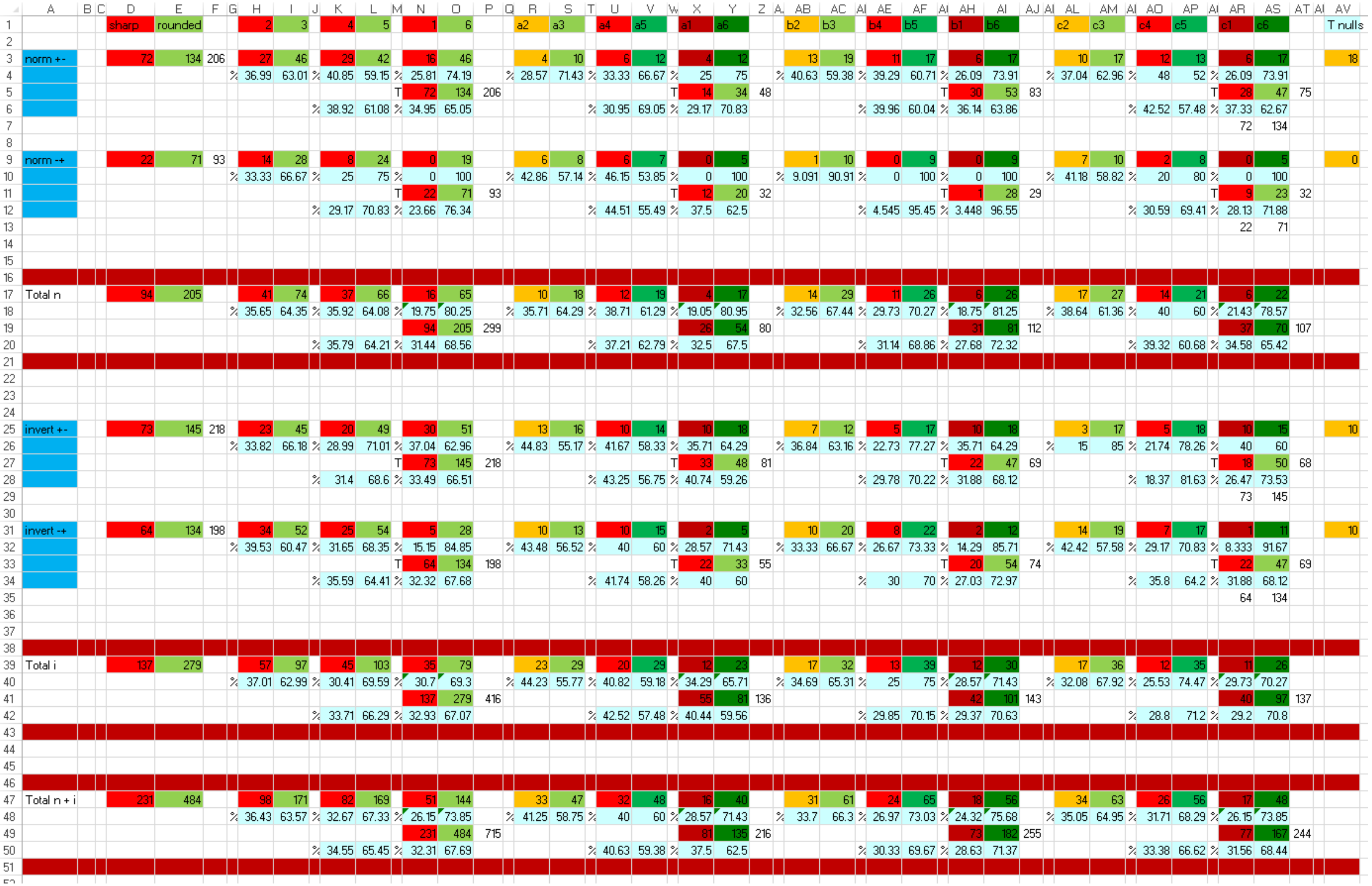


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1				sharp	rounded	T		2	3		4	5		1	6	
2	AP	m		4	20	24		1	1		1	4		2	15	
3	CG	f		22	30	52		15	15		7	15		0	0	
4	DM	m		3	32	35		2	11		0	11		1	10	
5	DO	m		6	28	34		3	15		3	13		0	0	
6	EP	m		29	20	49		10	10		10	10		9	0	
7	JP	m		30	45	75		14	15		14	15		2	15	
8	JV	m		29	24	53		13	10		14	11		2	3	
9	MP	f		40	37	77		14	11		11	12		15	14	
10																
11																
12																
13																
14																
15																
16																
17				64	134	###		34	52		25	54		5	28	
18							%	39.5	60.5	%	31.6	68.4	%	15.2	84.8	
19													T	64	134	###
20										%	35.6	64.4	%	32.3	67.7	
21																
22	Total images				18x5x15			1350								
23	Total positive responses							198								
24	Total negative responses							1142								
25	Total Nulls							10								
26																

	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1		a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6	
2		1	0		1	0		2	5			0	1		0	3		0	5	
3		5	5		4	5		0	0			5	5		3	5		0	0	
4		0	1		0	1		0	0			0	5		0	5		1	5	
5		0	5		0	4		0	0			1	5		1	5		0	0	
6		0	0		0	0		0	0			5	5		5	5		5	0	
7		4	5		4	5		0	5			5	5		5	5		1	5	
8		4	2		5	5		0	0			4	4		4	4		1	2	
9		5	4		4	5		5	4			5	4		5	5		5	5	
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17		10	13		10	15		2	5			10	20		8	22		2	12	
18	%	43.5	56.5	%	40	60	%	28.6	71.4		%	33.3	66.7	%	26.7	73.3	%	14.3	85.7	
19							T	22	33	55							T	20	54	74
20				%	41.7	58.3	%	40	60					%	30	70	%	27	73	
21																				
22																				
23																				
24		34	52		25	54		5	28											
25																				
26																				

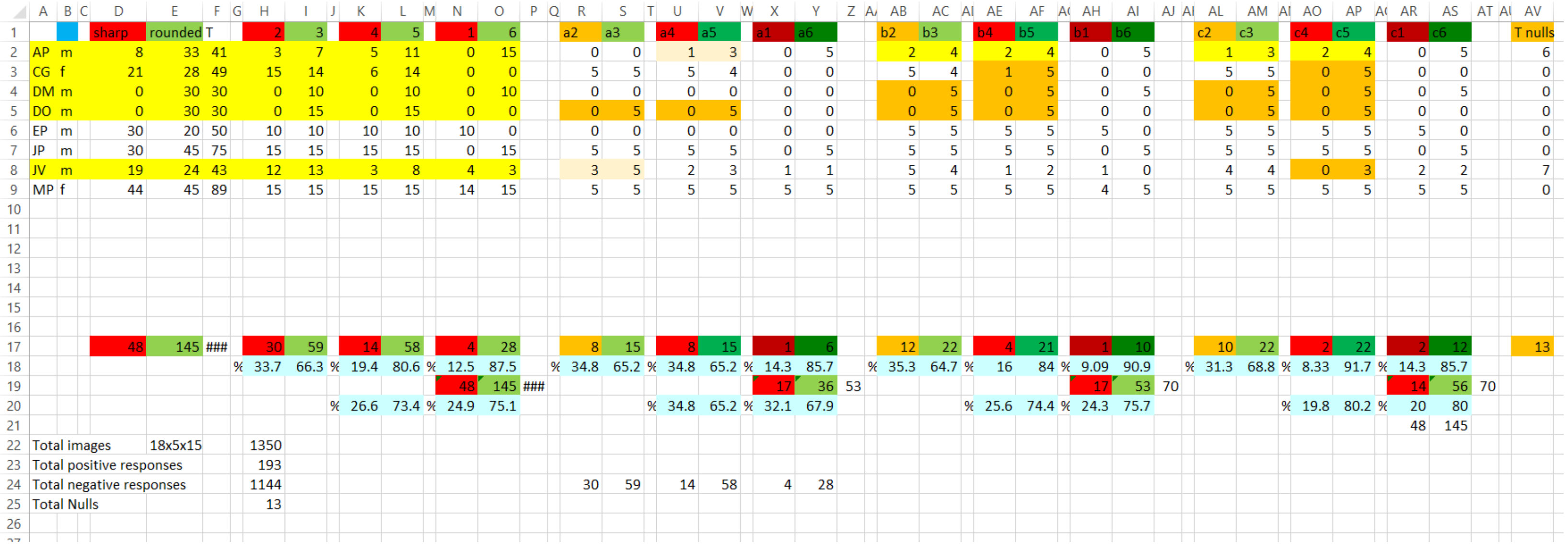
	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
1		c2	c3		c4	c5		c1	c6			T nulls
2		0	0		0	1		0	5			4
3		5	5		0	5		0	0			0
4		2	5		0	5		0	5			0
5		2	5		2	4		0	0			1
6		5	5		5	5		4	0			0
7		5	5		5	5		1	5			2
8		5	4		5	2		1	1			5
9		4	3		2	2		5	5			1
10												
11												
12												
13												
14												
15												
16												
17		14	19		7	17		1	11			10
18	%	42.4	57.6	%	29.2	70.8	%	8.33	91.7			
19							T	22	47	69		
20				%	35.8	64.2	%	31.9	68.1			
21								64	134			
22												
23												
24												
25												
26												

Screenshot XV. Consistent response data arrangement from all participants of group A - Experiment 2 - approach-avoidance decision run, 1st sequence. This analysis was repeated for all 4 groups.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			72	134	206		27	46		29	42		16	46			4	10		6	12		4	12			13	19		11	17		6	17			10	17		12	13		6	17			18
4							%	36.99	63.01	%	40.85	59.15	%	25.81	74.19		%	28.57	71.43	%	33.33	66.67	%	25	75		%	40.63	59.38	%	39.29	60.71	%	26.09	73.91		%	37.04	62.96	%	48	52	%	26.09	73.91			
5													T	72	134	206							T	14	34	48							T	30	53	83							T	28	47	75		
6										%	38.92	61.08	%	34.95	65.05					%	30.95	69.05	%	29.17	70.83					%	39.96	60.04	%	36.14	63.86					%	42.52	57.48	%	37.33	62.67			
7																																												72	134			
8																																																
9	norm -+			22	71	93		14	28		8	24		0	19			6	8		6	7		0	5			1	10		0	9		0	9			7	10		2	8		0	5			0
10							%	33.33	66.67	%	25	75	%	0	100		%	42.86	57.14	%	46.15	53.85	%	0	100		%	9.091	90.91	%	0	100	%	0	100		%	41.18	58.82	%	20	80	%	0	100			
11													T	22	71	93							T	12	20	32							T	1	28	29							T	9	23	32		
12										%	29.17	70.83	%	23.66	76.34					%	44.51	55.49	%	37.5	62.5					%	4.545	95.45	%	3.448	96.55					%	30.59	69.41	%	28.13	71.88			
13																																												22	71			
14																																																
15																																																
16																																																
17	Total n			94	205			41	74		37	66		16	65			10	18		12	19		4	17			14	29		11	26		6	26			17	27		14	21		6	22			
18							%	35.65	64.35	%	35.92	64.08	%	19.75	80.25		%	35.71	64.29	%	38.71	61.29	%	19.05	80.95		%	32.56	67.44	%	29.73	70.27	%	18.75	81.25		%	38.64	61.36	%	40	60	%	21.43	78.57			
19														94	205	299								26	54	80								31	81	112								37	70	107		
20										%	35.79	64.21	%	31.44	68.56					%	37.21	62.79	%	32.5	67.5					%	31.14	68.86	%	27.68	72.32					%	39.32	60.68	%	34.58	65.42			
21																																																
22																																																
23																																																
24																																																
25	invert +-			73	145	218		23	45		20	49		30	51			13	16		10	14		10	18			7	12		5	17		10	18			3	17		5	18		10	15			10
26							%	33.82	66.18	%	28.99	71.01	%	37.04	62.96		%	44.83	55.17	%	41.67	58.33	%	35.71	64.29		%	36.84	63.16	%	22.73	77.27	%	35.71	64.29		%	15	85	%	21.74	78.26	%	40	60			
27													T	73	145	218							T	33	48	81							T	22	47	69							T	18	50	68		
28										%	31.4	68.6	%	33.49	66.51					%	43.25	56.75	%	40.74	59.26					%	29.78	70.22	%	31.88	68.12					%	18.37	81.63	%	26.47	73.53			
29																																												73	145			
30																																																
31	invert -+			64	134	198		34	52		25	54		5	28			10	13		10	15		2	5			10	20		8	22		2	12			14	19		7	17		1	11			10
32							%	39.53	60.47	%	31.65	68.35	%	15.15	84.85		%	43.48	56.52	%	40	60	%	28.57	71.43		%	33.33	66.67	%	26.67	73.33	%	14.29	85.71		%	42.42	57.58	%	29.17	70.83	%	8.333	91.67			
33													T	64	134	198							T	22	33	55							T	20	54	74							T	22	47	69		
34										%	35.59	64.41	%	32.32	67.68					%	41.74	58.26	%	40	60					%	30	70	%	27.03	72.97					%	35.8	64.2	%	31.88	68.12			
35																																												64	134			
36																																																
37																																																
38																																																
39	Total i			137	279			57	97		45	103		35	79			23	29		20	29		12	23			17	32		13	39		12	30			17	36		12	35		11	26			
40							%	37.01	62.99	%	30.41	69.59	%	30.7	69.3		%	44.23	55.77	%	40.82	59.18	%	34.29	65.71		%	34.69	65.31	%	25	75	%	28.57	71.43		%	32.08	67.92	%	25.53	74.47	%	29.73	70.27			
41														137	279	416								55	81	136								42	101	143								40	97	137		
42										%	33.71	66.29	%	32.93	67.07					%	42.52	57.48	%	40.44	59.56					%	29.85	70.15	%	29.37	70.63					%	28.8	71.2	%	29.2	70.8			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			231	484			98	171		82	169		51	144			33	47		32	48		16	40			31	61		24	65		18	56			34	63		26	56		17	48			
48							%	36.43	63.57	%	32.67	67.33	%	26.15	73.85		%	41.25	58.75	%	40	60	%	28.57	71.43		%	33.7	66.3	%	26.97	73.03	%	24.32	75.68		%	35.05	64.95	%	31.71	68.29	%	26.15	73.85			
49														231	484	715								81	135	216								73	182	255								77	167	244		
50										%	34.55	65.45	%	32.31	67.69					%	40.63	59.38	%	37.5	62.5					%	30.33	69.67	%	28.63	71.37					%	33.38	66.62	%	31.56	68.44			
51																																																

Screenshot XVI. Consistent response data arrangement for all groups A B C and D - Experiment 2 - approach-avoidance decision run, 1^{st} sequence.

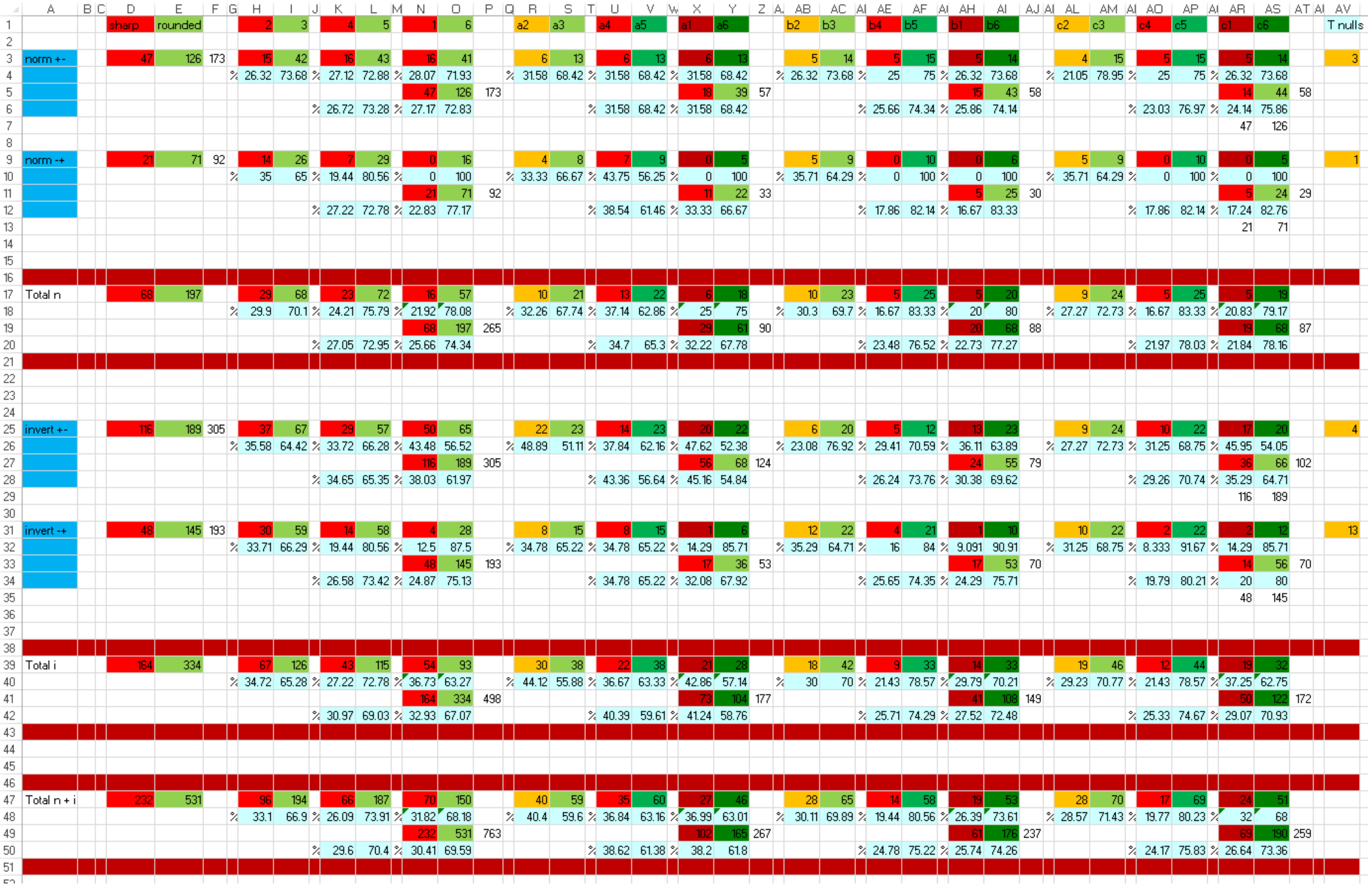


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		🟦		sharp	rounded	T		2	3		4	5		1	6		
2	AP	m		8	33	41		3	7		5	11		0	15		
3	CG	f		21	28	49		15	14		6	14		0	0		
4	DM	m		0	30	30		0	10		0	10		0	10		
5	DO	m		0	30	30		0	15		0	15		0	0		
6	EP	m		30	20	50		10	10		10	10		10	0		
7	JP	m		30	45	75		15	15		15	15		0	15		
8	JV	m		19	24	43		12	13		3	8		4	3		
9	MP	f		44	45	89		15	15		15	15		14	15		
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17				48	145	###		30	59		14	58		4	28		
18							%	33.7	66.3	%	19.4	80.6	%	12.5	87.5		%
19														48	145	###	
20										%	26.6	73.4	%	24.9	75.1		
21																	
22	Total images				18x5x15			1350									
23	Total positive responses							193									
24	Total negative responses							1144									
25	Total Nulls							13									
26																	

	R	S	T	U	V	W	X	Y	Z	A/	AB	AC	AI	AE	AF	A(
1	a2	a3		a4	a5		a1	a6			b2	b3		b4	b5	
2	0	0		1	3		0	5			2	4		2	4	
3	5	5		5	4		0	0			5	4		1	5	
4	0	0		0	0		0	0			0	5		0	5	
5	0	5		0	5		0	0			0	5		0	5	
6	0	0		0	0		0	0			5	5		5	5	
7	5	5		5	5		0	5			5	5		5	5	
8	3	5		2	3		1	1			5	4		1	2	
9	5	5		5	5		5	5			5	5		5	5	
10																
11																
12																
13																
14																
15																
16																
17	8	15		8	15		1	6			12	22		4	21	
18	34.8	65.2	%	34.8	65.2	%	14.3	85.7		%	35.3	64.7	%	16	84	%
19							17	36	53							
20			%	34.8	65.2	%	32.1	67.9					%	25.6	74.4	%
21																
22																
23																
24	30	59		14	58		4	28								
25																
26																

	AH	AI	AJ	AI	AL	AM	AI	AO	AP	A(	AR	AS	AT	AI	AV
1	b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2	0	5			1	3		2	4		0	5			6
3	0	0			5	5		0	5		0	0			0
4	0	5			0	5		0	5		0	5			0
5	0	0			0	5		0	5		0	0			0
6	5	0			5	5		5	5		5	0			0
7	0	5			5	5		5	5		0	5			0
8	1	0			4	4		0	3		2	2			7
9	4	5			5	5		5	5		5	5			0
10															
11															
12															
13															
14															
15															
16															
17	1	10			10	22		2	22		2	12			13
18	9.09	90.9		%	31.3	68.8	%	8.33	91.7	%	14.3	85.7			
19	17	53	70								14	56	70		
20	24.3	75.7					%	19.8	80.2	%	20	80			
21											48	145			
22															
23															
24															
25															
26															

Screenshot XVII. Consistent response data arrangement from all participants of group A - Experiment 2 - approach-avoidance decision run, 2nd sequence. This analysis was repeated for all 4 groups.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A.	AB	AC	AI	AE	AF	AI	AH	AI	AJ	AI	AL	AM	AI	AO	AP	AI	AR	AS	AT	AI	AV
1				sharp	rounded			2	3		4	5		1	6			a2	a3		a4	a5		a1	a6			b2	b3		b4	b5		b1	b6			c2	c3		c4	c5		c1	c6			T nulls
2																																																
3	norm +-			47	126	173		15	42		16	43		16	41			6	13		6	13		6	13			5	14		5	15		5	14			4	15		5	15		5	14			3
4							%	26.32	73.68	%	27.12	72.88	%	28.07	71.93		%	31.58	68.42	%	31.58	68.42	%	31.58	68.42		%	26.32	73.68	%	25	75	%	26.32	73.68		%	21.05	78.95	%	25	75	%	26.32	73.68			
5														47	126	173								18	39	57								15	43	58								14	44	58		
6										%	26.72	73.28	%	27.17	72.83					%	31.58	68.42	%	31.58	68.42					%	25.66	74.34	%	25.86	74.14					%	23.03	76.97	%	24.14	75.86			
7																																												47	126			
8																																																
9	norm -+			21	71	92		14	26		7	29		0	16			4	8		7	9		0	5			5	9		0	10		0	6			5	9		0	10		0	5			1
10							%	35	65	%	19.44	80.56	%	0	100		%	33.33	66.67	%	43.75	56.25	%	0	100		%	35.71	64.29	%	0	100	%	0	100		%	35.71	64.29	%	0	100	%	0	100			
11														21	71	92								11	22	33								5	25	30								5	24	29		
12										%	27.22	72.78	%	22.83	77.17					%	38.54	61.46	%	33.33	66.67					%	17.86	82.14	%	16.67	83.33					%	17.86	82.14	%	17.24	82.76			
13																																												21	71			
14																																																
15																																																
16																																																
17	Total n			68	197			29	68		23	72		16	57			10	21		13	22		6	18			10	23		5	25		5	20			9	24		5	25		5	19			
18							%	29.9	70.1	%	24.21	75.79	%	21.92	78.08		%	32.26	67.74	%	37.14	62.86	%	25	75		%	30.3	69.7	%	16.67	83.33	%	20	80		%	27.27	72.73	%	16.67	83.33	%	20.83	79.17			
19														68	197	265								29	61	90								20	68	88								19	68	87		
20										%	27.05	72.95	%	25.66	74.34					%	34.7	65.3	%	32.22	67.78					%	23.48	76.52	%	22.73	77.27					%	21.97	78.03	%	21.84	78.16			
21																																																
22																																																
23																																																
24																																																
25	invert +-			116	189	305		37	67		29	57		50	65			22	23		14	23		20	22			6	20		5	12		13	23			9	24		10	22		17	20			4
26							%	35.58	64.42	%	33.72	66.28	%	43.48	56.52		%	48.89	51.11	%	37.84	62.16	%	47.62	52.38		%	23.08	76.92	%	29.41	70.59	%	36.11	63.89		%	27.27	72.73	%	31.25	68.75	%	45.95	54.05			
27														116	189	305								56	68	124								24	55	79								36	66	102		
28										%	34.65	65.35	%	38.03	61.97					%	43.36	56.64	%	45.16	54.84					%	26.24	73.76	%	30.38	69.62					%	29.26	70.74	%	35.29	64.71			
29																																												116	189			
30																																																
31	invert -+			48	145	193		30	59		14	58		4	28			8	15		8	15		1	6			12	22		4	21		1	10			10	22		2	22		2	12			13
32							%	33.71	66.29	%	19.44	80.56	%	12.5	87.5		%	34.78	65.22	%	34.78	65.22	%	14.29	85.71		%	35.29	64.71	%	16	84	%	9.091	90.91		%	31.25	68.75	%	8.333	91.67	%	14.29	85.71			
33														48	145	193								17	36	53								17	53	70								14	56	70		
34										%	26.58	73.42	%	24.87	75.13					%	34.78	65.22	%	32.08	67.92					%	25.65	74.35	%	24.29	75.71					%	19.79	80.21	%	20	80			
35																																												48	145			
36																																																
37																																																
38																																																
39	Total i			164	334			67	126		43	115		54	93			30	38		22	38		21	28			18	42		9	33		14	33			19	46		12	44		19	32			
40							%	34.72	65.28	%	27.22	72.78	%	36.73	63.27		%	44.12	55.88	%	36.67	63.33	%	42.86	57.14		%	30	70	%	21.43	78.57	%	29.79	70.21		%	29.23	70.77	%	21.43	78.57	%	37.25	62.75			
41														164	334	498								73	104	177								41	108	149								50	122	172		
42										%	30.97	69.03	%	32.93	67.07					%	40.39	59.61	%	41.24	58.76					%	25.71	74.29	%	27.52	72.48					%	25.33	74.67	%	29.07	70.93			
43																																																
44																																																
45																																																
46																																																
47	Total n + i			232	531			96	194		66	187		70	150			40	59		35	60		27	46			28	65		14	58		19	53			28	70		17	69		24	51			
48							%	33.1	66.9	%	26.09	73.91	%	31.82	68.18		%	40.4	59.6	%	36.84	63.16	%	36.99	63.01		%	30.11	69.89	%	19.44	80.56	%	26.39	73.61		%	28.57	71.43	%	19.77	80.23	%	32	68			
49														232	531	763								102	165	267								61	176	237								69	190	259		
50										%	29.6	70.4	%	30.41	69.59					%	38.62	61.38	%	38.2	61.8					%	24.78	75.22	%	25.74	74.26					%	24.17	75.83	%	26.64	73.36			
51																																																

Screenshot XVIII. Consistent response data arrangement for all groups A B C and D - Experiment 2 - approach-avoidance decision run, 2nd sequence.

Appendix F

Experimental study’s results ANOVA tests

```
USE ALL.
COMPUTE filter_$=(n_p = 1).
VARIABLE LABELS filter_$ 'n_p = 1 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
ONEWAY sequence BY geometry
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Experiment 1 - aesthetic judgement run, 1st sequence. General analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	98,724	5	19,745	4,675	,000
Within Groups	2407,635	570	4,224		
Total	2506,359	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) geometry	(J) geometry	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-,573	,297	,384	-1,42	,28
		3	-1,052*	,297	,006	-1,90	-,20
		4	-,479	,297	,589	-1,33	,37
		5	-1,042*	,297	,006	-1,89	-,19
		6	-,073	,297	1,000	-,92	,78
	2	1	,573	,297	,384	-,28	1,42
		3	-,479	,297	,589	-1,33	,37
		4	,094	,297	1,000	-,75	,94
		5	-,469	,297	,612	-1,32	,38
		6	,500	,297	,542	-,35	1,35
	3	1	1,052*	,297	,006	,20	1,90
		2	,479	,297	,589	-,37	1,33
		4	,573	,297	,384	-,28	1,42
		5	,010	,297	1,000	-,84	,86
		6	,979*	,297	,013	,13	1,83

	4	1	,479	,297	,589	-,37	1,33
		2	-,094	,297	1,000	-,94	,75
		3	-,573	,297	,384	-1,42	,28
		5	-,563	,297	,405	-1,41	,29
		6	,406	,297	,745	-,44	1,25
	5	1	1,042*	,297	,006	,19	1,89
		2	,469	,297	,612	-,38	1,32
		3	-,010	,297	1,000	-,86	,84
		4	,563	,297	,405	-,29	1,41
		6	,969*	,297	,015	,12	1,82
	6	1	,073	,297	1,000	-,78	,92
		2	-,500	,297	,542	-1,35	,35
		3	-,979*	,297	,013	-1,83	-,13
		4	-,406	,297	,745	-1,25	,44
		5	-,969*	,297	,015	-1,82	-,12
Scheffe	1	2	-,573	,297	,589	-1,56	,42
		3	-1,052*	,297	,029	-2,04	-,06
		4	-,479	,297	,760	-1,47	,51
		5	-1,042*	,297	,032	-2,03	-,05
		6	-,073	,297	1,000	-1,06	,92
	2	1	,573	,297	,589	-,42	1,56
		3	-,479	,297	,760	-1,47	,51
		4	,094	,297	1,000	-,90	1,08
		5	-,469	,297	,777	-1,46	,52
		6	,500	,297	,724	-,49	1,49
	3	1	1,052*	,297	,029	,06	2,04
		2	,479	,297	,760	-,51	1,47
		4	,573	,297	,589	-,42	1,56
		5	,010	,297	1,000	-,98	1,00
		6	,979	,297	,055	-,01	1,97
	4	1	,479	,297	,760	-,51	1,47
		2	-,094	,297	1,000	-1,08	,90
		3	-,573	,297	,589	-1,56	,42
		5	-,563	,297	,609	-1,55	,43
		6	,406	,297	,866	-,58	1,40
	5	1	1,042*	,297	,032	,05	2,03
		2	,469	,297	,777	-,52	1,46
		3	-,010	,297	1,000	-1,00	,98
		4	,563	,297	,609	-,43	1,55
		6	,969	,297	,060	-,02	1,96

	6	1	,073	,297	1,000	-,92	1,06
		2	-,500	,297	,724	-1,49	,49
		3	-,979	,297	,055	-1,97	,01
		4	-,406	,297	,866	-1,40	,58
		5	-,969	,297	,060	-1,96	,02
Bonferroni	1	2	-,573	,297	,809	-1,45	,30
		3	-1,052*	,297	,006	-1,93	-,18
		4	-,479	,297	1,000	-1,35	,40
		5	-1,042*	,297	,007	-1,92	-,17
		6	-,073	,297	1,000	-,95	,80
	2	1	,573	,297	,809	-,30	1,45
		3	-,479	,297	1,000	-1,35	,40
		4	,094	,297	1,000	-,78	,97
		5	-,469	,297	1,000	-1,34	,41
		6	,500	,297	1,000	-,37	1,37
	3	1	1,052*	,297	,006	,18	1,93
		2	,479	,297	1,000	-,40	1,35
		4	,573	,297	,809	-,30	1,45
		5	,010	,297	1,000	-,86	,88
		6	,979*	,297	,015	,10	1,85
	4	1	,479	,297	1,000	-,40	1,35
		2	-,094	,297	1,000	-,97	,78
		3	-,573	,297	,809	-1,45	,30
		5	-,563	,297	,877	-1,44	,31
		6	,406	,297	1,000	-,47	1,28
	5	1	1,042*	,297	,007	,17	1,92
		2	,469	,297	1,000	-,41	1,34
		3	-,010	,297	1,000	-,88	,86
		4	,563	,297	,877	-,31	1,44
		6	,969*	,297	,017	,09	1,84
	6	1	,073	,297	1,000	-,80	,95
		2	-,500	,297	1,000	-1,37	,37
		3	-,979*	,297	,015	-1,85	-,10
		4	-,406	,297	1,000	-1,28	,47
		5	-,969*	,297	,017	-1,84	-,09

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05	
	geometry	N	1	2
Tukey HSD[a]	1	96	2,20	
	6	96	2,27	
	4	96	2,68	2,68
	2	96	2,77	2,77
	5	96		3,24
	3	96		3,25
	Sig.		,384	,384
Scheffe[a]	1	96	2,20	
	6	96	2,27	2,27
	4	96	2,68	2,68
	2	96	2,77	2,77
	5	96		3,24
	3	96		3,25
	Sig.		,589	,055

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 96,000.

```
ONEWAY sequence BY space_type
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	45,573	2	22,786	5,306	,005
Within Groups	2460,786	573	4,295		
Total	2506,359	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) space_type	(J) space_type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	a	b	-,651*	,212	,006	-1,15	-,15
		c	-,521*	,212	,037	-1,02	-,02
	b	a	,651*	,212	,006	,15	1,15
		c	,130	,212	,812	-,37	,63
	c	a	,521*	,212	,037	,02	1,02
		b	-,130	,212	,812	-,63	,37
Scheffe	a	b	-,651*	,212	,009	-1,17	-,13
		c	-,521*	,212	,049	-1,04	,00
	b	a	,651*	,212	,009	,13	1,17
		c	,130	,212	,827	-,39	,65
	c	a	,521*	,212	,049	,00	1,04
		b	-,130	,212	,827	-,65	,39
Bonferroni	a	b	-,651*	,212	,007	-1,16	-,14
		c	-,521*	,212	,042	-1,03	-,01
	b	a	,651*	,212	,007	,14	1,16
		c	,130	,212	1,000	-,38	,64
	c	a	,521*	,212	,042	,01	1,03
		b	-,130	,212	1,000	-,64	,38

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	space_type	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a]	a	192	2,34	
	c	192		2,86
	b	192		2,99
	Sig.		1,000	,812
Scheffe[a]	a	192	2,34	
	c	192		2,86
	b	192		2,99
	Sig.		1,000	,827

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 192,000.

```
USE ALL.
COMPUTE filter_$=((n_p = 2) ).
VARIABLE LABELS filter_$ '(n_p = 2)  (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
ONEWAY sequence BY geometry
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Experiment 1 - aesthetic judgement run, 2nd sequence. General analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	114,139	5	22,828	4,596	,000
Within Groups	2831,167	570	4,967		
Total	2945,306	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) geometry	(J) geometry	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-,688	,322	,270	-1,61	,23
		3	-1,188*	,322	,003	-2,11	-,27
		4	-,521	,322	,586	-1,44	,40
		5	-1,219*	,322	,002	-2,14	-,30
		6	-,281	,322	,953	-1,20	,64
	2	1	,688	,322	,270	-,23	1,61
		3	-,500	,322	,629	-1,42	,42
		4	,167	,322	,995	-,75	1,09
		5	-,531	,322	,565	-1,45	,39
		6	,406	,322	,805	-,51	1,33
	3	1	1,188*	,322	,003	,27	2,11
		2	,500	,322	,629	-,42	1,42
		4	,667	,322	,303	-,25	1,59
		5	-,031	,322	1,000	-,95	,89
		6	,906	,322	,056	-,01	1,83

	4	1	,521	,322	,586	-,40	1,44
		2	-,167	,322	,995	-1,09	,75
		3	-,667	,322	,303	-1,59	,25
		5	-,698	,322	,254	-1,62	,22
		6	,240	,322	,976	-,68	1,16
	5	1	1,219*	,322	,002	,30	2,14
		2	,531	,322	,565	-,39	1,45
		3	,031	,322	1,000	-,89	,95
		4	,698	,322	,254	-,22	1,62
		6	,938*	,322	,043	,02	1,86
	6	1	,281	,322	,953	-,64	1,20
		2	-,406	,322	,805	-1,33	,51
		3	-,906	,322	,056	-1,83	,01
		4	-,240	,322	,976	-1,16	,68
		5	-,938*	,322	,043	-1,86	-,02
Scheffe	1	2	-,688	,322	,472	-1,76	,39
		3	-1,188*	,322	,019	-2,26	-,11
		4	-,521	,322	,758	-1,59	,55
		5	-1,219*	,322	,014	-2,29	-,14
		6	-,281	,322	,979	-1,36	,79
	2	1	,688	,322	,472	-,39	1,76
		3	-,500	,322	,789	-1,57	,57
		4	,167	,322	,998	-,91	1,24
		5	-,531	,322	,742	-1,61	,54
		6	,406	,322	,902	-,67	1,48
	3	1	1,188*	,322	,019	,11	2,26
		2	,500	,322	,789	-,57	1,57
		4	,667	,322	,508	-,41	1,74
		5	-,031	,322	1,000	-1,11	1,04
		6	,906	,322	,162	-,17	1,98
	4	1	,521	,322	,758	-,55	1,59
		2	-,167	,322	,998	-1,24	,91
		3	-,667	,322	,508	-1,74	,41
		5	-,698	,322	,454	-1,77	,38
		6	,240	,322	,990	-,83	1,31
	5	1	1,219*	,322	,014	,14	2,29
		2	,531	,322	,742	-,54	1,61
		3	,031	,322	1,000	-1,04	1,11
		4	,698	,322	,454	-,38	1,77
		6	,938	,322	,133	-,14	2,01

	6	1	,281	,322	,979	-,79	1,36
		2	-,406	,322	,902	-1,48	,67
		3	-,906	,322	,162	-1,98	,17
		4	-,240	,322	,990	-1,31	,83
		5	-,938	,322	,133	-2,01	,14
Bonferroni	1	2	-,688	,322	,495	-1,64	,26
		3	-1,188*	,322	,004	-2,14	-,24
		4	-,521	,322	1,000	-1,47	,43
		5	-1,219*	,322	,003	-2,17	-,27
		6	-,281	,322	1,000	-1,23	,67
	2	1	,688	,322	,495	-,26	1,64
		3	-,500	,322	1,000	-1,45	,45
		4	,167	,322	1,000	-,78	1,11
		5	-,531	,322	1,000	-1,48	,42
		6	,406	,322	1,000	-,54	1,35
	3	1	1,188*	,322	,004	,24	2,14
		2	,500	,322	1,000	-,45	1,45
		4	,667	,322	,580	-,28	1,61
		5	-,031	,322	1,000	-,98	,92
		6	,906	,322	,075	-,04	1,85
	4	1	,521	,322	1,000	-,43	1,47
		2	-,167	,322	1,000	-1,11	,78
		3	-,667	,322	,580	-1,61	,28
		5	-,698	,322	,457	-1,65	,25
		6	,240	,322	1,000	-,71	1,19
	5	1	1,219*	,322	,003	,27	2,17
		2	,531	,322	1,000	-,42	1,48
		3	,031	,322	1,000	-,92	,98
		4	,698	,322	,457	-,25	1,65
		6	,938	,322	,056	-,01	1,89
	6	1	,281	,322	1,000	-,67	1,23
		2	-,406	,322	1,000	-1,35	,54
		3	-,906	,322	,075	-1,85	,04
		4	-,240	,322	1,000	-1,19	,71
		5	-,938	,322	,056	-1,89	,01

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	geometry	N	Subset for alpha = 0.05		
			1	2	3
Tukey HSD[a]	1	96	2,01		
	6	96	2,29	2,29	
	4	96	2,53	2,53	2,53
	2	96	2,70	2,70	2,70
	3	96		3,20	3,20
	5	96			3,23
	Sig.		,270	,056	,254
Scheffe[a]	1	96	2,01		
	6	96	2,29	2,29	
	4	96	2,53	2,53	
	2	96	2,70	2,70	
	3	96		3,20	
	5	96		3,23	
	Sig.		,472	,133	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 96,000.

```
ONEWAY sequence BY space_type
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	62,233	2	31,116	6,184	,002
Within Groups	2883,073	573	5,032		
Total	2945,306	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) space_type	(J) space_type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	a	b	-,760*	,229	,003	-1,30	-,22
		c	-,609*	,229	,022	-1,15	-,07
	b	a	,760*	,229	,003	,22	1,30
		c	,151	,229	,787	-,39	,69
	c	a	,609*	,229	,022	,07	1,15
		b	-,151	,229	,787	-,69	,39
Scheffe	a	b	-,760*	,229	,004	-1,32	-,20
		c	-,609*	,229	,030	-1,17	-,05
	b	a	,760*	,229	,004	,20	1,32
		c	,151	,229	,804	-,41	,71
	c	a	,609*	,229	,030	,05	1,17
		b	-,151	,229	,804	-,71	,41
Bonferroni	a	b	-,760*	,229	,003	-1,31	-,21
		c	-,609*	,229	,024	-1,16	-,06
	b	a	,760*	,229	,003	,21	1,31
		c	,151	,229	1,000	-,40	,70
	c	a	,609*	,229	,024	,06	1,16
		b	-,151	,229	1,000	-,70	,40

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	space_type	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a]	a	192	2,20	
	c	192		2,81
	b	192		2,96
	Sig.		1,000	,787
Scheffe[a]	a	192	2,20	
	c	192		2,81
	b	192		2,96

Sig.		1,000	,804

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 192,000.

```
FILTER OFF.
USE ALL.
EXECUTE.
ONEWAY sequence BY geometry
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Experiment 1 - aesthetic judgement run, 1st sequence. Consistent response analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	135,026	5	27,005	8,832	,000
Within Groups	697,128	228	3,058		
Total	832,154	233			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

						95% Confidence Interval	
	(I) geometry	(J) geometry	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Tukey HSD	1	2	-,231	,396	,992	-1,37	,91
		3	-1,641*	,396	,001	-2,78	-,50
		4	-,179	,396	,998	-1,32	,96
		5	-1,590*	,396	,001	-2,73	-,45
		6	,256	,396	,987	-,88	1,39
	2	1	,231	,396	,992	-,91	1,37
		3	-1,410*	,396	,006	-2,55	-,27
		4	,051	,396	1,000	-1,09	1,19
		5	-1,359*	,396	,009	-2,50	-,22
		6	,487	,396	,822	-,65	1,63
	3	1	1,641*	,396	,001	,50	2,78
		2	1,410*	,396	,006	,27	2,55
		4	1,462*	,396	,004	,32	2,60
		5	,051	,396	1,000	-1,09	1,19
		6	1,897*	,396	,000	,76	3,04
	4	1	,179	,396	,998	-,96	1,32
		2	-,051	,396	1,000	-1,19	1,09

		3	-1,462*	,396	,004	-2,60	-,32
		5	-1,410*	,396	,006	-2,55	-,27
		6	,436	,396	,881	-,70	1,57
	5	1	1,590*	,396	,001	,45	2,73
		2	1,359*	,396	,009	,22	2,50
		3	-,051	,396	1,000	-1,19	1,09
		4	1,410*	,396	,006	,27	2,55
		6	1,846*	,396	,000	,71	2,98
	6	1	-,256	,396	,987	-1,39	,88
		2	-,487	,396	,822	-1,63	,65
		3	-1,897*	,396	,000	-3,04	-,76
		4	-,436	,396	,881	-1,57	,70
		5	-1,846*	,396	,000	-2,98	-,71
Scheffe	1	2	-,231	,396	,997	-1,56	1,10
		3	-1,641*	,396	,005	-2,97	-,31
		4	-,179	,396	,999	-1,51	1,15
		5	-1,590*	,396	,008	-2,92	-,26
		6	,256	,396	,995	-1,07	1,59
	2	1	,231	,396	,997	-1,10	1,56
		3	-1,410*	,396	,029	-2,74	-,08
		4	,051	,396	1,000	-1,28	1,38
		5	-1,359*	,396	,041	-2,69	-,03
		6	,487	,396	,911	-,84	1,82
	3	1	1,641*	,396	,005	,31	2,97
		2	1,410*	,396	,029	,08	2,74
		4	1,462*	,396	,021	,13	2,79
		5	,051	,396	1,000	-1,28	1,38
		6	1,897*	,396	,001	,57	3,23
	4	1	,179	,396	,999	-1,15	1,51
		2	-,051	,396	1,000	-1,38	1,28
		3	-1,462*	,396	,021	-2,79	-,13
		5	-1,410*	,396	,029	-2,74	-,08
		6	,436	,396	,943	-,89	1,77
	5	1	1,590*	,396	,008	,26	2,92
		2	1,359*	,396	,041	,03	2,69
		3	-,051	,396	1,000	-1,38	1,28
		4	1,410*	,396	,029	,08	2,74
		6	1,846*	,396	,001	,52	3,18
	6	1	-,256	,396	,995	-1,59	1,07
		2	-,487	,396	,911	-1,82	,84

		3	-1,897*	,396	,001	-3,23	-,57
		4	-,436	,396	,943	-1,77	,89
		5	-1,846*	,396	,001	-3,18	-,52
Bonferroni	1	2	-,231	,396	1,000	-1,41	,94
		3	-1,641*	,396	,001	-2,82	-,47
		4	-,179	,396	1,000	-1,35	1,00
		5	-1,590*	,396	,001	-2,76	-,42
		6	,256	,396	1,000	-,92	1,43
	2	1	,231	,396	1,000	-,94	1,41
		3	-1,410*	,396	,007	-2,58	-,24
		4	,051	,396	1,000	-1,12	1,23
		5	-1,359*	,396	,011	-2,53	-,18
		6	,487	,396	1,000	-,69	1,66
	3	1	1,641*	,396	,001	,47	2,82
		2	1,410*	,396	,007	,24	2,58
		4	1,462*	,396	,004	,29	2,64
		5	,051	,396	1,000	-1,12	1,23
		6	1,897*	,396	,000	,72	3,07
	4	1	,179	,396	1,000	-1,00	1,35
		2	-,051	,396	1,000	-1,23	1,12
		3	-1,462*	,396	,004	-2,64	-,29
		5	-1,410*	,396	,007	-2,58	-,24
		6	,436	,396	1,000	-,74	1,61
	5	1	1,590*	,396	,001	,42	2,76
		2	1,359*	,396	,011	,18	2,53
		3	-,051	,396	1,000	-1,23	1,12
		4	1,410*	,396	,007	,24	2,58
		6	1,846*	,396	,000	,67	3,02
	6	1	-,256	,396	1,000	-1,43	,92
		2	-,487	,396	1,000	-1,66	,69
		3	-1,897*	,396	,000	-3,07	-,72
		4	-,436	,396	1,000	-1,61	,74
		5	-1,846*	,396	,000	-3,02	-,67

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	geometry	N	Subset for alpha = 0.05 1	2
Tukey HSD[a]	6	39	1,31	
	1	39	1,56	
	4	39	1,74	
	2	39	1,79	
	5	39		3,15
	3	39		3,21
	Sig.		,822	1,000
Scheffe[a]	6	39	1,31	
	1	39	1,56	
	4	39	1,74	
	2	39	1,79	
	5	39		3,15
	3	39		3,21
	Sig.		,911	1,000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 39,000.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14,846	2	7,423	2,098	,125
Within Groups	817,308	231	3,538		
Total	832,154	233			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) space_type	(J) space_type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	a	b	-,615	,301	,104	-1,33	,10
		c	-,346	,301	,485	-1,06	,36
	b	a	,615	,301	,104	-,10	1,33

		c	,269	,301	,645	-,44	,98
	c	a	,346	,301	,485	-,36	1,06
		b	-,269	,301	,645	-,98	,44
Scheffe	a	b	-,615	,301	,126	-1,36	,13
		c	-,346	,301	,518	-1,09	,40
	b	a	,615	,301	,126	-,13	1,36
		c	,269	,301	,671	-,47	1,01
	c	a	,346	,301	,518	-,40	1,09
		b	-,269	,301	,671	-1,01	,47
Bonferroni	a	b	-,615	,301	,127	-1,34	,11
		c	-,346	,301	,755	-1,07	,38
	b	a	,615	,301	,127	-,11	1,34
		c	,269	,301	1,000	-,46	1,00
	c	a	,346	,301	,755	-,38	1,07
		b	-,269	,301	1,000	-1,00	,46

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05
	space_type	N	1
Tukey HSD[a]	a	78	1,81
	c	78	2,15
	b	78	2,42
	Sig.		,104
Scheffe[a]	a	78	1,81
	c	78	2,15
	b	78	2,42
	Sig.		,126

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 78,000.

Experiment 1 - aesthetic judgement run, 2nd sequence. Consistent response analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	110,079	5	22,016	4,985	,000
Within Groups	1086,476	246	4,417		
Total	1196,556	251			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) geometry	(J) geometry				Lower Bound	Upper Bound
Tukey HSD	1	2	-,262	,459	,993	-1,58	1,06
		3	-1,262	,459	,069	-2,58	,06
		4	,071	,459	1,000	-1,25	1,39
		5	-1,500*	,459	,015	-2,82	-,18
		6	,143	,459	1,000	-1,17	1,46
	2	1	,262	,459	,993	-1,06	1,58
		3	-1,000	,459	,251	-2,32	,32
		4	,333	,459	,978	-,98	1,65
		5	-1,238	,459	,079	-2,56	,08
		6	,405	,459	,950	-,91	1,72
	3	1	1,262	,459	,069	-,06	2,58
		2	1,000	,459	,251	-,32	2,32
		4	1,333*	,459	,045	,02	2,65
		5	-,238	,459	,995	-1,56	1,08
		6	1,405*	,459	,029	,09	2,72
	4	1	-,071	,459	1,000	-1,39	1,25
		2	-,333	,459	,978	-1,65	,98
		3	-1,333*	,459	,045	-2,65	-,02
		5	-1,571*	,459	,009	-2,89	-,25
		6	,071	,459	1,000	-1,25	1,39
	5	1	1,500*	,459	,015	,18	2,82
		2	1,238	,459	,079	-,08	2,56

		3	,238	,459	,995	-1,08	1,56
		4	1,571*	,459	,009	,25	2,89
		6	1,643*	,459	,005	,33	2,96
	6	1	-,143	,459	1,000	-1,46	1,17
		2	-,405	,459	,950	-1,72	,91
		3	-1,405*	,459	,029	-2,72	-,09
		4	-,071	,459	1,000	-1,39	1,25
		5	-1,643*	,459	,005	-2,96	-,33
Scheffe	1	2	-,262	,459	,997	-1,80	1,28
		3	-1,262	,459	,186	-2,80	,28
		4	,071	,459	1,000	-1,47	1,61
		5	-1,500	,459	,061	-3,04	,04
		6	,143	,459	1,000	-1,40	1,68
	2	1	,262	,459	,997	-1,28	1,80
		3	-1,000	,459	,449	-2,54	,54
		4	,333	,459	,991	-1,21	1,87
		5	-1,238	,459	,204	-2,78	,30
		6	,405	,459	,978	-1,13	1,94
	3	1	1,262	,459	,186	-,28	2,80
		2	1,000	,459	,449	-,54	2,54
		4	1,333	,459	,137	-,21	2,87
		5	-,238	,459	,998	-1,78	1,30
		6	1,405	,459	,099	-,13	2,94
	4	1	-,071	,459	1,000	-1,61	1,47
		2	-,333	,459	,991	-1,87	1,21
		3	-1,333	,459	,137	-2,87	,21
		5	-1,571*	,459	,042	-3,11	-,03
		6	,071	,459	1,000	-1,47	1,61
	5	1	1,500	,459	,061	-,04	3,04
		2	1,238	,459	,204	-,30	2,78
		3	,238	,459	,998	-1,30	1,78
		4	1,571*	,459	,042	,03	3,11
		6	1,643*	,459	,028	,10	3,18
	6	1	-,143	,459	1,000	-1,68	1,40
		2	-,405	,459	,978	-1,94	1,13
		3	-1,405	,459	,099	-2,94	,13
		4	-,071	,459	1,000	-1,61	1,47
		5	-1,643*	,459	,028	-3,18	-,10
Bonferroni	1	2	-,262	,459	1,000	-1,62	1,10
		3	-1,262	,459	,096	-2,62	,10

		4	,071	,459	1,000	-1,29	1,43
		5	-1,500*	,459	,018	-2,86	-,14
		6	,143	,459	1,000	-1,22	1,50
	2	1	,262	,459	1,000	-1,10	1,62
		3	-1,000	,459	,452	-2,36	,36
		4	,333	,459	1,000	-1,03	1,69
		5	-1,238	,459	,111	-2,60	,12
		6	,405	,459	1,000	-,95	1,76
	3	1	1,262	,459	,096	-,10	2,62
		2	1,000	,459	,452	-,36	2,36
		4	1,333	,459	,060	-,03	2,69
		5	-,238	,459	1,000	-1,60	1,12
		6	1,405*	,459	,037	,05	2,76
	4	1	-,071	,459	1,000	-1,43	1,29
		2	-,333	,459	1,000	-1,69	1,03
		3	-1,333	,459	,060	-2,69	,03
		5	-1,571*	,459	,011	-2,93	-,21
		6	,071	,459	1,000	-1,29	1,43
	5	1	1,500*	,459	,018	,14	2,86
		2	1,238	,459	,111	-,12	2,60
		3	,238	,459	1,000	-1,12	1,60
		4	1,571*	,459	,011	,21	2,93
		6	1,643*	,459	,006	,28	3,00
	6	1	-,143	,459	1,000	-1,50	1,22
		2	-,405	,459	1,000	-1,76	,95
		3	-1,405*	,459	,037	-2,76	-,05
		4	-,071	,459	1,000	-1,43	1,29
		5	-1,643*	,459	,006	-3,00	-,28

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05		
	geometry	N	1	2	3
Tukey HSD[a]	6	42	1,67		
	4	42	1,74		
	1	42	1,81	1,81	

	2	42	2,07	2,07	2,07
	3	42		3,07	3,07
	5	42			3,31
	Sig.		,950	,069	,079
Scheffe[a]	6	42	1,67		
	4	42	1,74		
	1	42	1,81	1,81	
	2	42	2,07	2,07	
	3	42	3,07	3,07	
	5	42		3,31	
	Sig.		,099	,061	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 42,000.

```
ONEWAY sequence BY space_type
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4,389	2	2,194	,458	,633
Within Groups	1192,167	249	4,788		
Total	1196,556	251			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

						95% Confidence Interval	
	(I) space_type	(J) space_type	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Tukey HSD	a	b	-,274	,338	,697	-1,07	,52
		c	,012	,338	,999	-,78	,81
	b	a	,274	,338	,697	-,52	1,07
		c	,286	,338	,675	-,51	1,08
	c	a	-,012	,338	,999	-,81	,78
		b	-,286	,338	,675	-1,08	,51
Scheffe	a	b	-,274	,338	,720	-1,11	,56

		c	,012	,338	,999	-,82	,84
	b	a	,274	,338	,720	-,56	1,11
		c	,286	,338	,699	-,55	1,12
	c	a	-,012	,338	,999	-,84	,82
		b	-,286	,338	,699	-1,12	,55
Bonferroni	a	b	-,274	,338	1,000	-1,09	,54
		c	,012	,338	1,000	-,80	,83
	b	a	,274	,338	1,000	-,54	1,09
		c	,286	,338	1,000	-,53	1,10
	c	a	-,012	,338	1,000	-,83	,80
		b	-,286	,338	1,000	-1,10	,53

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05
	space_type	N	1
Tukey HSD[a]	c	84	2,18
	a	84	2,19
	b	84	2,46
	Sig.		,675
Scheffe[a]	c	84	2,18
	a	84	2,19
	b	84	2,46
	Sig.		,699

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 84,000.

```
USE ALL.
COMPUTE filter_$=((n_p = 1) ).
VARIABLE LABELS filter_$ '(n_p = 1)  (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
ONEWAY sequence BY geometry
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Experiment 2 – approach-avoidance decision run, 1st sequence. General analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	202,696	5	40,539	9,800	,000
Within Groups	2357,802	570	4,136		
Total	2560,498	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) geometry	(J) geometry				Lower Bound	Upper Bound
Tukey HSD	1	2	-1,021*	,294	,007	-1,86	-,18
		3	-1,750*	,294	,000	-2,59	-,91
		4	-,802	,294	,071	-1,64	,04
		5	-1,698*	,294	,000	-2,54	-,86
		6	-,844*	,294	,048	-1,68	,00
	2	1	1,021*	,294	,007	,18	1,86
		3	-,729	,294	,131	-1,57	,11
		4	,219	,294	,976	-,62	1,06
		5	-,677	,294	,193	-1,52	,16
		6	,177	,294	,991	-,66	1,02
	3	1	1,750*	,294	,000	,91	2,59
		2	,729	,294	,131	-,11	1,57
		4	,948*	,294	,016	,11	1,79
		5	,052	,294	1,000	-,79	,89
		6	,906*	,294	,026	,07	1,75

	4	1	,802	,294	,071	-,04	1,64
		2	-,219	,294	,976	-1,06	,62
		3	-,948*	,294	,016	-1,79	-,11
		5	-,896*	,294	,029	-1,74	-,06
		6	-,042	,294	1,000	-,88	,80
	5	1	1,698*	,294	,000	,86	2,54
		2	,677	,294	,193	-,16	1,52
		3	-,052	,294	1,000	-,89	,79
		4	,896*	,294	,029	,06	1,74
		6	,854*	,294	,043	,01	1,69
	6	1	,844*	,294	,048	,00	1,68
		2	-,177	,294	,991	-1,02	,66
		3	-,906*	,294	,026	-1,75	-,07
		4	,042	,294	1,000	-,80	,88
		5	-,854*	,294	,043	-1,69	-,01
Scheffe	1	2	-1,021*	,294	,035	-2,00	-,04
		3	-1,750*	,294	,000	-2,73	-,77
		4	-,802	,294	,190	-1,78	,18
		5	-1,698*	,294	,000	-2,68	-,72
		6	-,844	,294	,144	-1,82	,14
	2	1	1,021*	,294	,035	,04	2,00
		3	-,729	,294	,292	-1,71	,25
		4	,219	,294	,990	-,76	1,20
		5	-,677	,294	,379	-1,66	,30
		6	,177	,294	,996	-,80	1,16
	3	1	1,750*	,294	,000	,77	2,73
		2	,729	,294	,292	-,25	1,71
		4	,948	,294	,066	-,03	1,93
		5	,052	,294	1,000	-,93	1,03
		6	,906	,294	,092	-,07	1,89
	4	1	,802	,294	,190	-,18	1,78
		2	-,219	,294	,990	-1,20	,76
		3	-,948	,294	,066	-1,93	,03
		5	-,896	,294	,099	-1,88	,08
		6	-,042	,294	1,000	-1,02	,94
	5	1	1,698*	,294	,000	,72	2,68
		2	,677	,294	,379	-,30	1,66
		3	-,052	,294	1,000	-1,03	,93
		4	,896	,294	,099	-,08	1,88
		6	,854	,294	,134	-,13	1,83

	6	1	,844	,294	,144	-,14	1,82
		2	-,177	,294	,996	-1,16	,80
		3	-,906	,294	,092	-1,89	,07
		4	,042	,294	1,000	-,94	1,02
		5	-,854	,294	,134	-1,83	,13
Bonferroni	1	2	-1,021*	,294	,008	-1,89	-,16
		3	-1,750*	,294	,000	-2,62	-,88
		4	-,802	,294	,097	-1,67	,06
		5	-1,698*	,294	,000	-2,56	-,83
		6	-,844	,294	,063	-1,71	,02
	2	1	1,021*	,294	,008	,16	1,89
		3	-,729	,294	,199	-1,59	,14
		4	,219	,294	1,000	-,65	1,08
		5	-,677	,294	,322	-1,54	,19
		6	,177	,294	1,000	-,69	1,04
	3	1	1,750*	,294	,000	,88	2,62
		2	,729	,294	,199	-,14	1,59
		4	,948*	,294	,020	,08	1,81
		5	,052	,294	1,000	-,81	,92
		6	,906*	,294	,032	,04	1,77
	4	1	,802	,294	,097	-,06	1,67
		2	-,219	,294	1,000	-1,08	,65
		3	-,948*	,294	,020	-1,81	-,08
		5	-,896*	,294	,036	-1,76	-,03
		6	-,042	,294	1,000	-,91	,82
	5	1	1,698*	,294	,000	,83	2,56
		2	,677	,294	,322	-,19	1,54
		3	-,052	,294	1,000	-,92	,81
		4	,896*	,294	,036	,03	1,76
		6	,854	,294	,056	-,01	1,72
	6	1	,844	,294	,063	-,02	1,71
		2	-,177	,294	1,000	-1,04	,69
		3	-,906*	,294	,032	-1,77	-,04
		4	,042	,294	1,000	-,82	,91
		5	-,854	,294	,056	-1,72	,01

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05		
	geometry	N	1	2	3
Tukey HSD[a]	1	96	2,01		
	4	96	2,81	2,81	
	6	96		2,85	
	2	96		3,03	3,03
	5	96			3,71
	3	96			3,76
	Sig.		,071	,976	,131
Scheffe[a]	1	96	2,01		
	4	96	2,81	2,81	
	6	96	2,85	2,85	
	2	96		3,03	
	5	96		3,71	
	3	96		3,76	
	Sig.		,144	,066	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 96,000.

```
ONEWAY sequence BY space_type
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	168,962	2	84,481	20,241	,000
Within Groups	2391,536	573	4,174		
Total	2560,498	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) space_type	(J) space_type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	a	b	-1,229*	,209	,000	-1,72	-,74
		c	-1,047*	,209	,000	-1,54	-,56
	b	a	1,229*	,209	,000	,74	1,72
		c	,182	,209	,657	-,31	,67
	c	a	1,047*	,209	,000	,56	1,54
		b	-,182	,209	,657	-,67	,31
Scheffe	a	b	-1,229*	,209	,000	-1,74	-,72
		c	-1,047*	,209	,000	-1,56	-,54
	b	a	1,229*	,209	,000	,72	1,74
		c	,182	,209	,683	-,33	,69
	c	a	1,047*	,209	,000	,54	1,56
		b	-,182	,209	,683	-,69	,33
Bonferroni	a	b	-1,229*	,209	,000	-1,73	-,73
		c	-1,047*	,209	,000	-1,55	-,55
	b	a	1,229*	,209	,000	,73	1,73
		c	,182	,209	1,000	-,32	,68
	c	a	1,047*	,209	,000	,55	1,55
		b	-,182	,209	1,000	-,68	,32

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	space_type	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a]	a	192	2,27	
	c	192		3,32
	b	192		3,50
	Sig.		1,000	,657
Scheffe[a]	a	192	2,27	
	c	192		3,32
	b	192		3,50
	Sig.		1,000	,683

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 192,000.

```
USE ALL.
COMPUTE filter_$=((n_p = 2)).
VARIABLE LABELS filter_$ '(n_p = 2) (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
ONEWAY sequence BY geometry
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Experiment 2 – approach-avoidance decision run, 2nd sequence. General analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	261,868	5	52,374	11,182	,000
Within Groups	2669,792	570	4,684		
Total	2931,660	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) geometry	(J) geometry	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-,938*	,312	,033	-1,83	-,04
		3	-1,917*	,312	,000	-2,81	-1,02
		4	-,583	,312	,423	-1,48	,31
		5	-1,844*	,312	,000	-2,74	-,95
		6	-,927*	,312	,037	-1,82	-,03
	2	1	,938*	,312	,033	,04	1,83
		3	-,979*	,312	,022	-1,87	-,09
		4	,354	,312	,867	-,54	1,25
		5	-,906*	,312	,044	-1,80	-,01
		6	,010	,312	1,000	-,88	,90
	3	1	1,917*	,312	,000	1,02	2,81
		2	,979*	,312	,022	,09	1,87
		4	1,333*	,312	,000	,44	2,23
		5	,073	,312	1,000	-,82	,97
		6	,990*	,312	,020	,10	1,88

	4	1	,583	,312	,423	-,31	1,48
		2	-,354	,312	,867	-1,25	,54
		3	-1,333*	,312	,000	-2,23	-,44
		5	-1,260*	,312	,001	-2,15	-,37
		6	-,344	,312	,881	-1,24	,55
	5	1	1,844*	,312	,000	,95	2,74
		2	,906*	,312	,044	,01	1,80
		3	-,073	,312	1,000	-,97	,82
		4	1,260*	,312	,001	,37	2,15
		6	,917*	,312	,040	,02	1,81
	6	1	,927*	,312	,037	,03	1,82
		2	-,010	,312	1,000	-,90	,88
		3	-,990*	,312	,020	-1,88	-,10
		4	,344	,312	,881	-,55	1,24
		5	-,917*	,312	,040	-1,81	-,02
Scheffe	1	2	-,938	,312	,111	-1,98	,11
		3	-1,917*	,312	,000	-2,96	-,87
		4	-,583	,312	,626	-1,63	,46
		5	-1,844*	,312	,000	-2,89	-,80
		6	-,927	,312	,119	-1,97	,12
	2	1	,938	,312	,111	-,11	1,98
		3	-,979	,312	,082	-2,02	,06
		4	,354	,312	,936	-,69	1,40
		5	-,906	,312	,137	-1,95	,14
		6	,010	,312	1,000	-1,03	1,05
	3	1	1,917*	,312	,000	,87	2,96
		2	,979	,312	,082	-,06	2,02
		4	1,333*	,312	,003	,29	2,38
		5	,073	,312	1,000	-,97	1,12
		6	,990	,312	,076	-,05	2,03
	4	1	,583	,312	,626	-,46	1,63
		2	-,354	,312	,936	-1,40	,69
		3	-1,333*	,312	,003	-2,38	-,29
		5	-1,260*	,312	,007	-2,30	-,22
		6	-,344	,312	,944	-1,39	,70
	5	1	1,844*	,312	,000	,80	2,89
		2	,906	,312	,137	-,14	1,95
		3	-,073	,312	1,000	-1,12	,97
		4	1,260*	,312	,007	,22	2,30
		6	,917	,312	,128	-,13	1,96

	6	1	,927	,312	,119	-,12	1,97
		2	-,010	,312	1,000	-1,05	1,03
		3	-,990	,312	,076	-2,03	,05
		4	,344	,312	,944	-,70	1,39
		5	-,917	,312	,128	-1,96	,13
Bonferroni	1	2	-,938*	,312	,042	-1,86	-,02
		3	-1,917*	,312	,000	-2,84	-1,00
		4	-,583	,312	,935	-1,50	,34
		5	-1,844*	,312	,000	-2,76	-,92
		6	-,927*	,312	,047	-1,85	-,01
	2	1	,938*	,312	,042	,02	1,86
		3	-,979*	,312	,027	-1,90	-,06
		4	,354	,312	1,000	-,57	1,27
		5	-,906	,312	,058	-1,83	,01
		6	,010	,312	1,000	-,91	,93
	3	1	1,917*	,312	,000	1,00	2,84
		2	,979*	,312	,027	,06	1,90
		4	1,333*	,312	,000	,41	2,25
		5	,073	,312	1,000	-,85	,99
		6	,990*	,312	,024	,07	1,91
	4	1	,583	,312	,935	-,34	1,50
		2	-,354	,312	1,000	-1,27	,57
		3	-1,333*	,312	,000	-2,25	-,41
		5	-1,260*	,312	,001	-2,18	-,34
		6	-,344	,312	1,000	-1,26	,58
	5	1	1,844*	,312	,000	,92	2,76
		2	,906	,312	,058	-,01	1,83
		3	-,073	,312	1,000	-,99	,85
		4	1,260*	,312	,001	,34	2,18
		6	,917	,312	,052	,00	1,84
	6	1	,927*	,312	,047	,01	1,85
		2	-,010	,312	1,000	-,93	,91
		3	-,990*	,312	,024	-1,91	-,07
		4	,344	,312	1,000	-,58	1,26
		5	-,917	,312	,052	-1,84	,00

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	geometry	N	Subset for alpha = 0.05		
			1	2	3
Tukey HSD[a]	1	96	2,05		
	4	96	2,64	2,64	
	6	96		2,98	
	2	96		2,99	
	5	96			3,90
	3	96			3,97
	Sig.		,423	,867	1,000
Scheffe[a]	1	96	2,05		
	4	96	2,64		
	6	96	2,98	2,98	
	2	96	2,99	2,99	
	5	96		3,90	
	3	96		3,97	
	Sig.		,111	,076	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 96,000.

```
ONEWAY sequence BY space_type
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	133,399	2	66,700	13,658	,000
Within Groups	2798,260	573	4,884		
Total	2931,660	575			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) space_type	(J) space_type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	a	b	-1,026*	,226	,000	-1,56	-,50
		c	-1,016*	,226	,000	-1,55	-,49
	b	a	1,026*	,226	,000	,50	1,56
		c	,010	,226	,999	-,52	,54
	c	a	1,016*	,226	,000	,49	1,55
		b	-,010	,226	,999	-,54	,52
Scheffe	a	b	-1,026*	,226	,000	-1,58	-,47
		c	-1,016*	,226	,000	-1,57	-,46
	b	a	1,026*	,226	,000	,47	1,58
		c	,010	,226	,999	-,54	,56
	c	a	1,016*	,226	,000	,46	1,57
		b	-,010	,226	,999	-,56	,54
Bonferroni	a	b	-1,026*	,226	,000	-1,57	-,48
		c	-1,016*	,226	,000	-1,56	-,47
	b	a	1,026*	,226	,000	,48	1,57
		c	,010	,226	1,000	-,53	,55
	c	a	1,016*	,226	,000	,47	1,56
		b	-,010	,226	1,000	-,55	,53

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	space_type	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a]	a	192	2,41	
	c	192		3,42
	b	192		3,43
	Sig.		1,000	,999
Scheffe[a]	a	192	2,41	
	c	192		3,42
	b	192		3,43
	Sig.		1,000	,999

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 192,000.

Experiment 2 – approach-avoidance decision run, 1st sequence. Consistent response analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	255,476	5	51,095	14,909	,000
Within Groups	966,438	282	3,427		
Total	1221,913	287			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) geometry	(J) geometry	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-,979	,378	,103	-2,06	,11
		3	-2,500*	,378	,000	-3,58	-1,42
		4	-,646	,378	,527	-1,73	,44
		5	-2,458*	,378	,000	-3,54	-1,37
		6	-1,938*	,378	,000	-3,02	-,85
	2	1	,979	,378	,103	-,11	2,06
		3	-1,521*	,378	,001	-2,61	-,44
		4	,333	,378	,951	-,75	1,42
		5	-1,479*	,378	,002	-2,56	-,39
		6	-,958	,378	,117	-2,04	,13
	3	1	2,500*	,378	,000	1,42	3,58
		2	1,521*	,378	,001	,44	2,61
		4	1,854*	,378	,000	,77	2,94
		5	,042	,378	1,000	-1,04	1,13
		6	,563	,378	,672	-,52	1,65
	4	1	,646	,378	,527	-,44	1,73
		2	-,333	,378	,951	-1,42	,75
		3	-1,854*	,378	,000	-2,94	-,77
		5	-1,813*	,378	,000	-2,90	-,73
		6	-1,292*	,378	,009	-2,38	-,21
	5	1	2,458*	,378	,000	1,37	3,54
		2	1,479*	,378	,002	,39	2,56

		3	-,042	,378	1,000	-1,13	1,04
		4	1,813*	,378	,000	,73	2,90
		6	,521	,378	,740	-,56	1,61
	6	1	1,938*	,378	,000	,85	3,02
		2	,958	,378	,117	-,13	2,04
		3	-,563	,378	,672	-1,65	,52
		4	1,292*	,378	,009	,21	2,38
		5	-,521	,378	,740	-1,61	,56
Scheffe	1	2	-,979	,378	,246	-2,25	,29
		3	-2,500*	,378	,000	-3,77	-1,23
		4	-,646	,378	,712	-1,91	,62
		5	-2,458*	,378	,000	-3,72	-1,19
		6	-1,938*	,378	,000	-3,20	-,67
	2	1	,979	,378	,246	-,29	2,25
		3	-1,521*	,378	,007	-2,79	-,25
		4	,333	,378	,978	-,93	1,60
		5	-1,479*	,378	,010	-2,75	-,21
		6	-,958	,378	,270	-2,22	,31
	3	1	2,500*	,378	,000	1,23	3,77
		2	1,521*	,378	,007	,25	2,79
		4	1,854*	,378	,000	,59	3,12
		5	,042	,378	1,000	-1,22	1,31
		6	,563	,378	,818	-,70	1,83
	4	1	,646	,378	,712	-,62	1,91
		2	-,333	,378	,978	-1,60	,93
		3	-1,854*	,378	,000	-3,12	-,59
		5	-1,813*	,378	,000	-3,08	-,55
		6	-1,292*	,378	,042	-2,56	-,03
	5	1	2,458*	,378	,000	1,19	3,72
		2	1,479*	,378	,010	,21	2,75
		3	-,042	,378	1,000	-1,31	1,22
		4	1,813*	,378	,000	,55	3,08
		6	,521	,378	,862	-,75	1,79
	6	1	1,938*	,378	,000	,67	3,20
		2	,958	,378	,270	-,31	2,22
		3	-,563	,378	,818	-1,83	,70
		4	1,292*	,378	,042	,03	2,56
		5	-,521	,378	,862	-1,79	,75
Bonferroni	1	2	-,979	,378	,151	-2,10	,14
		3	-2,500*	,378	,000	-3,62	-1,38

		4	-,646	,378	1,000	-1,76	,47
		5	-2,458*	,378	,000	-3,58	-1,34
		6	-1,938*	,378	,000	-3,06	-,82
	2	1	,979	,378	,151	-,14	2,10
		3	-1,521*	,378	,001	-2,64	-,40
		4	,333	,378	1,000	-,79	1,45
		5	-1,479*	,378	,002	-2,60	-,36
		6	-,958	,378	,176	-2,08	,16
	3	1	2,500*	,378	,000	1,38	3,62
		2	1,521*	,378	,001	,40	2,64
		4	1,854*	,378	,000	,74	2,97
		5	,042	,378	1,000	-1,08	1,16
		6	,563	,378	1,000	-,56	1,68
	4	1	,646	,378	1,000	-,47	1,76
		2	-,333	,378	1,000	-1,45	,79
		3	-1,854*	,378	,000	-2,97	-,74
		5	-1,813*	,378	,000	-2,93	-,69
		6	-1,292*	,378	,011	-2,41	-,17
	5	1	2,458*	,378	,000	1,34	3,58
		2	1,479*	,378	,002	,36	2,60
		3	-,042	,378	1,000	-1,16	1,08
		4	1,813*	,378	,000	,69	2,93
		6	,521	,378	1,000	-,60	1,64
	6	1	1,938*	,378	,000	,82	3,06
		2	,958	,378	,176	-,16	2,08
		3	-,563	,378	1,000	-1,68	,56
		4	1,292*	,378	,011	,17	2,41
		5	-,521	,378	1,000	-1,64	,60

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05		
	geometry	N	1	2	3
Tukey HSD[a]	1	48	1,06		
	4	48	1,71		

	2	48	2,04	2,04	
	6	48		3,00	3,00
	5	48			3,52
	3	48			3,56
	Sig.		,103	,117	,672
Scheffe[a]	1	48	1,06		
	4	48	1,71		
	2	48	2,04	2,04	
	6	48		3,00	3,00
	5	48			3,52
	3	48			3,56
	Sig.		,246	,270	,818

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48,000.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8,424	2	4,212	,989	,373
Within Groups	1213,490	285	4,258		
Total	1221,913	287			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) space_type	(J) space_type				Lower Bound	Upper Bound
Tukey HSD	a	b	-,406	,298	,361	-1,11	,30
		c	-,292	,298	,591	-,99	,41
	b	a	,406	,298	,361	-,30	1,11
		c	,115	,298	,922	-,59	,82
	c	a	,292	,298	,591	-,41	,99
		b	-,115	,298	,922	-,82	,59
Scheffe	a	b	-,406	,298	,396	-1,14	,33
		c	-,292	,298	,620	-1,02	,44
	b	a	,406	,298	,396	-,33	1,14

		c	,115	,298	,929	-,62	,85
	c	a	,292	,298	,620	-,44	1,02
		b	-,115	,298	,929	-,85	,62
Bonferroni	a	b	-,406	,298	,521	-1,12	,31
		c	-,292	,298	,985	-1,01	,43
	b	a	,406	,298	,521	-,31	1,12
		c	,115	,298	1,000	-,60	,83
	c	a	,292	,298	,985	-,43	1,01
		b	-,115	,298	1,000	-,83	,60

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05
	space_type	N	1
Tukey HSD[a]	a	96	2,25
	c	96	2,54
	b	96	2,66
	Sig.		,361
Scheffe[a]	a	96	2,25
	c	96	2,54
	b	96	2,66
	Sig.		,396

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 96,000.

```
FILTER OFF.
USE ALL.
EXECUTE.
ONEWAY sequence BY geometry
  /MISSING ANALYSIS
  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Experiment 2 – approach-avoidance decision run, 2nd sequence. Consistent response analysis.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	344,767	5	68,953	17,958	,000
Within Groups	1082,813	282	3,840		
Total	1427,580	287			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

						95% Confidence Interval	
	(I) geometry	(J) geometry	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Tukey HSD	1	2	-,542	,400	,754	-1,69	,61
		3	-2,583*	,400	,000	-3,73	-1,44
		4	,083	,400	1,000	-1,06	1,23
		5	-2,438*	,400	,000	-3,59	-1,29
		6	-1,667*	,400	,001	-2,81	-,52
	2	1	,542	,400	,754	-,61	1,69
		3	-2,042*	,400	,000	-3,19	-,89
		4	,625	,400	,624	-,52	1,77
		5	-1,896*	,400	,000	-3,04	-,75
		6	-1,125	,400	,058	-2,27	,02
	3	1	2,583*	,400	,000	1,44	3,73
		2	2,042*	,400	,000	,89	3,19
		4	2,667*	,400	,000	1,52	3,81
		5	,146	,400	,999	-1,00	1,29
		6	,917	,400	,201	-,23	2,06
	4	1	-,083	,400	1,000	-1,23	1,06
		2	-,625	,400	,624	-1,77	,52

		3	-2,667*	,400	,000	-3,81	-1,52
		5	-2,521*	,400	,000	-3,67	-1,37
		6	-1,750*	,400	,000	-2,90	-,60
	5	1	2,438*	,400	,000	1,29	3,59
		2	1,896*	,400	,000	,75	3,04
		3	-,146	,400	,999	-1,29	1,00
		4	2,521*	,400	,000	1,37	3,67
		6	,771	,400	,388	-,38	1,92
	6	1	1,667*	,400	,001	,52	2,81
		2	1,125	,400	,058	-,02	2,27
		3	-,917	,400	,201	-2,06	,23
		4	1,750*	,400	,000	,60	2,90
		5	-,771	,400	,388	-1,92	,38
Scheffe	1	2	-,542	,400	,871	-1,88	,80
		3	-2,583*	,400	,000	-3,92	-1,24
		4	,083	,400	1,000	-1,26	1,42
		5	-2,438*	,400	,000	-3,78	-1,10
		6	-1,667*	,400	,005	-3,01	-,33
	2	1	,542	,400	,871	-,80	1,88
		3	-2,042*	,400	,000	-3,38	-,70
		4	,625	,400	,785	-,72	1,97
		5	-1,896*	,400	,001	-3,24	-,56
		6	-1,125	,400	,165	-2,47	,22
	3	1	2,583*	,400	,000	1,24	3,92
		2	2,042*	,400	,000	,70	3,38
		4	2,667*	,400	,000	1,33	4,01
		5	,146	,400	1,000	-1,19	1,49
		6	,917	,400	,388	-,42	2,26
	4	1	-,083	,400	1,000	-1,42	1,26
		2	-,625	,400	,785	-1,97	,72
		3	-2,667*	,400	,000	-4,01	-1,33
		5	-2,521*	,400	,000	-3,86	-1,18
		6	-1,750*	,400	,002	-3,09	-,41
	5	1	2,438*	,400	,000	1,10	3,78
		2	1,896*	,400	,001	,56	3,24
		3	-,146	,400	1,000	-1,49	1,19
		4	2,521*	,400	,000	1,18	3,86
		6	,771	,400	,592	-,57	2,11
	6	1	1,667*	,400	,005	,33	3,01
		2	1,125	,400	,165	-,22	2,47

		3	-,917	,400	,388	-2,26	,42
		4	1,750*	,400	,002	,41	3,09
		5	-,771	,400	,592	-2,11	,57
Bonferroni	1	2	-,542	,400	1,000	-1,73	,64
		3	-2,583*	,400	,000	-3,77	-1,40
		4	,083	,400	1,000	-1,10	1,27
		5	-2,438*	,400	,000	-3,62	-1,25
		6	-1,667*	,400	,001	-2,85	-,48
	2	1	,542	,400	1,000	-,64	1,73
		3	-2,042*	,400	,000	-3,23	-,86
		4	,625	,400	1,000	-,56	1,81
		5	-1,896*	,400	,000	-3,08	-,71
		6	-1,125	,400	,079	-2,31	,06
	3	1	2,583*	,400	,000	1,40	3,77
		2	2,042*	,400	,000	,86	3,23
		4	2,667*	,400	,000	1,48	3,85
		5	,146	,400	1,000	-1,04	1,33
		6	,917	,400	,340	-,27	2,10
	4	1	-,083	,400	1,000	-1,27	1,10
		2	-,625	,400	1,000	-1,81	,56
		3	-2,667*	,400	,000	-3,85	-1,48
		5	-2,521*	,400	,000	-3,70	-1,34
		6	-1,750*	,400	,000	-2,93	-,57
	5	1	2,438*	,400	,000	1,25	3,62
		2	1,896*	,400	,000	,71	3,08
		3	-,146	,400	1,000	-1,33	1,04
		4	2,521*	,400	,000	1,34	3,70
		6	,771	,400	,824	-,41	1,95
	6	1	1,667*	,400	,001	,48	2,85
		2	1,125	,400	,079	-,06	2,31
		3	-,917	,400	,340	-2,10	,27
		4	1,750*	,400	,000	,57	2,93
		5	-,771	,400	,824	-1,95	,41

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets -- sequence

	geometry	N	Subset for alpha = 0.05		
			1	2	3
Tukey HSD[a]	4	48	1,38		
	1	48	1,46		
	2	48	2,00	2,00	
	6	48		3,13	3,13
	5	48			3,90
	3	48			4,04
	Sig.		,624	,058	,201
Scheffe[a]	4	48	1,38		
	1	48	1,46		
	2	48	2,00	2,00	
	6	48		3,13	3,13
	5	48			3,90
	3	48			4,04
	Sig.		,785	,165	,388

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48,000.

Oneway

ANOVA

sequence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5,028	2	2,514	,504	,605
Within Groups	1422,552	285	4,991		
Total	1427,580	287			

Post Hoc Tests -- Multiple Comparisons

Dependent Variable: sequence

	(I) space_type	(J) space_type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	a	b	,313	,322	,597	-,45	1,07
		c	,083	,322	,964	-,68	,84
	b	a	-,313	,322	,597	-1,07	,45
		c	-,229	,322	,757	-,99	,53

	c	a	-,083	,322	,964	-,84	,68
		b	,229	,322	,757	-,53	,99
Scheffe	a	b	,313	,322	,626	-,48	1,11
		c	,083	,322	,967	-,71	,88
	b	a	-,313	,322	,626	-1,11	,48
		c	-,229	,322	,777	-1,02	,56
	c	a	-,083	,322	,967	-,88	,71
		b	,229	,322	,777	-,56	1,02
Bonferroni	a	b	,313	,322	1,000	-,46	1,09
		c	,083	,322	1,000	-,69	,86
	b	a	-,313	,322	1,000	-1,09	,46
		c	-,229	,322	1,000	-1,01	,55
	c	a	-,083	,322	1,000	-,86	,69
		b	,229	,322	1,000	-,55	1,01

Homogeneous Subsets -- sequence

			Subset for alpha = 0.05
	space_type	N	1
Tukey HSD[a]	b	96	2,47
	c	96	2,70
	a	96	2,78
	Sig.		,597
Scheffe[a]	b	96	2,47
	c	96	2,70
	a	96	2,78
	Sig.		,626

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 96,000.

```
NPAR TESTS
  /BINOMIAL (0.50)=NonprominetSharphigh NonprominetRoundedhigh
  /MISSING ANALYSIS.
```

Testes de NPar

[ConjuntodeDados1] C:\Marina_OLD\PASTA DESKTOP 2018\Miguel_Carreiro\Dados_Maio_2018\Avaliação dos estímulos correspondentes_gosto_alteração.sav

Self-questionnaire. Aesthetic judgement data.

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Non-prominet/Sharp-high	Grupo 1	0	17	,53	,50	,860
	Grupo 2	1	15	,47		
	Total		32	1,00		
Non-prominet/Rounded-high	Grupo 1	1	17	,53	,50	,860
	Grupo 2	0	15	,47		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=NonprominetSharptight NonprominetRoundedtight
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Non-prominet/Sharp-tight	Grupo 1	0	26	,81	,50	,001
	Grupo 2	1	6	,19		
	Total		32	1,00		
Non-prominet/Rounded-tight	Grupo 1	1	24	,75	,50	,007
	Grupo 2	0	8	,25		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=NonprominetSharploose NonprominetRoundedloose
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Non-prominet/Sharp-loose	Grupo 1	0	28	,88	,50	,000
	Grupo 2	1	4	,13		
	Total		32	1,00		
Non-prominet/Rounded-loose	Grupo 1	1	27	,84	,50	,000
	Grupo 2	0	5	,16		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=RailprominetSharphigh RailprominetRoundedhigh
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Rail-prominet/Sharp-high	Grupo 1	0	21	,66	,50	,110
	Grupo 2	1	11	,34		
	Total		32	1,00		
Rail-prominet/Rounded-high	Grupo 1	1	21	,66	,50	,110
	Grupo 2	0	11	,34		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=RailprominetSharptight RailprominetRoundedtight
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Rail-prominet/Sharp-tight	Grupo 1	0	26	,81	,50	,001
	Grupo 2	1	6	,19		
	Total		32	1,00		

Rail-prominet/Rounded-tight	Grupo 1	1	26	,81	,50	,001
	Grupo 2	0	6	,19		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=RailprominetSharploose RailprominetRoundedloose
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Rail-prominet/Sharp-loose	Grupo 1	1	4	,13	,50	,000
	Grupo 2	0	28	,88		
	Total		32	1,00		
Rail-prominet/Rounded-loose	Grupo 1	0	4	,13	,50	,000
	Grupo 2	1	28	,88		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=SpotprominetSharphigh SpotprominetRoundedhigh
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Spot-prominet/Sharp-high	Grupo 1	0	19	,59	,50	,377
	Grupo 2	1	13	,41		
	Total		32	1,00		
Spot-prominet/Rounded-high	Grupo 1	1	19	,59	,50	,377
	Grupo 2	0	13	,41		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=SpotprominetSharptight SpotprominetRoundedtight
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Spot-prominet/Sharp-tight	Grupo 1	0	26	,81	,50	,001
	Grupo 2	1	6	,19		
	Total		32	1,00		
Spot-prominet/Rounded-tight	Grupo 1	1	26	,81	,50	,001
	Grupo 2	0	6	,19		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=SpotprominetSharploose SpotprominetRoundedloose
  /MISSING ANALYSIS.
```

Testes de NPar

Teste binomial

		Categoria	N	Proporção observada	Proporção de teste	Sig exata (bilateral)
Spot-prominet/Sharp-loose	Grupo 1	0	29	,91	,50	,000
	Grupo 2	1	3	,09		
	Total		32	1,00		
Spot-prominet/Rounded-loose	Grupo 1	1	29	,91	,50	,000
	Grupo 2	0	3	,09		
	Total		32	1,00		

```
GET
  FILE='C:\Users\maan\Desktop\Miguel_Carreiro\Dados_Maio_2018\Avaliação dos
estímulos correspondentes_entro_alteração.sav'.
DATASET NAME DataSet1 WINDOW=FRONT.
NPAR TESTS
  /BINOMIAL (0.50)=NonprominetSharphigh NonprominetRoundedhigh
  /MISSING ANALYSIS.
```

Self-questionnaire. Approach-avoidance decision data.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Non-prominet/Sharp-high	Group 1	0	18	,56	,50	,597
	Group 2	1	14	,44		
	Total		32	1,00		
Non-prominet/Rounded-high	Group 1	1	18	,56	,50	,597
	Group 2	0	14	,44		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=NonprominetSharptight NonprominetRoundedtight
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Non-prominet/Sharp-tight	Group 1	0	26	,81	,50	,001
	Group 2	1	6	,19		
	Total		32	1,00		
Non-prominet/Rounded-tight	Group 1	1	24	,75	,50	,007
	Group 2	0	8	,25		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=NonprominetSharploose NonprominetRoundedloose
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Non-prominet/Sharp-loose	Group 1	0	28	,88	,50	,000
	Group 2	1	4	,13		
	Total		32	1,00		
Non-prominet/Rounded-loose	Group 1	1	27	,84	,50	,000
	Group 2	0	5	,16		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=RailprominetSharphigh RailprominetRoundedhigh
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Rail-prominet/Sharp-high	Group 1	0	21	,66	,50	,110
	Group 2	1	11	,34		
	Total		32	1,00		
Rail-prominet/Rounded-high	Group 1	1	21	,66	,50	,110
	Group 2	0	11	,34		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=RailprominetSharptight RailprominetRoundedtight
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Rail-prominet/Sharp-tight	Group 1	0	27	,84	,50	,000
	Group 2	1	5	,16		
	Total		32	1,00		
Rail-prominet/Rounded-tight	Group 1	1	27	,84	,50	,000
	Group 2	0	5	,16		

	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=RailprominetSharploose RailprominetRoundedloose
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Rail-prominet/Sharp-loose	Group 1	1	4	,13	,50	,000
	Group 2	0	28	,88		
	Total		32	1,00		
Rail-prominet/Rounded-loose	Group 1	0	4	,13	,50	,000
	Group 2	1	28	,88		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=SpotprominetSharphigh SpotprominetRoundedhigh
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Spot-prominet/Sharp-high	Group 1	0	19	,59	,50	,377
	Group 2	1	13	,41		
	Total		32	1,00		
Spot-prominet/Rounded-high	Group 1	1	19	,59	,50	,377
	Group 2	0	13	,41		
	Total		32	1,00		

```
NPAR TESTS
  /BINOMIAL (0.50)=SpotprominetSharptight SpotprominetRoundedtight
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Spot-prominet/Sharp-tight	Group 1	0	27	,84	,50	,000
	Group 2	1	5	,16		
	Total		32	1,00		
Spot-prominet/Rounded-tight	Group 1	1	27	,84	,50	,000
	Group 2	0	5	,16		
	Total		32	1,00		

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NPAR TESTS
  /BINOMIAL (0.50)=SpotprominetSharploose SpotprominetRoundedloose
  /MISSING ANALYSIS.
```

NPar Tests

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Exact Sig. (2-tailed)
Spot-prominet/Sharp-loose	Group 1	0	29	,91	,50	,000
	Group 2	1	3	,09		
	Total		32	1,00		
Spot-prominet/Rounded-loose	Group 1	1	29	,91	,50	,000
	Group 2	0	3	,09		
	Total		32	1,00		

Appendix G

‘Overview on Rational Thought and Form’

2. Discourse on Human Nature, Western Thought and Its Representation and Production

Note to the reader: The material contained in this 'Appendix G' was a part of this thesis' Chapter 2. It was framed by section "2.1. Framework on Thought and the Importance of Historic Background" and section "2.3. The Revolutions", current section 2.2. The above, original chapter's title was maintained, as the chapter, sections and sub-section's names and numbering, in case the reader wishes to accompany this thesis' previously followed discourse.

2.2. Overview on Rational Thought and Form[1]

2.2.1. In Principio[2]

In principio erat Verbum et Verbum erat apud Deum et Deus erat Verbum

John 1:1[3]

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[1] Introductory note: We believe that the basis and evolution of our rational thought had the ability to characterize our way of thinking. Along this section we will identify those historic key events that may have contributed to shape our character and identity. We will focus on some of the oldest writing sources that have arrived to our time and centre on philosophy, mathematics and geometry as a 'new' scientific research methodology and representative processes and go through cases from the 'beginning and ordering of everything there is', as an allusion to the Pentateuch's Genesis, to the classical Greek, Medieval and Modern Era thought in search for these events.

[2] Introductory note: In this section we will briefly address to the core ideas of the Pentateuch's Genesis, due to the reason that it constitutes one of the oldest sources of human history and thought where we assist to the 'born' of basic concepts that will be a target of more development further ahead in this document, such as creation, order and moral virtues.

We have already pointed out that man is a rational animal. It is easy for us to have, or have gain, relatively accurate knowledge on rationality. As rational beings we can rationalize about rationality and we have been doing it or being confronted by it if not from the beginning at least from quite early times. This may have happened when we became intellectually aware of things.

To become intellectually aware of things has led us to question. Question about ourselves, about our existence, question about the world and everything that happened around us. Question about what we were unable to understand, find an answer and acknowledge it. These were most certainly, the main reasons that led us to religion and philosophy: a mean to give comprehensible answers to what was unexplainable, at least at a present time, and to communicate them (Russel 1961; Abbagnano 2013; Cordón and Martínez 2014).

In this way, it is our opinion that, in order to have a clear understanding of what we are, it is essential for us to go back in time. Into those times when we started to find answers to existentialist questions. The days when thought began to be represented, to future notice, through methods of expression, when pioneer religions and philosophies were born and carried on. Basically when humans began to engrave the answers to his most primeval fears and philosophic questions. This is the reason why, in order to understand who and what we are, I believe to be so crucial an overview study of early religions, where the theories of the beginnings are identified, and philosophy.

The Pentateuch

The Pentateuch is known as one of our most ancient writing sources. Its origins go back to the time when God spoke to Moses and all the Jewish people[4] at Mount Sinai

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[3] Gospel of John, 1:1. In the beginning was the Word, and the Word was with God, and the Word was God. Available from: www.biblegateway

[4] The Jewish people did not believe in Moses our teacher because of the miracles he performed. If one believes in something because of miracles, he may suspect that they were performed through sleight of hand or sorcery… We believe in Moshe because of what happened at Mount Sinai. Our

(Spiro 2008). It is said that back then Moses spent 40 days listening to God speaking the 613 commandments and the Oral Law, the principles how to apply them (idem). He later spent another 40 years writing the words of God in what would be known as the Written Law: the Torah, the five books of Moses or, as we know then in the western Christian tradition, the Pentateuch (idem).

If we choose to accept that these documents were dictated to Moses during his long life span (13th and 12th centuries BC) and not the result of a secular or millenary oral tradition later assembled by one or more individuals, it is more certain that books dated from a 'few years' later, like the *Iliad* and the *Odyssey*, from the 8th century BC, where actually a direct result of a "long, epic oral tradition" (Lourenço in Homero 2014, p.7) that was carried on for several centuries, before alphabetic writing was imposed in Greece, and culminated in the supposed opera of the Great Poet (Ibidem, p.9; Russel 1961, p.28). History and knowledge had begun to be engraved in formats that are in its essence more long lasting than the ephemeral and easily perishable human mind.

It is in such early works that we can find the ideas and concerns of distant time's realities. They 'talk' to us with the same words that they did to those from that time. And since, as stated before, in this document we propose to do an overview on the evolution of human thought based on the evolution of the notions and understandings of ideas, aesthetics and form, it is in these texts, as expressed time capsuled thoughts, that we can find the earliest known ideas of it. And although these ideas may not completely fit in the definition of aesthetics, as we understood it, they are the closest we can get to it in between resources like analogies and metaphors.

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own eyes saw, not a stranger's, our own ears heard, and not another's...The revelation at Sinai is the only real proof that Moses' prophecy was true and above suspicion... (Yad, Yesodei HaTorah 8:1.). Found in Spiro 2008.

Light and Darkness – A Sense of Order

> *1 In the beginning God created the heaven and the earth.*
>
> *2 And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters.*
>
> *3 And God said, Let there be light: and there was light.*
>
> *4 And God saw the light, that it was good: and God divided the light from the darkness.* [5]

It is in the very early beginning of one of the most ancient texts of our history that Moses reveals how God created the heaven and the earth and everything there is. In the beginning there was darkness and God said, "Let there be light; and there was light". He likes it and He separates the light from the darkness. He had divided the day from the night and he creates time. He then gives light to the day and he also gives light, yet lesser, to the night. He had begun to set a sense of order into everything there would be.

Besides ordering the world, these passages of the Genesis give us a light on what is considered to be good and bad in those times. Since we depends on our senses to perceive and interact with the world, that vision is one of our *early* senses and that there is no vision without light, following our primordial nature, light is good. We know now that the sunlight, with all its properties, is an indispensable factor for existence, either for the presence, continuation or stable condition, physical or psychological, of life. Apart from this basic, unavoidable aspect, we also better assure our odds of survival when in the presence of light. We hunt better with light. In the absence of it, it is with the recreation of light that we restore the conditions of the open day environment and avoid the cold and protect ourselves.

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[5] The Book of Genesis, chapter 1. King James Version. Found at Bible Gateway in 'Genesis 1'. Available from: https://www.biblegateway.com, visited on July, 14, 2016

As we will see further ahead when talking about aesthetics in the early Greek period, with special focus on the words of Socrates, we often found beauty in something that fells or is good for us, either individually or as individuals in a society group. By creating light and separating it from darkness, Moses may have given us one of our most ancient suggestion of aesthetics. And so, aesthetics may have then been since beginning of its existence deeply associated with the notion of good and order and, by turn, good and order intimately associated with aesthetics.

Good and Moral

Several are the passages over the Pentateuch that allude in a more direct way to light and darkness towards good and bad connotations. Light is here often associated with good[6] and well-being[7] and darkness with evil[8] or unpleasant conditions.

The God of the Pentateuch and the Old Testament[9] is in general not the forgiving and graceful God of the New Testament. He is a judging and punisher God. It is mainly by violence that this God communicates what He believes to be good and bad for the Hebrew people and mankind. During the narrative of the Hebrew people's escape from Egypt and their travel towards the promised land of Israel, God shows his disappointment towards man in several occasions and acts, usually with violence, in order to give to the Hebrew people a direction towards what is to be considered good and moral, principles that are to be sought in the future. Noah's Ark and Sodom and Gomorra are only some of the probably most known episodes where we can testify God's wrath towards His people.

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[6] "Woe unto them that call evil good, and good evil; that put darkness for light, and light for darkness; that put bitter for sweet, and sweet for bitter!" Isaiah 5:20. Available from: https://www.biblegateway.com, visited on July, 23, 2016.

[7] "I form the light, and create darkness: I make peace, and create evil: I the LORD do all these things." Isaiah 45:7. Available from: https://www.biblegateway.com, visited on July, 23, 2016.

[8] See the two previous footnotes.

[9] Or the Hebrew Bible.

2.2.2. Philosophy - A Novel Scientific Methodology for the Examination of the Real. The Greeks[10]

Philosophy appeared, as a distinct form from theology, in the Greece of the 6th century B.C. (Russel 1961, p11). Its roots are linked with the inherited knowledge that began to arrive in Greece around this time from Babylon and Egypt. It is the case of Geometry, which was supposedly born in Egypt with the growing necessity to measure the land after the floods of the Nile, Astronomy, developed by the Babylonians to grew astrological believes, and Arithmetic's, also original from Egypt. However, it seems that these disciplines had a practical character in their native places that contrasted with the speculative and scientific nature that characterized the approach of such disciplines by the Greeks (Abbagnano 2013, p.17).

As Russel understands it, Philosophy is a "No Man's Land" (Russel 1961, p.11) which lies between the two other areas of knowledge: somewhere between science's 'definite' knowledge and theology's 'dogma' (idem). "Like theology, it consists of speculations on matters as to which definite knowledge has, so far, been unascertainable; but like science, it appeals to human reason rather than to authority, whether that of tradition or that of revelation" (ibidem, p.10).

Yet according with the vision of Russel, there were two great trends in ancient Greece: "one passionate, religious, mystical, other-worldly, the other cheerful, empirical, rationalistic, and interested in acquiring knowledge of a diversity of facts" (ibidem, p.39), being the latter better represented by Herodotus, the earliest Ionian philosophers and, "up to a point", Aristotle (idem). If the first points to the opera of Homer, through which the ancient Greeks learned almost everything that they knew about moral, theology and history, geography, navigation, military art or cosmology,

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[10] Introductory note: Philosophy is considered the first true science. The evolution of this rational, autonomous way of attempting to understand the truth about things and seize the incommensurability of the world that surrounds us have launched the basis for our current thought path with intimate, core associations with mathematics. Through this section we will accompany an evolution of events that shown to be decisive for the moulding of our character and identity.

the second settled on a criticism on popular wisdom and myth, in what was latter to be known as philosophy (Cordón and Martínez 2014, p.26).

While Popular wisdom, yet highly popular in the orient, embodied the gathered knowledge and tradition later transformed in teachings by the ancient poets and had begun to fall in disrepute (Cordón and Martínez 2014, p.26), the myth is an intellectual attitude that, facing the real world, will attempt to give answers and full explanations to the meaningful problems and enigmas about "the origin and nature of the universe, man, civilization and technique, social structure, etc" (idem).

Philosophy, as a branch of knowledge, will oppose to the irrational suppositions of the myth, criticizing the arbitrariness of the divine interventions but preserving the idea of such necessity, depriving it from its illogical and inscrutable character and preserving it as the rationality of the real (ibidem, p.27). Its foundation is that man does not possess wisdom but must seek it through research as opposition to tradition and easy myth responses. Descartes raised some restrictions at defining man as a rational animal, preferring to characterize him, as we have shortly seen, as a "thing that thinks" (Descartes 1911, pp.9-10). However difficult that it may be to define man as an animal and, moreover, an animal that reasons, the fact is that, without even trying to describe us in such terms, we are rational animals able to seek truth in an autonomous way. Aristotle would say that "all man tend, by nature, to knowledge" (Abbagnano 2013, p.18) in the way that he not only aims to this learning process but it is also in his reach to get it. As a consequence, Greek Philosophy is rational, autonomous research that does not settle in an already expressed, revealed truth but in the strength of reason as its only guide (idem). Philosophy is then an 'novel' scientific method that lays on autonomous, rational research (as in science) and indicates a specific research that in some way is essential to other (researches) but does not include them in itself (ibidem, p.19). It is rational explanation.

Philosophy's rational explanation takes place when arbitrariness is overcome by necessity as the conviction that things happen when and how they must do. To Cordón this conviction, yet elementary, is one of our western society's most important conquests (Cordón and Martínez 2014, p.28). Such idea, of necessity, is linked to an intellectual scheme within which Greek rational explanation takes place.

According to ancient Greek thought, things or ideas could be divided in paired opposed concepts, as we will better see further ahead when talking about Pythagoras. In this way, all the things that happened were identified with the ideas of constancy and variance. While (i) constancy referred to the essence (eidos) of things, what something is despite of its possible changes of appearance or state, what things truly are, (ii) its variance refers to its appearance, what things seem to be. Essence is then the unity of things compared to the multiplicity of its states and appearances and also the multiplicity of the individuals that share it. To know things is in this way to know and understand what they really are, or in other words, what they share in their constancy state. (ibidem, pp.29)

As these things, also the field of knowledge was characterized with an intrinsic duality: senses versus reason. Reality may then be pointed as a product of knowledge that is, by turn, divided in sensible and rational knowledge. Since we depend in our senses to seize the world but, at the same time, this sensible knowledge show us a multiplicity of individuals, appearances and states, it was at some point obvious that the senses were enough for us to reach the true being of things and that we had to rely on an intellectual, rational, reasonable effort in order to do so. While sensible knowledge is able to capture reality's plurality, what changes and what things appear to be; rational knowledge is able to get to the reality's unity, its constancy and what it truly stands for (ibidem, p.29). The heterogeneity of rational knowledge in comparison with sensible knowledge has been revealed to the Greeks mainly through the field of mathematics. With the specificity of mathematical reasoning and how the real world could be connected and represented by mathematical structures (idem).

Mathematics had begun to be recognized and directly linked with the real, a relationship that would unquestionably characterize the multidisciplinary philosophy, reasoning and thought of the ancient Greek world. While Philosophy arose as an unprecedented scientific research methodology in the search to understand the true meaning of things, why they were and behaved the way they did, mathematics established as the mean to achieve and support the interpretation and knowledge of such reality.

However, the role of mathematics in the 6th century BC was merely the beginning of a new age to come. While attempting to translate and represent the knowledge of the real, ironically it became the root of a new reasoning age as it settled as the basis of the western society's thinking process.

Thales, Geometry and the Mathematical Proof

Thales of Miletus is pointed as the first authentic representative of the Greek philosophy (Abbagnano 2013, p. 21). One of the Seven Sages (or Seven Wise Man), it is attributed to him the aphorism "know thyself" (idem; Pierce 2016, p.17), probably in a direct reference to the philosophical quest, or methodological research, for the self. Besides being the first philosopher (Russel 1961, p. 27), he is also pointed as the western father of the science of geometry (ibidem, p.47) and mathematics.

It was with the Greeks that mathematics began to be faced as a study area instead of being just considered a simple set of techniques to measure, count and calculate (Devlin 2002, p.8). Although the basis of mathematics, the origin and symbols of the numbers, written numeric systems and early counting systems go back to the Vedas, the Sumerians, the Babylonians and the Egyptians (Devlin 2002, pp.16-20) and geometry can, by turn, be traced back to the Babylonian, Chinese and Hindu civilizations and is ultimately defined as the measure of the land in ancient Egypt (Herodotus; Pierce 2016, pp.9/40; Pierce 2013, p.3; Franco de Oliveira 1995, p.21; Russel 1961, p.47), the concept of abstract number and, in a general sense, mathematics, is most probably situated in the 6th century B.C. when Thales developed his research work on Geometry (Devlin 2002, p.20).

Until this time, intuition, empiric research and experimentation were the only channels of knowledge (Franco de Oliveira 1995, p.21). However, with the introduction of the idea that mathematic statements with precise formulations could be verified in a logic way through formal argumentation (Devlin 2002, p.8) and deductive thinking, the demonstrations or deduction thru known or accepted hypotheses that enable us to arrive to the veracity of geometric propositions (Franco de Oliveira 1995, p.21), we have transformed these disciplines into science (Pierce 2016, pp.64-65; Abbagnano 2013, p.27). In the Preface of the B Edition of 'The Critique of Pure Reason', Immanuel Kant attributes to "the person who demonstrated the isosceles triangle[11] (whether he was called 'Thales' or had some other name)" (Kant in Pierce 2016, p.65)[12], the discovery of mathematical proof, a revolution in human thought (Pierce 2016, pp.64-65; Pierce 2013, p.1). Such 'mathematical demonstrations' signed the appearance of the theorem and constitutes the ground and first principle of what is and has been mathematics (Devlin 2002, p. 8, 20) and geometry.

Mathematics (and geometry) had been born as a pure system of abstract representation of a reality not so abstract at all. Devlin writes that "none of the entities that form the substrate of mathematics exist in the physic world; numbers, points, lines and planes, surfaces, geometric figures, functions, etc., are pure abstractions that only exist in mankind's collective mind" (Devlin 2002, p.12-13). However, the abstractions of mathematics as science of patterns have become to include the real essence of our physical, biologic and sociologic levels as the hidden world of our mind and thought. Mathematics, as an abstract representation system, would then begin to be intrinsically associated with thought since the beginning of the ancient Greek period.

The Principle of Everything

For the Miletus philosophers – Thales, Anaximander and Anaximenes – there was possible to establish one only principle (Cordón and Martínez 2014, p.37), the essence, a unity that "constitutes its being, the only law that regulates its future" (Abbagnano 2013, p.27). This principle, *arché*, substance or nature, *physis*, is simultaneously the origin, substrate and cause of everything there is (Cordón and Martínez 2014, p.34). "It is the beginning not only in the sense of explaining its origin but yet and mainly in of becoming intelligible and reconduct to the unity its multiplicity and mutability that appears, at a first sight, so rebel to all unitary consideration (...) the substance as a

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[11] Among other theorems, it is also attributed to Thales the theorem that a diameter bisects a circle (Pierce 2016, pp.7, 40).

[12] Preface to the B Edition of the Critique of Pure Reason.

principle of action and intelligibility of everything that is multiple and future" (Abbagnano 2013, p.27).

Aristotle would write in Metaphysics: "Of the first philosophers, then, most thought the principles which were of the nature of matter were the only principles of all things. That of which all things that are consist, the first from which they come to be, the last into which they are resolved (the substance remaining, but changing in its modifications), this they say is the element and this the principle of things and therefore they think nothing is either generated or destroyed, since this sort of entity is always conserved, as we say Socrates neither comes to be absolutely when he comes to be beautiful or musical, nor ceases to be when loses these characteristics, because the substratum, Socrates himself, remains. Just so they say nothing else comes to be or ceases to be; for there must be some entity—either one or more than one—from which all other things come to be. Yet they do not all agree as to the number and the nature of these principles. Thales, the founder of this type of philosophy, says the principle is water (for which reason he declared that the earth rests on water), getting the notion perhaps from seeing that the nutriment of all things is moist, and that heat itself is generated from the moist and kept alive by it (and that from which they come to be is a principle of all things). He got his notion from this fact, and from the fact that the seeds of all things have a moist nature, and that water is the origin of the nature of moist things. Some think that even the ancients who lived long before the present generation, and first framed accounts of the gods, had a similar view of nature; for they made Ocean and Tethys the parents of creation, and described the oath of the gods as being by water, to which they give the name of Styx; for what is oldest is most honourable, and the most honourable thing is that by which one swears. It may perhaps be uncertain whether this opinion about nature is primitive and ancient, but Thales at any rate is said to have declared himself thus about the first cause. Hippo [of Samos] no one would think fit to include among these thinkers, because of the paltriness of his thought. Anaximenes and Diogenes make air prior to water, and the most primary of the simple bodies, while Hippasus of Metapontum and Heraclitus of Ephesus say this of fire, and Empedocles says it of the four elements (adding a fourth earth to those which have been named); for these, he says, always remain and do not come to be, except that they come to be more or fewer, being aggregated into one and segregated out of one. Anaxagoras of Clazomenae, who, though older than Empedocles, was later in his philosophical activity, says the principles are infinite in number; for he says almost all the things that are made of parts like themselves, in the manner of water or fire, are generated and destroyed in this way, only by aggregation and segregation, and are not in any other sense generated or destroyed, but remain eternally" (Pierce 2016, p.59-61).

The Number is All

For Pythagoras, this substance and principle of everything is the number or is formed by numbers (Bonell 1994, p.75).

The Pythagoreans believed that the principles of mathematics were the principles of all things. And instead of turning to a corporeal substance to explain the order of the world, as did the Ionians, they make the substance of the world out of that same order. For them, the number appears as both substance of the world and the hypothesis of a measurable order of phenomena (Abbagnano 2013, p.39). According to Abbagnano, their great legacy to the history of western science was the recognition of the mathematic measure's main function to comprehend the order and the unity of the world. "As substance of [this] world, the number is the original model of all things since, in its perfect ideal, it represents the order in them implied" (idem).

In this doctrine, the arithmetic and geometric meanings of the number appear as one, geometrically determining an ordered spatial magnitude and expressing it thru a number. The circle follows the '1'; the *vessica piscis*, the '2'; the triangle, the '3' and in fourth place appears the *tetraktys*, the sacred figure that embodies the true meaning of the Pythagorean number. Obtained by the sum of the first positive natural numbers, the *tetraktys* represents the number '10' through a construction of an equilateral triangle with a side of four units. It is either a geometric figure that expresses a number or a number that expresses a geometric figure but, in both cases, the concept that it encloses is that of the measurable order (Abbagnano 2013, p.40).

Since "the number is the substance of [all] things, all the oppositions among things reduce to oppositions between numbers" (idem), and the oppositions in relation to the measurable order, to the limit – that enclosures the measure – and the unlimited – that excludes it. We have then the case that to each of the ten numbers correspond ten fundamental oppositions:

- To the ‘1’, the unity, limit and unlimited;
- To the ‘2’, odd and even;
- To the ‘3’, unity and multiplicity;
- To the ‘4’, right and left;
- To the ‘5’, male and female;
- To the ‘6’, quietness and movement;
- To the ‘7’, straight and curve;
- To the ‘8’, light and darkness;
- To the ‘9’, good and evil and;
- To the ’10, square and rectangle.

Since the limit represents order and perfection, everything that is located at this side on this list of opposites has a positive connotation and consequently, everything that is set on the other side, a negative connotation. The conflict between opposites reconciles and balances, however, through a principle of harmony. Such harmony represents for the Pythagoreans the ultimate meaning of things.

It is also attributed to Pythagoras or the Pythagoreans the idealization of the five regular polyhedrons, later popularized by Plato and Johannes Kepler, and the discovery of the fixed intervals of the musical scale. While the ‘platonic solids’ consummate, through geometry, the relation between numbers and the physical world (to each of the solids there was assigned one of the four elements: earth to the cube, fire to the pyramid [or tetrahedron], air to the octahedron and water to the icosahedron and finally, the incommensurability of the cosmos to the tangible dodecahedron), the division of a cord, based on the rationales proportions of the tetraktys (1:2:3:4), produced musical consonances that translated the universal harmony, order, structural perfection and beauty of the cosmos (Bonell 1994, pp. 78-79).

The musical scale “constituted the surprising synthesis of quality and quantity, tone and number, complemented by the synthesis between arithmetic and geometry, in which numeric ratios and proportions could be seen and understood through geometric figures. Therefore, reason and proportion could be directly experimented through the senses and, at the same time, be understood as fundamental and eternal principles. Cosmos itself was considered a harmonic system of ratios”. (Bonell 1994, pp.78-79)

Following the early intentions that sprout philosophy in the first place, mathematics embraces the basis of the scientific spirit and the totality of gnosis. More than abstract relationships with numbers, the science of mathematics represented qualities, Man himself, the micro and the macrocosm (Bonell 1994, p.78). These were most probably the main steps for the discussion of the human cosmos’ order translated in formulations that were accessible to human comprehension – measure, number, proportion and geometry – and the recognition of the polarity of what was considered good and bad, beautiful and ugly and predominance of the former over the latter.

The Beauty of Morality

In the second half of the 5th century BC takes place a significant anthropologic change in the level of intellectual interests of the ancient Greek world. Instead of the being centred in themes of nature and cosmology, philosophy turns to questions more related with the human being, education, morality and politics (Cordón and Martínez 2014, p.47).

The Sophists, mainly the second generation of these thinkers, used the child and the animal, as examples of what is human nature, to define the essence of moral principles, avoiding in this way the acquired cultural elements. Through these two models, they deduce that there are only two natural norms of behaviour: The search for pleasure – as when a child cries when feels pain and smiles when is happy and experiences pleasure – and the domain of the stronger over the weaker. According to them, morality should follow these two norms and when it does not, it is consider unnatural (Cordón and Martínez 2014, p.53).

Despite of standing strongly against the Sophists, Socrates shares with them the interest for man, political and moral questions and their relationship with the problems of language. As Pythagoras, Socrates didn’t leave anything written.

Everything that we know about him arrived mainly in the words of Xenophon, Plato and Aristotle (Cordón and Martínez 2014, p.47; Abbagnano 2013, p.74; Russel 1961, p.103). Socrates practiced and developed Zeno's dialectics method in order to seek knowledge (Russel 1961, p.111). For him, it is of the outmost importance to search for knowledge in order for us to achieve virtue. He doesn't actually teach anything, for we do not actually now nothing, but through maieutics, through a constant dialogue with the others and thyself, that expands the boundaries of the individuality, it is possible the search for the self, true knowledge and virtue as a better living condition (Abbagnano 2013, p.77). For him, knowledge is virtue and virtue conducts us to reason. Virtue in this sense is science since it is autonomous investigation of the values over which life should lay on.

In his dialogues, Socrates associates beauty with good[13] and virtue[14] (Xenophon 2013). According to him, we should seek these concepts in order to achieve the standards of a good life. By comparing what is beautiful with good, Socrates points us beauty as something that we should seek and preserve and elevates the beautiful to a standard level of happiness and pleasant life style.

Reason, Senses and Proportions

"The knowledge of which geometry aims is the knowledge of the eternal"

Plato, Republic[15], 4th century BCE

Plato lived between 427 and 347 BC. He was student and Socrates and it is he, Socrates, that in Plato's dialogues occupies the position of main interlocutor.

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[13] "… in general all things capable of being used by man are regarded as at once beautiful and good relatively to the same standard." Xenophon, Memorabilia, 4th century BCE (2013).

[14] "… generally all things 'beautiful and good', are wrought with virtue". Xenophon, Memorabilia, 4th century BCE (2013).

[15] Book VII, 52.

The central doctrine of Plato's philosophy is the theory of forms. According to Plato, knowledge is divided in 2 forms: Intellectual – or intelligible – and sensible knowledge. To each of these forms correspond a different kind of reality: to intellectual knowledge correspond the ideas – eternal and immutable realities that form the essence, the unity of things and what they really are – and to sensible knowledge correspond the reality of the physical world – the matter or substrate from which things are made of and is characterized by the mutability and inconsistency and dispersion of what things appear to be. If through the later, the senses, we can gain the awareness of things, it is only through the former, reason, that we are able to seize the real essence that form the world of ideas. It is also within the dimension of the immaterial, absolute and universal ideas that belong moral and politic concepts – as kindness and justice –, the idea or form of physical beings and mathematical entities and proportion. From it results anything that is good, harmonic and proportional in the physical world. "Good as prime idea, supreme principle is expression of order and sense of the intelligibility of the real" (Cordón and Martínez 2014, pp. 63-9).

By associating justice, kindness and all the other moral virtues with the concept of ideas, Plato makes them independent of the territory of opinions and subjectivity and connects them with rationality. In this way, Plato agrees with the Sophists when they use human nature to address the essence of moral virtues but, disagrees with their analysis and conclusion for they do not include one of the most principle aspects that characterizes man: Reason (Cordón and Martínez 2014, p.73-4).

For Plato however, 'good' is not a supersubstance, a principle included in the nature of man but a form of his life, something to be searched and achieved. According to him, our lives should neither be entirely based on pleasure, for that would by principle exclude the conscience of pleasure, something which it is proper of animals and not of man, nor should be a life of pure intelligence, for it would be a divine and not a human life. The perfect form of 'good' is achieved by a fair proportion between pleasure and intelligence and constitutes a problem of measure, proportion, convenience: "moral investigation is transformed in a metaphysic research with mathematical ground" based on the Pythagorean principles of the 'limit' and the 'unlimited' (Abbagnano 2013, p.127).

While the unlimited encompasses, generally, all that is susceptible of being increased or decreased into infinity, the limit is the order, the measure or/and the number essential to specify and define the unlimited. “The limit function is to gather and unify what is dispersed, concentrate what is spread, order what is disordered, give number and measure to what is devoid of one and another. The limit as number suppresses the opposition between the one and the multiple because specifying the multiple’s number means reducing it to its unity, since the number is always an ordered set. For instance, within the unlimited set of sounds, music distinguishes the fundamental three sounds – treble, medium and bass – reducing, in this way, the unlimited to a numeric order. From the union between limit and unlimited it is obtained the mixed gender, to which belong all things that have proportion and beauty; and the cause of the mixed gender is intelligence, which together with the limit, the unlimited and the mixed gender, is the fourth constitutive element of good” (ibidem, pp.127-8). Human life is then a mixed gender, a proportional mixture between pleasure and intelligence triggered by the latter. To it should belong all orders and kinds of knowledge – from the highest, (dialectics) to pure sciences (as mathematics), applied sciences (as music, medicine…), until opinion – and pure pleasures – those not connected with the pain of necessity thus, knowledge and aesthetic pleasures, deriving from the contemplation of whatever is beauty. “From this, result that the better and highest thing to man is supreme good, order, measure and the fair middle. To this value follows everything that is proportional, beautiful, complete. In third position is intelligence as cause of proportion and beauty; in fourth, sciences and opinion; in fifth, pure pleasures” (idem).

The order, Ratio and Beauty of the Cosmos

Through the concept of the Demiurge exposed in Plato’s discourse about nature, the Timaeus (Bonell 1994, p.85), it is possible to understand not only this theory of the forms but also almost everything that we have been, until now, talking about and believe to have profoundly influenced the roots of western societies’ thought structure as organization and preference principles and models.

As occurred in the Pentateuch’s Genesis, considering that order is preferable to disorder, in this dialogue we assist to the ordering of the previously disharmonic cosmos, this time, by the Demiurge. After ordering the matter he gives a soul to the visible and tangible bodies that was, in its essence, composed by (i) unity, the self, indivisible substance always identic to itself; (ii) plurality, the alter, corporeal and divisible substance and; (iii) a third stage that was a combination of the former and proportionally divided to include proportional ratios. Plato later refers to the Pythagorean's arithmetic, geometry and harmony of music, based on the consonances of the numbers '1', '2', '3' and '4' that constructs the tetraktys and insists on the role of mathematics as ground of the philosophic knowledge. Space and time are justified as prepositions of numeric properties and geometric harmony; and the four elements, and the atom, appear related with the composition of the bodies and connected with the 4 + 1 regular solids that result from the triangle geometry. The third part of this text ends with considerations about good and morality. "Choosing good is to make proportion, order and harmony (…) to be preserved by its original relationships of quantity, hierarchy, position and balance" (ibidem, p.106). "All that is good is beautiful and beautiful do not happen without regular relationships or proportions" (idem). Following the Socrates thoughts and ideas, Plato still makes time to refer to the virtue of man in the path of life and the necessity, in order to achieve truth and real happiness, to get closer to love, science and true thoughts and avoid all vicious and ill things and behaviours (ibidem, p.83-109). "The Demiurge is then, the cause for everything that in the world is order, ratio and beauty" (Abbagnano 2013, p.129)[16].

Aristotle, Happiness and the Fair Middle

According to Aristotle, Plato's main teaching is the close existing relationship between virtue and happiness. However, we can only reach 'good', which is happiness itself, by a rigorous research oriented by science aimed to the being.

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[16] In the same *Timaeus*, Plato also associates "number with the creation of all living world and [speaks] of symmetry and geometric proportions as means to unify its endless variety" (Fletcher 2000, p.76). In this context, symmetry, which stands for "in due measure" or "the harmony of the parts with each other and with the whole", is seen as a synonymous of the quality of harmony that bind together various forms of life, from the micro to macrocosm – plants, animals, human life, planets and stars – through proportion and measure (idem).

Philosophy is then, the search for the being and, through this, the fulfilment of man's life. Science is a path to enlightenment, virtue that, by turn, conducts to happiness. To Aristotle, however, knowledge is no longer man's unique search for good and happiness but an objective science composed by several specific, singular sciences that determine a kind of complex encyclopaedia of knowledge (Abbagnano 2013, p.152). Each art, each research, each action and each choice is made, according to Abbagnano (ibidem, p.174), in relation to an 'end' that seems 'good' and desirable. Whatever we desire, be it wealth or health, we do it for the satisfaction and the pleasure that they may bring forward. If all the 'ends' are 'goods', there must be one which is desirable for itself: a supreme end, a supreme good, from which all the others – ends and goods – are dependable. To Aristotle, this end is happiness. And the path for such happiness, the answer to what it is, lies in whatever is the task of man. Since this task of man's life may not be vegetative life, since that is what he has in common with plants; and may not be a life based on the senses, since that is what he has in common with the animals; it must be a life of reason; and this life is virtue. Happiness is then, by principle, virtue (ibidem, pp.174-5). Since the soul of man is then divided in reason and pleasure and the latter lacks reason but can be dominated and addressed by it, there are two fundamental virtues: Intellective or rational virtue – the exercise of reason itself – and moral virtue – the domain of reason over sensible impulses that is responsible, for instance, for good manners.

Moral virtue, according to Aristotle and following a concept already seen under Plato's view, consists in the disposition of choosing a 'fair middle' adapted to our nature, which, according to Abbagnano, may be determined by reason and the wise man. The 'fair middle' has the particularity of excluding the two vicious extremes of excess and defect, and aims to balance, a middle term among things. It stands for moderation (of pleasures), prudence (of wealth), rigorousness (of opinion) (idem).

As to the ideal of beauty, if Plato follows and evolves Socrates' vision of associating beauty with 'virtue' and 'good', Aristotle follows the previous two and connects beauty with order, measure, geometric proportion, balance, harmony, symmetry, definiteness and a 'fair middle' between moral virtue's reason and pleasure, always addressed to a happiness end state (Aristotle in Sartwell 2016[17], Aristotle 1908[18]).

The Born of Rationality's Conceptualization

Addressing to the core of scientific research, Akin (2006) clarifies the distinctions between the different types of sciences: "There are three categories through which the domain of scientific research can be described: explored problems, obtained results and applied methods" (Akin 2006, p.17). The results of scientific inquiry in natural sciences are, by turn, the set of principles, theorems and hypothesis, whose contents describe specific aspects of individual phenomenon and, when in harmony, are able to describe a coherent and complete picture of the natural sciences' phenomena (idem, p.19). The two primary and necessary methods to discover the underlying principles of such natural phenomena were raised in the period of ancient Greece by Socrates and Aristotle. Such logical foundations are induction and deduction reasoning and together constitute the two basic kinds of rationality able to drive to scientific knowledge: the truth about 'things'.

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[17] "To be beautiful, a living creature, and every whole made up of parts, must … present a certain order in its arrangement of parts." Aristotle, Poetics, volume 2, 2322 (1450b34).

[18] "Since the good and the beautiful are different (for the former always implies conduct as its subject, while the beautiful is found also in motionless things), those who assert that the mathematical sciences say nothing of the beautiful or the good are in error. For these sciences say and prove a great deal about them; if they do not expressly mention them, but prove attributes which are their results or their definitions, it is not true to say that they tell us nothing about them. The chief forms of beauty are order and symmetry and definiteness, which the mathematical sciences demonstrate in a special degree. And since these (e.g. order and definiteness) are obviously causes of many things, evidently these sciences must treat this sort of causative principle also (i.e. the beautiful) as in some sense a cause." Aristotle, Metaphysics, Book XIII (1908).

The Essence of Induction

Aristotle talks about how Socrates' group researches, before him, contributed to the development of ancient logic. According to him, there are two things that can be, with good reasons, attributed to Socrates: inductive reasoning and the definition of universal. Inductive reasoning is the method through which the examination of specific cases, statements or individual observed events conduct to a general statement that expresses a concept not included but yet applicable to all premises (Abbagnano 2013, p.82; Akin 2006, p.19). "Induction consists essentially of statistical reasoning, in which the truth of the premises makes the conclusion likely to be true, even though it could still be false" (Rey 2015) but it has the power to address to the essence of 'things', to what a thing can truly be. By applying it to his group researches to uncover the highest values of human condition – virtue and good –, Socrates is pointed as someone that truly embodies the spirit of Greek philosophy, the first to organize autonomous research at its highest level according to a rigorous methodology (Abbagnano 2013, p.82) that aims to objectivity and philosophy as the first true science.

Deductive 'Mathematical' Proof and Abstraction

Aristotle's work on logic would, later, considerable change the way we reason and think, interfering in a most direct way with our ability to deal with and create knowledge. He would use the relatively new acquired and gathered knowledge that related mathematical proof with scientific research and the 'good path of life' – in the moulds that we have been addressing to – and would apply it in such a way that it would significantly change the fields of thought and language, together with those of expression, representation, communication and, even, at a profound level, the construction processes of thought.

He introduces another type of rationality[19]. Typical reasoning is, according to him, deductive reasoning. While induction is valid only and if all valid cases are comprised, being, in this way, of limited use, not fully suitable for science but for dialectics and oratory, as a tool of exercise or persuasion (Abbagnano 2013, p.188), deduction is a kind of ideal of reason, in which the truth of the conclusion is absolutely guaranteed by the truth of the premises (Rey 2015). Such makes from it the ideal form to fit the basic requirements of objective, scientific research methodologies.

Explaining the roles of induction and deduction and the importance of the synergy between these two kinds of reasoning, Ömer Akin refers to Turbayne's 'Arch of knowledge' as a metaphor for scientific methodology. In this figure, knowledge is able to sprout by means of induction from facts that are observable. Such process leads to the discovery of generalized rules or 'First Principles'. Often impossible to prove, these principles represent immutable truths from which, through a system of specific theorems and hypotheses and the use of deductive reasoning, phenomena and events can be explained or predicted, creating new connections, evolving knowledge and getting us closer to the truth about 'things'. "In such construct, one can envisage the discovery of the essence of things through induction, and, in turn, from these results, numerous other properties can be derived using deduction. This is a model akin to the theorem-axiom systems normally found in formal applications of science, such as those in geometry and mathematics", writes Akin (Akin 2006, p.23).

Aristotle calls it demonstrative or scientific (Abbagnano 2013, p.187). Aristotelian logic is then a 'rational' or 'logic' argumentation where a valid conclusion is logically deduced from previous given assumptions or facts ('first principles', rules or immutable truths) through a series of logical rules (Devlin 2002, p.44). Aristotle identified patterns in the correct and valid statements and expressed these norms, which should be followed in the construction of a correct demonstration, in the form

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[19] Socrates, in the words of Plato in the Republic's Book X, already offered, yet in a more complex than simply and reduced form, a deductive, rather mathematical, proof of the immortality of the soul (Pierce 2016, p.77).

of the syllogism, “a discourse in which, given some things, others necessarily follow” (Abbagnano 2013, p.187), using subject-predicate prepositions (Devlin 2002, p.45).

The typical syllogism is divided in three terms: subject, predicate and middle term. The example ‘All men are mortal; Socrates is a man; [therefor] Socrates is mortal’ demonstrates its logic and structure. In this example, ‘Socrates’ is the subject, ‘mortal’ is the predicate and ‘men’/’man’ is the middle term. “This simple argument (deductive arguments can be infinitely more complex) illustrate two important features of deductive reasoning: it need not be about real things, and it can be applied to any subject matter whatsoever – i.e., it is universal” (Rey 2015). In fact, it was such universality that made from the syllogism and deductive reasoning one of Aristotle’s greatest and significant contribution to western civilization’s history: the deduction of a general abstract pattern (Devlin 2002, p. 45).

Abstract from any concrete and particular meaning, the subject of the subject-predicate propositions can, for instance, be replaced for a ‘S’, the predicate for a ‘P’ and the middle term for a ‘M’. As in the substitution of mathematical entities for symbols, usually ‘x’, ‘y’ or ‘z’ but any other letters of the alphabet, ‘S’, ‘P’ and ‘M’ represent an arbitrary subject, predicate and middle term, eliminate particular meanings and create the background able to analyse the abstract patterns of reasoning. The former given example can then be translated as following: MaP; SaM; [therefor] SaP. The basis of this system is quite simple and can be read, as in the most simple mathematical proofs and demonstrations, ‘if’ A, ‘than’ B. Additionally, Aristotle discovered that there could be two forms of subject quantification – all and some –, two forms of predicate – positive and negative –, and that the conjugation between subject, predicate and middle term could be arranged in another set (of four) different classes (idem, pp.45-7).

Logic deduction is an indispensable research technique that turns to syntax in order to analyse the fundamental structure of scientific knowledge and the being (Abbagnano 2013, p.184). In this way, it stands as proof to general knowledge as, in previously times, Thales first discovered and attested mathematical proof. Although Aristotle’s deduction and syllogisms is nowadays recognized as merely a special case of a deduction (Rey 2015), it “is the sort of rationality that is the central concern of traditional logic” (idem) and has remained almost unchanged for almost 2000 years, until the 19th centuries' mathematical studies on rational argumentation patterns (Devlin 2002, pp. 45/48).

The Axiomatic Method

"All mathematics leads with abstraction" (Devlin 2002, p.57). Despite of the connections between mathematics and the real world and the fact that mathematics is able to describe this physic reality, the real realm of mathematics is pure abstractions – numbers, geometric figures, patterns and structures. While physics, chemistry or, for instance, biology are able to accept or reject hypothesis based on experimentation, the confirmation of mathematical truth is achieved not by this methodology or based on subjective opinion but only by demonstration. All mathematical truth, as we have addressed before, are basically represented by the form 'if' A, 'than' B. It was this [Thales original] rule that, in time, however disappointing it may have been, showed the Pythagoreans the existence of irrational numbers. Some lengths just did not match any known, natural number (idem, pp.57-8) therefor there must be other numbers besides these. The secret of the axiom method is that it is based on significant and correct patterns to explain and predict phenomena.

Like deductive reasoning's 'first principle' elements, sprout by means of induction, "mathematical facts are demonstrated by deduction from a set of initial suppositions known as axioms (from latin axioma, which means 'a beginning'). When a mathematic theory says that a specific fact (B) is 'true', it means is that the 'fact' was demonstrated based on a set of assumed axioms (A)" (idem, p.58). 'B is true' as long as the A axioms are 'obvious' or widely accepted, however strange or contra-intuitive they might seem. What they cannot be is wrong or inconsistent. "A set of inconsistent axioms is completely useless" (idem, p.64). Devlin compares them to the foundations of a building. If they are not strong, everything that is build afterwards may collapse. Or in case of mathematics or thought processes, be wrong or senseless is, therefore, completely useless as valid knowledge.

The relationship between mathematics, thought, language, and so many other fields that belong to human knowledge and behaviour, is so tight that the development of a new branch of mathematics followed the same logic that Aristotle applied to the development of deductive reasoning and the syllogisms. First it calls the identification of a pattern. Then, this pattern is transformed into an abstract structure. As a consequence of the study of such abstract concept, the observed patterns can lead to the formulation of axioms. Such axioms have the property to enclose the knowledge, the phenomena that in first place conducted to their formulation. Once the axioms exist and are faced as such, valid, accepted, knowledge can sprout based on deductive methods and logic demonstrations in a purely abstract scenario. From this level, other 'superior' levels of abstraction can be achieved as long as all the concepts of each steps is respected, leading to more and more complex relationships and knowledge levels. This reality has been observed in the most diverse fields of human knowledge inside and outside mathematics from literature to music and, for instance, the visual arts (idem, pp.61-2).

The methods of inductive and deductive reasoning increased rationality exponentially. Rational thinking could have been around for quite some time now, evolving since the time that we have started to develop the facility to think, but now, it had unquestionably a structure and a methodology associated. We have begun to think not in an arbitrary way but by means of reasoning, putting it in practice with logical, understood means. In a way, in a general sense and in accordance to what we understand to be thinking in nowadays, a direct result from these cradle contributions, we had only just begun to think.

The Elements

Around the 4th/3rd century BC, Euclid of Alexandria wrote 'The Elements', a reference that would follow Socrates and Aristotle's work on logic and discourse and another one to substantially influence the construction and identity of the western civilization's thought. As in Plato's Demiurge, that gathered the essential of these times' Greek's philosophy, structure and organization concepts, in this books we can find an overview of the last years' gathered knowledge and the demonstration of a way of thinking and performing.

As we have seen before, it was Thales that began the development of geometry as a subject of mathematics, actually the first of its subjects (Devlin 2002, p.113). From the period of Thales and Pythagoras, the advances on mathematics were several, spread among the works of Socrates, Plato, Aristotle and Eudoxus of Cnidus' 'Theory of Proportions' (ibidem, p.23). Euclid's Elements appear some years later, as the probably successor of Hippocrates of Chios' (the mathematician, not the physician) lost homonymous book (Franco de Oliveira 1995, p.24). Since Pythagoras that the 'quadrivium' gathered the subjects that each cultured person should study and dedicate time on. As the name points, such subjects were four: arithmetic, harmony (the mathematics of music), geometry and astronomy. Euclid wrote about all of them but in 'The Elements' focuses on the first and the third (ibidem, p.27).

'The Elements' are then mostly a document about geometry, the study of the regular form 'as they can be observed in the physical world' (Devlin 2002, p.113/122). Divided in thirteen books, "it establishes the basis of classic geometry, principles of which are [mostly] still in use" (Akin 2006, p.23), works it with a synthetic approach – without numbers and easily to be demonstrated –, and presents a body of theorems in a systematic way – through formal proofs, from first principles (or priori axioms) and definitions (Idem; Franco de Oliveira 1995, pp.24/35). Although with some after to be identified flaws, it represents an excellent example of the application of the 'mathematical method', via deduction, from basic suppositions to result facts to be demonstrated with the use of the former (Devlin 2002, p.24). "These theorems derive their validity from the validity of the axioms and the methods of deductive reasoning, which are used to prove them" (Akin 2006, p.23). In this way it enclosures a perfect example of these times' identity and a reference that would prevail in time and in history, moulding the identity of western thought, as are able to testify its more than 2000 editions (Devlin 2002, p.24).

Its first six books are dedicated to plan geometry; the followed three (VII to IX) to the nowadays knows as theory of numbers, the study of natural numbers; the tenth to incommensurable quantities or irrational numbers; and the last three (XI to XIII) to the geometry of solids, three dimension objects (idem). From its remarkable content, some of them are of great importance for the discourse of the present document. "In book one of The Elements, Euclid tried to represent the abstract regular forms at a plan level, namely, straight lines, polygons and circles, by means of a postulates (axioms) and definitions systems of what would become known as Euclidean

Geometry” (ibidem, p.112). There are presented 23 definitions or basic notions, after which Euclid introduced the five basic postulates, through which and a purely logic reasoning, all geometric facts were supposed to be derived. Conceived with the goal to try to represent everything possible with a ruler and a compass (ibidem, p.116), such axioms were supposed to represent some of the fundamental patterns of nature, the truth about the world, and to be proven only by themselves. Although few in number, they have revealed to be enough and adequate, allowing Euclid to developed a major part of his geometry, namely, prove the 48 propositions that followed them and culminated with the presentation and demonstration of the Pythagoras Theorem. Additionally, Euclid still presents five ‘facts’ or common notions (ibidem, pp.112-3).

Euclid still makes reference to the definition of prime numbers or the only five existing regular polyhedrons, the previously presented platonic solids, and, in Book VI, he refers to the golden ratio[20]. The Golden Ratio, also known as the Golden Mean, Golden Section or the Divine Proportion, have been for a long time associated with the notions of beautiful (aesthetics), proportion and perfection. It stands for a ratio that is obtained by dividing a line in two parts in such a way that the reason between the full line’s length and the bigger divided part is equal to the proportion between the bigger and the smaller divided parts. Its value is communicated by the expression (1+ √5)/2, something that translates in approximately 1,618 units. The golden ratio appears in many mathematical branches. One of its most known examples appear in the reason between two connected numbers of the ‘Fibonacci’s Sequence’, where, starting with number one, the following number is the sum of the previous two. The greater the numbers, the more the reason between two connected numbers gets to the golden ratio. It manifestation is visible in several natural examples from the algorithmic spiral of the nautilus shell, flowers, fruits to different relationships between parts of the human body. This proportion is of such significance that, since at least the Parthenon to present time, that it is applied to architecture planning as a reference of the ideal, most perfect proportion between, for instance, the sides of a rectangle (ibidem, pp.114-5).

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[20] “A straight-line is said to have been cut in extreme and mean ratio when as the whole is to the greater segment so the greater (segment is) to the lesser.”

Euclid is together with Archimedes of Syracuse and Apollonius of Perga, the great geometer, the three major exponents of the so-called first Alexandria School. At the image of what Euclid had done in 'The Elements', when gathered in one document much of one era's acquired knowledge, the latter's treaty on conics, divided in eight volumes, gathered and systematized most of the work that the ancient Greeks had done on curvature. It is the case of the ellipse (the circle is a special case of ellipse), the parabola and the hyperbola. At first sight they seem quite different from each other. We only understand what unifies and drives them together when we observer how they are achieved from different plan sections applied to a double, inverted cone structure. The works of these three mathematicians have largely influenced Johannes Kepler several centuries later when, driven more by the aesthetics than its practical appliance of the result, he used them to explain the thesis of the elliptic planetary movements around the sun, once again, in an attempt to describe through mathematics the pattern and order of the world (ibidem, pp120-3).

From this period it is still noteworthy the work on astronomy developed by Claudius Ptolomy, which prevailed valid for several centuries until the switch from a geocentric to a heliocentric view of the universe in the 16th century, with Nicolas Copernicus' 'The Revolutionibus Orbium Coelestium'. After the death of Ptolomy, the golden period of the ancient Greek's mathematical and scientific knowledge began to decline. Most of the relevant work developed in these areas afterwards was directly connected with Euclid's 'Elements'. Mostly centred in Alexandria, the new city of knowledge, Hero, Diophantus, Pappus, Theon and Proclus were either commentators or publishers of 'The Elements' or have developed important work on the fields of physics or arithmetic. The latter's comments on this document's first book contains valuable information about Euclidean geometry and has accompanied this work through time. After having studied in Alexandria, Proclus moved to Athens were he became director of Plato's Academia. In the year of 529, the emperor Justinian I closed this institution due to its supposed pagan and perverse teachings. "That year marked the beginning of the 'Dark Ages'" (Franco de Oliveira 1995, p.25).

2.2.3. *De Architectura Libri Decem*, the Greco-Roman Treaty, and the Production of Form[21]

Vitruvius' Ten Books on Architecture is the first reference that we dedicate attention as being a significant direct influence to the construction of a western civilization standard and to the subject of architecture in particular. For the information that it contains on the form of Greek (and Roman) Architecture, it is able to relate the contents that we have been exploring as the building character of a period's civilization and how the level of such thought and knowledge is translated and expressed in form. In this way, it is also the last reference that we will present from the period that we have been addressing to.

Written between the years 30 and 20 BC, in the era of Augustus, it stands as the only Greco-Roman document that has arrived, in its complete form, to our days. "True 'summa' of all ancient times' architectonic knowledge, Vitruvius' opera was copied several times (…) in all the countries of the world (…) and constitutes, without a doubt, a central text of our cultural tradition and the artistic treaty of major influence in the Western's history" (Olivier Domingo in Vitruvius 1995, p.1). However, as many others before him, such as Plato, Aristotle or Euclid's main pieces, Vitruvius' work does not seem to be and entirely original work but, based on previous works, some of them lost to time.

Divided in ten volumes or books, it generally addresses to the "architect's ideal education and the principles of architecture and town planning (book I); the origins of buildings and the materials employed in their construction (book II); mathematics and correct proportions of columns and temples (book III); Doric, Ionic, and Corinthian architectural orders (book IV); Roman buildings and harbours (book V); the effect of climate and private homes (book VI); paving, vaults, and wall-paintings including the

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[21] Introductory note: Although belonging to the Roman period, Vitruvius' *De Architectura* make a global overview of the concepts developed in the previous classic period with the extension that it applies them to the discipline of Architecture. In the next section we will approach its more important revelations within this thesis discourse.

best colours and their origins and history of use (book VII); water, its sources and conveyance via aqueducts (book VIII); the study of astronomy and its relevance to architecture and the measurement of time using sundials and water-clocks (book IX); [and] various machinery such as distance measuring devices, water-driven machines and weapons" (Cartwright 2015).

There we can find a systematic examination of all the aspects that an architect should know and be aware of in the course of his professional activity (Idem). *De Architectura* is a wide work on architecture and machinery, where it is presented the concept of how architecture is understood by a defined culture on time, associating it with a multidisciplinary science, art and nature, and how this subject affects, in both aesthetic and practical ways, the everyday life of citizens (idem).

However, besides the fact that, in these pages, we can find a systematization of the factors that the architect shall take under account while projecting architecture spaces, they also tell us how the line of thought and knowledge developed and acquired in such times' last centuries have influenced the construction and formalization of an architecture form. In them, Vitruvius elaborates on the attention factors that are due to this subject and that, all together, contribute to the materialization of a specific form and way of production. Since one of the goals of the present document is to establish the existing relationships between the set of ideas or events that were strong enough to characterize a period in time, and how such ideas and events contributed to the definition of specific constructed forms, this text, and the connections that it creates, are of great importance to the discourse of this work.

The following exposition of ideas will be divided in three sections based on distinct chapters and books of *De Architectura*:

(i) An overview on the essentials of the architect's education – chapter I of book I: 'The Education of the Architect';

(ii) The principles over which architecture should stand – chapters II and III of book I: 'The Fundamental Principles of Architecture' and 'The Departments of Architecture', respectively; and

(iii) The contribution of such principles on the definition of architectural form – broadly books III and IV with special attention to chapter I of book III: 'On Symmetry: In Temples and In the Human Body'.

Between these three sections we will assist how Vitruvius shows a deep knowledge of the classical concepts that we have been addressing to, acknowledges their great importance and frames the pertinence of their presence in civilization and the life of man and, especially, in the reality of architecture and the architect. By doing so, he contributes in an active and direct way to the settlement and propagation of such ideal concepts within the subject of architecture but also in the construction of a western civilization's identity. We will refer to the role and importance of a series of different sciences in the formation of the architect, including those that formed the previously presented Greek '*quadrivium*'; principles of order, rhythm, symmetry, proportion, harmony, balance or beauty, of both science and nature, applied to the thinking of architecture and; in a general sense, to the composition of the temples and the orders as the result of the character of a time's thinking and knowledge transposed to the form of a product.

Section I - The education of the Architect

Vitruvius begins *De Architectura* talking about the education of the architect. This professional should be a person with knowledge of many branches of study and learning, essential to the construction of a judgement through which is work will be tested. Such knowledge is the result of practice and theory (Vitruvius 1914 [1st century BCE], p.17). "Practice is the continuous and regular exercise and employment where manual work is done with any necessary material according to the design of a drawing", and theory, "the ability to demonstrate and explain the productions of dexterity on the principles of proportion" (idem).

Vitruvius then continues differentiating between two points that architecture in particular shares with all matters: "the thing signified and that which gives it its significance. That which is signified is the subject of which we may be speaking; and that which gives significance is a demonstration on scientific principles". The architect should be well versed with both principles. He must, therefore, be equally natural gifted and opened to instruction since the perfect artist is built upon a balance between both. Vitruvius suggests, therefor, a multidisciplinary education in philosophy (which includes physics, the principles of law), drawing, geometry, arithmetic, music or astronomy – the four subjects of the classical 'quadrivium' – as well as in medicine and jurisprudence: "Let him be educated, skilful with the pencil, instructed in geometry, know much history, have followed the philosophers with attention, understand music, have some knowledge of medicine, know the opinions of the jurists, and be acquainted with astronomy and the theory of the heavens" (ibidem, pp.17-8).

> "Geometry (…) teaches us the use of the rule and compasses, by which especially we acquire readiness in making plans for buildings in their grounds, (…) rightly apply the square, the level, and the plummet" and solve "difficult questions involving symmetry (ibidem, p.18).
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> "By means of optics, the light in buildings can be drawn from fixed quarters of the sky" and "from astronomy we find the east, west, south, and north, as well as the theory of the heavens, the equinox, solstice, and courses of the stars" (idem).
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> "It is by arithmetic that the total cost of buildings is calculated and measurements are computed" (idem).
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> "As for philosophy, it makes an architect high-minded and not self-assuming, but rather renders him courteous, just, and honest without avariciousness (…) [and] let him with dignity keep up his position by cherishing a good reputation. (...) Furthermore philosophy treats of physics (in Greek φυσιολογία) where a more careful knowledge is required because the problems which come under this head are numerous and of very different kinds; as, for example, in the case of the conducting of water." (ibidem, p.20).
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> "Music, also, the architect ought to understand so that he may have knowledge of the canonical and mathematical theory, and besides be able to tune ballistae, catapultae, and scorpions to the proper key" (ibidem, p.21).

> “The architect should also have a knowledge of the study of medicine on account of the questions of climates, air, the healthiness and unhealthiness of sites, and the use of different waters. For without these considerations, the healthiness of a dwelling cannot be assured” (ibidem, p.23).

> “And as for principles of law, he should know those which are necessary in the case of buildings having party walls, with regard to water dripping from the eaves, and also the laws about drains, windows, and water supply” (idem).

Section II - The Fundamental Principles

In Chapter II, Vitruvius describes the fundamental principles on what architecture depends. They are order, arrangement, eurythmy (rhythm), symmetry, propriety and economy (distribution).

Since the first reference that we have used in order to deconstruct the evolution of concepts that have accompanied our own evolution and the construction of a very specific identity – if not of absolute character at least of strong, definitive influence and character forming – that the concepts of order, symmetry, proportion, harmony or balance have been deeply associated with the good path of life and, for this reason and due to its aesthetic, pleasing and non-conflict results, to the concept of beauty itself. In this text, Vitruvius follows the inherited Greek tradition, and reinforces the importance of basic and higher concepts with the fundamental principles of architecture. According to him, order is the measure of the parts and the symmetry and proportion of the whole. Eurythmy is associated with the concept of beauty, proportion and symmetry; symmetry with the proportional relation between the parts; propriety with perfection of something built upon and oriented towards approved principles and proportion (also aiming to the healthiness of space); and economy to management (of materials) and balance (between cost, needs and common sense). Due to their central, recursive and justified attention over time, these concepts seem to achieve further and further a highlighted position as something that should be sought and preserved, something that is, has we will be able to see, far from ceasing in this period. At this point, Vitruvius is just another one to emphasize their pertinence and relevance but, probably, one of the firsts to associate them with the subject of architecture and form.

Also, when talking about arrangement, Vitruvius refers to groundplan, elevation and perspective, a method through which it is possible to have a global or approximate view and perception of the whole. These are presented as forms of expression and shall be understood as forms of representation of architecture in particular but also, generally, thought. When describing the latter, Vitruvius states that, in this method, all lines meet in the centre of a circle. By being aware of that, Vitruvius positions himself among the firsts to refer to perspective as an innovative visualization method but also linear perspective, the drawing method were all lines perpendicular to be observer's plan, converge to a single point in the abstract horizon' line, presently known as vanishing point. As we will shortly see, this discovery is often attributed to Filippo Brunelleschi and the significant development of such methodology to Leon Battista Alberti, in the 15th century (Evans 2000, pp. 100/251).

> "Order gives due measure to the members of a work considered separately, and symmetrical agreement to the proportions of the whole. It is an adjustment according to quantity" (Vitruvius in 1914 [1st century BCE], p.27).

> "Arrangement includes the putting of things in their proper places and the elegance of effect which is due to adjustments appropriate to the character of the work. Its forms of expression (Greek ἰδέαι) are these: groundplan, elevation, and perspective. A groundplan is made by the proper successive use of compasses and rule, through which we get outlines for the plane surfaces of buildings. An elevation is a picture of the front of a building, set upright and properly drawn in the proportions of the contemplated work. Perspective is the method of sketching a front with the sides withdrawing into the background, the lines all meeting in the centre of a circle. All three come of reflexion and invention. Reflexion is careful and laborious thought, and watchful attention directed to the agreeable effect of one's plan. Invention, on the other hand, is the solving of intricate problems and the discovery of new principles by means of brilliancy and versatility" (ibidem, p.27-8).

> "Eurythmy is beauty and fitness in the adjustments of the members. This is found when the members of a work are of a height suited to their breadth, of a breadth suited to their length, and, in a word, when they all correspond symmetrically" (ibidem, p.28).

> "Symmetry is a proper agreement between the members of the work itself, and relation between the different parts and the whole general scheme, in accordance with a certain part selected as standard. Thus in the human body there is a kind of symmetrical harmony between forearm, foot, palm, finger, and other small parts; and so it is with perfect buildings" (idem). "Propriety is that perfection of style which comes when a work is authoritatively constructed on approved principles. It arises from prescription (Greek: θεματισμῴ), from usage, or from nature" (idem).

> "Economy denotes the proper management of materials and of site, as well as a thrifty balancing of cost and common sense in the construction of works" (ibidem, p.30).

In chapter III, Vitruvius writes on the three departments of architecture: (i) the art of building, (ii) the making of timepieces, and (iii) the construction of machinery; and also about the type of existing buildings and the qualities upon which these should be build. Here we can find the reference to what has become known as the Vitruvian triad *firmitas, utilitas venustas*, which translated stands for something like strength (or durability, firmness), convenience (or utility) and beauty. These concepts are here presented as guidelines of past but also for future architecture constructions. If some of the most prominent architecture examples of the past already seem to follow these recommendations, they will be of great importance in the architecture to come, specially, during and after the Renaissance, period when this treaty will be of recover and constitute a reference work.

> "All these must be built with due reference to durability, convenience, and beauty. Durability will be assured when foundations are carried down to the solid ground and materials wisely and liberally selected; convenience, when the arrangement of the apartments is faultless and presents no hindrance to use, and when each class of building is assigned to its suitable and appropriate

> exposure; and beauty, when the appearance of the work is pleasing and in good taste, and when its members are in due proportion according to correct principles of symmetry" (ibidem, pp.31-2).

Section III - The Proportions and Symmetry of the Human Body and the Architecture of the Temples

On chapter I of book III, 'On Symmetry: In Temples and in the Human Body', Vitruvius returns to the definition of the principles of symmetry and proportion, in this case on the universe of the human body. According to his description, the ideal form of the human body follows particular symmetrical proportions among some of its parts that confer a sense of harmony to its whole composition. This harmony is a result of balanced proportions shared by some of the human body's parts, which, by turn, share a symmetry relationship with other equivalent parts that are equidistant in relation to a vertical, central axis. Vitruvius then finds a central point in the human body and states that a circular outline can be drawn from this central reference, the navel, towards the fingers and toes of both hands and feet. Aside this circumference, another figure, a 'perfect' square, can also be drawn, framing the equally distances of the height of the body and the length of its outstretched arms. This description has inspired several artists to represent a composition that has become known as the Vitruvian Man. The apparent perfection of the description and its representation has contributed to the conversion of this composition in an icon of the equally perfection, measure, unity, proportion, symmetry, balance and harmony of the natural human form.

> "For the human body is so designed by nature that the face, from the chin to the top of the forehead and the lowest roots of the hair, is a tenth part of the whole height; the open hand from the wrist to the tip of the middle finger is just the same; the head from the chin to the crown is an eighth, and with the neck and shoulder from the top of the breast to the lowest roots of the hair is a sixth; from the middle of the breast to the summit of the crown is a fourth. If we take the height of the face itself, the distance from the bottom of the chin to the under side of the nostrils is one third of it; the nose from the under side of the nostrils to a line between the eyebrows is the same; from there to the

> lowest roots of the hair is also a third, comprising the forehead. The length of the foot is one sixth of the height of the body; of the forearm, one fourth; and the breadth of the breast is also one fourth. The other members, too, have their own symmetrical proportions, and it was by employing them that the famous painters and sculptors of antiquity attained to great and endless renown." (ibidem, pp.94-5)
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> "Then again, in the human body the central point is naturally the navel. For if a man be placed flat on his back, with his hands and feet extended, and a pair of compasses centred at his navel, the fingers and toes of his two hands and feet will touch the circumference of a circle described therefrom. And just as the human body yields a circular outline, so too a square figure may be found from it. For if we measure the distance from the soles of the feet to the top of the head, and then apply that measure to the outstretched arms, the breadth will be found to be the same as the height, as in the case of plane surfaces which are perfectly square." (ibidem, p.95)

It is also within in the human body that Vitruvius finds the basis for two of the main mathematic systems with which we still work in nowadays, the ones of base 6 and 10 (another of this systems is the power of 2, which constitute the ground base of all computer technology). Pythagoras and Plato turned to the simplicity of the number to comprehend the multiplicity of the universe. The number was a commensurable unit able to translate the complexity of everything, as much incommensurable as it might be. Vitruvius alludes to these theories but also describes how mathematics cannot only be used to represent and measure the density of nature but, also, how nature itself, namely the human body, can be used as the basic measure of mathematics.

According to Vitruvius, "it was from the members of the body that they derived the fundamental ideas of the measures which are obviously necessary in all works, as the finger, palm, foot, and cubit" (ibidem, pp.95-6). The 'ten' is Pythagoras' perfect and ideal number, the soul of the tetraktys. It can be found in the sum of the fingers of both hands and "it is from the number of the fingers of the hand that the palm is found, and the foot from the palm" (ibidem, p.96). Additionally, if base 10 is considered, the ten fingers of the hands are able to constitute, for instance, an accessible tool that suits perfectly the auxiliary act of counting. 'Six', on another hand, is the 'mathematicians' perfect number "because this number is composed of integral parts which are suited numerically to their method of reckoning (…) The foot is one sixth of a man's height, the height of the body as expressed in number of feet being limited to six, they held that this was the perfect number, and observed that the cubit consisted of six palms or of twenty-four fingers" (ibidem, pp-96-7). Many if not most of the ancient civilizations already known and used base 6 mathematics. This legacy manifests yet in our days in many most of the time unperceivable everyday examples. It is due to this mathematical root that the Babylonians divided the wholeness of the circle not in 10, 100 nor 1000 but in 360 degrees. When later Hipparchus of Nicaea (190-120 BC) founded the basis of astronomy on the principles of Greek's geometry, he settled the basis of trigonometry in 360 degrees and 60 minutes (Mankiewicz 2000, p.20). The division of spheres is done yet today thru the same 360 degrees divided by 60 minutes, which are in turn one more time divided by 60 seconds. Also time was also divided in multiples of 6: 24 hours, 60 minutes and 60 seconds

By referring to the measures of the human body to systematise measuring units and the metric of a mathematic measure, Vitruvius points to an anthropomorphic base measuring system that would be later used and "necessary in all works" (Vitruvius 1914 [1st century BCE], p.95). The units of the human body would then be present in the units of architecture spaces. Even though some of them, mainly the temples, were not actually thought to reflect the image of man but that of Gods, human measure and proportions were, for all that mattered, there present and inscribed. In future times to come, when we will assist at a transition between the scale of the Gods towards a more and even exclusive human centred consideration, this systems will be of major reference and importance. Within the western culture, such systems would achieve their climax during the Renaissance and Humanistic period, when we will assist to the reborn of this Classic ideas and Vitruvius' *De Architectura* will receive, once again, special attention. Or even as late as in the 20th century, when Corbusier, in the sequence of the Modern Movement, proposes an anthropomorphic measure system reflected in the image of the Modulor.

> "Further, it was from the members of the body that they derived the fundamental ideas of the measures which are obviously necessary in all works, as the finger, palm, foot, and cubit. These they apportioned so as to form the

"perfect number," called in Greek τέλειον, and as the perfect number the ancients fixed upon ten. For it is from the number of the fingers of the hand that the palm is found, and the foot from the palm. Again, while ten is naturally perfect, as being made up by the fingers of the two palms, Plato also held that this number was perfect because ten is composed of the individual units, called by the Greeks μονάδες. But as soon as eleven or twelve is reached, the numbers, being excessive, cannot be perfect until they come to ten for the second time; for the component parts of that number are the individual units" (ibidem, p.95-6).

"The mathematicians, however, maintaining a different view, have said that the perfect number is six, because this number is composed of integral parts which are suited numerically to their method of reckoning: thus, one is one sixth; two is one third; three is one half; four is two thirds, or δίμοιρος as they call it; five is five sixths, called πεντάμοιρος; and six is the perfect number. As the number goes on growing larger, the addition of a unit above six is the ἔφεκτος; eight, formed by the addition of a third part of six, is the integer and a third, called ἐπίτριτος; the addition of one half makes nine, the integer and a half, termed ἡμιόλιος; the addition of two thirds, making the number ten, is the integer and two thirds, which they call ἐπιδίμοιρος; in the number eleven, where five are added, we have the five sixths, called ἐπίπεμπτος; finally, twelve, being composed of the two simple integers, is called διπλάσιος" (ibidem, p.96).

"And further, as the foot is one sixth of a man's height, the height of the body as expressed in number of feet being limited to six, they held that this was the perfect number, and observed that the cubit consisted of six palms or of twenty-four fingers. This principle seems to have been followed by the states of Greece. As the cubit consisted of six palms, they made the drachma, which they used as their unit, consist in the same way of six bronze coins, like our *asses*, which they call obols; and, to correspond to the fingers, divided the drachma into twenty-four quarter-obols, which some call dichalca others trichalca" (ibidem, p.96-7).

> “But our countrymen at first fixed upon the ancient number and made ten bronze pieces go to the denarius, and this is the origin of the name which is applied to the denarius to this day. And the fourth part of it, consisting of two asses and half of a third, they called "sesterce." But later, observing that six and ten were both of them perfect numbers, they combined the two, and thus made the most perfect number, sixteen. They found their authority for this in the foot. For if we take two palms from the cubit, there remains the foot of four palms; but the palm contains four fingers. Hence the foot contains sixteen fingers, and the denarius the same number of bronze *asses*” (ibidem, p.97).

> “Therefore, if it is agreed that number was found out from the human fingers, and that there is a symmetrical correspondence between the members separately and the entire form of the body, in accordance with a certain part selected as standard, we can have nothing but respect for those who, in constructing temples of the immortal gods, have so arranged the members of the works that both the separate parts and the whole design may harmonize in their proportions and symmetry” (idem).

Vitruvius then talks about how nature with its attributes of order, proportion, symmetry or harmony influenced the design of architecture and the temples in particular. Emphasizing the continuously importance of such concepts in life, nature and architecture, he explains the relationship that exists between symmetry, proportion and temples: “The design of a temple depends on symmetry, the principles of which must be most carefully observed by the architect. They are due to proportion. Proportion is a correspondence among the measures of the members of an entire work, and of the whole to a certain part selected as standard. From this result the principles of symmetry. Without symmetry and proportion there can be no principles in the design of any temple; that is, if there is no precise relation between its members, as in the case of those of a well-shaped man. (…) Similarly, in the members of a temple there ought to be the greatest harmony in the symmetrical relations of the different parts to the general magnitude of the whole” (ibidem, p.94-5). Vitruvius then relates the members of a temple with “the greatest harmony in the symmetrical relations of the different parts to the general magnitude of the whole” (ibidem, p.95) and connects the principles of symmetry, proportion and harmony with eternity: “Since nature has designed the human body so that its members are duly proportioned to the frame as a whole, it appears that the ancients had good reason for their rule, that in perfect buildings the different members must be in exact symmetrical relations to the whole general scheme. Hence, while transmitting to us the proper arrangements for buildings of all kinds, they were particularly careful to do so in the case of temples of the gods, buildings in which merits and faults usually last forever" (idem).

The descriptions of the temples and the orders that we find in books III and IV have a direct correspondence with the Greek's philosophical and scientific principles of composition and also those of the human body. Even though the process of their construction and architecture in general did not follow the 'architectural composition' that would later characterize the Renaissance's thinking process of architecture, things were not made casually but with precise meanings. As nature and the human body, also the wholeness of the temples was built from a series of smaller elements. By turn, the arrangement of such elements was also thought as the composition of other smaller elements.

The image of the temples "of the immortal gods" (ibidem, p.97) was determined following the rules of symmetry and "arranged on principles developed with a view to convenience, beauty, and strength" according to different styles, or rules, that ought to be follow to achieved these previously given symmetry and proportion results. The architectural orders that gave identity to them were three: Doric, Ionic and Corinthian, the ones "which exhibit the greatest delicacy of proportion in their symmetrical measurements" (ibidem, p.120). At the image of nature and the human body, the elements that composed them shared specific proportions, set in parts, between and among each other.

The Doric order "was the first one to arise and in early times", named after "Dorus, the son of Hellen and the nymph Phthia, was king of Achaea and all the Peloponnesus" and because a temple of this kind was built in the states of the Dorians, in a period when the "rules of symmetry were not yet in existence". In the attempt to "render them fit to bear a load and also a satisfactory beauty appearance (…) but not having rules for their symmetry, (…) they measured the imprint of a man's foot and compared this with his height" to discover that "the foot was one sixth of the height". They then "applied the same principle to the column, and reared the shaft, including the capital, to a height six times its thickness at its base. Thus the Doric column, as used in buildings, began to exhibit the proportions, strength, and beauty of the body of a man" (ibidem, pp.121-3).

The Ionic showed with the "desired to construct a temple to Diana in a new style of beauty. They translated these footprints into terms characteristic of the slenderness of women, and thus first made a column the thickness of which was only one eighth of its height, so that it might have a taller look. At the foot they substituted the base in place of a shoe; in the capital they placed the volutes, hanging down at the right and left like curly ringlets, and ornamented its front with cymatia and with festoons of fruit arranged in place of hair, while they brought the flutes down the whole shaft, falling like the folds in the robes worn by matrons. Thus in the invention of the two different kinds of columns, they borrowed manly beauty, naked and unadorned, for the one, and for the other the delicacy, adornment, and proportions characteristic of women." (Ibidem, p.123)

"The third order, called Corinthian, is an imitation of the slenderness of a maiden [of Corinth]; for the outlines and limbs of maidens, being more slender on account of their tender years, admit of prettier effects in the way of adornment. It is related that the original discovery of this form of capital was as follows. A free-born maiden of Corinth, just of marriageable age, was attacked by an illness and passed away. After her burial, her nurse, collecting a few little things which used to give the girl pleasure while she was alive, put them in a basket, carried it to the tomb, and laid it on top thereof, covering it with a roof-tile so that the things might last longer in the open air. This basket happened to be placed just above the root of an acanthus. The acanthus root, pressed down meanwhile though it was by the weight, when springtime came round put forth leaves and stalks in the middle, and the stalks, growing up along the sides of the basket, and pressed out by the corners of the tile through the compulsion of its weight, were forced to bend into volutes at the outer edges. Just then Callimachus, whom the Athenians called κατατηξίτεχνος for the refinement and delicacy of his artistic work, passed by this tomb and observed the basket with the tender young leaves growing round it. Delighted with the novel style and form, he built some columns after that pattern for the Corinthians, determined their symmetrical proportions, and established from that time forth the rules to be followed in finished works of the Corinthian order.” (ibidem, pp123-5)

The orders were then based on the body of a man, a woman and a young maid together with the growing leaves of tomb basket. And the whole composition of the temples, notwithstanding their order, followed the principles of symmetry and proportion found in both parts and whole of nature and the human body’s structure in search for a pleasing and beauty appearance. The search for beauty and perfection through *De Architectura*’s recurring concepts of symmetry and proportion, and also those of measure, unity, balance or harmony, achieved such an importance that the Greeks and the Romans became obsessed by their pursue. Not only they ought to be sought between the parts but also they ought to be present in the whole’s final, composite result. The natural perfection of nature, including that of the human body, had for a long time influenced the construction of these ideas but, at this point, the subjectivity of humans overlaps the universal objectivity of the abstract concepts.

Even though the parts and the whole was thought and designed to look perfect and beautiful, a condition of human perception avoided the cognition of these objects in their abstract perfection: the distortion of perception through the human eye. Due to its anatomy, the human eye is able to perceive perfect geometrically thought structures in a distorted, imperfect way. Even though such constructions were carefully thought and build upon the concepts of beauty and perfection, what ultimately counts and is retained is the final subjective perception of the whole. Since such perception did not fulfil its previous goal and “the eye is always in search for beauty and (…) pleasure”, in order to do so, to compensate and “counteract the ocular deception” and restore perfection, it was requested “an adjustment of proportions” (ibidem, pp.107-8). The Greeks had found the lie that fits human’s natural imperfection.

Knowledge on the basic principles of ‘universal’ concepts kept growing and settling. The ‘Ten Books on Architecture’ is an unavoidable reference of Greek and Roman’s thought concepts, representation and construction systems. It focuses on the previously achieved and accepted knowledge on the principles of philosophy as the science of observed patterns and phenomena, including nature and human perfection and imperfection, to deliver perfect, beautiful and pleasant considered results. The product of such thought in form followed these same principles, standing as an extension of the mind.

Just as important, such knowledge was being registered. Documents like this and long-life architecture, built with strength, convenience and beauty, are of major importance to bypass the temporary human condition and secure, as far as time allows, not only the propagation of knowledge but, also, the basis on which it is grounded, making possible to track its evolution.

As we have already pointed and will see further ahead, Vitruvius work will be of great importance to the identity of the, yet to come, Renaissance period: “one decisive canonical code for the architects [and understanding] of Renaissance, as it theory’s starting point and basic justification” (Oliver Domingo in Vitruvius 1995, p.23)

2.2.4. Reason and Faith in the Middle Ages[22]

The Greek ancient period had developed or decoded 'universal' principles that framed the existence of man in the world including with his fellows. The Romans inherited this legacy and substantially evolved, more than at an intellectual level, at a pragmatic engineering level, developing materials, constructions and systems that would substantially improve the life quality conditions of civilizations and prevail in history for its inventions and geniality.

If Vitruvius personifies the spread of the ancient Greek's sprout knowledge outside the reality of Greece and its colonies, namely the North Africa and Sicily territories, with especial focus to the cities of Alexandria and Syracuse, respectively, in the following times we would assist to the intensification of this trend. The ancient ideas would be several times recaptured influencing the ideas of other times and, in this way, contributing to the development of others, not entirely originals but most of the time bringing something new, which contributed to the strengthen of a wide, spread identity.

However, another factor would, in the time of the Romans, significantly and active contribute to a changing course on the evolution of knowledge: the appearance of new messiah. The culture that would emerge around Christianity would revolutionize the incoming next centuries and millennia and be unquestionable attached to the identity of not only the western culture but, also, many other regions of the world.

The Medieval Aesthetics

The ideas from the Middle Ages were influenced by much of the knowledge constructed and acquired by previous cultures. Umberto Eco says that "most of the

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[22] Introductory note: In this next section we will dedicate our attention to the development of knowledge in the Middle Ages. We will focus specifically on Saint Augustine, Thomas Aquinas and the result of such thoughts on this period's theological form, which in great part borrowed from their Greek ancestors, results on a merge between reason and faith.

aesthetic issues that were discussed in the Middle Ages were inherited from classical Antiquity (…) the Bible and the Fathers ” (Eco, 1986, p.4), pointing soon after that “it has been said that, where aesthetics and artistic production are concerned, the Classical world turned its gaze on nature but the Medievals turned their gaze on the Classical worlds; the medieval culture was based, not on a phenomenology of reality but on a phenomenology of a cultural tradition” (idem). Yet not necessarily untrue, Eco promptly adds that “this is not an adequate picture of the medieval critical viewpoint” (idem). They have respected the inherited concepts, which appeared to enclosure truth and wisdom, turned towards nature as a reflection of the transcended world but have demonstrated the ability to develop an innovative reflection and production. Ultimately, Christianity as a cultural event and an inspirational reference has conferred a distinctive character to this period. Such traditions and new factors were “absorbed into a new and systematic philosophical world” (idem).

To this have directly contributed the ideas of Pythagoras, on the essence of the numbers as systematic representation of reality and music; Plato, on the explanation of the world’s formation; Aristotle, on the immortality of the world, the scientific demonstration of the existence of god and the ‘end’ of happiness and, Vitruvius, mainly on the concepts of proportion and symmetry and the figure of the human body, especially from the 9th century onwards, constantly referenced in philosophical and technical manuals. Together with this cultural inherited tradition from the Classical world and new factor of Christianity, it were the visions of Saint Augustine and Boethius that, based on the classics, most influenced the identity of the Middle Ages character: “It was from these sources, then, that the theory of proportion descended to the Middle Ages. At the borders between the classical and the medieval worlds we find St. Augustine and Boethius. Both of these transmitted onwards the more Pythagorean aspects of the philosophy of proportion, for they dealt with it chiefly in the context of musical theory” (ibidem, pp.29-30).

The Precursors

Augustine, influenced by the biblical themes and the number’s Pythagorean philosophy, will introduce the concept of Christianity-as-philosophy (Wassel 2000, p.164), a reconciliation between classical, mostly pagan, philosophy with the increasingly power of the church's doctrine. In his ideas, there is a passage from Salomon's Book of Wisdom whose interpretation has transformed in the keystone of the worlds medieval vision and has contributed to the definition of Augustine as an authority of this period: "thou hast ordered all things in measure and number and weight" (Wisdom of Solomon 11:20). Augustine found in this passage a way to apply the Pythagorean and Platonic mysticism of the number to the interpretation of a new Christian universe, ordered from chaos and avoiding it by means of order, establishing in this way the cosmologic theory that prevailed until the later arrival of the Aristotelian view, especially through Thomas Aquinas.

Augustine finds in music the ultimate incarnation of this spirit. In *De Musica*, Augustine's first book, he defines music as "the science of good modulation" (von Simson 1991, p.41). According to him, our involvement with music has two different sides depending on the level that one gives in: It can be reproduced or appreciated by instinct and practical experience, as someone that is aware of the things that enjoys – a posture that Augustine negatively calls art; and it can be comprehended by someone that really understands the laws of its true, scientific and mathematical essence. Perfect geometric proportions can, according to him, be perceived by the ear in the same way that optical impressions are perceived by the eye (*De Musica*, I, 32).

The principles of good modulation are then, to Augustine, mathematical principles. As the musical intervals in the monochord are found by divisions in a string, the perfect arithmetic relations of the consonances constitute mathematical proportions between different parts of a line (von Simson 1991, p.42). "And since Augustine deduced the perfect consonances' musical value from the metaphysic dignity of the relationships on which they were based, it was natural to conclude [as Pythagoras did] that the beauty of certain proportions were based on the simple relations of the first tetraktys" (idem). The most admirable relation within the measure of all musical unities is that of equality or symmetry, the relation 1:2, where the union or consonance between the parts is perfectly balanced. This measure was understood as the octave. To it follows the other two perfectly balanced consonances of the perfect fifth, 2:3, and the perfect fourth, 3:4.

Through geometry, music, as the other liberal arts, integrated what has been known in the medieval times as the 'analogic' function of geometry, or the ability to conduct the world's appearance of sensible forms towards a divine order. The number was able to connect the perception of all created things to the invisible truth of God (ibidem, pp.42-3). Music was able to enclosure the beautiful and perfect mathematical proportion and harmony of the world and participated in a sacred harmony that transcended them. Musical harmony, better in the form of eternal symphonies, was able to lead to supreme pleasure and happiness states and conduct the soul to the experience of God. This ability made from music a privileged form to express the existence of God and was used by the Christian church in such a way that it still prevails in our days.

Augustine considered that, simultaneously with music, architecture also experienced the same transcendental element. To him, music and architecture are as sisters, both descended from the number. They share of equal dignity and architecture has the ability to spread the eternal harmony that is found in the sounds of music. As he had done with music, Augustine uses architecture to demonstrate that all artistic creations participate from the laws of numbers, and the number is, in its simple perfect relations and proportions, the source of all aesthetic perfection. Like Vitruvius did, he considers that no beautiful building is conceived unless the laws of number are considered, applied and visible to those who perceive and contemplate it (ibidem, p.42). It is by no chance then, that music and architecture somehow rule the last-longing references of the expressions of such Middle Ages.

Other authors (e.g. Cordón and Martinez 2014) associate the philosophy of Augustine more with Plato's ideas rather than with the systemization that we find in Pythagoras' theory of the number. To them, Augustine follows Plato, mainly his thoughts on immortality and its connection with the ideas (found in *Fedón*), and the origin and formation of the universe (found in *Timaeus*), to demonstrate the existence of God and create, around this figure, a dogma, proven by discourse, but, at the same time, towards which no demonstration is needed (Cordón and Martínez 2014, p.120).

To Augustine, like in Plato, through interiorization man is able to achieve an ascending process that carries him beyond himself. In him, in his mutable condition, there are superior truths that transcend him. Such ideas are the authentic object of knowledge, immutable and necessary. They are of logic or metaphysic (truth, similarity, unity…), mathematic (numbers, figures) or ethic and aesthetic orders (good, kindness, beauty…), and being immutable and necessary they cannot be found within the human soul. On the contrary, the fundament of the ideas is placed in the divine mind of God, an immutable reality and absolute truth. "Ideas are archetype forms or permanent and immutable essences of things, that were not formed but, existing eternally and immutably, are contained in the divine intelligence" (Ibidem, pp.125-6).

Although we can say that Augustine introduced Christianity-as-philosophy, since he "doesn't draws precise frontiers between faith and reason, the content of the Christian revelation and the accessible truths of pure rational knowledge, (…) he is not a philosopher in the strict sense of the word if, by philosopher, we understand a thinker that sticks to what can be known by exclusive rational means, without appealing to faith in the course of his rational argumentation (ibidem, p.122). To him, faith and reason are accomplices and have both the mission of unveiling and comprehend the truth, the Christian truth. Faith and reason work together to fundament and justify each other leading to an absolute religious knowledge.

In both their Neo-Pythagorean and Neo-Platonic forms, Augustine's ideas will dominate the medieval philosophy until the 13th century when, another thinker of Christianity, Thomas Aquinas, arises with Aristotle based ideas (ibidem, p.121).

Boethius, the last of Roman philosophers (ibidem, p.143) and a great mathematical authority (Simson 1991, p.48), follows Augustine's ideas and also speaks of music as the mathematical science of 'musical' laws (Eco 1986, p.30). Once again, Pythagoras is taken as a reference. To him, sound is governed by number; consonance "regulates all musical modulations" and is "a mixture of high and low sounds striking the ear sweetly and uniformly", transmitting a pleasant sensation to the listener; and the aesthetic experience of music is grounded in the principles of proportion (ibidem, p.31). According to Boethius' theory of proportion, "the soul and the body, he said, are subjects to the same laws that govern music, and these same proportions are to be found in the cosmos itself. Microcosm and macrocosm are tied by the same knot, simultaneously mathematical and aesthetic. Man conforms to the measure of the world and take pleasure in every manifestation of this conformity: 'we love similarity, but hate and resent dissimilarity'" (idem).

The Late Middle Ages

As said, it were the ideas of Augustine and Boethius, together with those on which they were based, that largely influence the reality of the Medieval Ages. The thought of these thinkers have deeply influenced some intellectual movements in the Europe of the 12th century, namely the school of the Chartres Cathedral. In the root of this movement appear, once again, the classical ideas of Pythagoras and Plato associated with the Christian image of God.

The theories of the creation of the Universe from the Genesis and the Demiurge reappear in this period with great strength, and mathematics and geometry are considered to be the link between God and the world and the magical tool able to unveil the secrets of both, including the act of the divine artist in his creation (ibidem, p.44). Theology is transformed and, by turn, also supported by geometry and geometric proportion. The mystery of the holy trinity is demonstrated by geometric means, through an equilateral triangle and, through the recurring tetraktys and perfect proportions, the Demiurge divides the soul of the world 'in measure and number and weight' establishing a cosmic order. God is portrayed with a compass as an architect or a geometer that, like the Demiurge, composed the universe according to the laws of geometry (ibidem, pp.50-1).

In this period architecture becomes a science, in the Augustinian sense of it (ibidem, p.50). The cathedral represented a model of the cosmos, organized according to the laws of harmonic proportion, projecting the perfect order of both existing and yet to come worlds. And, "although the Pythagorean-Platonic concept the numerical ratios of the musical scale never disappeared from the mediaeval theological, philosophical and aesthetic thought [and] there was no over-riding need to apply them to art and architecture" (Wittkower 1971, p.159), the same doesn't apply to geometric configurations and, for all that matters, music as an audible element able to orient the manifestation of an idea. Together with geometric proportions and the 'intoxicating' consonance of music and symphonies, light will be the third major element to be used in the construction of the atmosphere of such temples. To Plato, the semi-mythic experience of light is the cause of the being, the essence and knowledge (ibidem, p.62). In the Middle Ages light has been a fundamental symbol of the Christian space and form. Through it, Christianity found a way to connect the materiality that characterizes this world and the immateriality of the one from above. As a spiritual element, the light interacts with the material elements, transforms the natural and anthropomorphic matter and gives a new sense of transcendence to the things of our world (Norberg-Schulz 1999, pp.94/99-101/111). Light was faced as the noblest natural phenomenon, the creating principle of all things also able to conduct to the perfect order of the cosmos, the image of the creator and the achievement of truth (Wittkower 1971, p.62). Filtering through the walls of the gothic cathedral, the stained windows transform the natural light in a mysterious element, an unreal 'lux mirabilis et continua' celestial phenomenon, able to apparently demonstrate the immediate existence and presence of God (Norberg-Schulz 1999, pp.94/99-101/111). Light was a physical aesthetic phenomenon able to enhance the spiritual and mystic religious reflexion and, at the same time, be close to the senses. The distinction between its physic nature and theological meaning was connected by a notion of corporeal light, as an 'analogy' to divine light (Wittkower 1971, p.62). On another hand, the churche's opened structure made its spiritualized space and celestial image visible and sensed also from the exterior, and transmitted to the society the symbolic order achieved thought light and matter and converts the church into 'De Civitate Dei' (Norberg-Schulz 1999, pp.94/99/111-2).

Although based on physical, natural phenomena and its systematic representations, the transcendent divine factor that so well represents the Middle Ages, contributes for a swift in this reality, from a physical towards a metaphysical principle. Everything or most of the things used in this period have a double sense and specially, a final, very specific end. Their roots are to be respected but, in turn, also used to represent and give answer to a higher entity that, ultimately and by all means, is to be contemplated, achieved and acknowledge.

Thomas Aquinas

In the 13th century, with Thomas Aquinas, we assist at a transition from a Pythagorean/Platonic based vision of Christianity to a Platonic/Aristotelian understanding of this reality. Its change and references will be the ones that, from this period on, will better represent the character of such time.

Aquinas surpasses the previous Augustine's theory of the existence of God, which was based on his characteristic understanding of reason and faith as one and the same thing, and, also based on the same principle, Saint'Anselm's 'ontological argument', through which the proof of the existence of God is based on the own idea of this figure (Cordón and Martínez 2014, p.147). "Faith was the starting point and its goal was the full comprehension of the divine existence meaning. Such attitude is expressed in the words of Saint Anselm of Canterbury 'credo ut intelligam': I believe to understand" (Norberg-Schulz 1999, p.113). While Augustine and his followers, found God through interiorization and the ideas' immutability and necessity that man discovers within his mutable soul, Aquinas, under the influence of Aristotle, considers that the demonstration of this existence is based on movement, and achieved through the knowledge that the sensible experience of the universe and the mutability of his beings has proportioned us (Cordón and Martínez 2014, p.147). Aquinas also accepts the Aristotelian principle that happiness is the ultimate goal of man, and that perfect happiness sprouts from contemplation, the activity of knowledge (Ibidem, 149).

"In the history of western culture gothic architecture closed an era that we can call 'the age of faith" (Norberg-Schulz 1999, p.113). The ecclesiastic architecture of such time gives special importance to the human comprehension of the divine, the divine revelation and its relation with terrestrial life. "According to Saint Thomas, 'the sacred doctrine makes use of human reason not to demonstrate faith but to clarify everything exposed by such doctrine'" (idem). The structure and organization of the medieval cosmos was presented by the scholastic philosophy as a systematic articulation: "The whole was divided in 'parts' that by turn could be divided in smaller 'parts', the 'parts' in 'members', 'questions' or 'distinctions' and these in 'articles'" (idem). The proper gothic architecture articulation and the medieval vision of reason were developed under these same rules, being able to be "tied and untied" without losing the idea of the whole. In this way, gothic 'illumination' was more than just the presence of divine light: it was clarification and comprehension of the spirit of God through light, matter and thought. Due to its rationalism and visual logic, the gothic cathedral embraces a new mysticism in the image of the cosmic order (idem).

It is clear then, a twist from the Augustine's point of view on the connection between reason and faith. These are two distinct forms of knowledge able to reach different but also similar truths. As information and knowledge sources, they are apparent autonomous and independent. Reason can provide and provides roots able to assist and sustain faith. This posture is significantly different from the one defended by Augustine. It could almost seem that the absolute paths of faith did not interfere with the science of reason, anticipating the revolutionary times that were to come, in respect to the, again, autonomous search for truth and knowledge. However, this was not quite the case. In the same way that reason provided a grounded path to faith, also faith could assist and provide a sustainable ground to reason. In the cases in which reason achieved a different conclusion from that of faith, and since there cannot be more than one truth, the 'reasoning' and premises of the former had to be reformulated in order correct its flaws and to fit within the truth of faith, sustaining both compatible statements. Although reason and faith were not understood as one and the same thing, the fact that faith assists reason, contributes to reason not to be a completely autonomous field (Cordón and Martínez 2014, pp.152-4). After all we were still in a period where the existence and prevalence of God had to be, ultimately, assured.

2.2.5. Renaissance and the Modern Age[23]

Renaissance can be understood as a transition period between the medieval and modern philosophies. The modern thought that takes ground in the 15th century AD develops in open confrontation with the ideals that reflected the culture and the ideals of medieval times. If the fundamental problem of the Medieval Ages' thought can be summarized as the relationship problem between reason and faith, how one interfered with the other and vice-versa, Renaissance would stay for history as the period when

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[23] Introductory note: This section focuses on the Renaissance period. At this time we assist to the dethroning of God as a higher order and to the re-instauration of the human figure as the centre and measure of the universe. Although still mostly based on ancestral ideas, the Renaissance will come forwards as the time of the reborn of such concepts. We will highlight a new comprehension of the architecture composition system and representation, as in perspective, which, without forgetting its bases, look upon them at a completely different level.

man departed from God and theology, as absolute and central consideration, and brought himself closer to a scale built at his own and nature's image. With Renaissance's Humanism, the anthropocentric and naturalist vision of man and the cosmos from classical times return allied with new scientific posture and contributions and lead to a new vision of the world, the universe and the position that man takes within both.

Humanism, the protestant reformation and the continuous progress of science constitute this period's greatest and more significant three cultural forces. By turn, its scientific progress was driven by two fundamental factors: the improvement of technical-practical necessities, such as ballistics and navigation, and the discovery of the great ancient Greek scientists, especially Pythagoras, Plato and Archimedes. On one hand, the attention that is given to these philosophers is considerable different than the one previously assumed by Augustine or Boethius, with intimate associations with a Christian God, and, on the other hand, lead to the abandon of the late medieval adopted Aristotelian physics of a closed, finite and theological ordered system. The discovery of the Pythagorean tradition gave a new strength to the idea, previously abandoned by influence of Aristotle's philosophy, that the universe possesses a mathematical structure and order and therefor, the laws that rule the natural phenomena are able to be translated by mathematical formulations. Copernicus, Galileo, Kepler together with Newton, brought a new science and scientific methodology, with fundamental grounds on mathematics to explain the universe and physical phenomena, rejecting rudimentary scientific ideas that have been prevailing for a long time. With the falling of the Medieval philosophy and 'science', thought would be once again intrinsically connected with reason in an autonomous way. Reason is understood as a supreme principle, independent from any other instance, on which knowledge and science will settle in the attempt to give answer to philosophic questions about man, society and history (Cordón and Martínez 2014, pp.197-8/205-12).

The beginning of the 15th century seeks inspiration, once again in history, in the classic tradition. The rediscover of the culture heritage of ancient Greece and Italy will contribute to the reborn of the classic ideas that were developed in these times. This attention focused mainly in the two forms of knowledge that were preserved in time: The arts, mainly Architecture and sculpture, and old documents which, either in the forms of originals or copies and translations, managed to mislead the wear of time. Architecture and treaties, together with other liberal arts, will be, by turn, the main 'selected' forms of expression to manifest this time's identity (Furnani 1995, p.175).

Among such old documents, Vitruvius' *De Architectura Libri Decem* will be of particular importance. The classical Greek central ideas that we can find there gathered and explained, together with the description of the appliance of such concepts to architecture, namely the classic orders and the general proportions that were present in the composition of the part and the whole of ancient Greek and Roman architecture buildings, will influence the reality and works of such period. The production of treatises on architecture, beginning with Leon Battista Alberti's *De Re Aedificatoria* and Filarete and Andrea Palladio's opus, will provide the conceptual and physical foundation for the architecture of the Renaissance (idem). Equally, "experiments on painting and developments in philosophy [will] create the premises for a profound change in the spatial conception of the physical environment and, as a consequence, of architecture as well" (idem). Theoretical works on painting such as Alberti's *Della Pittura*, dedicated to the figurative arts, as painting and the drawing of perspective, mainly through geometric principles, or Piero della Francesca, Leonardo da Vinci and Raphael's practical works, provided "ground for the application of the laws of perspective to the representation of reality" (idem). Several works on philosophy "ranging from Hasdai Crescas' early reflection on the infinity of the universe, through the works of Telesio, Patrizi and Giordano Bruno, to Descarte's later theories of the *res extensa*, contributed to the evolution of thought with concepts that are decisive for the definition of perspective space" (idem).

The reborn of classic achieved knowledge would unquestionably influence the work of the Renaissance. The systems of proportions reappear with particular attention, and intention, and its results are felt in the forms of architecture and the visual arts. The orders return. Alberti, and later Palladio, bring to this time's reality, as happened before, the Greek, Pythagorean musical theory of proportions and apply it to architectural theory (Kappraff 1996, p.116).

Nevertheless, like in the Middle Ages, however strong these references have shown to be in channelling the course of new knowledge and building the identity of a period, it will be distinctive factors that will, ultimately, characterize this period. If in the medieval times, the character of a celestial divinity has mainly manifested in architecture in the form of an immaterial, yet corporeal felt majestic work on light and music, in the Renaissance we could say that such a character hits architecture from within rather than from outside, external factors. In other words, despite of all the references that will interfere with this form, it will be the own tools and methods that are applied in the development of such subject that will influence the way it is worked and, ultimately, its final result and appearance. Architectural composition, the applied measure and proportion systems, and the development of innovative architecture representation techniques, with concrete, specific consideration reasons, such as perspective, are, from our point of view, the three factors that may have been decisive for this end.

Architectural Composition

In this period of the Renaissance took place an architectural phenomenon that would change the whole thinking process of this subject. In the process of developing the project's core ideas, the architect would make use of drawing instruments in order to investigate the possible solutions for the definition of the form and general organization, and disposition of the building. The final product, as the set of parts that compose it, will be achieved through the use of typological and formal references and a system of rules – measure and proportion systems – able to give a sense of unity and harmony to the whole of its elements. This process of architectural construction can be defined as 'architectural composition', "a process capable of ordering and harmonizing, in a closed system, a series of limited architectonic elements defined in form and structure" (Furnari 1995, p.175).

The adoption of such compositional method will considerable change the process of architectural planning as well as impose a clear distinction between this process and the one that belongs to the materialization of the idea, construction. The architect will assume an intellectual central position, moving away from that of the builder, that through means of drawing methodologies and techniques – plan, elevation, section, perspective and reference grids –, and mainly classical principles – strength, convenience and beauty and order, proportion, symmetry or alignments –, work the contextualization, harmony and balance of both parts and whole of the architecture composition. It is in this period of the Renaissance that such operative methodology of composition, that would prevail and be further and further explored in time, and still of crucial pertinence in nowadays, founds its roots (ibidem, pp.175-6).

The Acknowledgement and Search for Beauty as a Period's Identity

> *"Renaissance architecture in Italy pursued its course and assumed its various forms rather from an aesthetic, and, so to say, internal impulsion than under the dictates of any external agencies. The architecture of the Renaissance is pre-eminently an architecture of Taste. The men of the Renaissance evolved a certain architectural style, because they liked to be surrounded by forms of a certain kind"*

Geoffrey Scott, *The Architecture of Humanism*[24], 1914

> *"The central idea of the Italian Renaissance is that of perfect proportion. In the human figure as in the edifice, this epoch strove to achieve the image of perfection at rest within itself. Every form developed to self-existent being, the whole freely co-ordinated: nothing but independently living parts…. In the system of a classic composition, the single parts, however firmly they may be rooted in the whole, maintain a certain independence. It is not the anarchy of primitive art: the part is conditioned by the whole, and yet does not cease to have its own life. For the spectator, that presupposes an articulation, a progress from part to part, which is a very different operation from perception as a whole."*

Wölfflin, *Principles of Art History*, 1932[25]

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[24] Scott 1914, p.32.

[25] 9–10, 15. Found at Sartwell 2016.

As happened in the other periods that we have been trying to decompose, the search for beauty and the production of something able to be recognized as beautiful, is a central concern of this period, and seen as a propriety able to elevate the individual. Alberti would write that the pleasure and delight that we feel when standing in front of a building is an effect of beauty and ornament. He defines beauty as an harmony between the parts, which, together with proportion and connection, define perfect opera[26] (Alberti 1986 [15th century AD], pp.356/8, Furnari 1995, p.183). Beauty is then, once again, understood at the image of the Vitruvian principles of strength, convenience and beauty, as well as proportion and harmony between the parts, which can be interpreted as his concepts of eurythmy and symmetry. Yet according to Alberti, the beautiful harmonic balance of the forms can be achieved by two different types of actions: (i) arranging through proportion and (ii) through discourse (Furnari 1995, p.183). While the former (i) refers the achievement of beauty and harmony to be linked to mathematical and geometrical systems of proportion, and the concept of proportion is associated with the absolute numbers and anthropometry, conceptions that contributed to development and, by turn, also reflect the result of treatises as *De Re Aedificatoria* or Luca Pacioli's *De Divina Proportione*, the later (ii) refers to beauty as the necessary, correct and coherent articulation of the elements of a structure's composition and, in search for the perfect balance between the parts, takes under consideration their "appropriate position, exact proportion, just disposition and harmonious order", and is thereby better assisted and controlled by drawing instruments and techniques, either of bi-dimensional or tri-dimensional nature (Furnari 1995, p.183). The development of thought and form in the Renaissance will, mostly, either follow one or another of these kinds of actions. The following text will attempt to address to both of these form, starting with (i) the mathematical and geometrical measure and proportion systems and ending with (ii) the use of such drawing tools and techniques to achieve a beautiful and perfect articulation that would, for their original approach, characterize a great identity of this period.

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[26] "… it is generally allowed, that the Pleasure and Delight which we fell at the view of any Building arise from nothing else but Beauty and Ornament [and] (…) whatever you build may be not only useful and convenient, but also handsomely adorned. (…) I shall define Beauty to be the Harmony of all parts, in whatsoever Subject it appears, fitted together with such Proportion and Connection, that nothing could be added, diminished or altered, but for the Worse."

(i) Measure and Proportion Systems in the Renaissance

The Renaissance man seeks a way to express the cosmic order and the architect attempts to represent this order through a system of harmonic relationships able to transfer to his art an absolute level of beauty. Such harmony should rely on a series of practical, easy rules able to be applied to the complexion of a building, controlling it and, at the same time, conferring it the ultimate goal of achieving a perfection or beauty in absolute value, "attained only when the various parts achieve an ideal, reciprocal equilibrium in the three dimensions" (Furnari 1995, p.184). "Proportion was the thread used to stitch everything together"; it would provide the building the bonding for a coherent, ordered universe not always expressed with the transparency of pure forms but a "'hidden cause', a 'secret ingredient', as something 'inherent and implanted'" able to contribute to the sensation of a present underlying order (Evans 2000, pp.243/9), but also, according to Wittkower, a pure, simple and lucid architecture of elementary forms (Payne 1994, p.326).

The use of proportion in the design and articulation of forms made possible to relate the measures of a bi-dimensional form, functioning as a tool to control the dimensions and harmony between both parts and whole of a structure, and allow the architect, the artist or any other producer of form to, within the limits and the applicable progressive measures of the proportional system, gain a relative freedom in the design process, not limiting the possibilities of a composition but assuring that the composition of the parts, between the parts and the whole, satisfy the fundamental requirements of harmony[27] (Furnari 1995, pp.184/7).

If classic philosophy was the reason science of natural observable phenomena and the medieval spirit followed the faith of the celestial light, the Renaissance and Renaissance architecture, as one if not the most important of this period's expressions, returns to a scientific view over the things from this world and the other.

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[27] "Beauty will result from the form and the correspondence of the whole, with respect to the several parts, of the parts with regard to each other, and of these again to the whole; that the structure may appear an entire and complete body, wherein each member agrees with the other, and all necessary to compose what you intend to form." Palladio 1738 [1570]

The symbolic forms extracted from the philosophic (and scientific) study of nature and the "visible materialization of the intelligible mathematical symbols" reveal a Neo-Pythagorean, Platonic and Euclidean geometric conception between micro, macro and Divine cosmos: "Architecture was regarded by them [Renaissance artists] as a mathematical science which worked with spatial units… For the men of the Renaissance, this architecture, with its strict geometry, the equipoise of its harmonic order, its formal serenity, and above all, with the sphere and the dome, echoed and at the same time revealed the perfection, omnipotence and goodness of God (…) The conviction that architecture is a science and that each part of a building, inside as well as outside, has to be integrated into one and the same system of mathematical ratios, may be called the basic axiom of Renaissance architects" (Wittkover in Payne 1994, p.325-6). Mathematics and geometry proportion occupied a central role in the aesthetics of the Renaissance as such and previous time's interest and intentions to decode nature's hidden, but implicit, mathematical orders, which conferred to them their perfection and beauty, and apply them, already decoded and simplified, through more pure and direct forms, identically perfect and beautiful, more easily perceived by the eye. "Alberti, Bramante, Leonardo, Palladio all concurred in a mathematical definition of beauty manifested as 'logic of the plan', 'precision, geometrical economy', 'symphonic quality', 'lucidity of the geometrical scheme', 'evidence of the structural skeleton', a 'crystalline vision of architecture' and 'devotion to pure geometry'" (Wittkower and Payne in Payne 1994, p.326).

The Aesthetics of the Whole and Irrational Numbers

The Pythagorean musical consonances have been of special importance and took a highlighted position in this period's vision and form production themes. To this have contributed this period's wide diffusion of the neo-Platonic doctrines, especially the *Timaeus*, where the Pythagorean rules, and series of simple relationships based on mathematical ratios of small whole numbers appear mentioned and described (Furnari 1995, p.184), but also Vitruvius' treaty or Augustine and Boethius' homonymous opus *De Musica*.

From the 15th to the 18th centuries, architectural theory makes use of the harmonies of the musical scale as evidence that exact ratios underlay our perceptions of beauty in all things. Concerned with the search of a system for proportion and composition, architecture would merge together with music (as a mathematical science) and seize the latter aesthetics of ratios. “Since measure was as important to architecture as it was to music (although for quite different reasons), similar harmonies, as exact as those found within the musical scale, were sought to account for the harmonious disposition of parts in buildings” (Evans 2000, p.241). However, “Renaissance artists did not mean to translate music into architecture, but took the consonant intervals of the musical scale as the audible proofs for the beauty of the ratios of the small numbers 1:2:3:4” (Wittkower in Payne 1994, p.326), considering the original proportional relationships of musical measures and harmonies in spatial terms and transforming it in visual beauty and perfection proof. As in the past, these proportions are based on the classic octave, 1:2, fifth, 2:3, and fourth, 3:4 (expressed in the monochord with the also perfect proportions of the tetraktys 1:2:3:4), being, however, also able to acquire some more complex combinations (Furnari 1995, p.184).

“Like most Renaissance artists, Palladio, following Alberti, subscribed to the mathematical definition of beauty” and, since he “can be either documented or inferred to be familiar with both musical theory and a mathematical conception of aesthetics and thus participate knowledgeably in a discourse that united architects, mathematicians, and music theorists”, plays the so well-known and characteristic Renaissance’s role of the uomo universalis (Payne 1994, p.327).

However important the use of such “beauty of the ratios of small whole numbers”, also other proportions discovered in ancient times but belonging to the realm of irrational numbers were widely used in this period. Within such system, the Pythagorean uncomfortable root of two, which indicates the relationship between the side of a square and its diagonal, and the golden section, the existing relationship between one side of a pentagon and the line that connects two of its non-consecutive vertices, are two of the most recurring and used proportions (Furnari 1995, p.184).

The Aesthetics and Articulation of Man

"...because it is a certain thing, that the members of architecture derive from the members of man. Who has not been or is not a good master of the human body, and most of all anatomy, cannot understand anything of it."

Michelangelo[28], ~1560

"As man is the image of God and the proportions of his body are produced by divine will, so the proportions in architecture have to embrace and express the cosmic order."

Wittkower, Architectural Principles[29], 1971

Also the measure of man and the human body arise in this period as another proportional system, and probably the one with higher expression. As the previously mentioned examples of proportional systems, the one on the measure and proportions of man also appear associated with the revival of references from the past. In this case however, it is the Vitruvian description of the human body proportions and symmetry, and these concepts applied, for instance, to the relationships between the elements of the classical orders, that is mostly responsible for this system's reappearance. Framed within the developments (and shifts) on thought brought by the humanism, the Vitruvian *homo ad circulum and ad quadratum* returns as a Renaissance ideal, dethroning the medieval central position given to an absolute divine entity, and making from man a reference of absolute order, the measure of all things (Furnari 1995, p.183). Vitruvius' proportional description and the drawings that, according to it, have later been developed, have gathered and putted in contact the natural world of man and the artificial world of geometry, exposing the position that history have been constructing, and even trying to prove, at least since Pythagoras, on the apparent existing relationship between nature and the abstraction of mathematics and geometry. On such relationship, Filarete would write "all figures whatsoever, circles

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[28] Payne 1994, p.334.

[29] Idem.

and squares, and every other measurement, are derived from Man". Man becomes an harmonic or a mechanical proportional reference and the body a symbol of unity. To this, contribute the relations between the parts, or members, with the whole of the body, including their specific use and function within the larger harmonic and unitary model of the whole. Such relationships would be adapted to architecture and used to articulate the different parts and functions of a building within its understanding as a unity. "I will show the building to be as a living man", would also state Filarete according to such relations (Furnari, 1995, p.183).

The Aesthetics of the Orders

Together with the proportional systems used in order to assure the harmony of the parts, the beauty of the Renaissance building was also obtained by the use of the classical orders "and the dignity that they lend" (Furnari 1995, p.187). The "three manners of adorning a building" extracted from nature (Alberti in idem), the Doric, Ionic and Corinthian orders, not only raise the formal quality of a building, but also enable the articulation of the space and its overall perspective perception thought the rhythmic interval disposition. According to their nature and the relationship between each of their pre-established element proportions, the orders represent a whole, or three different whole systems of proportions and measurements, each one chosen and applicable with the goal to achieve a certain, specific aimed result which implies different formal repertoires, symbolic associations, and the characteristic dimensional relationships of a style, regulated by a series of grammatical and syntactical rules. Once again widely popular in this period of the Renaissance, the Vitruvius work has influenced the treatises of Alberti and Francesco di Giorgio, or the comparative tables of Serlio and Vignola on this matter (idem).

(ii) Drawing Techniques and Articulation as Thought Developing Tool in the Renaissance and the Overall Proportions of Tri-Dimensional Space

As seen earlier, in *De Archittectura Libri Decem* Vitruvius makes reference to groundplan, elevation and perspective as forms of expression of a tri-dimensional form. With the Renaissance's 'architecture composition' these forms of representation gain a substantial new pertinent relevance. And, although not depreciating the value of the former (plans, sections and façade elevations) as bi-dimensional tools of space organization (with all the attributes and focuses that we have been addressing to), special when the consideration of one takes the others under intensely account, unfolding the consideration of a tri-dimensional space, it will be the latter, perspective, that would actually make a significant difference in the way architecture space, as form, would be faced on such time.

The use of orthogonal bi-dimensional space representations in architecture guarantied the correct application of any kind of proportional system when each of these expressions were considered, in the sense that the measures of such systems were considered in their true dimensions. However, one factor was left outside of these representations and not one that can easily be excluded from architecture practice: Depth. Even though the plan is able to deal with this concept in an abstract, uniform way, it does not contemplate the extension and progression of depth, and hence, the fullness of the architectural space three-dimensions. Perspective appears then in the 15th century as a method through which was not only possible the representation of the three-dimensions but also as a valid instrument to control the disposition and articulation of/and between the elements contained in the space's void, either if they respect a bi-dimensional or volumetric nature. Perspective drawing presented then a simple technique of representation and also a complex methodology able to consider and verify the volumetric potential of spaces, and examine the special implications of the conventional bi-dimensional representation techniques (ibidem, p.178/183).

Architecture and painting were the two areas that have particularly explored perspective and, at the same time, been deeply influenced by it. Some authors actually state that the Italian architects of such time were trained as painters, for the qualities that perspective brought into the thinking of architectural spaces (Evans 2000, p.107). However, in this period emerged two different forms of this at least as old as Vitruvius' technique. Each form was able to present different representation results, all ruled by mathematical and geometrical principles, which fulfilled different intentions and approaches towards a specific, defined end. Such forms were based on parallel (orthogonal) and linear methodologies. While the first appeared to be more suitable for use within the architecture context, the latter seemed to be perfectly adjustable for schemes of painting representation (ibidem, p.110). Although both of them had the particularity of bringing space and depth into paintings or overall bi-dimension platforms of representation, recreating in one piece the complex tri-dimensionality of physical reality, while:

> Parallel projection had the singularity of being constructed directly from the other bi-dimensional forms of representation, was able to present an overall view of a building and, according to the visible spectrum, preserve the true dimension of the proportions also explored in plans or elevations, which made possible the study of its general tri-dimensional proportions, namely through bird's eye point of view representation, or similar, and, for this reason, better suited the purposes of the architect;
>
> Linear perspective fitted painting in the sense that it was able to represent things in the way humans visual perceive every visual things that surround them, and, also because, previously worked bi-dimensional proportions got, in this kind of linear representation, distorted, reason why it seemed not suitable for architecture expression and representation.

Nevertheless, despite of the determinants that the latter comprised to architecture study and composition, it was also able to present an undeniable benefit to this subject in the way that it was able to express, even though from a single (and monocular), subjective point of view, among the almost incommensurable set of many others possible, and if the height of the observer's point of view was taken into account, a reliable representation of how things would really be and be experienced at the constructed final product.

Notwithstanding the dubious, vague reference that Vitruvius makes about perspective as a "method of sketching a front with the sides withdrawing into the background" with "the lines all meeting in the centre of a circle" (Vitruvius 1914, p.27-8), Brunelleschi is pointed as the father of linear perspective (Evans 2000, p.251), and Alberti the one how has theorized this subject when writing Della Pittura, referring to it as an easy and practical method (ibidem, p.110). According to Alberti's proposal, the linear perspective result was achieved by a plan, grounded modular grid (a network able to order and control space progression) and a central point (vanishing point) situated in 'the prince of the rays' (the horizon line) which commanded anything in its path, traveling from the observer's eye, parallel to the ground, towards the horizon. Like light, 'the prince of rays' travels in a continuous straight line and is the organizing force in the perspective methodology (ibidem, p.111). Through such technique the architect was then able to perceive the idea of a product in time, a middle term between the abstract representation and the real object, being consciously aware of the progression of the elements through the evolution depth and distance of space and, at the image of what the Greeks did with the Parthenon's proportions distortions, in order to achieve perfect human perception, better organize the architectural composition with the always present intention of making all the parts of the building fitting together and within the whole, finding in this way the 'harmony with the entire universe'.

Man as Measure

It is within the consideration of linear perspective that Man and its scale complement the above mention importance and pertinence inside the characteristic line of thought and performing of the Renaissance. With linear perspective and its origin point, normally taken from the height of a standard scale observer's eye, the focus that the Humanism gave to the position of Man reinforced its strength. Since in perspective, space develops in depth according to mathematical and geometrical three-dimensional laws, where horizontal lines and aligned references converge towards points in the 'prince of rays', and the applicable bi-dimensional proportional systems appear distorted to any other system but the one ruled by the eye, Man is the only valid proportional system. After conquering his placed in the centre of the humanism universe, Man truly becomes the measure of all things, in both proportional principle and physical scale dimension. He is the architectural measure-module and the unit of the dimension structure of space defined by the perspective vision system (Furnari 1995, p.183).

Yet in reference to this period's three-dimensional consideration, in his *Quattro Libri*, Palladio refers to the known Pythagorean means as a way to connect the length and width of a space with its height. Through three mathematical formulas, the arithmetic, geometric and harmonic means, it was possible to consider a close system of proportions between two dimensions but also extend it to the space's third dimension, considering the relationship between its bi-dimensional plans and also its volumetric relation. Though each one of this means, space as a whole, tri-dimension structure, would be controlled and its desirable cosmic harmony satisfied (ibidem, p.187)

The Renaissance Form

As pointed in the beginning of this chapter, the development of this period's thought follows closely, and is at turn followed, by the developments of form, namely and mainly within the subjects of architecture and painting.

In the Renaissance, architecture as the production of form, follows its medieval predecessor sought cosmic order but, instead of centred in the Reign of God, it searches for a cosmos translated through the mathematical science of numbers, proportions and Man. The building no longer aimed to represent the medieval spiritualized space of 'De Civitate Dei' but the image of an ideal, mathematical organized universe. The previous period's central theme, focused on a God-Man relationship, turned to a more humanized vision that, without forgetting the consideration of god, centres on Man; and the notion of perfection replaces the transcendent ideal by a nature, human based aesthetics (Norberg-Schulz 1999, p.115/129-30).

In this period we assist to the return of the nature classical thought and representation. To Pythagoras, 'all was number and to Plato, 'cosmos', 'order' and 'beauty' were synonymous. Like such ideas, the architecture of the Renaissance brings back the platonic theories and the Greek archetypes through ideal, perfect and beautiful form concepts and can be understood as a synthesis between the classic theories and Christianity, as a consequence and unity of most of the past developments on thought, representation and expression (ibidem, p.130). It settles in three fundamental characteristics: (i) the reintroduction of the classic anthropomorphic elements, through the orders' symbolism and the relationship between the parts and the whole, so patent and characteristic in the harmonic articulation of the human body; (ii) the intensive use of elementary geometric relations, through the simple mathematical proportions of whole and irrational numbers; and (iii) the accentuation of spatial centralization, in both senses of this statement: Space becomes an homogeneous unity within the perfect, absolute geometric orders of the cosmos (ibidem, p.115/119/129) and, with the transition from the Ptolemaic-Aristotelian to a Copernican vision of the world and the universe, space becomes a great, infinite, autonomous container (Furnari 1995, p.178). Space has been converted in a kind of structure, 'substance' unitary container, brought together by geometry; and perspective, as a description tool of space as a whole, confers to it, its never lost, but however never also previously considered, comprehensive three dimensions (at least at the level that they are nowadays), where people and objects dwell, elevating and once again centring the position of Man as principal measure of space.

Sometime later, Descartes would define and describe spatial reality as *res extensa*, "expanding unitarily and infinitely in all directions around it. Three-dimensionality cancels out the static simultaneity of the ancient conception of space, and the conquest of depth transforms it into a place where infinite spatial sequences follow one another according to a compositional principle which, in architecture, has passed from being addictive, i.e., based on the two axes (longitudinal and vertical) of the Gothic architecture, to comprehensive: structured in the three 'Cartesian' axes (longitudinal, transverse, and vertical) found in churches with central-plan system" (idem).

2.2.6. Modern Era Discourse on Thought, Objectivism and Subjectivism over Rationalism, Empiricism and Illuminism[30]

"Philosophy [nature] is written in that great book which ever is before our eyes - I mean the universe - but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. The book is written in mathematical language, and the symbols are triangles, circles and other

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[30] Introductory note: The next to be addressed section is dedicated to the thought, science and knowledge of the Rationalism, Empiricism and Illuminism periods. This section closes our discourse on 'Overview on the Rational Thought and Form'.

> *geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth."*
>
> Galileu Galilei, Il Saggiatore, 1623

In the early decades of the 17th century, we will assist to the definitive establishment of science, and the beginning of modern philosophy, with Galileo, Kepler and Descartes as leading exponents (Cordón and Martínez 2014, p.208/33).

In the 16th century, Copernicus arise as the first protagonist of the new, already started but yet to come forward, scientific transformation. Based on the traditions and the classical Greek scientific knowledge, Copernicus "promotes a Pythagorean and Platonic attitude towards reality: the mathematical structure of the real. The configuration of the new science and the primacy conceded to mathematics, as interpretation of the universe, determined, consequently, a new interpretation of reason and a new scientific method" (ibidem, p.233). The new science would destroy definitely the basic fundaments and principles of the Aristotelian physics and its image of the universe and would eliminate the geocentric theory of the universe in favour of a heliocentric view over this matter.

Chronologically, Francis Bacon recovers the Aristotelian induction (and deduction) as scientific methods of examination and verification of the truth, basically in the same moulds that these kinds of knowledge were thought at that time, and Galileo contributes for the instauration of the experimental methodology through which reason should drive observation (ibidem, p.266). Galileo's resolute-composite method (analysis and synthesis), is based on three steps: the resolution or analysis of the data, through sensible experience, in order to achieve its essence (Resolution); the construction or synthesis of a supposition, or hypothesis, from the previously gathered essence properties, through which a series of consequences can later be deduced (Composition); and, finally, the proof of the hypothesis deducted effects (Experimental Resolution) (ibidem, p.271). With this methodology, Galileo expected to achieve the genuine expression of the Renaissance: the nature of an autonomous reason whose essence was considered to be mathematically translated. The new modern world appears due to an absolute thrust in projective reason, and this essence of modernity is experienced in the words of Galileo: "reason disconnects from all authority, be that of tradition or of the senses" (ibidem, p.272).

Rationalism appears in the 17th century as the first great movement of the Modern Age (ibidem, p.300). With Descartes, Leibniz, Espinoza and Malebranche at its head, it establishes that our valid and true knowledge about reality proceed from reason, from understanding itself (ibidem, p.277). Descartes opens then, a new era of philosophy characterized by the absolute autonomy of reason. Reason is faced as supreme and only principle on which knowledge is supposedly grounded, and the mathematics, for its abstract domain, as the best vehicle to achieve such ideal level of thought (ibidem, p.275). According to Rationalism, the understanding of things should find within the fundamental truths, the entire realm of our knowledge (ibidem, p.281).

Descartes follows Bacon's Aristotelian revival and considers that there are two modes through which knowledge can be achieved: induction and deduction (ibidem, p.279). In this way, he revives also the Aristotelian based logic system of the axiomatic method that hides behind Euclid's Elements. However, unlike Bacon, the ideal of the new science of rationalism is constructed through a deductive system where the laws are deduced from certain first principles, concepts or basic ideas, which may not only be achieved by means of induction. In the search for the truth about things, Descartes finds these immutable truths in the form of 'innate ideas'. Such innate knowledge is in his opinion able to substitute the search for the 'first principles' or immutable truths' of the axiomatic method, through induction, and can be used as the necessary axiomatic basis of this method (Akin 2006, p.24-5). Actually, together with the conviction that the domain of reason, of thought, is necessary, and that the domain of such thought corresponds exactly to the domain of reality, the ideal of the new science based on a deductive system that follows a mathematic model, or in other words, that it is possible to deduce the system of our knowledge about the universe from certain obvious and primitive ideas and principles, is one of the fundamental characteristics of rationalism (Cordón and Martínez 2014, pp.300-1).

But in the search for the best and most accurate scientific methods, Descartes also makes use of the Galileo's experimental resolute-composite method based on analysis and synthesis. Induction or innate knowledge and deduction constitute the intern and specific dynamism of knowledge, and should be first applied in an analysis process, which is able to extract the essence or the simple nature of the considered elements and, secondly, in a synthesis process of deductive reconstruction from simple to a more complex form (ibidem, p.281). In the Principles of Cartesian Philosophy, Spinoza summarizes the Cartesian Method in four rules: "I believe that the four following would prove perfectly sufficient for me, provided I took the firm and unwavering resolution never in a single instance to fail to observe them. The first was never to accept anything for true, which I did not clearly know to be such… The second, to divide each of the difficulties under examination into as many parts as possible, and as might be necessary for its adequate solution. The third, to conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend by little and little, and, as it were, step by step, to the knowledge of the more complex… And the last, in every case to make enumerations so complete, and reviews so general that I might be assured that nothing was omitted" (Spinoza in Akin 2006, pp.24-5). This method of thought has since then "been hailed as the archetypal rational thought process" (ibidem, p.24) and has been of a direct and incisive influence in the processes of thought development, including the yet to come Newtonian and later revolutions.

The rationalism is followed, in the discourse of history, by a reaction movement and historic response that would return the origin of knowledge to sensible experience. While Rationalism defended that knowledge could, and should, be acquired through reason from first principles or innate ideas, without recurring to experience, Empiricism, the second great movement of the Modern Era, deny the existence of innate knowledge and, hence, all of our knowledge should proceed, ultimately, from the senses and sensible experience (Cordón and Martínez 2014, p.277/307). However early, Bacon can be seen as the premature figure of this movement. According to him, the deductive, central method from Rationalism "was a mere tool for arriving at the consequences of known principles and did not offer the possibility of understanding the causality underlying these principles. Furthermore, the correct way of going about understanding the 'laws of nature' started with the objective observation of nature. For this, Bacon proposed a method, which has been characterized as Presuppositionless Observation. In this method, natural phenomena are stripped off of biases or myth from the past. Instances of the phenomena (say, straight lines) are observed exhaustively, both when they are present and when they are absent. Based on this observations one can induce the casual factors that underlie the true nature of the phenomena, such as proposition that there are no perfectly straight lines in nature. This empirical idealism proved to be one of the most influential bases of the Empiricist movement in philosophy" (Akin 2006, p.27). Locke is, together with Berkeley and Hume, the major representatives of such knowledge movement. To him, Locke, knowledge is perception and perception is the knowledge of ideas. Such ideas are the immediate object of our knowledge, images or representations from the exterior reality, and, how Berkley has added, they are in fact things that are meant to be perceived.

In the 18th century, the century of illustration or of the lights, the Illuminism settles as a wide movement of ideas through which was pursued a clarification towards the aspects and dimensions of the human life (Cordón and Martínez 2014, p.333) and emphasises the autonomy of reason. Through Newton we assist to the peak of a scientific revolution. A real, new revolution already initiated with Copernicus, Kepler and Galileo that, based on knowledge, reason and the senses, would dictate the departure from the classical and medieval visions towards the inauguration of a new level of knowledge, with pronounced identity and character, and that would completely change the way we faced the world around, beneath and above us. In search for the perfection of an experimental methodology of philosophy and science, Newton reinforces that the method of science is induction (or transduction) and looks on mathematics rather as a mean than a fundament within the natural philosophy (physics). His works on this matter, from the behaviour of bodies in steady or movement phases, to time and space as absolute parameters, will directly influence the yet to come significant scientific advances of the next centuries (ibidem, pp.341-51).

Further ahead, in *Critique of Pure Reason*, Emmanuel Kant would submit reason to judgment in the attempt to find its place, function and pertinence within the recent reality of its application or even occlusion from Rationalism, with its almost unique and undeniable central consideration, Empiricism, with its exclusion in favour of the senses and experience or Irrationalism, with its negation in favour of an overvaluation of the sentiment, mystic faith and subjective enthusiasm (ibidem, p.376-7).

State of play

The discourse and evolution on thought as well as the evolution of the methods and methodologies used in order to better express and represent it, together with such knowledge's result forms, have contributed to the characterization of punctual cultures and their evolution through time. For a long time that the purpose of knowledge has been the understanding of things: to comprehend what things really are and how they behave. If not in an absolute way, at least in a way that would make sense according to what was in such time believed to be true or acceptable.

From where we stand we could continue onwards towards the ideas that have constructed the 'recent' age of contemporary philosophy, from around the beginning of the 19th century until present time. Like the previous referred ideas, these discourse would come around these times' scientific considerations or revolutions about the vision of the world and everything that surrounds us, including our believes, for instance on God and the divine (one of our oldest and, at the same time, yet most active current concerns), good, virtue and happiness, and, according to the discourse that we have been applying to this document, the way how such understandings have influenced and moulded the form of forms that we have been producing though time.

However, in our opinion, more important events have, for the last centuries, deeply interfered with our production of form. Not that our philosophic and scientific perception of things have not, because it did and still does, but due to the fact that other events have influenced it in a more active way. As such events we are referring to the revolutions that have started around the second half of the 18th century and have managed to reach global resonance: The Industrial and Digital Revolutions.

In the next main section, the last one of this thesis current Chapter 2, we will address these revolutions and how they have actively contributed to the trend of form that still remains in and characterizes our days.

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Erratum

The current erratum was presented to the PhD board of examiners in May 28, 2020, during the thesis' public examination.

- Replace 'angular, sharp' with 'sharp-angled, rectilinear' in all cases;
- Replace 'curved, rounded' with 'rounded, curvilinear' in all cases;
- In the first reference to techniques and technologies, add 'techniques (including methods) and technologies (including, for instance, tools, mechanisms, systems and processes);
- Replace 'methods, techniques and technologies' with 'techniques (methods included) and technologies' in all cases;
- Replace 'Due to the diverse nature of stimuli used in such experimental studies' with 'Based on the diverse nature of stimuli used in such experimental studies' in p. 138;
- Replace 'methods, techniques, tools and technologies' with 'techniques (methods included) and technologies in pp. 152 and 155 and in all additional cases;
- Replace 'curved or sharp-angled shapes and forms' with 'rounded or sharp-angled shapes and forms' in p. 160 and in all additional cases;
- Replace 'Angular, sharp-angled' with 'Sharp-angled' in p. 160 and in all additional cases;
- In the 'future work' section add 'Include data analysis methods from the literature review experimental studies' (e.g. ANOVA) in the 'methodology domain' proposed taxonomy (see p. 140 – "including the data collection [and analysis] methods").

Corrected in the thesis document:

- Corrected 'Willian Hogarth' to 'William Hogarth' in p. 8;
- Corrected '(H1', to 'H4')' to '(H1' to 'H4')' in p. 15;

- Added blank pages to fit the paper print version of the thesis which resulted in an increase of the thesis' total pages and the update of the thesis' Index.