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Boosting Children's Creativity through Creative Interactions with Social Robots

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Abstract

Creativity is an ability with psychological and developmental benefits. Creative levels are dynamic and oscillate throughout life, with a first major decline occurring at the age of 7 years old. However, creativity is an ability that can be nurtured if trained, with evidence suggesting an increase in this ability with the use of validated creativity training. Yet, creativity training for young children (aged between 6-9 years old) appears as scarce. Additionally, existing training interventions resemble test-like formats and lack of playful dynamics that could engage children in creative practices over time. This PhD project aimed at contributing to creativity stimulation in children by proposing to use social robots as intervention tools, thus adding playful and interactive dynamics to the training. Towards this goal, we conducted three studies in schools, summer camps, and museums for children, that contributed to the design, fabrication, and experimental testing of a robot whose purpose was to re-balance creative levels. Study 1 (n = 140) aimed at testing the effect of existing activities with robots in creativity and provided initial evidence of the positive potential of robots for creativity training. Study 2 (n = 134) aimed at including children as co-designers of the robot, ensuring the robot's design meets children's needs and requirements. Study 3 (n = 130) investigated the effectiveness of this robot as a tool for creativity training, showing the potential of robots as creativity intervention tools. In sum, this PhD showed that robots can have a positive effect on boosting the creativity of children. This places social robots as promising tools for psychological interventions.

Keywords: creativity, social robots, children, intervention

PsycINFO Codes: 3500 Educational Psychology; 3350 Specialized Interventions; 4010 Human Factors Engineering; 4140 Robotics.

Resumo

Criatividade é uma habilidade com benefícios no desenvolvimento saudável. Os níveis de criatividade são dinâmicos e oscilam durante a vida, sendo que o primeiro maior declínio acontece aos 7 anos de idade. No entanto, a criatividade é uma habilidade que pode ser nutrida se treinada e evidências sugerem um aumento desta habilidade com o uso de programas validados de criatividade. Ainda assim, os programas de criatividade para crianças pequenas (entre os 6-9 anos de idade) são escassos. Adicionalmente, estes programas adquirem o formato parecido ao de testes, faltando-lhes dinâmicas de brincadeira e interatividade que poderão motivar as crianças a envolverem-se em práticas criativas ao longo do tempo. O presente projeto de doutoramento procurou contribuir para a estimulação da criatividade em crianças propondo usar robôs sociais como ferramenta de intervenção, adicionando dinâmicas de brincadeira e interação ao treino. Assim, conduzimos três estudos em escolas, campos de férias, e museus para crianças que contribuíram para o desenho, fabricação, e teste experimental de um robô cujo objetivo é ser uma ferramenta que contribui para aumentar os níveis de criatividade. O Estudo 1 (n = 140) procurou testar o efeito de atividade já existentes com robôs na criatividade e mostrou o potencial positivo do uso de robôs para o treino criativo. O Estudo 2 (n = 134) incluiu crianças como *co-designers* do robô, assegurando que o desenho do robô correspondeu às necessidades das crianças. O Estudo 2 (n = 130) investigou a eficácia deste robô como ferramenta para a criatividade, demonstrando o seu potencial para o treino da criatividade. Em suma, o presente doutoramento mostrou que os robôs poderão ter um potencial criativo em atividades com crianças. Desta forma, os robôs sociais poderão ser ferramentas promissoras em intervenções na psicologia.

Palavras-chave: criatividade, robôs sociais, crianças, intervenção

Acknowledgments

Doing a PhD is so much about the journey. I want to express my gratitude to everyone who walked with me during these years. I would like to start expressing my deepest gratitude to all of my supervisors, Patrícia Arriaga, Guy Hoffman, and Ana Paiva. I have been honored to work with them and everything I accomplished would not have been possible without their mentorship, guidance, and trust. Each of my supervisors comes from a different discipline and the combination of this interdisciplinary mentorship from the fields of psychology, computer science, mechanical engineering, and robotics, enabled me to grow and expand in ways I could never image. I want to thank Patrícia for her incredible capacity to work side-by-side with me, and for teaching me to deepen my scientific thought over and over again. This empowered me with the necessary tools to achieve my PhD goals and extended my capacity as a researcher. It was in those moments that I re-connected with the passion that brought me to academia in the first place. I would like to thank Guy for being such an incredible role model. I could not have asked for a more inspirational, passionate, and visionary mentor. Our weekly meetings, the classes, and the lab discussions taught me the precious value of hard work. Guy helped me stick through the hard times of my PhD, to never give up, and to see the beauty of the process. This strengthen my persistence and endurance and showed me the importance of owing my own work. I am deeply grateful for having Ana as my supervisor. Ana has been a passionate mentor even before the beginning of my PhD as we have been working together for 7 years now! Ana's vast experience guided me throughout the different aspects of the academic world, teaching me how grow into an independent researcher. I am grateful for all the opportunities that Ana provided and for always being available to mobilize resources which resulted in unique opportunities for connecting and collaborating with others.

I am profoundly grateful to Cecília Aguiar, who was part of my external committee since the very beginning of my PhD. The annual feedback from Cecilia was essential to clarify where I made progress and where I should be focusing next.

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List of Acronyms

HRI……………………………………………...……………………………Human-Robot Interaction

HCI……………………………………………………………………….Human-Computer Interaction

WoZ……………………………………………………………………………………………Wizard of Oz

UCD…………………………………………………………………………...User-Centered Design

PD……………………………………………………………………………….Participatory Design

AI……………………………………………………………………………….Artificial Intelligence

ML…………………………………………………………………………………Machine Learning

"Num país e num mundo onde há famílias sem casa e doentes sem tratamento e sem hospital a questão da liberdade de criação artística e intelectual pode parecer uma questão secundária. Mas sabemos que a cultura influi na estrutura social e na estrutura política. E, por isso, a questão da liberdade na cultura é uma questão primordial."

Sophia de Mello Breyner Anderson

Intervenção na Assembleia Constituinte em 1975

(In English)

"In a country and in a world where there are families without a home and patients without treatment and a hospital, the issue of freedom of artistic and intellectual creation may seem a secondary issue. But we know that culture influences the social structure and the political structure. And, therefore, the issue of freedom in culture is a primary issue."

Sophia de Mello Breyner Anderson

Intervention at the Constitutional Assembly in 1975.

Chapter 1. General introduction

Overview of the Current Thesis

Robinson (2001) characterized creativity as being at the heart of what it means to be human. During childhood, we spend most of our time between fantasy and pretend play, creating new worlds, exploring, and living in fantasy (Russ, Robins, & Christiano, 1999). As we grow older, critical thinking skills take over and gradually we let go of the creative elasticity that our brain was functioning for. Despite becoming more efficient and skilled as adults, we also become less risk-taking, exploratory, and original (Gopnik, Griffiths, & Lucas, 2015; Roberts, & Mroczek, 2008). We, therefore, might trait our fearless creative imagination for a more grounded sense of the world.

Creativity is considered one of the highest human cognitive abilities with innumerous benefits to health and personal growth (Krathwohl, & Anderson, 2009). It is a skill related to one's well-being and healthy development (Collard, & Looney, 2014) and relates to our sense of self-expression and identity (Collard & Looney, 2014; Robinson, 2011). It sets up the mood for joy, wonder, excitement, efficiency, and pleasure into moments of our lives (Baer, 2017; Kaufman, 2018b). Creativity is considered a transferable skill since it benefits different areas of human development and growth (Chadha, 2006). Additionally, competencies of problem-solving and thinking outside of the box and rewarded in later life stages (Kaufman, 2018b) as they constitute one of the most sought-after workforce skills due to the shift of developed societies from industrialized to creative economies (Robinson, 2011). Indeed, creativity during childhood appears as a predictor of creativity levels in adulthood (Ayman-Nolley, 1992). Therefore, it is crucial to stimulate this ability in the early stages of life.

Despite its benefits, creativity levels are dynamic during life and tend to suffer a first major oscillation around the age of 7 years old (Kogan, 1973; Sawyer et al., 2003; Spodek &

Saracho, 2014). At this age, a tendency for creativity levels to decrease is reported to occur in a phenomenon named "creativity crisis" (Kim, 2011). This decline has been associated with diverse factors, such as formal education and conformity behaviors towards peers, among others (Runco, Acar, & Cayirdag, 2017). Nonetheless, creativity is a skill that can be developed if trained (Scott, Leritz, & Mumford, 2004). Existing creativity training programs for young children have been designed, developed, and validated. While some of these programs include play dynamics that engage children in the training process, others still resemble test-like formats, lacking joyful and playful elements. Therefore, there is a need to continue developing programs that are pleasurable for children (Chan, & Yuen, 2014; Kogan, 1973; Runco, Acar, & Cayirdag, 2017).

Given the benefits of creativity but also its decline in early ages of life, this thesis aims to contribute to nurturing this ability in young children. As current intervention programs for creativity are scarce and given the willingness of children to interact with technology (Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018), we proposed to use social robots as tools for creativity interventions. Towards this goal, we have designed, fabricated, and tested a social robot for storytelling interactions with children. During the interaction with the robot in the context of storytelling, we expect to positively impact on their creativity levels. This thesis thus relies on knowledge from different disciplines, including Psychology, Design Research, and Human Robot-Interaction (HRI) (see Figure 1).

The primary goal of this PhD work was to contribute to increasing creativity in children. To do so, we have developed a social robot named YOLO that was used as part of an intervention to promote creativity. The intervention for creativity development consisted of a

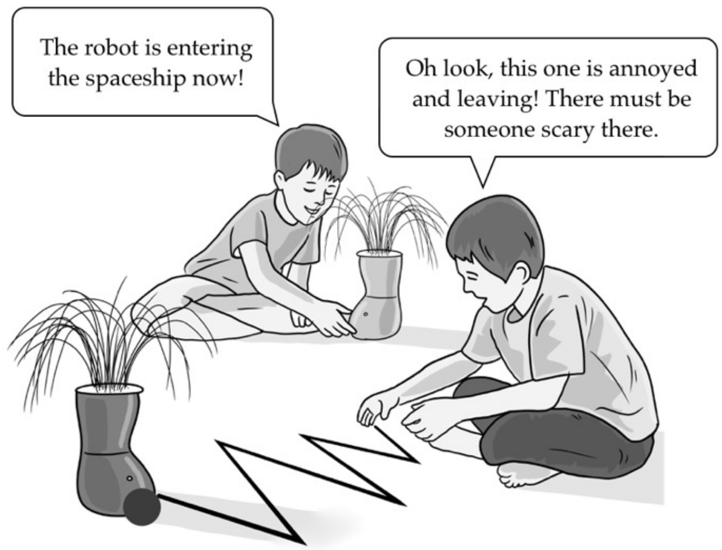

Figure 1. Example of an interaction between children and YOLO during storytelling play. Children move the robots on the floor as a storytelling character stand-in. Based on the trajectories detected by the robots' motion sensors, they take on different personalities that either mirror or contrast the children's story lines, as a creativity-stimulating technology intervention. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).

storytelling activity between children and the robot in which the robot autonomously acted as a character for children's stories. Through the interaction between children and the robot, creativity is expected to be promoted (see Figure 1)[1] (Alves-Oliveira, Arriaga, Paiva, & Hoffman, 2020). For this to occur, the robot behavior was designed to include behaviors that potentially could trigger creativity responses during the interaction. This thesis includes literature review om creativity, the development of a robotic character as a way to innovate creativity training, and an experimental study to test the effects of the intervention. The present document is organized as follows (see Figure 2):

[1]We present a video describing the research intervention and technical features of the robot that designed and developed to be an intervention tool for creativity:
https://www.youtube.com/watch?v=e-K3J5UZ9M4&feature=youtu.be.
This video is part of the publication Alves-Oliveira, Arriaga, Paiva, and Hoffman (2020).

Chapter 1 presents a general introduction for this thesis, explaining the interdisciplinary nature of this work and framing the contributions accordingly.

Chapter 2 introduces the theoretical underpinnings relevant to this thesis. We address key concepts from the field of HRI, such as the notion of what is a social robot and what research efforts have been developed for the inclusion of robots as research tools. Secondly, we clarify notions from the field of Design Research that grounded this work, namely concepts related to User-Centered Design (UCD), Participatory Design (PD), and the role of children when designing technologies. Thirdly, we provide literature on creativity research, including variables associated with creativity and different methods to measure creativity in children derived from the field of Psychology.

Chapter 3 concerns a systematic literature review of interventions for creativity dedicated to children. We presented a review of evidence on creativity interventions for children from 5-12 years old by systematically reviewing publications from 1950 to 2018. Therefore, this review included 68 years of research and provided an additional classification system with multiple levels of analysis for characterizing intervention programs, thus expanding the literature on this topic. The collected evidence from this work supported the choice of techniques for stimulating creativity within the scope of our work. Specifically, this review informed what methods could be used to design a social robot whose interaction modalities with children that would raise their creativity levels.

Chapter 4 reports on our first experimental study aimed at investigating if activities with robots promote creativity in children. Towards this goal, we have studied existing activities with robots already implemented in schools to understand the potential of using this type of

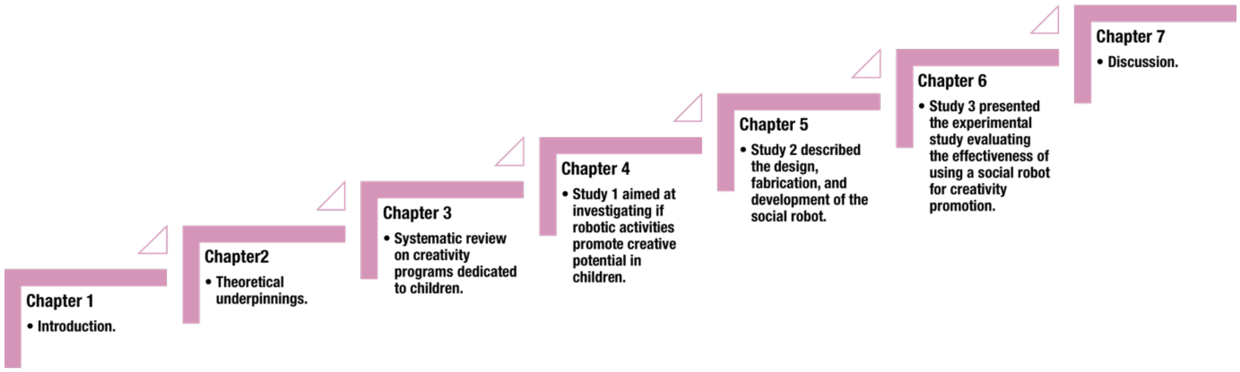

Figure 2. Roadmap for the present thesis' chapters.

interactive technology for creativity stimulation. We have chosen schools that include Science, Technology, Engineering, and Mathematics programs (STEM) and within these, we chose activities in which children either code or design a robot. This study demonstrated that activities with robots, with special emphasis on coding robots, promote the creative potential of children.

Chapter 5 includes a description of the social robot that was designed, fabricated, and developed during this PhD. This chapter presents studies with children conducted in schools and museums for children. Taking into account methods and practices from Design Research, we included children at all design stages, resulting in children having an active role in the design of the robot. Additionally, concepts from Mechanical Engineering, Computer Science, and Robotics were learned throughout this the time of this thesis to enable the development of this robot. Instead of using off-the-shelf robotic platforms, we proposed to design our robot tailored for the specific purpose of stimulating creativity in children.

Chapter 6 presents the final experimental study in which the developed social robot was tested in the context of summer camps. During this study, children interacted with the social robot by creating a story and using it as an active character. We considered different comparison

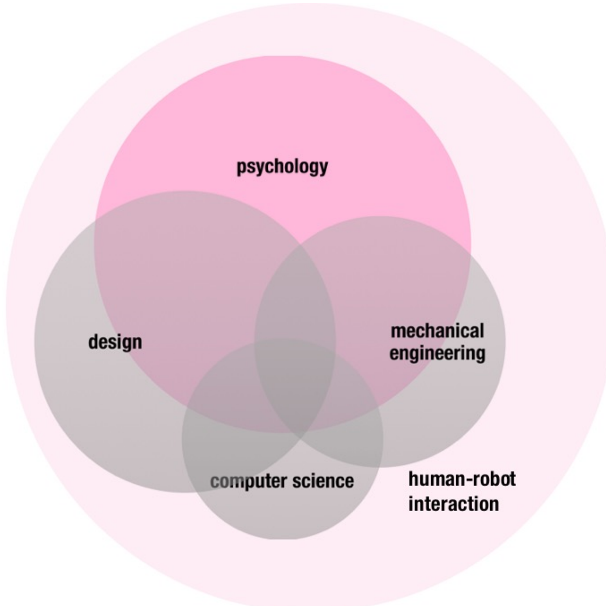

Figure 3. Research space of the current thesis.

groups that triggered different interaction dynamics between children and the robot.

Chapter 7 provides a discussion and conclusion for this thesis in which finding from the different studies are summarized and integrated in the state of the art. We conclude this thesis with a reflection for future research in child-robot interactions for creativity, combing the results from the studies with the interdisciplinary nature of this work.

Studying Social Robotics with a Psychology Lens

Nowadays, technology is everywhere. It has reached a maturity level that enables us to contact, connect, establish, and maintain relationships at a distance or even just to serve as an additional communication modality (Brey, 2018). Until a few years ago, the role of robotics has been mainly tailored to the manufacturing, corporative, or military sectors. These areas benefited from technology to provide societal advancement and economic growth (Ramesh, & Devadasan, 2007). Nowadays, technology costs have lowered and made accessible to most populations.

Additionally, the Maker Movement has made innovations within the scope of robotics and small gadgets open to everyone, especially within the field of education (Dougherty, 2012, 2013; Halverson, & Sheridan, 2014; Martin, 2015; Peppler, & Bender, 2013).

Together with the technological advances, robotics applications have been extended beyond their traditional role in manufacturing and industry, to coexist with humans in their daily life (Campa, 2016; Šabanović, 2010; Salvini, Laschi, & Dario, 2010). Social robots, or robots with the capability of perceiving and interacting with humans, have been included as part of the household (Cakmak, & Takayama, 2013), in education (Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018; Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013; Toh et al., 2016), as a social assistive technology for the elderly (Broekens, Heerink, & Rosendal, 2009; Mordoch, Osterreicher, Guse, Roger, & Thompson, 2013) and in the context of autism spectrum disorder (Diehl, Schmitt, Villano, & Crowell, 2012; Pennisi, et al., 2016), to mention a few.

A unique aspect of social robotic technology is the evocative power of social interaction that comes with a physical coexistence of robots. This qualifies robots as tools for investigation in many fields. For example, designers and artists have been interested in investigating aesthetics of robots and their application in art settings (e.g., Moura, 2007), engineers use robots as testbeds for algorithms that are envisioned to go beyond simulation and become real-world applications (e.g., Bhattacharjee, Cabrera, Caspi, Cakmak, & Srinivasa, 2019), and social scientists use robots as reliable platforms capable of replication the same movements for testing theories or exploring new research endeavors to then inform the field of psychology itself (e.g., Cangelosi, & Schlesinger, 2018). In particular, Psychology is a field of research with solid foundations that can support the advancement of the field of HRI, which is a newer field, while at the same time benefiting from it. For example, HRI heavily relies on developed questionnaires and scales from

Psychology that are adapted to fit an intervention with a robot. However, most of the time, the scales are informally adapted and lack proper validation processes. In this sense, Psychology can provide important contributes to the validation of metrics specially developed and validated for the field of HRI. Additionally, because robots are such reliable platforms, they can be used by psychologists to replicate paradigms and used widely between cultures and even between laboratories and universities.

The present thesis views robots primarily from the latter perspective. Therefore, we relied on social robots as a research tool to study novel ways to investigate human creativity. At the same time, we grounded our research in psychological theories, methods, and experimental designs. To achieve our goal, we also delved into other research fields to gain knowledge on robot design, fabrication, and programming. As a result, the contributions of this thesis extend beyond the field of Psychology and have the potential to inform the field of Design by providing information about how to design robots for creativity interventions. Additionally, this thesis can contribute to the field of HRI and Robotics by enriching the applications for which robots are being developed for. See Figure 3 for a visual representation of the research space that this thesis encompassed.

Chapter 2. Theoretical Underpinnings

This chapter was based on the following papers:

*Baraka, K., *Alves-Oliveira, P., & Ribeiro, T. (2020). An extended framework for characterizing social robots. *arXiv preprint arXiv:1907.09873*. (Chapter submitted and accepted to the Evaluation Methods Standardization in Human-Robot Interaction Book, Springer. *In press*).

Giger, J. C., Piçarra, N., Alves-Oliveira, P., Oliveira, R., & Arriaga, P. (2019). Humanization of robots: Is it really such a good idea? *Human Behavior and Emerging Technologies*, *1*(2), 111-123.

Paiva, A., Mascarenhas, S., Petisca, S., Correia, F., & Alves-Oliveira, P. (2018). Towards more humane machines: Creating emotional social robots. In *New interdisciplinary landscapes in morality and emotion* (pp. 125-139). Routledge.

*Both authors contributed equally to the paper.

Abstract

We provide a broad-ranging overview of the main relevant topics of this work. Firstly, we detail on aspects related to the field of Human-Robot Interaction and characterize several relevant dimensions that are important when discussing social robots. The dimensions we discussed are: social robots' appearance, social capabilities, purpose and application area, relational role between humans and robots, and the difference between autonomy and intelligence. Secondly, we detail the design space of technologies that are developed to impact human creativity. Specifically, we provide an overview of user-centered design practices, including participatory design with children, and present research efforts on the design of social robots aimed at promoting human creativity. Thirdly, we provide a theoretical overview of the field of creativity research, as creativity is the core concept of this thesis. Specifically, we discuss several existing definitions for the term "creativity" and elaborate on how creativity is framed within this thesis. In addition, we provide an overview of how creativity skills change according to human developmental stages. Finally, we elaborate on the different measures and methods to assess, quantify, and analyze creativity. This Chapter is meant to serve as a resource for researchers, designers, and developers within and outside the field of social robotics and creativity. It is intended to provide them with the knowledge to better understand and position existing social robots and their role in human creativity stimulation.

Keywords: Social robots, design, creativity

Social Humans and Social Robots

Humans are inherently social beings, spending a great deal of their time establishing a diverse range of social connections. Their social nature is not only demonstrated by their social behavior (Homans, 1974), but also possesses a biological basis (Frith, & Frith, 2010). This social dimension prompts human beings to involuntarily ascribe social qualities even to non-human media, such as technological artifacts, often treating them similarly to how they would treat humans or other living beings (Nass, Steuer, & Tauber, 1994). This disposition stems from the general human tendency of ascribing human-like qualities to non-human entities, called “anthropomorphism”, which has been observed and demonstrated in several contexts (Epley, Waytz, & Cacioppo, 2007). These phenomena, therefore, place technologies capable of social interactions with humans as unique technological innovations. In particular, *social robots*, i.e., robots deliberately designed to interact with humans socially, open up a new paradigm for humans to communicate, interact, and relate to robotic technologies.

The integration of a social dimension in the design of robots has generally been following two approaches. First, existing robotic technologies are being enhanced with social capabilities for more fluid interactions with humans. Second, social robots are being developed for new application areas where the social dimension is central, and beyond a mere interface. Social robots offer a spectrum of interactions that is being continuously enriched by researchers from a variety of disciplines. The field of HRI, as an expanding field of research, reflects this observation.

HRI is a multidisciplinary field bringing together researchers from an eclectic set of disciplines, including robotics, computer science, engineering, artificial intelligence, machine learning, human-computer interaction, design, art, animation, cognitive science, psychology,

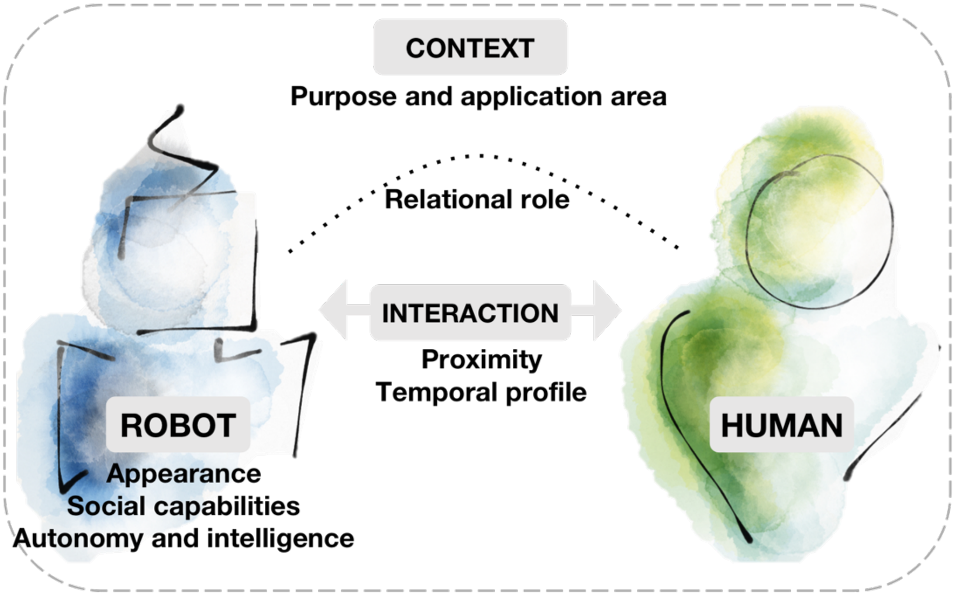

Figure 4. Visual summary of the seven dimensions of the Extended Classification Framework, positioned in relation to the robot, the interaction, the context, and the human that are present during a human-robot social interaction (Baraka, Alves-Oliveira, & Ribeiro, 2020).

sociology, ethology, and anthropology (Alves-Oliveira, Küster, Kappas, & Paiva, 2016; Baxter, Kennedy, Senft, Lemaignan, & Belpaeme, 2016; Eyssel, 2017; Fong, Nourbakhsh, & Dautenhahn, 2003; Irfan et al., 2018; Murphy, Nomura, Billard, & Burke, 2010). The multidisciplinary inherent to this field of research provides contributions and advancements nurtured by scholars from different backgrounds in the conception, design, and implementation of social robots. In addition to development, HRI aims to evaluate how well such robots perform or serve the purpose they were designed for, being concerned with proper evaluation, testing, and refinement of these technologies. The result is a rich multidisciplinary effort to create engaging robots that can sustain personalized interactions with humans, adapt to the task at hand and the interaction flow, but also understand and model aspects about humans, such as affect and cognition (Ho, Dautenhahn, Lim, & Du Casse, 2010; Leite, Martinho, & Paiva, 2013).

The Extended Classification Framework proposed by Baraka, Alves-Oliveira, and Ribeiro (2020) provides a holistic understanding about the state of the art in HRI, while aiming at unifying, clarifying, and extending key concepts to be considered in the design of social robots. Specifically, this framework comprises several dimensions identified to be of major relevance to the design of social robots. Some of these dimensions relate to the robot itself, namely appearance, social capabilities, and autonomy/intelligence, others relate to the interaction, namely proximity and temporal profile, and the remaining ones relate to the context, namely robot's relational role and purpose/application area (see Figure 4). In the context of this thesis, we focused our work mainly in the appearance of the robot as it was designed and fabricated by us, instead of using off-the-shelf robotic planforms. We also dedicated attention to its social capabilities, as we have programmed the robot according to the creativity techniques and social behaviors desired for its application context of creativity stimulation. Additionally, our robot acted autonomously and was not remotely controlled, and its purpose/application area was well-established from the beginning of this research, which concerned primarily concerned using it as a tool for creativity research training.

Social Robot Appearance

The mere physical presence of robots in a shared time and space with humans sparks crucial aspects of a social interaction. Indeed, *embodiment*, a term used to refer to the idea that "intelligence cannot merely exist in the form of an abstract algorithm but requires a physical instantiation, a body" (Pfeifer, & Scheier, 2001) plays an important role in the perception and experience of interacting with intelligent technology. Indeed, literature supports that physical embodiment influences the interaction between humans and robots (Fasola, & Mataric, 2011; Kennedy, Baxter, & Belpaeme, 2015; Lee, Jung, Kim, & Kim, 2006; Li, 2015; Mumm, & Mutlu, 2011; Powers, Kiesler, Fussell, & Torrey, 2007; Wainer, Feil-Seifer, Shell, & Mataric, 2007). In particular, the physical appearance of a robot per se, was shown to have a strong influence on people regarding aspects like perception, expectations, trust, engagement, motivation and usability (Jordan, 1998; DiSalvo, & Gemperle, 2003; Breazeal, 2004).

Several taxonomies were developed to create representative classifications for a robot's appearance. To cite a few, Shibata (2004) classified robots as being human type, familiar animal type, unfamiliar animal type, or imaginary animals / new character type. Additionally, Fong, Nourbakhsh, and Dautenhahn (2003) considered anthropomorphic, zoomorphic, caricatured, and functional categories. The amount of classifications presented in the literature urges for a unified and broad classification for social robot appearances. Building upon the existing classifications, this Extended Classification Framework introduces a broad classification that encompasses main categories described by other authors, as well as new categories and subcategories. This Framework targets only and exclusively a robot's physical appearance, as distinct from any type of robot behavior, i.e., "robot at rest".

The robot developed in the scope of this PhD was included in the Taxonomy of Baraka, Alves-Oliveira, and Ribeiro (2020), as an imaginary artifact-shaped robot (see Figure 5). The robot developed for this thesis is the one on the right side of the "imaginary" ellipse). According to Baraka, Alves-Oliveira, and Ribeiro (2020), the category of artifact-inspired robots bears robots whose appearance comes from human creations or inventions. They may be inspired by objects, such as furniture and everyday objects. They may also be inspired by an existing apparatus, demonstrating how existing apparatuses can become robotic systems while maintaining the same appearance, such as self-driving cars[2], but also everyday apparatuses like a

[2] Google self-driving car: https://waymo.com/

toaster, washing machine, etc. Additionally, artifact-shaped robots may be imaginary, i.e., translating the invention of the designer, such as the Greeting Machine (Anderson-Bashan et al., 2018).

Social Robot Capabilities

Social robots vary greatly in their social capabilities, i.e., how they can engage in and maintain social interactions of varying complexities. As such, researchers have classified and defined them according to those social capabilities. Based on the work of Fong, Nourbakhsh, and Dautenhahn (2003), the different components of a social robot's capabilities are as follows:

- **Communicating using natural language or non-verbal modalities -** Examples of these ways of communication include natural speech (Williams, Thames, Novakoff, & Scheutz, 2018), motion (Dragan, Lee, & Srinivasa, 2013; Knight, 2011), possibly including gaze (Admoni, & Scassellati, 2017), gestures or facial expressions, lights (Baraka, & Veloso, 2018; Szafir, Mutlu, & Fong, 2015), sounds (Bethel, & Murphy, 2006), or a combination of them (Löffler, Schmidt, & Tscharn, 2018). Mavridis (2015) provided a review on verbal and non-verbal interactive communication between humans and robots, defining different types of existing communications such as interaction grounding, affective communications, speech for purpose and planning, among others.
- **Expressing affect and/or perceiving human emotions -** Beyond Ekamn's five basic emotions (Ekman, 1992) - anger, disgust, fear, happiness, sadness, and surprise -, this may include more complex affective responses such as empathy. For example, Paiva,

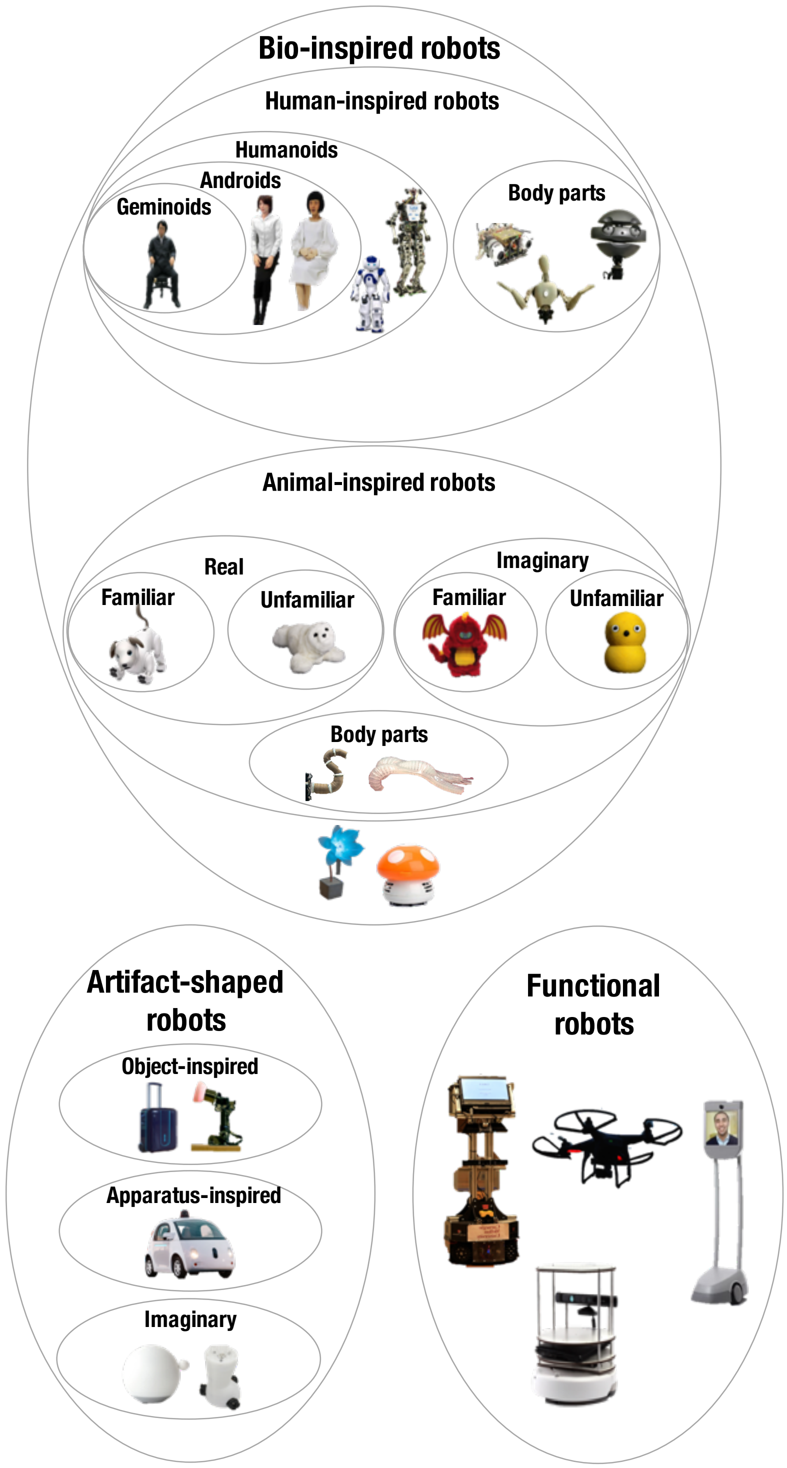

Figure 5. Summary of robot's appearance classification. This classification was based on prior work from Fong, Nourbakhsh, and Dautenhahn (2003) and Shibata (2004), and was unified, extended, elaborated, and clarified in the context of the Extended Framework by Baraka, Alves-Oliveira, and Ribeiro (2020).

Leite, Boukricha, and Wachsmuth (2017) analyzed different ways by which robots and other artificial agents can simulate and trigger empathy in their interactions with humans.

- **Exhibiting distinctive personality and character traits -** The major components to be considered, according to Robert (2018), are human personality when interacting with a robot, robot personality when interacting with humans, dissimilarities or complementary in human-robot personalities, and aspects that facilitate robot personality. Some companies such as Misty Robotics[3] are prioritizing the user personalization of a robot's personality as an important feature for future commercial social robots.
- **Modeling and recognizing social aspects of humans -** Modeling human agents allows for robots to interpret aspects of human behavior or communication and appropriately respond to them. Rossi, Ferland, and Tapus, (2017) provide a survey of sample works aimed at profiling users according to different types of features. More advanced models may have to consider theory of mind approaches (Scassellati, 2002).
- **Learning and developing new social skills and competencies -** In addition to being programmed to have social skills, social robots may have the ability to refine those skills with time through adaptation, or even developing new skills altogether. An active area of research that looks at such paradigms is the area of developmental robotics (Lungarella, & Metta, 2003).
- **Establishing and maintaining social relationships -** Relationships operate over a timespan that goes beyond a few interactions. A number of questions arise when one considers long-term interactions of robots with humans and what it means for a robot to proactively establish and maintain a relationship that is two-sided. Leite, Martinho, and

[3] Misty Robotics website: https://www.mistyrobotics.com/

Paiva (2013) established some initial guidelines for the design of social robots for long-term interaction. These include continuity and incremental robot behaviors (e.g., recalling previous activities and self-disclosure), affective interactions and empathy (e.g., displaying contextualized affective reactions), and memory and adaptation (e.g., identifying new and repeated users).

In the case of the robot developed during this PhD, it uses non-verbal communication modalities of lights with different colors and movements at different speeds to communicate with children. The robot can model the play patterns of children thus adapting the interaction and behaviors o different play moments.

Purpose and Application Area of Social Robots

Usually, the physical characteristics of a technological device (e.g., toaster, microwave, typewriter, manufacturing machine) tend to be strongly coupled with its purpose, i.e., the task it was designed to achieve. With the advent of personal computers and smartphones, we moved away from defining those devices solely by their purpose. For instance, it would be inappropriate to call a modern computer an "electronic typewriter" or even a smartphone an "electronic phone", because those devices can serve an immense variety of uses, thanks to software applications that constantly create new purposes for them. Similarly, even though some robots may currently be designed for a specific purpose in mind, some robots may possess a set of skills that can prove useful in a variety of scenarios, sometimes across completely different application areas. As a result, (1) many different robots can be programmed to be used for the same purpose, but also (2) a single robot can be used for many different purposes. For example, a robot such as NAO[4] has been used across a large variety of purposes, both in research and industry, from

[4]NAO robot from SoftBank Robotics: https://www.softbankrobotics.com/emea/en/nao

playing soccer (Graf, Härtl, Röfer, & Laue, 2009) to assisting individuals with cognitive impairments (Shamsuddin et al., 2012) or teaching children (Alves-Oliveira, Sequeira, Melo, Castellano, & Paiva, 2019).

According to Baraka, Alves-Oliveira, and Ribeiro (2020), the main application areas for social robots are healthcare and therapy; industry; education, entertainment and the arts; home and workplace; search and rescue; public service; and social sciences. In the scope of this PhD thesis, we used a social robot for two main application areas: education and social sciences.

Robots in education are mainly used with children because they can increase engagement in learning while favoring an interactive and playful component, which may be lacking in a traditional classroom setting (Kanda, Sato, Saiwaki, & Ishiguro, 2007; Tanaka, Cicourel, & Movellan, 2007). There is a number of formats that educational scenarios can take, where the robot has a different role. Beyond being a teacher delivering material, the robot can also act as a social mediator between children, encouraging dyadic, triadic, and group interactions (Kozima, Michalowski, & Nakagawa, 2009). Moreover, the robot may play the role of a learner in learning-by-teaching scenarios, in which the child teaches the robot and, in this process, develops their own skills (Jacq, Lemaignan, Garcia, Dillenbourg, & Paiva, 2016). In the case of our work, our robot acts as a toy for children and can be used in schools, summer camps, and children's playgrounds. Therefore, despite not having the purpose of directly impacting learning content and generating learning gains in children, the robot has the purpose of empowering creative abilities that are beneficial to other contexts of learning as a transferable skill.

In our work, we also used the *robot for social sciences*. Due to the possibility of programming robots to exhibit mechanisms of cognition similar to those of humans, a less-publicized purpose of robots is in fields of the social sciences for the study of social development, social interaction, emotion, attachment, and personality (Fong, Nourbakhsh, & Dautenhahn, 2003). The idea is to use robots as test subjects in controlled laboratory experiments, leveraging the fact that such robots can reproduce consistent behaviors repeatedly and can be controlled to test predictions of human models of cognition. For example, the Cog robot (Scassellati, 2003) was used to investigate models of human social cognition. Similarly, a doll-like robot, Robota (Billard, Robins, Nadel, & Dautenhahn, 2007) was used in comparative studies for social development theories (Dautenhahn, & Billard, 1999). Additionally, robots (human-inspired or other types) can be used as stimuli to elicit behaviors from humans for the development and refinement of theories about human behavior and cognition. For a more detailed discussion on cognitive robotics and its applications outside of technology-related fields, consult Lungarella, Metta, Pfeifer, and Sandini, (2003). Our robot was used mainly as a tool in psychology research. By being programmed with the same creative technique, the interactions with children across the different groups varied according to code programmed in the robot, thus making it a perfect platform for the social sciences. Additionally, we have released the hardware (Alves-Oliveira, Arriaga, Paiva, & Hoffman, 2019) and software (Alves-Oliveira, et al., 2020) of this robot in open-access publications, making it an accessible tool in research.

Relational Role Between Humans and Robots

One of the relevant dimensions that shape human-robot interaction is the role that the robot is designed to fulfill. The concept of role is an abstract one, for which various different perspectives can be presented. We specifically looked at the relational role of the robot towards the human. This is the role that a robot is designed to fulfill within an interaction, and is not necessarily tied to an application area. The relational role the robot has been designed to have is critical to the perception, or even the relationship, that arises between robot and human.

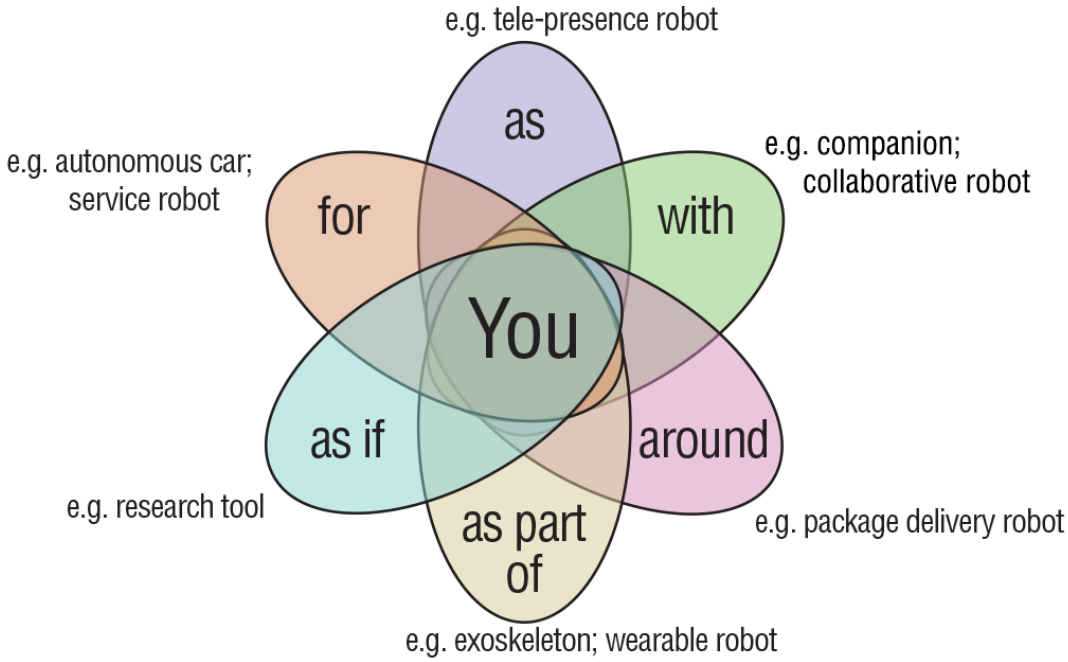

Figure 6. Classification of relational roles of robots towards humans (represented as the "you") by Baraka, Alves-Oliveira, and Ribeiro (2020).

Towards clarifying the concept of relational role, it is important to distinguish relational role from role in an activity or application. In a specific activity or application, we may expect to find activity-specific roles (as in role-playing), such as teacher, driver, game companion, cook, or therapist. These types of roles are defined by the type of activity performed between the robot and humans, therefore making it an open-ended list that is likely to stay in constant evolution, as robots become applied to new fields and tasks. Given the fuzziness of this concept in the HRI field, there have not been many attempts at generalizing the concept of role of robots within and in relation to humans. Therefore, Baraka, Alves-Oliveira, and Ribeiro (2020) attempted to gather previous literature on robot roles towards humans (Breazeal, 2004b; Goodrich, & Schultz, 2008; Norman, 1986; Scholtz, 2003) and provided a visual classification for these roles (see Figure 6). This classification system does not necessarily add or propose new roles, but instead, redefined them from a relational perspective, placing emphasis on how the robot relates from a human's perspective. As such, Baraka, Alves-Oliveira, and Ribeiro (2020) considered the following roles that a robot may have towards you (the human):

- A robot **"for you"** serves some utility on a given task. This is the most traditional role of a tool or a servant and is inspired by most previous classifications (e.g., Dautenhahn, 2005). Despite closely related to the concept of a tool, this role is framed as a broader type of robotic tool, which can even include robots like autonomous cars.
- A robot **"as you"** plays the role of a proxy, namely, but not limited to, telepresence. However, it does not necessarily imply interaction from far away as in Breazeal's (2004b) classification. This type of role can exist even when inter-actors are co-located, as long as the robot is acting in place of another person who operates it (e.g., shared autonomy scenarios).
- A robot **"with you"** is typically collaborative, with various levels of autonomy, including being part of a group with you. It is used in applications in which both the human and the robot act together, as a team, or towards common goals, and also includes robots for companionship. The robot and the human are not necessarily co-located, such as for example human-robot teams that have to communicate remotely.
- A robot **"as if you"** emulates particular social or psychological traits found in humans. These robots are mainly used as social sciences research tools in which, e.g., a human can control remotely control a robot without the participant being aware to investigate the effects of interacting with robots. This method is called the Wizard-of-Oz (WoZ) and is commonly used for research contexts in which the development of an autonomous version of the interaction is still not attainable or requires too much time to develop considering the research timeline (Steinfeld, Jenkins, & Scassellati, 2009; Riek, 2012).

To date, robots have been used to examine, validate and refine theories of social and biological development, psychology, neurobiology, emotional and non-verbal communication, and social interaction.

- A robot **“around you”**, shares a physical space and common resources with the human. It differs from a “robot with you” by the fact that it is necessarily co-located with the human, but not necessarily collaborating with them. These are typically called co-operating, co-present, or bystanders, as previously proposed in Scholzt’s (2003) classification.
- A robot **“as part of you”** extends the human body’s capabilities. These robots typically have nonexistent or very limited autonomy but provide humans with physical capabilities that they could not otherwise perform using their own biological bodies. Such robots can be used for pure embodiment extension (e.g., strength-enhancing exoskeletons), or for close-range HRI collaboration, such as the robotic wearable forearm (Vatsal, & Hoffman, 2018) whose function is to serve as a supernumerary third arm for shared workspace activities.

The list of relational roles presented defines non-exclusive roles, meaning that for some particular applications, we may design and develop robots that take more than one of these roles, or take a different role when more than one human is involved in the interaction. An example would be of a robot used in an office, which can be used “for the users” to deliver mail and packages to different locations, while at the same time acting “around the users” when navigating the office space. In the context of this thesis, the proposed robot was under two different roles taking into account the viewpoint of the researchers (i.e., us) and of the children (i.e., as study participants). Therefore, the robot was designed “for you” as it acted as a tool “for the research" to use with the specific purpose of a creativity intervention context. At the same time, the robot was designed "with you" as the nature of the task between children and the robot consists of a collaborative storytelling activity. In this sense, the robot and the children participant collaborate on the creation of a story.

Robot Autonomy and Intelligence

The concepts of autonomy and intelligence are hard to define, and there does not seem to be unique accepted definitions (Beer, Fisk, & Rogers, 2014). In particular, existing definitions in the literature seem to differ depending on the context of application, and the main field of focus of the author(s). When considering social robots, concepts of autonomy and intelligence arise and become necessary aspects to consider when characterizing the behavior of robots. Although related, these are two distinct concepts that are often inconsistently and confusingly used in existing literature (Gardner, Kornhaber, & Wake,1996; Gunderson, & Gunderson, 2004). In particular, it is often assumed that a high level of robot autonomy implies both a high level of intelligence and of complexity. In reality, some fully autonomous systems can possess very low intelligence (e.g., a traditional manufacturing machine) or complexity (e.g., a simple self-operated mechanism). A better clarification of the concepts of autonomy and intelligence, and their relation, is needed, especially in the context of social robotics.

It may seem somewhat paradoxical to talk about autonomy in the context of interactive robots, because traditionally fully autonomous robots are involved in minimal interactions with humans; in other words, reduced interaction with humans is a by-product of increased robot autonomy. For social robots however, this relation between the amount of human interaction and robot autonomy is questioned. Highly autonomous social robots are expected to carry out more fluid, natural, and complex interactions, which does not make them any less autonomous. There exists a very large number of definitions of autonomy for general agents, however central to most existing definitions is the amount of control the robot has over performing the task(s) it was designed to fulfill (or that it sets to itself), as emphasized by Beer, Fisk, and Rogers, (2014). For social robots, tasks may include well-defined goal states (e.g., assembling furniture) or more elusive ones (e.g., engaging in conversation).

The concept of autonomy should also account for learning (Baraka, Alves-Oliveira, and Ribeiro, 2020. Indeed, many learning paradigms include human-in-the-loop approaches, such as active learning (Chao, Cakmak, & Thomaz, 2010) learning by demonstration (Rybski, Yoon, Stolarz, & Veloso, 2007), and corrective human feedback learning (Meriçli, Veloso, & Akın, 2011), used within the context of interactions in applications involving human teachers such as learning-by-teaching educational scenarios (Jacq, Lemaignan, Garcia, Dillenbourg, & Paiva, 2016) or general collaborative scenarios (Breazeal, Hoffman, & Lockerd, 2004).

As a result, Baraka, Alves-Oliveira, and Ribeiro (2020) extended the definition from Beer, Fisk, and Rogers, (2014) to make it applicable to social robots, and defined autonomy of a social robot as *"The extent to which a robot can operate in the tasks it was designed for (or that it creates for itself) without external intervention."* The same authors extended the definition proposed initially by Gunderson, & Gunderson (2004) to be applicable to social robots and defined intelligence as *"The ability to determine behavior that will maximize the likelihood of goal satisfaction under dynamic and uncertain conditions, linked to the environment and the interaction with other (possibly human) agents."*

Additionally, the design of social robots is that a robot's *perceived* intelligence (Bartneck, Kulić, Croft, & Zoghbi, 2009) can be drastically different from its actual intelligence, which leads us to ways of measuring autonomy and intelligence. Both autonomy and intelligence can be seen as belonging to a continuum, taking into account aspects of robot perception, cognition, execution, and learning (Gunderson, & Gunderson, 2004; Yanco, & Drury, 2004). As a result, autonomy is a dimension that one designs for, constrained by possible achievable levels of intelligence. As a general rule, the higher the autonomy and intelligence is, the higher the complexity of the system is.

For a highly heterogeneous technology such as a social robot that involves a combination of hardware, software architecture, cognition mechanisms, intelligent hardware control, just to name a few, it is important to define dimensions about aspects such as autonomy and intelligence. The overall assessment of these aspects would then depend on a combination of assessments over individual dimensions. Researchers at IBM have proposed to define "dimensions of (general artificial) intelligence", as a way to define an updated version of the Turing test (Turing, 2009). Their list is more task-oriented but can serve as a basis to think about general dimensions for both intelligence and autonomy. Based on Baraka, Alves-Oliveira, and Ribeiro (20202) work, the following dimensions of intelligence and autonomy are defined: perception of environment-related and human-related factors, modeling of environment and human(s), planning actions to interact with environment and human(s), executing plans under physical and social constraints, and learning through interaction with the environment or humans.

The dimensions above span most existing building blocks for the intelligence of a social robot. However, depending on their implementation and complexity, some robots may not include one or more of the above dimensions. Those dimensions are generally separated in the design and implementation of most robots, hence as a result, intelligence and autonomy on each dimension may be completely different. As technology advances, higher amounts of robot intelligence will be achievable, unlocking new possible levels of autonomy for more complex tasks; however, the amount of autonomy of a system (within possible technological limits) will remain a design choice.

Our robot was designed considering the dimension of planning actions to interact with environment and humans in terms of its intelligence/autonomy as within this dimension the decision-making of a robot is reduced to creating plans for robot actions that take into account the shape of the task, the goal, and the current state of the world, including the robot, the environment, and the human(s). Indeed, our robot collected only patterns from the play motions of children to plan its next behavior. No personal data from the children themselves (e.g., facial expressions) is collected. This was a deliberate design decision to protect children's privacy.

Social Robot Design Space

The actual design process of social robots, which includes a robot's physical shape and its behavior, has benefited from several design approaches inspired by design practices from a variety of fields such as engineering, computer science, Human-Computer Interaction (HCI), design research, and human factors. For example, design patterns can be reused without having to start from scratch every time a robot is designed (Kahn et al., 2008). There generally exist three broad design approaches, each of which may be valid depending on the intended context and objectives. For this thesis, we will be focusing on user-centered design approaches with special emphasis on participatory design.

User-centered design. UCD's central paradigms concerns the involvement of the intended user population as part of most development stages, including identifying needs and requirements, brainstorming, conceptualizing, creating solutions, testing, and refining prototypes through an iterative design process (Abras, Maloney-Krichmar, & Preece, 2004; Norman, 2013).

In the HRI context, the main assumption is that humans have their own communication mechanisms and unconsciously expect robots to follow human social communication modalities, rules, conventions and protocols. From an evaluation point of view, UCD relies strongly on subjective self-reports of users to measure their perceptions and complement more objective measures such as task performance. Additionally, UCD grounds most of the intermediate design evaluations on Formative research, a research methodology that is used to guides an entire design process and has the benefit of allowing for ongoing intermediate assessments to improve current systems (Van den Akker, 1999; Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006).

By including users in the design process, UCD reflects a methodology that supports designers to be sensitive to their unexamined biases, directly within the technology design processes. Examples of these methodologies are *reflective design* in which the reflection on unconscious values is the core principle of technology design (Sengers, Boehner, David, & Kaye, 2005), *value-sensitive design* in which the design of any technological artifact accounts for human values in a principled and comprehensive way (Friedman, 1996; Friedman, & Hendry, 2019), *participatory design* in which stakeholders of the technology are actively involved in the design process to help ensure the result meets their needs and that the technology is usable and will be accepted (Björgvinsson, & Hillgren, 2010; Nesset, & Large, 2004). These critical design approaches explore technology designs as a way to engender positive social changes for various issues and its core idea is to empower users by giving them a voice in the design of products that are meant to be used by them. In our work, we used a participatory design approach with

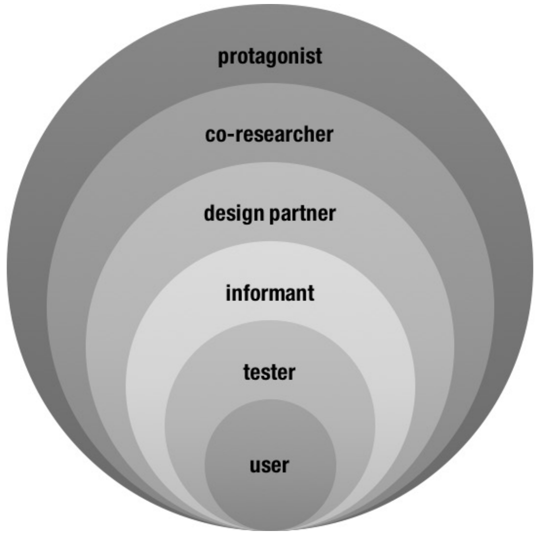

Figure 7. The six roles that children might have in the design of new technologies according to Druin (2002), Van Doorn (2016), and Iversen, Smith, and Dindler (2017).

children as a way to include them at the core of the design process of the robot's appearance and behaviors.

Participatory design with children. Children can acquire different roles when included in participatory design research (Landoni, Rubegni, Nicol, & Read, 2016). Druin (2002) was the first author to define the different roles that children can have when they are included in the design of technologies, postulating that children can act as *users*, *testers*, *informants*, and *design partners*. Later on, Van Doorn (2016) added the role of children as *co-researchers*, and Iversen, Smith, and Dindler (2017) extended this classification to add children as *protagonists*. We further describe these roles below and visually represented them in Figure 7.

- **Children as users -** With this role, children use technology and researchers conduct behavioral observation about this usage. At this stage, the technology is not being developed and changed anymore; instead, it has already been developed and it is being distributed for commercial or research purposes. The methods used are mostly observational (using video recordings or in situ) or testing children before/after using the technology (e.g., by using child-friendly toolkits (Read, 2008)). If in higher developmental stages, children's impressions can also be collected via interviews and qualitative surveys.

- **Children as testers -** With this role, prototypes of future technological artifacts are tested with children before any commercial release. The intention is to collect information about the usability, utility, and experiential qualities of the proposed technology. The methods used are based on observation and directed interaction (Van Kesteren, Bekker, Vermeeren, & Lloyd, 2003). When acting as testers, children help to shape the technology, however, have no involvement during the design stages;
- **Children as informants -** With this role, children play a part in the design process before the process starts. Researchers gain insights to inform the design at various stages of the design process by eliciting and including children's expert knowledge. Direct observation, sketching, and story- or comic-boarding are used to elicit graphic visualizations to illustrate an interaction scenario (Hart, 2008). Children can be invited to draw or have an adult drawing their ideas for them (Moraveji, Li, Ding, O'Kelley, & Woolf, 2007);
- **Children as partners -** With this role, children are equal stakeholders during the design process. Cooperative inquiry (Abbas, Tootell, Freeman, & Ellmers, 2018) co-design (Melonio & Gennari, 2012), and other methods, are used during workshop activities and design sessions. As design partners, children have an enormous impact on the design and development of technologies. It is through the empowerment of children by giving them a voice in design that meaningful technologies are developed;

- **Children as co-researchers –** With this role, children share, gather, and analyze data from their practice during technology usage. Together, researchers and children gain contextual knowledge by jointly studying children's practices. This process can become detached from design work, since the emphasis here is on knowledge production over design information. Methods involved are interviews (Poole & Lamb, 1998) and thinking aloud techniques (Als, Jensen, & Skov, 2005; Donker, & Reitsma, 2004);
- **Children as protagonists –** With this role, children carry out a complete design process in which process and product reflection is a central component. The goal is to encourage children to be the main agents in leading the design process and thereby to develop skills to design and reflect on technology and its role in their life. The stances that children develop during the design process are reflective of their options towards technology in their lives, also reflecting political environments of development. Methods used vary from prototyping (Walsh et al., 2020), to ideation and field studies (Iversen, Smith, & Dindler, 2017).

In our work, children were involved under different roles when designing the robot for creativity, depending on the design stage. Children took the role of design *partners* in the early stages of the robot conception and design, as *informants* and *testers* during design improvements, and as *users* when acting as participants in the validation study of the creativity intervention. These roles and their relation to the design of the robot are further detailed in Chapter 4. We would like to note that the sample pool of children involved in the different design stages under different roles is unrelated.

The Role of Technology in Promoting Human Creativity

Technology appears as promising in the field of creativity (Frich, MacDonald Vermeulen, Remy, Biskjaer, & Dalsgaard, 2019). Lubart (2005), envisions computers promoting creativity in different ways and has defined fours possible future roles for computers in the field of creativity, described below:

- **Computer as nanny** - Computers encourage creativity by monitoring the working process and supporting the potentially creative person according to the progress made.
- ***Computer as pen-pal*** - Computers facilitate the exchange of creative ideas between diverse people by integrating and represent them in a physical space.
- **Computer as coach** - Computers can support the creative process by providing information in different ways to foster idea generation, serving as analogs to jump-start the creative process.
- **Computer as colleague** - Computers work in a real partnership in the creative process with humans, being this the most ambitious vision for human-computer interaction.

Although the aforementioned taxonomy was created considering computers, we found it extremely useful to frame the scope of our creativity intervention in which the robot created was used as a *coach* since it was used as a character for the story that actively provides triggers for new storylines through the interaction with children.

Creativity-Flavored Technologies

We now present a brief review of previous work on how technology has been used in the context of creativity. Generally, we found there are two main areas related to technology and creativity. The first idea concerns the development of technologies that mimic or emulate human creativity and that can be considered creative on their own. We named this approach as *technologies with creativity*. The second idea concerns the development of technologies, including robots, to serve as tools to stimulate creativity in humans, without necessarily being creative. We named this approach as *technologies for creativity*. We revise both approaches below to situate our work.

Technologies with creativity. These types of technologies are expected to engage in creative processes. For example, Simon Colton's software, called The Painting Fool, creates paintings by extracting regions of color in images, abstracting these regions and then altering them, changing their color, painting style and type of fill. Adding to this process, the software uses imaginative behavior, including the creation of objects and elements (Colton, 2012) and picks the rendering of the painting style autonomously, having created paintings with styles difficult for people to achieve, thus strengthening The Painting Fool mark in this artistic medium (Colton et al., 2015). Furthermore, Google created a computer vision program called DeepDream which uses a convolution neural network to find and enhance patterns in images, thus creating a dream-like hallucinogenic appearance in the deliberately over-processed images (Mordvintsev, Olah, & Tyka, 2015a,b). Additionally, algorithms have been designed for the automatic generation of poetry based on different approaches, such as generative, evolutionary, and case-based reasoning (Oliveira, 2009). Specifically, poetry-making tools were created for several languages, such as PoeTryMe for Portuguese (Oliveira & Cardoso, 2015), ASPERA for Spanish, (Gervás, 2011), and I, Poet for Chinese (Yan, 2016). Furthermore, an online platform for anyone that wants to test computational poetry can perform a Turing test on the poems by trying to guess whether the poem was written by a human or an algorithm[5]. Another application of technologies with creativity includes an algorithm responsible for writing the screenplay for the short sci-fi

[5] "Bot or not", a n online platform for taking Turing tests of poems: http://botpoet.com/

film “Sunspring”. In this case, the algorithm acted as the film Writer[6]. In the field of music, artists such as Brian Eno, an expert in ambient music, created the album “Reflections” that uses generative algorithms to create songs. Therefore, when playing the album using a dedicated app, the songs suffer changes in their melodies according to the time of the day resulting in an album that never repeats entirely its content[7]. A last example is the “artrobots” created by the artists Leonel Moura that paint. A set of small-sized robots that have information about each other, in so called-swarm behaviors similar to the behavior of ants and bees, navigate throughout a canvas and decide which colors and what abstract patterns to use in the painting according to randomness the of positive/negative feedback (Moura, 2007, 2018).

Technologies with creativity. These types of technologies are expected to act as tools to stimulate human creativity. These types of technologies include both virtual and physical agents. In a virtual context, an agent named Sam was developed to collaboratively support children in storytelling (Ryokai, Vaucelle, & Cassell, 2003). This peer-like agent adapted to the children’s cognitive skills for storytelling, enabling them to externalize and explain their thought process to improve their communication and literacy skills. Other virtual tools, such as Scratch, a programming language for children (Honey & Kanter, 2013; Resnick et al., 2009; Resnick & Robinson, 2017) and coding music for adults have been used to support and enhance their creative abilities (Brown & Sorensen, 2009; Collins, McLean, Rohrhuber, & Ward, 2003; Magnusson, 2011). In the domain of game design, 3Buddy is a tool that was designed for junior level designers to explore the possible creative design space of a level (Lucas & Martinho, 2017). A mixed virtual-and-reality application platform that uses an interactive character whose embodiment transitions from an animated character on-screen to a small mobile robot, enables

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[6] “Sunspring” film starring Thomas Middleditch: https://www.youtube.com/watch?v=LY7x2Ihqjmc
[7] “Reflections”, by Brian Eno: http://www.brian-eno.net/

children to engage storytelling, providing opportunities for deeper immersion as they become co-protagonists of the story (Robert & Breazeal, 2012).

Towards physical contexts, robots have also been used to stimulate creativity in humans. A social robot acted as a collaborator in a task where participants had to generate creative ideas for a Zen Rock Garden. The results from this study showed that participants engaged in the creativity task for longer periods and provided almost twice the number of creative expressions in the robot condition compared to the PowerPoint condition (Kahn Jr et al., 2016). While this task was performed with an adult population, additional some studies were conducted with children. Therefore, a study suggested that curiosity, an important creative trait, can be stimulated when children interact with a curious robot, compared to the interaction with a non-curious robot and a tablet (Gordon, Breazeal, & Engel, 2015). Additionally, a study investigated if a robot with a growing mindset, a variable that comprises aspects that relate with creativity such as preserverance and grit, estimulates creativity in children. Results have shown that interacting with a peer-like robot that displayed a growing mindset, in comparison with a robot that displayed a neutral mindset, promoted the same growing mindset in children. This was illustrated by children trying harder to solve a challenging task when interacting with the robot that displayed a growing mindset (Park, Rosenberg-Kima, Rosenberg, Gordon, & Breazeal, 2017). A different study investigated if a robot that demonstrates creative behavior can help children think creatively. Results showed that when participants interacted with the creative robot, in comparison with the non creartive one, generated significantly higher number of ideas (Ali, Moroso, & Breazeal, 2019).

While several technologies have been developed to nurture and potentiate human creativity, to the best of our knowledge there is no research on the usage of robots as catalysts of human creativity whose design of the interactive behavior was grounded on psychological theories. For this reason, we now revise literature on creativity, including its definitions, development, and measurement types.

Creativity Definition, Development, and Measurement

Creativity Definition(s)

Creativity is a multi-faced concept and is now a thriving field of research (Ford & Harris III, 1992; Kaufman & Sternberg, 2010; Parkhurst, 1999; Runco & Pritzker, 1999; Sawyer, 2011; Sternber, 1988, 1999; Sternberg & Kaufman, 2018a; Taylor, 1988). The definition of creativity has changed over time contributing to a field of research with a rich but sometimes problematic terminology (Sternberg, 1999).

It is important to recognize that the concept of creativity has its own history. In ancient Greece, creativity was associated with mysticism and inspiration attributed to non-rational sources, such as muses or spirits (Lubart, Mouchiroud, Tordjman, & Zenasn, 2015). As a counterpoint, Aristotle viewed creativity as an ability that finds its source inside the individual through mental associations. After the Roman Empire had collapsed and the feudal system established, discussions about creativity became an emergent part of societal and philosophical debates again. During the Renaissance the role of artists in society shifted to become a primary source of creativity. While this undoubtedly benefited society, creativity started being associated with the idea that only a few had the skill to be creative, and thus, creativity could not be learned, improved, mastered, or enjoyed by others (Albert & Runco, 1999). Nowadays, many authors agree not only that this creativity can exist in all humans, and it can be developed and enhanced (Baer, 2017; Barbot & Heuser, 2017; Beghetto & Kaufman, 2010; Cropley, 1997; Erat & Gneezy, 2016; Fink, et al., 2010; Miller, 2015; Nickerson, 1999; Soh, 2017). It is thereby imperative to encourage the growth of creativity skills from a very young age in schools (Mellou, 1996).

Researchers still have different viewpoints as to what creativity is (Kampylis & Valtanen, 2010). The absence of a common definition may be partially responsible for the proliferation of alternative theories that can sometimes hold contradictory ideas (Kozbelt, Beghetto, & Runco, 2010; Lubart, 2001). As such, over 60 definitions of the concept of creativity are present in the field of psychology alone (Mayer, 1999; Taylor, 1988). While the earliest definitions of creativity described this concept as a function of an individual ability (Guilford, 1967), recent definitions view creativity has an interaction of many factors, including the individual and environment (Plucker, Beghetto, & Dow, 2004). Taylor (1988) attempted to propose a standard definition of creativity (Runco & Laeger, 2012). In another quest to define this concept, authors have tried to define what is *not* creativity (Simonton, 2018). Table 1 summarizes selected definitions of creativity according to their theoretical model in a timescale manner.

Additionally, the terms divergent and convergent thinking have been associated with the definition of creativity (Guilford, 1968). While divergent thinking is the process by which ideation moves into new and different directions, convergent thinking is involved when ideation lean towards conventional ideas. While these definitions imply that these two forms of creative thinking are opposites, in reality they operate in a spectrum and are part of a continuum of thought processes (Eyseck, 2003). In fact, if a creative idea requires effectiveness and usefulness, it needs not only to be original (divergent thinking) but to converge in an actual form (convergent thinking). In our work, we follow this theoretical model and view creativity as a series of processes that involve both divergent and convergent ways of thinking, and that is influenced by variables related with the creative person (e.g., motivation knowledge).

Table 8. *Summary of selected definitions of creativity in timeline order. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).*

Author(s)	**Creativity definition**
Wallas (1926)	Process that encompasses four stages: preparation (investigation of the problem), incubation (time until illumination), illumination (insight about the problem) and verification (deliberate effort to validate the idea with respect to the problem).
Guilford (1967)	Embodiment of a thought in the form of an external behavior measured using fluency, flexibility, and originality.
Torrance (1988)	Series of flows, including problem identification, speculation, construction of hypothetical assumption, and the sharing of ideas with others.
Amabile (1996)	Process of idea generation or problem solving as a function of the person's expertise, creative-thinking skills, and motivation.
Sternberg and Lubart (1996)	Creative performance occurs in the interaction between intellectual abilities, knowledge, thinking styles, personality, motivation, and environment.
Boden (2004)	Psychological-creativity involves coming up with a surprising idea that is new to the person who invented; historical-creativity represents ideas that no one else has had before and that had arisen for the first time in human history.
Baer and Kaufman (2005)	Explained by the Amusement Park Theory in which creativity weaves both domain-general and domain-specific factors.
Kaufman and Beghetto (2009); Simonton (2010)	Explained by the Four C Model of Creativity: mini-c involves any learning acquisition; little-c are everyday problem solving and creative expression; Pro-C are creative ideas exhibited by professionally expert people in a professional venue; Big-C occurs when creativity is considered great in the given field.
Csikszentmihalyi (1999), Sawyer (2017)	Group emergence where flow, collaboration, and improvisation processes take place. When group synchrony is reached, it becomes difficult to discriminate the individual contribution of each person, as "the whole is greater than the individual parts'".
Cronin and Loewenstein (2018)	Process of following cues to generate insights that change our perspectives, which with craft we can use to form inventions and enlightenment.

Creativity Development

Freud (1959) was the first to propose that childhood is filled with imagination and fantasies, attributes of the creative thought, which have the potential to grow into adulthood.

Piaget (1971) viewed creativity in light of a constructionist approach in which children need to pass various developmental stages, usually in a fixed order, for creative growth (Piaget & Cook, 1952; Piaget, 1959, 1971). Aligned with Piaget's theory of development Vygotsky (1990, 2004) considered "any human act that gives rise to something new is referred to as a creative act", in which learning – including creative acts – is dependent on the interpersonal context of development (Vygotsky, 1980).

Creative growth has different peaks over a lifespan, not being a steady-state or consistently increasing (Claxton, Pannells, & Rhoads, 2005; Dacey, 1989; Feldman, 1999; Kogan, 1973; Runco & Cayirdag, 2006; Sawyer, et al., 2003; Spodek & Saracho, 2014). One of the stages concerns the "creativity crisis" that occurs at the elementary school aged-children (Kim, 2011; Raina, 1982; Runco, 1999; Torrance, 1968). The reasons for this crisis are multi-faceted. Some relate with formal education and conformity rules (e.g., children learn to raising hands before speaking, sitting in rows, and following a precise daily schedule) (Gardner & Gardner, 2008; Nash, 1974; Runco, Acar, & Cayirdag, 2017; Runco & Cayirdag, 2006; Torrance, 1968). Yet, part of this crises is maturational and concerns biological changes, as the nervous system may become increasingly sensitive to conventions at this stage, decreasing behaviors related with original thinking (Gardner, 1982; Kohlberg, 1966; Runco & Charles, 1993), accompanied by a decrease in curiosity (Axtell, 1966). Changes can be due to developmental transitions related to cognitive sophistication (Piaget, 1950; Smith & Carlsson, 1983; Vygotsky, 1987; Vygotsky, 1990) and with anxiety present in some stages of development, as well as other mental health issues (Smith & Carlsson, 1985). Economic factors, such as economic crises, are also perceived to influence the decrease in creativity levels (Gabe, Florida, & Mellander, 2012; Sawicki, 2003). But rest assured, research has shown that creativity is a skill that can be trained, nurtured, and stimulated through interventions presenting encouraging levels of effectiveness in putting creativity levels up again (Birdi, 2016; Ma, 2009; Mansfield, Busse, & Krepelka, 1978; Rose & Lin, 1984; Scott et al., 2004a).

Creativity Measurement

Creativity can be evaluated and measures according to four different categories: (a) *the creative process*, by measuring how the creative work is produced; (b) *the creative person*, by measuring the cognitive and personality characteristics of the creator; (c) *the creative product*, by measuring what makes a work great; (d) *the press or environment*, by measuring the contextual factors that facilitate or inhibit creativity expression. This framework is called the Four P's of Creativity and is essential to understand metrics in these four different creativity domains (Rhodes, 1961).

Since the beginning of research in creativity that the question of how to measure this ability has been at the forefront of research agendas. However, pitfalls made this task challenging, such as the inexistence of validated measures for creativity, or the need for adequate standards of assessment. Notwithstanding, much effort in creativity research has been dedicated to the improvement of metrics, showing a fast and reliable contribution to this topic (Barbot, & Reiter-Palmon, 2019). To ground our work on existing validated interventions for creativity, a systematic literature review was conducted as is presented in the next Chapter.

Chapter 3. A systematic review of creativity interventions for children

This chapter is based on the following paper:

Alves-Oliveira, P., Xavier, C., Arriaga, P., Hoffman, G., & Paiva, A. (second revision). Creativity Landscapes: Systematic Review Spanning 68 Years of Creativity Interventions for Children. *Journal of Creativity Research.*

Abstract

Creativity plays a central role in children's development and well-being, being considered a crucial skill to thrive in the personal and professional lives. Given its importance, researchers and educators have been highlighting the need to enhance creativity in individuals across the lifespan. However, a decline in creative skills around elementary school age has been documented. Therefore, there is a need to understand how interventions and programs can promote creativity at an early age. The goal of this systematic review is to collect, summarize, and present evidence on research about fostering and nurturing creativity in children of elementary school age (5-12 years old), by systematically reviewing publications from 1950-2018, spanning 68 years of research. We additionally contribute to a classification system for characterizing creativity research by expanding on existing literature on the topic. This review resulted in the characterization of existing trainings that stimulate creativity in children, defined according to the different levels of analysis of creativity interventions. We discuss the results taking into account possible implications for practice and policymaking in creativity research.

Keywords: Systematic review, creativity, intervention, program, children

Introduction

Creativity brings joy, wonder, excitement, efficiency, and pleasure into our lives (Baer, 2017; Kaufman, 2018a). It relates to individual well-being, self-expression, and sense of identity (Collard & Looney, 2014; Robinson, 2011). Indeed, we live in a constant drive to find new and better ideas for almost every aspect of our professional and personal circles (Amabile, 1989). The inherent curiosity (Feldman, 1999), search for newness and exploration (Urban, 1991), are constitutional to human behavior, initiating in early childhood and never really wearing off. Creativity during childhood is positively associated with adaptation, development, learning, and growth (Gardner & Gardner, 2008) and appears to be a predictor of creativity in adulthood (Ayman-Nolley, 1992; Russ, 2016). Despite its importance, a tendency for creativity levels to drop is reported to occur in the elementary school years. This phenomenon is named “creativity crisis” and is defined by a decrease or a gap in creativity levels during developmental stages, mostly affecting children in elementary school age and adolescents (Kim, 2011).

Creativity is a precious good in society (Glaveanu, 2018). Different sectors seek individuals with creative abilities, recognizing its functions in improving and healing societal problems, from the economy to personal well-being (Moran, 2010). Consequently, economies of developed societies are changing. The manufacturing and repetitive work that determined industrial markets are now being replaced by services and products whose values are related to innovation, communication, collaboration, and new inventions. This is called the creative economy era (Burnett & Haydon, 2017; Dubina, Carayannis, & Campbell, 2012; Mellander & Florida, 2013; Pink & Unwin, 2005). Much research has been dedicated to harnessing the creative potential, such as changes in curriculum content, modifications of teaching approaches, and the use of education for empowerment (Davies, 2006).

An "upgrade" was proposed to the Bloom's Taxonomy. It is a widely used taxonomy which presents a set of hierarchical models that classify educational goals for student performance evaluation (Bloom, 1956). In this upgrade, creativity was included and elevated as the most complex of the cognitive processes (Hanna, 2007). Additionally, policy makers are highlighting the importance of creativity. For example, according to the New Skills Agenda for Europe delivered by the European Commission, creativity was considered one of the Key Competences for Lifelong Learning (Cachia, Ferrari, Ala-Mutka, & Punie, 2010; European Comission, 2006). Additionally, UNESCO's Sustainable Developmental Goals highlighted the importance of creativity and innovation to empower and promote society and economy (UNESCO, 2017). Lastly, the World Economic Forum declared that by 2022 no less than 54% of all employees will require significant re- and up-skilling, with creativity in the frontline of these skills (World Economic Forum, 2018).

Theoretical Background

Given the concern about the decrease in creativity during key-developmental stages, several interventions have been developed to nurture and stimulate creativity. Scott et al. (2004a) presented a review about the effectiveness of creativity training programs, demonstrating that different types of training had value on its own but with varying levels of effectiveness. In this sense, idea production and cognitive training proved to be particularly effective compared to commonly used training strategies (e.g., imagery). Additionally, Ma (2009) conducted a meta-analysis to identify the most relevant variables associated with the creative person, the creative process, the creative product, and the environment. However, both reviews were general and not focusing on children, which limits the understanding of the type of interventions for creativity targeting children and the identification of the most successful programs/interventions. For children, in particular, we highlight the systematic review conducted by Davies et al. (2013), which was developed to understand the learning environments that promote creativity. Some of the most important environmental factors were the flexible use of space and time, the availability of appropriate materials, working outside the classroom/school, the playful or game-based approaches, and the opportunities for peer collaboration. Despite the relevance of their work, Davies et al. (2013) focused on environmental factors contributing to creativity, and not on interventions or programs that were specifically developed to stimulate creativity. Davies et al. (2014) also conducted a systematic review, but their focus was on the teacher's roles in promoting students' creativity. Their findings suggest that awareness of the learners' needs, flexible lessons that balance freedom and structure, and specific interaction types (e.g., building positive relationships), support creativity. Chan (2013) contributed to the same topic highlighting the importance of a flexible structure, collaboration, and self-expression, as creativity facilitators. Gajda, Karwowski, and Beghetto (2017) conducted a meta-analysis investigating the relationship between creativity and academic achievement of children from elementary school to college/university level. The authors concluded that, on average, there is a positive (albeit modest) relationship between these two variables. This body of work shows the importance of having environments for creativity that balance task structure with freedom for exploration and autonomy of the children.

Additionally, a meta-analysis conducted by de Jesus, Rus, Lens, and Imaginário (2013) identified a positive relationship between intrinsic motivation and creativity related to the creative product. Other previous meta-analyses have studied the relationship between intelligence and creativity (Kim, 2005, 2008; Silvia, 2008), denoting the relevance of the characteristics of the creative person. However, little or no evidence exists on the level of analysis for interventions to improve creativity. Additional systematic reviews and meta-analysis were conducted, focusing on the role of the family in fostering creativity (Miller, & Gerard, 1979), stressors that hinder creativity (Byron, Khazanchi, & Nazarian, 2010), teachers beliefs in the ability to nurture creativity (Bereczki & Kárpáti, 2018), and the usage of pedagogy to ground learning for creative thinking (Sawyer, 2017).

All in all, existing literature does not provide a comprehensive summary of existing interventions for creativity. As such, a summary of evidence about the effects of interventions is needed as the problem with individual research findings studies is that each study only shows a partial contribution to the full story of creativity (Cronin & Loewenstein, 2018). This hinders researchers and practitioners that aim to perform creativity interventions to find the best programs and interventions that fit their needs, as well as hampers a holistic understanding of the advancements in this field.

Our Contribution

This Chapter presents a systematic review of the literature about creativity interventions dedicated to children. Creativity research lacks an understanding of existing programs for creativity stimulation in children and the effectiveness of such programs. This holds true especially for interventions focused on children. The research in this area appears scattered; hindering researchers from searching, selecting, and applying these interventions. By providing a systematic summary of evidence of creativity interventions, we can better understand how creativity is being measured and the efficacy of the programs. The results from this work also inform policy makers and practitioners about evidence-based intervention aiming for creativity stimulation (Beelmann, 2006).

Additionally, there is a need to classify creativity interventions according to a structured level of analysis as different terms, labels, expressions, and definitions, have been used interchangeably in the field of creativity. Scholars recognize the difficulties in reaching a consensus about how to classify creativity (Runco, Nemiro, & Walberg, 1998). For example, authors discussed the existence of different labels to refer to “problem-solving” (Abdulla & Cramond, 2018), and urged for clarity between the terms “creative potential” and “creative behavior” (Ivcevic, 2009). This systematic review contributes to the clarification of levels of analysis of creativity interventions by extending a coding scheme (Scott, Leritz, & Mumford, 2004a). This classification system provides researchers with a common ground to compare the efficacy of existing interventions and design future ones. It is composed of the following levels: cognitive processing skills, training techniques, delivery media, practice exercises, creative target, ambient of the intervention, administrator, and dimension. Therefore, the research question for this work is: *What characterizes interventions that foster creativity in children?*

Method

Protocol and Registration

A systematic review was conducted to investigate evidence-based creativity interventions and programs dedicated to children (Beelmann, 2006). We used the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to report our findings (Moher et al., 2015). The protocol for this systematic review was registered on PROSPERO (Unique ID number: PROSPERO 2016 CRD42016052101) and is available in full on Alves-Oliveira, Arriaga, Nogueira, Hoffman, and Paiva (2016).

Table 9. *Inclusion and exclusion criteria according to PICO Framework (Schardt et al, 2007). Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).*

	Inclusion criteria	**Exclusion criteria**
Population	Children between 5-12 years old.	Studies with restricted populations such as children with physical (e.g., motor disabilities), mental disorders (e.g., autism spectrum disorder) or gifted; and children with different age-ranges, unless the average age is within the scope of our age criteria.
Intervention	Literature reporting the outcomes of creativity interventions on creativity.	Studies that only investigated effects of other interventions (e.g., arts and crafts activities) on creativity, or investigated the relation or effects of creativity on other outcomes (e.g., reward, instruction, affect/emotion).
Comparison	No intervention, different treatment, control group, pre-test and post-test measures.	n/a
Outcome	Quantitative (statistical) results reporting the effect of creativity interventions on creativity levels. Results can include both quantitative and qualitative results, if qualitative findings are meant to deepen the understanding of the quantitative results.	Articles of exclusively qualitative and/or theoretical approach.
Study design	Experimental studies presenting the methodological design, including sample size, measures and statistical analyses.	Literature lacking the description of the intervention or information about the study design.

Eligibility Criteria

Study characteristics. PICOS framework was used to describe the inclusion and exclusion criteria according to the Population (P), Intervention (I), Comparison (C), Outcome (O), and Study design (S) (see Table 2) (Schardt, Adams, Owens, Keitz, & Fontelo, 2007).

Report characteristics. The present systematic review includes articles from 1950-2018. We included articles from 1950, because it is the date when J. P. Guilford highlighted the need in studying creativity empirically in the American Psychological Association (Guilford, 1950). We included peer-reviewed articles written in English and Portuguese, but excluded grey literature (e.g., opinion pieces), book chapters, dissertations, abstracts, and technical reports.

Information Sources

We started our search by reading systematic reviews and meta-analysis, such as (Jausovec, 1994; Cropley, 1997; Mansfield et al., 1978; Nickerson, 1999; Scott et al., 2004a). Hand-search was performed by consulting the citations to identify candidate articles of interest for the present systematic review. The most recent systematic review on creativity programs is from 2004. The difference between our systematic review and those referred above is that our systematic review summarizes evidence of interventions and/or creativity training programs exclusively dedicated to children at elementary school age. The reason why we focus on this target age is because previous research has shown that children in this age experience a decrease in their creativity (i.e., the “creativity crisis”). It is also a key-stage where creativity can be nurtured and developed.

Then, a more complete search was performed using the following electronic databases: ISI Web of Science, Scopus, PubMed, and EBSCO. Using EBSCO, we searched the following

Table 10. *Search-terms used in different databases. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).*

Databases	**Search codes**
PsycARTICLES	(creativity) N10 (program OR train* OR promot* OR enhanc* OR develop* OR measur* OR evaluat*) AND (child*)
PubMED	((((creativeness[MeSH Terms]) OR "creativity"[MeSH Terms]) AND training program[MeSH Terms]) AND "child"[MeSH Terms]) AND "education"[MeSH Terms]
IEEE	((creativity) AND (promote OR evaluate OR train OR enhance OR develop OR measure) AND (child*))
ACM	(creativity) AND (promote OR evaluate OR enhance) AND (children)
Psychology of Aesthetics, Creativity, and the Arts Journal	(creativity) NEAR/10 (program OR train* OR promot* OR enhanc* OR develop* OR measur* OR evaluat*) AND (child*)
ISI Web of Knowledge; SCOPUS; Journal of Creative Behavior; Thinking Skills and Creativity; Creativity Research Journal; Journal of Creative Studies; International Conference on Computational Creativity Creativity & Cognition Conference; International Conference on Design Creativity; Google Scholar Search Engine	(creativity) AND (program OR train* OR promot* OR enhanc* OR develop* OR measur* OR evaluat*) AND (child*)

databases: PsycARTICLES, ERIC (Education Resources Information Center), Psychology and Behavioral Sciences Collection, PsycINFO, and MEDLINE. Google Scholar search portal was additionally used to identify publications not indexed in the above-mentioned databases. Other

Publishers, such as the Institute of Electrical and Electronics Engineers (IEEE) and the Association for Computing Machinery (ACM) were consulted. Additionally, we searched for articles that focused on the topic of this systematic review in the following selected journals: “Psychology of Aesthetics, Creativity, and the Arts”, “Journal of Creative Behavior”, “Thinking Skills and Creativity”, “Creativity Research Journal”, and “Creativity Studies”. The same procedure was conducted for selected conferences of interest: “International Conference on Computational Creativity”, “Creativity & Cognition Conference”, and “International Conference on Design Creativity”. This last step was to perform hand-search on the references of these articles and select articles not identified in previous searches. For all the selected articles, duplicates were then removed. Data collection ceased when we reached saturation, which occurred when all the newly identified articles already existed in the database no matter how many more articles were hand-searched (Morse, 1995).

Finally, we contacted several authors working on the field of creativity to avoid the file-drawer problem, which is considered the tendency of researchers to not submit articles with null results, or for journals to only publish studies with statistically significant results (Rosenthal, 1979). Therefore, 35 authors were contacted via email and asked whether they were aware of unpublished or ongoing studies in the scope of this systematic review, with 12 scholars returning responses; however, no author provided additional articles to include in this systematic review.

Search Strategy

Query terms used for this systematic review included the title, the abstract, and the body of the articles. Our search algorithm was composed of combinations that include Boolean and proximity operators, wild card characters or truncation operators, and MeSH terms (Medical Subject Headings), the latter is a comprehensive controlled vocabulary for indexing journal

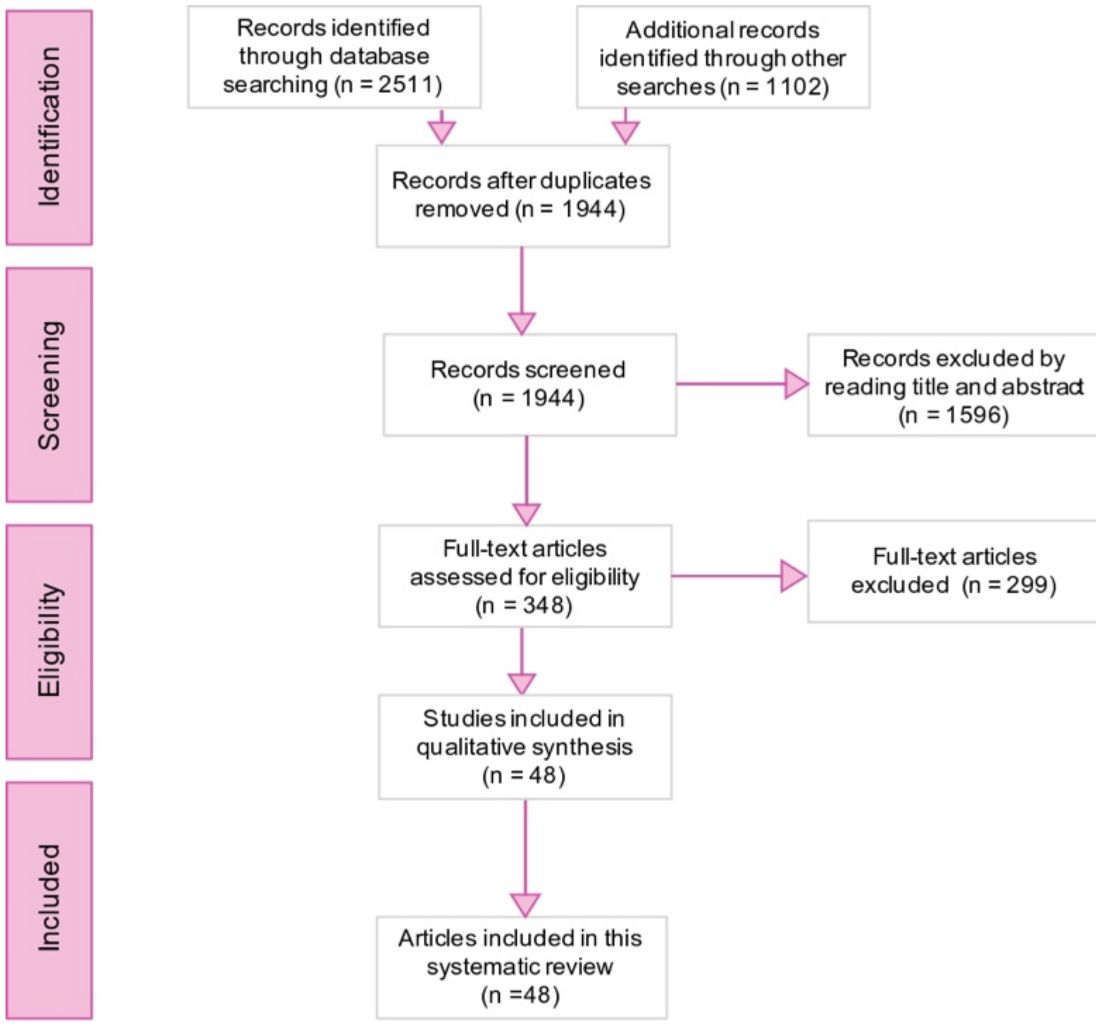

Figure 8. Flow chart of data collection of articles, according to PRISMA-P guidelines (Moher et al., 2015). Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

articles and books in the life sciences. A set of search codes was generated to accommodate distinct search engines and used across several databases (see Table 3).

Study Records

Data management. Endnote from Clarivate Analysis was used for citation management of the searches (Bramer, Giustini, de Jonge, Holland, & Bekhuis, 2016). A literature search was upload from Endnote to the Covidence Software (Babineau, 2014), an Internet-based software program that facilitates collaboration among reviewers during the selection of articles to be included in the systematic review.

Selection process. The search process returned a total of 2503 publications that included a total of 9406 participants. A flow chart of the literature selection process is illustrated in Figure 8. From the total pool of articles, 1102 through citations from previous systematic literature reviews and meta-analysis, 61 through ISI Web of Science, 1410 were identified through PsycARTICLES databases, 545 from selected journals and conferences, 119 with PubMed, 73 through SCOPUS, 70 through IEEE and ACM publishers, 225 using Google Scholar portal. From this pool of publications, 559 articles were identified as duplicates, resulting in a total of 1944 articles after duplicates removal. Title and abstract from these articles were screened by judging against the eligibility criteria, resulting in 1596 articles excluded during screening and deriving in 348 articles assessed for eligibility. After full-text reading, 299 articles were excluded after comparing them to the inclusion criteria. The final sample of included articles for this systematic review was 48. The search started in 2016 and was updated in 2019.

Data items. From the selected articles, we extracted the descriptors of the interventions, including sample details, intervention duration, controlled factors, intervention, measures, main findings, and limitations (see details in Table 4).

Quality Assessment

Criterion for quality assessment was defined according to methodological recommendations of the Strengthening the STROBE Statement (Reporting of Observational Studies in Epidemiology) (Von Elm et al., 2007). STROBE provides guidance for the report of observational studies, critical appraisal and interpretation of studies. For this systematic review, the quality of the

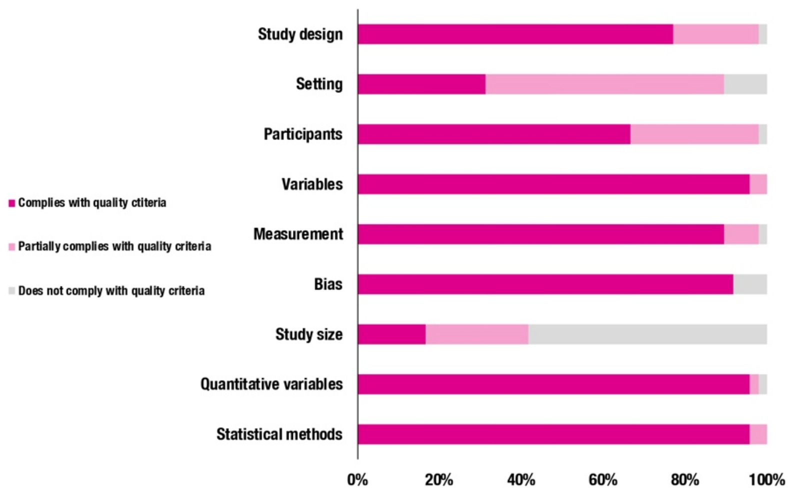

Figure 9. Quality assessment, demonstrating the risk of bias of the studies included in this systematic review, according to methodologically recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (Von Elm et al., 2007). Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

included studies was assessed using the checklist items for the method section which supports the understanding of the planned procedure with sufficient detail that allows others to understand the study essentials, to judge whether the methods were adequate to provide reliable and valid answers, and to assess whether any deviations from the original plan were reasonable (Von Elm et al., 2007). Therefore, each article was assessed for study design, setting, participants, variables, data sources/measurement, bias, study size, quantitative variables, and statistical methods (see Figure 9 and Table 5). For each of these items, the articles were measured according to the following criteria: (1) complies with STROBE recommended quality criterion; (2) does not comply with STROBE recommended quality criterion; (3) partially complies with STROBE recommended quality criterion.

Table 11. *Descriptors related with creativity of the studies included in this systematic review. Subtitles: Gender: F = Female, M = Male, Both = Male and Female; Dur. = Duration; Intervention: EX = Experimental condition, CT = Control condition, CM = Comparison condition. Limitations are stated as presented in the papers. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).*

Ref.	**Sample N, gender, age**	**Dur. (N sessions)**	**Controlled factors**	**Intervention**	**Measures**	**Findings**	**Limitations**
Feldhusen, Bahlke, and Treffinger (1969)	256, n/a, 8-12	23	Grade, gender, intelligence quotient	EX: Radio Series Program; CT: No intervention	Minnesota Tests of Creative Thinking	EX > CT	n/a
Shivley, Feldhusen, and Treffinger (1972)	377, n/a, 10-11	18	Creative abilities of the teachers	EX1: Purdue Creative Thinking Program; EX2: Productive Thinking Program w/ discussion; CM1: Purdue Creative Thinking Program with discussion; CM2: Productive Thinking Program w/ discussion	Torrance Test of Creative Thinking and Childhood Attitude Inventory for Problem Solving	EX1, EX2 > CM1, CM2; EX1 < EX2	n/a
Dansky and Silverman (1973)	90, both, 4-6	1	Ethnicity, socioeconomic status	EX: Free-play; CM: Imitation of object manipulation; CT: Painting activity	Alternate Uses Test and behavior analysis	EX > CM, CT; CM = CT	n/a
Alencar, Feldhusen, and Widlak (1976)	578, n/a, 9 − 11	14	Gender, grade level	EX: Purdue Creative Thinking Program; CM: Purdue Creative Thinking Program with reinforcement; CT: No training and no reinforcement	Torrance Test of Creative Thinking	EX, CM > CT; EX > CM	Only one metric was used to measure creativity
Houtz and Feldhusen	240, n/a,	45	Ethnicity, socioeconomic status	EX: Purdue Elementary Problem Solving	Purdue Inventory and Transfer test	EX, CM > CT; EX >	Children got used to the

(1976)	8-9			Inventory; CM: Purdue Elementary Problem-Solving Inventory with reward; CT: No training and no reward	with open ended problems	CM	reward time, removing its main effect and purpose
MacDonald, Heinberg, Fruehling, and Meredith (1976)	96, n/a, 10-11	1	Sociological type, gender, academic achievement	EX: Training of Original Responses; CT: Self-selection of activity	Original responses after intervention and after 10 months, and making inferences test	EX > CT	n/a
Moreno and Hogan (1976)	218, both, 10-12	15	Gender, race, social-class level, IQ, reading comprehension level	EX: Productive Thinking Program; CT: Gates-Peardon Reading Exercises	Torrance Test of Creative Thinking	EX > CT	n/a
Franklin and Richards (1977)	119, n/a, 9-10	6	Children: age, IQ, socioeconomic status; teachers: teaching style; schools: classroom environment	EX: Divergent Production Exercises; CT: Artistic work	Wallach and Kogan Tests of Alternate Uses, Similarities, Line Meanings, and Instances, Torrance Test of Creative Thinking, Guilford Test of Statements and Questions	EX > CT	n/a
Goor and Rapoport (1977)	142, both, 11-13	20	Children: disadvantaged background; administrator: age, socioeconomic status	EX: Creativity Games; CT: No intervention	Torrance Test of Creative Thinking and Origence and Intelligence of the Welsh Figure Preference Test	EX > CT	n/a
Huber, Treffinger, Tracy, and Rand (1979)	648, n/a, 8-12	12	Gifted children, ethnicity, socioeconomic status, IQ, performance, developmental factors, gender, race	EX: Purdue Creativity Training Program; CT: No intervention	Torrance Test of Creativity Thinking	EX > CT	Teachers lack training to implement the creativity programs;

							students seem to lack training in self-directed learning
Cliatt, Shaw, and Sherwood (1980)	37, both, 5-6	8	Children: socioeconomic status; teachers: performance when applying the creative training	EX: Divergent Thinking Questioning; CT: No training	Torrance Test of Creative Thinking	EX > CT	n/a
Dansky (1980)	96, both, 4-8	1	Socioeconomic status, equal distribution of players and nonplayers across conditions	EX: Free play with make believe; CM: Problem-solving with objects; CT: Imitation of object manipulation	Alternate Uses Test	EX > CM, CT	Lacks deeper study of the relationship between play and fluency and its duration effects
Haley (1984)	89, both, 4-6	42	Age, gender, socioeconomic status	EX: Sociodrama; CM: Verbal Training Method; CT: No Training	Torrance Test of Creative Thinking, and Thinking Creatively in Action and Movement Test	EX, CM > CT; EX > CM	n/a
Baer Jr (1988)	48, n/a, 12-13	3	School achievement, socioeconomic status	EX: Osborne-Parnes Creative Problem Solving; CT: No intervention	Divergent and convergent-thinking tests	EX > CT	Dropout of students from the study due to its long-term evaluation
Clements (1991)	73, both, 8	75	Socioeconomic status, ethnicity, achievement	EX: LOGO computer programming; CM: Computer exercises; CT: No intervention	Torrance Test of Creative Thinking	EX > CM, CT; EX, CM > CT	n/a

Nelson and Lalemi (1991)	40, n/a, 7 − 12	6	n/a	EX: Imagery training; CT: No training	Torrance Test of Creative Thinking	EX > CT	n/a
Flaherty (1992)	45, both, 8-9	12	Age, gender, IQ, socioeconomic status	EX: Holistic Creativity Program; CT: No intervention	Torrance Test of Creative Thinking, and Creativity Assessment Packet	EX > CT	n/a
Meador (1995)	107, n/a, 6	24	Giftedness of children	EX: Synectics Training; CT: No intervention	Torrance Test of Creative Thinking	EX > CT	n/a
Baer (1996)	157, n/a, 12-13	8	n/a	EX: Divergent-Thinking Program; CT: Arts' classes	Consensual Assessment Technique	EX > CT	n/a
Krampen (1997)	40, both, 8-10	1	Age, grade, gender, previous experiences with systematic relaxation exercises	EX: Systematic Relaxation Program; CT: Relaxation without instructions	TDK for ideational and associative fluency	EX > CT	n/a
Antonietti (2000)	450, n/a, 5-7	52	n/a	EX1: Real life Analogies; EX2: socioemotional analogies; EX3: Text Analogies; CT: No intervention	ABCD Test, Story Test, Problem Test, and Association Test	EX1, EX2, EX3 > CT	n/a
Luftig (2000)	615, both, 7-11	1 academic year	Ethnicity, economic status	EX: SPECTA+ program; CM: Innovative Program; CT: No intervention	Torrance Test of Creative Thinking	EX > CM, CT	n/a
Fleith, Renzulli, and Westberg (2002)	217, both, 8-12	15	Socioeconomic status, bilingual, monolingual children	EX: New Directions in Creativity Program; CT: No intervention	Torrance Test of Creative Thinking	EX > CT	Small sample size; cultural differences were not considered
Majid, Tan, and Soh (2003)	60, both, 10-11	5	Academic performance, Language proficiency, Competence in writing	EX: Writing with	Language Creativity Score Sheet; Creativity	CM > EX, CT	n/a

				SCAMPER; CM: Writing with Internet; CT: Normal writing task	Rating Scale		
Garaigordobil, and Landazabal (2005)	86, both, 10-11	1 academic year	Age, gender, academic aptitude, achievements, socio-cultural level	EX: Prosocial and Creative Play Program; CT: Ethics and arts exercises	Word Association Test and Kaufman Brief Intelligence Test	EX > CT	Lack of controlled characteristics of program administrators and setting's variables
Garaigordobil (2006)	86, both, 10-11	1 academic year	Children: age, gender, academic aptitude, achievement, socio-cultural level; parents: socioeconomic status, educational background	EX: Cooperative-Creative Play Program; CT: plastic arts	Torrance Test of Creative Thinking, and Creation of a painting	EX > CT	Lack of controlled characteristics of the program administrator and setting's variables
Hui and Lau (2006)	126, both, 7-9	16	n/a	EX: Drama Project; CT: No intervention	Wallach-Kogan Creativity Tests, Tests for Creative Thinking-Drawing Production, and Storytelling Test	EX > CT	n/a
Burke and Williams (2008)	178, both, 11-12	8	Socioeconomic status, ethnicity, registered disabilities	EX1: Individual Thinking Skills Program; EX2: Collaborative Thinking Skills Program; CT: No intervention	Thinking Skills Assessment	EX1, EX2 > CT; EX1 < EX2	Lacks control of the disposition to learn thinking skills
Justo (2008)	36, both, 5-6	50	n/a	EX: Creative Relaxation Program CT: Children lie down w/ eyes closed	Thinking Creatively in Action and Movement Test	EX > CT	n/a
Maker, Jo, and Muammar (2008)	1986, n/a,	3 years	Ethnicity of students and teachers,	DISCOVER Program	Test of Creative Thinking-Drawing	DISCOVER	Usage of only

	5-12		implementation expertise of teachers		Production	increased creativity over years	one instrument to measure creativity; dropouts during the study; heterogeneity of the sample; non-expert administrators of measures
Moore and Russ (2008)	50, both, 6-8	5	Ethnicity	EX1: Play imagination; EX2: Play-affect; CT: Puzzle play	Alternate Uses Test	EX1, EX2 < CT	Low power; different program administrator; poor testing conditions
Pagona and Costas (2008)	82, both, 9	36	Activities that influence motor behavior; area of living	EX: Special Physical Education Program; CT: No intervention	Motor Creativity Test	EX > CT	n/a
Cheung (2010)	60, n/a, 5-6	1	n/a	Movement Activity Program	Torrance Test of Creative Thinking	Movement Activity increased creativity skills in children from different schools	Children with limited experience in creative movement; no control condition; no pre-posttest design
Garaigordobil and Berrueco (2011)	86, both, 5-6	1 academic year	Age, gender, academic aptitudes and performance	EX: Cooperative-Creative Play Program; CT: No intervention	Torrance Test of Creative Thinking, and Scale of Creative Behaviors and Personality Traits	EX > CT	Lacks controlled characteristics of the person who

							administers the program
Smogorzewska (2012)	128, n/a, 5-6	4	n/a	EX1: Storyline Method; EX2: Associations Pyramid Method; CT: Telling stories	Ratings of external judges	EX1, EX2 > CT; EX1 = EX2	Unbalanced conditions; lacks pre-posttest design
Alfonso-Benlliure, Meléndez, and García Ballestros (2013)	44, both, 5-6	6	Age, gender, number of siblings	EX: Creativity Intervention Program; CT: Regular classes	Child Creativity Test	EX > CT	n/a
Dziedziewicz, Oledzka, and Karwowski (2013)	128, both, 4-6	10	Size, type, territorial location of educational institutions, gender, age	EX: Doodle-Book Program; CT: No intervention	Franck Drawing Completion Test, and Torrance Test of Creative Thinking	EX > CT	Priming effect; lacks control of external variables
Akar and Sengil-Akar (2013)	26, both, 10-11	9	School's achievement, age, socioeconomic status	CREACT	Conceptualization, drawing, and painting tasks	CREACT Was effective on developing children's creative thinking performance	Lacks control group
Kara, Aydin, and Cagiltay (2013)	90, both, 4-6	1	n/a	EX1: StoryTech Program individual; EX2: StoryTech Program collaborative; CT1: passive toy activity individual; CT2: passive toy activity individual	Story patterns, and number of imaginative objects	EX1, EX2 > CT 1, CT 2	n/a

Dziedziewicz, Gadja, and Karwowski (2014)	121, both, 8-12	30	Size, gender, age	EX: Creativity Compass Program; CT: No intervention	Franck Drawing Completion Test, and Torrance Test of Creative Thinking	EX > CT	Possible priming effect
Smogorzewska (2014)	460, both, 4-5	18	n/a	EX1: Storyline Method; EX2: Associations Pyramid Method; CT: Listen to stories	Behavior analysis of storytelling	EX1, EX2 = CT	Only one measure of creativity; Lacks measurement of motivation to perform the study
Gordon, Breazeal, and Engel (2015)	71, both, 3-8	1	Previous interactions with robots	EX: Curious robot; CM: Curious tablet; CT: Non-curious robot	Free Exploration, Question Generation, and Uncertainty Seeking	EX, CM > CT; EX = CM	n/a
Sowden, Clements, Redlich, and Lewis (2015) – Study 1	27, both, 9-10	1	Gender	EX: Dance improvisation Program; CM: Command-style dance	Consensual Assessment Technique, and Product Design Task	EX > CM	n/a
Sowden, Clements, Redlich, and Lewis (2015) – Study 2	34, n/a, 10-11	n/a	Gender	EX: Improvisation Games Program; CT: No intervention	Torrance Test of Creative Thinking	EX > CT	Lacks control for individual differences between participants
Doron (2016)	150, both, 9-13	10	Age, gender, socioeconomic status, religion	EX: Intervention Model for Enhancing Divergent Thinking; CT: No intervention	Tel Aviv Creativity Test	EX > CT	Lacks additional creativity evaluation metrics

Hoffmann and Russ (2016)	42, F, 5-8	6	Ethnicity, socioeconomic status	EX: Pretend Play Intervention; CT: Puzzles, coloring sheets, etc	Affect in Play Scale, Alternate Uses Task, Storytelling Task, and Behavior analysis	EX > CT	Small sample and gender specific
Azevedo, Morais, and Martins (2017)	131, both, 12 − 15	5	Gender	EX: Future Problem Solving Program International; CT: No intervention	Torrance Test Creative Thinking	EX > CT	Lacks control group
Doron (2017)	286, both, 10 − 14	10	Age, gender, socioeconomic status, religion	EX: Intervention Model for Enhancing Divergent Thinking; CT: No intervention	Tel Aviv Creativity Test	EX > CT	Lacks comparison condition

Table 12. Quality assessment of the method of included studies. Moon palette: ● – Complies with STROBE recommended quality criterion; ○ - Does not comply with STROBE recommended quality criterion; ◗ - Partially complies with STROBE recommended quality criterion. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

References	**Study design**	**Setting**	**Partici-pants**	**Variables**	**Measurement**	**Bias**	**Study size**	**Quantitative variables**	**Statistical method**
Feldhusen et al. (1969)	●	●	●	●	●	●	○	●	●
Shivley et al. (1972)	●	◗	◗	●	●	●	●	●	●
Dansky and Silverman (1973)	●	◗	◗	●	●	●	○	●	●
Piers and Morgan (1973)	●	◗	●	●	●	●	○	●	●
Alencar et al. (1976)	●	◗	●	●	●	●	○	○	●
Houtz and Feldhusen (1976)	●	◗	●	●	●	●	○	●	●
MacDonald et al. (1976)	●	◗	◗	●	●	●	○	●	●
Moreno and Hogan (1976)	●	◗	◗	●	◗	●	○	●	●
Franklin and Richards (1977)	◗	◗	●	●	●	●	○	●	●
Goor and Rapoport (1977)	●	◗	●	●	●	●	○	●	●
Huber et al. (1979)	●	◗	●	●	●	●	●	●	●
Cliatt et al. (1980)	●	◗	◗	●	◗	●	○	●	●
Dansky (1980)	●	◗	●	●	●	●	○	●	●
Haley (1984)	●	○	●	●	●	●	○	●	●

Baer (1988)	●	◗	●	●	●	●	●	●	◗
Clements (1991)	●	◗	◗	●	●	●	◗	●	●
Nelson and Lalemi (1991)	●	◗	○	●	●	●	○	●	◗
Flaherty (1992)	●	●	◗	●	◗	●	◗	●	●
Meador (1995)	●	◗	●	●	●	●	○	●	●
Baer (1996)	●	◗	●	●	●	●	○	●	●
Krampen (1997)	●	○	◗	●	○	●	○	●	●
Antonietti (2000)	○	◗	●	●	●	●	○	●	●
Luftig (2000)	●	●	●	●	●	●	○	●	●
Fleith et al. (2002)	●	●	●	●	●	●	○	●	●
Majid et al. (2003)	●	●	●	●	●	●	○	●	●
Garaigordobil Landazabal (2005)	●	●	●	●	●	●	○	●	●
Garaigordobil (2006)	●	●	●	●	●	●	○	●	●
Hui and Lau (2006)	●	◗	●	●	●	●	○	●	●
Burke and Williams (2008)	◗	◗	●	●	●	●	○	●	●
Justo (2008)	●	◗	●	●	●	●	◗	●	●
Maker et al. (2008)	●	◗	◗	●	●	○	◗	●	●
Moore and Russ (2008)	●	◗	◗	●	●	●	◗	●	●
Pagona and Costas (2008)	●	●	◗	◗	◗	○	○	◗	●

Cheung (2010)	●	○	◗	●	●	○	○	●	●
Garaigordobil and Berrueco (2011)	●	●	●	●	●	●	◗	●	●
Smogorzewska (2012)	●	○	◗	●	●	●	○	●	●
Alfonso-Benlliure et al. (2013)	●	◗	●	●	●	●	○	●	●
Dziedziewicz et al. (2013)	◗	◗	●	●	●	●	●	●	●
İbrahim and Sengil-Akar (2013)	◗	◗	●	●	●	○	◗	●	●
Kara et al. (2013)	●	●	●	◗	●	●	●	●	●
Dziedziewicz et al. (2014)	●	●	●	●	●	●	●	●	●
Smogorzewska (2014)	●	○	◗	●	●	●	◗	●	●
Gordon et al. (2015)	●	◗	●	●	●	●	●	●	●
Sowden et al. (2015)	◗	◗	●	●	●	●	◗	●	●
Doron (2016)	●	◗	●	●	●	●	◗	●	●
Hoffmann and Russ (2016)	◗	●	●	●	●	●	●	●	●
Azevedo et al. (2017)	◗	●	●	●	●	●	●	●	●
Doron (2017)	◗	●	●	●	●	●	◗	●	●

Taxonomy of Creativity Interventions

Once we enter the field of creativity, many seemingly related or even equivalent definitions and concepts emerge, leading to a lack of conceptual grounding and mutual understanding in creativity research as a holistic and integrated field. As a limitation, it becomes difficult to describe and compare the reported effectiveness of existing interventions for creativity without a common taxonomy of the level of analysis for creativity interventions. A second limitation relates to the search of interventions for creativity that target specific creative cognitive processes. For example, if one wants to stimulate the generation of ideas and searches for an intervention/program dedicated to idea generation, then one is faced with many intervention options that do not necessarily focus on idea generation. In addition, programs targeting idea generation use different labels to refer to the same concept, and therefore, not appearing in the initial search.

The lack of a comprehensive and inclusive definition, which can both frame contributions to and is recognized by authors in the field of creativity stimulation, drove the core analysis of creativity interventions. We have performed a deductive coding scheme to systematize these levels by combining prior definitions developed by researchers in this field with concepts that lacked formal definition. In essence our coding scheme proposes a taxonomy of creativity interventions that properly defines key-terms of creativity training, and can be used in a comprehensive way to both serve and understand research on creativity. A comprehensive illustration of the structure of the coding scheme is present in Figure 10.

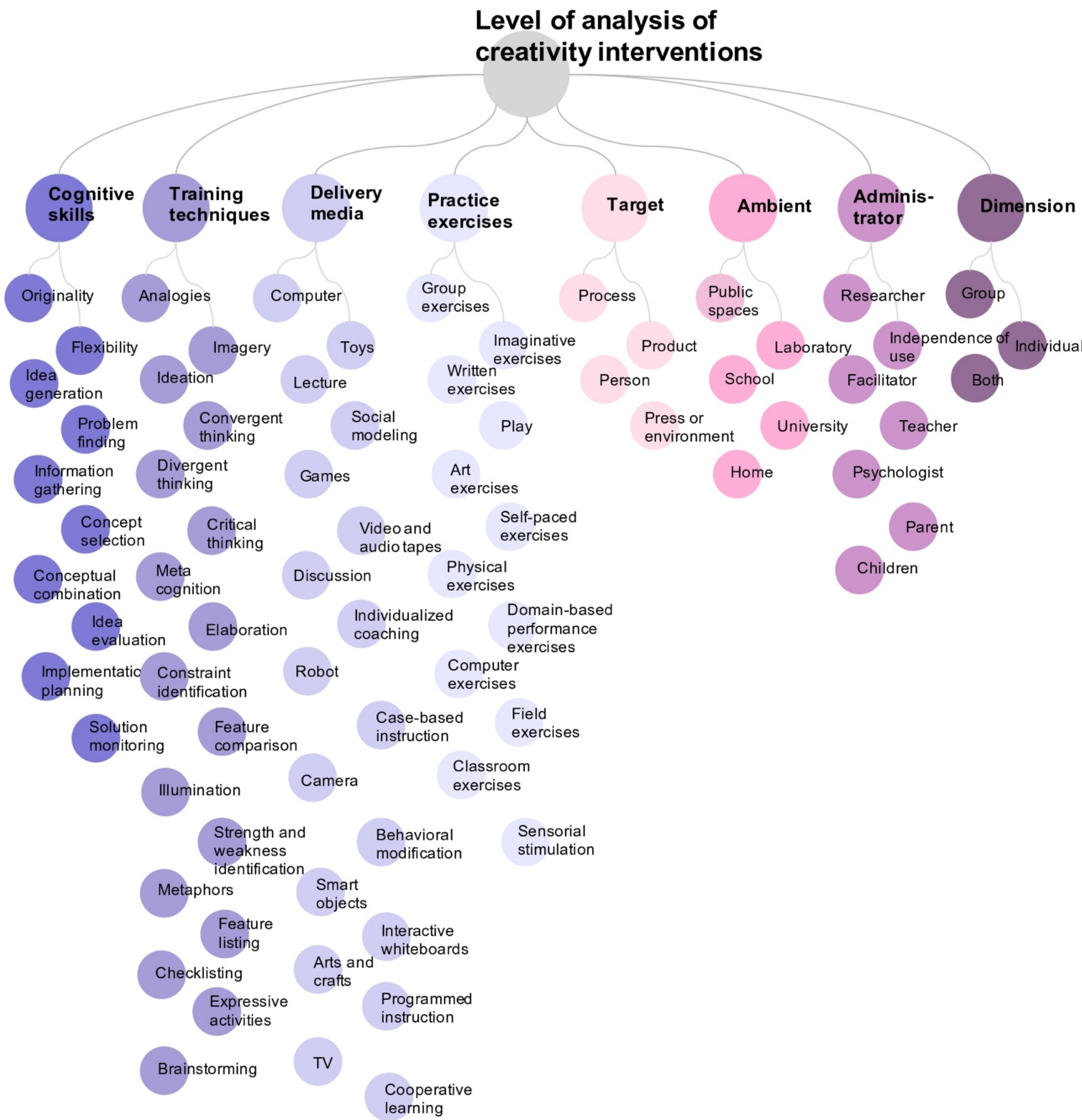

Figure 10. Taxonomy of Creativity Elements proposed by this systematic review, elaborated in Table 6. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

Coding Procedure

The creation of the coding scheme followed these steps: (1) gathering existing classification systems of creativity present in literature; (2) complementing these systems with new categories not represented; and (3) creating a taxonomy in which all the included labels of the coding scheme are associated with a definition based on prior publications. The classification from Scott, Leritz, and Mumford (2004b) included the following level of analysis of creativity interventions: cognitive processing skills, training techniques, delivery media, and practice exercises. Following this classification system, two independent coders coded the interventions. However, during the coding process, coders encountered attributes of interventions that were not represented by the Scott et al. (2004b) codification system. Therefore, to fully represent the scope of creativity interventions, which includes four new levels. Whenever a new element was added, the coders were instructed to name and define it. The end result is what we call the Taxonomy of Creativity Interventions, which includes four new levels of analysis: target, ambient, administrator, and dimension. Additionally, the coders included new items for the initial levels of the coding system.

Initially, the Delivery Media element proposed by Scott et al. (2004b) incorporated a set of 10 different media used to deliver the creativity interventions (e.g., lecture video and audio tapes), and so 8 new media were added by the coders (e.g., interactive whiteboards, robots). Furthermore, the coders provided definitions for each of the levels of analysis based on existing definitions in creativity research. To ensure consistency across coders, calibration exercises before starting the coding were performed until reaching stability, a process recommended to reach reliability in coding (Krippendorff & Bock, 2009). When the initial set of articles was coded, the coders met with the goal of solving discrepancies in their coding (Campbell, Quincy, Osserman, & Pedersen, 2013). Therefore, they compared their coding scheme to ascertain concordances (i.e., alignment in definitions, language, and coding logic). Whenever there were discrepancies in the coding, coders used the "negotiation agreement" and verbally discussed their coding in a mutual effort to reconcile disagreements and divergence (Garrison, Cleveland-Innes, Koole, & Kappelman, 2006; Hoyle, Harris, & Judd, 2002). Negotiations between coders regarding data collection were timed and lasted around 146.5 hours.

Level of Analysis of Creativity Interventions

Our taxonomy is composed of eight level of analysis of creativity interventions: cognitive processing skills, training techniques, delivery media, practice exercises, target, ambient, administrator, and dimension. Each of these levels is composed of a set of items that can be used to categorize and define each intervention or training program for creativity. Multiple items from the same level can be selected to define an intervention. The core level of analysis and their items are explained below, summarized in Table 6, and visually represented in Figure 10

- **Cognitive processing skills** — Major types of cognitive operations involved in creative thought: Problem finding, information gathering, concept selection, conceptual combination, idea generation, idea evaluation, implementation planning, solution planning, flexibility, and originality;
- **Training techniques** — General instructional methods held to develop one or more processing skills: Divergent thinking, convergent thinking, critical thinking, meta-cognition, ideation, elaboration, illumination, constraint identification, strength and weaknesses identification, feature comparison, feature listing, analogies, check listing, brainstorming, imagery, metaphors, and expressive activities;

- **Delivery media** — Media used to deliver the creativity intervention/program: Lectures, video and audio tapes, computer, individualized coaching, programmed instruction, discussion, social modeling, behavioral modification, cooperative learning, case-based instruction, smart objects, robot, TV, interactive whiteboards, toys, camera, art and crafts, and games;
- **Practice exercises** — Type of exercises embedded in the instructional training program: Classroom exercises, field exercises, group exercises, domain-based performance exercises, computer exercises, written exercises, self-paced exercises, imaginative exercises, sensory stimulation, physical exercises, art exercises, and play;
- **Target** — Where the impact of the creative training is intended to take place: Person, process, product, and environment;
- **Ambient** — Physical location where the creative intervention of program training is performed: Laboratory/University, public space, school, home, or work;
- **Administrator** — Person(s) that perform the creativity intervention or training program: Researcher, teacher, student, parent, psychologist facilitator, or self-directed/without administrator;
- **Dimension** — Social context of the intervention/training: Group, individual, or both.

Results

Profile of Creativity Interventions

All studies followed a quasi-experimental research design method. Since a majority of the studies were performed in the school context, studies selected classes and therefore used the school specifications (system of classes). In terms of the methodology used, 96% of the studies

Table 13. *Taxonomy of the Creativity Elements with its correspondent level of analysis. Items with an asterisk symbol (*) indicate they were added and defined in the scope of this systematic review to complement the coding scheme initiated by Scott et al. (2004b). Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).*

Level of analysis	Definition	Reference(s)
Cognitive processing skills		
Problem finding	Recognition of the existence of a problem, gaps, inconsistencies, or flaws, or recognition that unexploited opportunities exists, or that an unresolved problem is in need of a solution.	Lubart (2001); Zhou and George (2003)
Information gathering	Gather or being exposed to information that normally is not encountered on a day-to-day basis.	Zhou and George (2003)
Concept selection	Recognize and select concepts generated.	Rietzschel, Nijstad, and Stroebe (2010)
Conceptual combination	An attribute that is necessary for any of the parent concepts have to be inherited by the conjunction.	Hampton (1987)
Idea generation	Ability to come up with new ideas, including the process of creating, developing and communicating ideas which are abstract, concrete or visual.	Guilford (1967)
Idea evaluation	Evaluate ideas, verify feasibility, communicate ideas to others, forecast future implications.	Zhou and George (2003)
Implementation planning	Successful implementation of new ideas requires planning, which is a selection, organization, and execution of actions that facilitate the attainment of certain goals. Planning is also defined as an inherent generative activity involving the mental simulation of future actions.	Osburn and Mumford (2006)
Solution monitoring	Specific action steps which will lead to a successful installation of the new solution.	Smith (1995)

***Flexibility**	Ability to develop qualitatively different solutions. The more categories, the more flexible.	Guilford (1967)
***Originality**	Ability to produce rare and unusual ideas.	Guilford (1967)
Training techniques		
Divergent thinking	Involves producing multiple or alternative answers from available information.	Cropley (2006)
Convergent thinking	Oriented toward deriving the single best (or correct) answer to a clearly defined question.	Cropley (2006)
Critical thinking	The correct assessment of statement, including awareness of multiple perspectives and alternatives.	Ennis (1962)
Meta-cognition	Includes both the knowledge and the control that individuals have over their own cognitive processes.	Armbruster (1989)
Ideation	The generation and of multiple ideas without having the need of a specific goal.	Armbruster (1989)
Elaboration	The ability to expand, develop, particularize, and embellish ideas.	Guilford (1967)
Illumination	Related with the fast insight of ideas. Defined as the A-ha experience.	Callahan and Renzulli (1977)
Constraint identification	Constraints imposed by the exterior or interior that lead to new creations.	Johnson-Laird (1988)
Strength and weakness identification	Identifying strengths and weakness and how they can counteract creation.	Mayer (1999)
Feature comparison	Listing similarities and differences among objects or performance.	Michinov and Primois (2005)
Feature listing	Listing of different characteristics that can lead to unique associations.	Whiting

		(1958); Baughman and Mumford (1995); Ward (2007)
Analogies	Explaining the strange with familiar events.	Johnson-Laird (1989)
Checklisting	List of combinations, encouraging taking an action according to the available material.	Warren and Davis (1969)
Brainstorming	Verbalize thoughts in a group so that other person's ideas prompt others. Generating unconventional ideas by suppressing the common tendency to criticize or reject them.	Osborn (1953)
Imagery	Usage of vivid and descriptive language to add depth to a description. It appeals to human senses to transform and integrate different components or ideas. Includes the formation of mental images, figures, or likenesses of things, or of such images collectively; pictorial images, as in works of art, and the use of rhetorical images.	Roskos-Ewoldson, Intons-Peterson, and Anderson (1993)
Metaphors	Figure of speech that directly refers to one thing by mentioning another for rhetorical effect. It may provide clarity or identify hidden similarities between two ideas. It implies correspondences, or mappings, between a source and a target domain.	Lubart and Getz (1997); Kövecses (2010)
Expressive activities	Communicating in an expressive way, by using gestures or speech. E.g., drama, dance, meditation, breathing exercises and emotional expression, includes relaxation techniques, etc.	Torrance and Torrance (1972)
Delivery media		
Lecture	Oral presentation intended to present information about a particular subject. Used to convey critical information, history, background, theories, and equations.	Maker et al. (2008)

Video and audio tapes	Video-taped or audio-taped content, such as items presented to students using a tape recorder (frequently used in the Purdue Creativity Training Program)	MacDonald et al. (1976)
Computer	Use of a computer as a media to deliver the training.	n/a
Individualized coaching	Administrator works closely to participants, usually under a three-step procedure: the coach or program administrator gives instructions, participants have opportunities for practice, and a review stage of the performance.	Oden and Asher (1977)
Programmed instruction	Administrator gives verbal instructions to participants, making these instructions the media to deliver the training program.	Vargas and Vargas (1991)
Discussion	Process of analysis and ideas exchange about a given topic with another individual or a group to reach to a conclusion or agreement.	Hoffmann and Russ (2016)
Social modeling	To intentionally exert control over cues (such as environmental variables) in relation to the behavior of someone. Includes the opposite effect of analyzing how individuals react to certain environmental cues.	Bandura (1971)
Behavioral modification	Deliberate modification of behaviors as a way of delivering the program, e.g., relaxation.	Justo (2008)
Cooperative learning	Participants learn cooperatively with each other.	Smogorzewska (2014)
Case-based instruction	Instructions oriented towards specific cases or events.	Mayo (2002)
***Smart objects**	Objects that enhances the interaction. Includes interactions with physical world objects and to interaction with virtual objects.	Tablet, smartphone, interactive objects.
***Robot**	Related to "artificial intelligence" and the usage of robots with abilities to understand and interact with humans.	Sarrica, Brondi, and Fortunati, (2019)

***TV**	TV contents presented to explore different creative functions.	Movie clips, exercises, short TV series scenes, animated TV series, etc.
***Interactive whiteboards**	Large, interactive screen that connects a computer and a projector.	Majid et al. (2003)
***Toys**	Play object or figure.	Dolls, digital toys, board games, action figures, cars toys, etc.
***Camera**	Camera for photos or video recording.	Photos, video recording.
***Art and Crafts**	Crafts and manufactured elements or objects.	Crayons, paper, tissue materials, canvas, etc.
***Games**	Physical or intellectual activity with rules associated that can have an open- or closed-end.	PC game, electronic games, spontaneous game, etc.
Practice exercises		
Classroom exercises	Includes any classroom-like environment.	Smogorzewska (2012)
Field exercises	Includes all environments that are outside a classroom-type environment.	Schoolyard, playground, forest.
Group exercises	When participants take the training in organized groups.	Discussions, group exercises, etc.

Domain-based performance exercises	Creativity can be domain-specific with training programs focusing on specific types of creativity, such as figural (or visual creativity), or verbal creativity.	Baer (1998); Baer (2010); Plucker and Beghetto (2004); Kaufman and Baer (2005)
Computer exercises	Electronic/digital exercises.	Includes smart devices, such as tablets, etc.
Written exercises	Creative content expressivity using writing.	E.g., give a title to a text, write a story, etc.
Self-paced exercises	Exercises performed without having time as a pressing factor, being the exercises dependent on participants' pace.	Smogorzewska (2012)
Imaginative exercises	Exercises that stimulate the ability to reproduce on the mind, ideas, images, or sensations, without any immediate external or sensory input (such as to listen or to see).	E.g., create or listening to a story, meditation; mental projection in relaxation exercises, etc.
***Sensorial stimulation**	Exercises that involve the stimulation of any of five senses as the main component of the exercise, such as meditation.	Meditation, visual stimuli such as images in a story, physical stimulation such as touch, etc.
***Physical exercises**	Exercises that require participants to be physically active, such as motor exercises.	Dance, physical education, breathing exercises.

***Art exercises**	Require the presence of some type of artistic expression.	Painting, drama, colleagues, narrative or poem writing, story, dancing, draw, sculpting, etc.
***Play**	The act of playing is the central exercise.	Hoffmann and Russ (2016)
Target		
***Person**	The program is evaluated in terms of the impact it had on the participants creativity skills. Occurs if the program is evaluated with pre- and post-tests.	Validated creativity tests, such as pre-and post-tests that measure creative abilities.
***Process**	Requires the evaluation of the process of creativity development.	Behavioral observations or other media collected via audio and/or video recordings, enabling to analyze, e.g., the number of ideas generated during the training.
***Product**	The program is evaluated in terms of the final creative product or production.	Painting, composition, poem, story, etc.
***Press or environment**	Evaluation how changes in environment affect creativity. Or the effects of the program in the environment.	Impact of creativity levels in a country, impact of classroom

		structure in creativity levels, etc.
Ambient		
***Laboratory or University**	Creativity training programs are applied in laboratory or university context.	University labs.
***Public spaces**	Creativity training programs are applied in public context.	Summer camp, public park, etc.
***Home**	Creativity training programs are applied in home context.	Living room, bedroom of a house, etc.
***School**	Creativity training programs are applied in school context.	Classroom, playground, library, computer lab, school classroom, etc.
Administrator		
***Researcher**	Includes university staff (students, professors, researchers).	Dansky and Silverman (1973)
***Facilitator**	Someone acts as a facilitator of the program, with a peripheral role in the delivery and application of the intervention or program.	n/a
***Psychologist**	The program is coordinated by a psychologist.	Alfonso-Benlliure et al. (2013)
***Teacher or professor**	School teachers administer the program.	Smogorzewska (2012)
***Parent**	When (a) parents administer the program.	E.g., parent directs children in a given activity.

***Children**	When children are independent, acting individually or in group, without depending on external administrators.	E.g., children's free play and their effects on creativity.
***Independence of use**	When participants can use the training program mostly on their own, without depending on external administrators. Note that there can be someone supervising or monitoring the program (to check exercises' time), but it still has independence of use.	n/a
Dimension		
***Group**	When the program is meant for to be performed in pairs, a big group, or a small group.	Work in pairs on computers.
***Individual**	When the program is intended for an individual person.	Individual exercises, etc.
***Both**	In different moments, participants perform the program individually and in a group.	Franklin and Richards (1977)

included at least one control condition, 75% included a pre-test-and-post-test design, 90% performed quantitative analysis as the major outcome, and the remaining complemented quantitative results with qualitative analysis. The most common measurement type for data collection was scale-based metrics (79%), followed by behavioral observations (8%), combination of scale-based metrics and behavioral observations (6%), combination of scale-based metrics with interview material (4%), and more rarely combining of all the aforementioned metrics (2%). In 42% of the included articles, creativity was investigated alongside with other variables, and 58% of the studies focused exclusively on creativity measurement and evaluation. For the studies that paired creativity investigation with additional variables, the additional measures focused mainly on the evaluation of cognition (e.g., intelligence, performance, achievements), affect, emotion, personality, self-esteem, and culture.

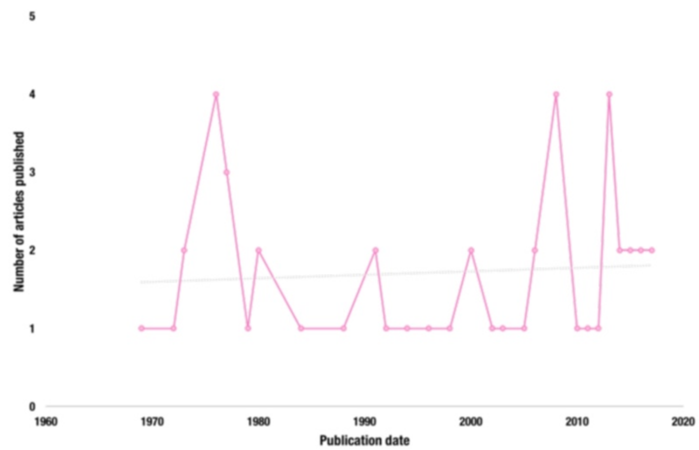

Figure 11. Recency of publications on creativity interventions for children. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

Since Guilford's discourse in 1950 (Guilford, 1950) about the need for more research on the topic of creativity, studies in the field started to emerge in 1960 with only 1 article published per year targeting the topic of interventions of creativity for children. Exceptions were the years of 1978, 2008, and 2013, with an increased number of published studies consisting of a maximum of 4 studies published. Figure 11 shows the number of articles published per year.

Most of these studies were conducted in the United States, followed by countries in Europe (Spain and Poland with 4 and 5 studies, respectively) and the remaining countries published between 1 to 3 articles, represented in lighter pink color. Figure 12 shows the location in which the studies were conducted given the authors' affiliations of the published articles.

We have also analyzed the keywords associated with each publication. The most frequent term used is "creativity", "thinking", "education", "creative development", and "children". Figure 13 shows a cloud chart of all the keywords present in the included articles. These keywords can inform search terms for trending words used in creativity research to facilitate the searching process of articles.

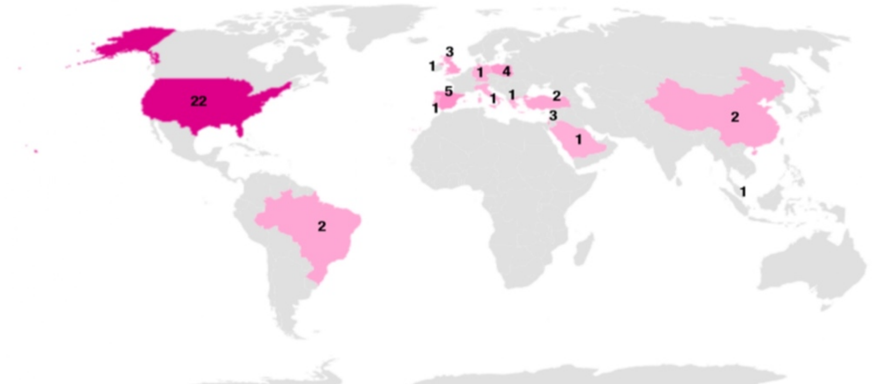

Figure 12. World map of publications of creativity interventions. Color palette: Deep pink represents countries with more publications. Number represent frequencies. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

Level of Analysis in Creativity Interventions

Two independent coders used the coding scheme described in Figure 10 to identify the level of analysis of creativity interventions presented in each study included in this systematic review. By analyzing Figure 14 we can see that the most stimulated cognitive processing skills are idea generation (18%), flexibility (14%), conceptual combination (11%), and idea evaluation (11%). By contrast, interventions target less solution monitoring and implementation planning. Additionally, the training technique mostly used by the interventions was divergent thinking (15%), expressive activities (12%), and elaboration (10%); while the least used were strength and weakness identification, constraint identification, and check listing was not used at all. This seems to show that interventions for children are mostly dedicated to the stimulation of quantities, namely divergent thinking processes, somehow dismissing convergent thinking. Many interventions used programmed instruction (31%), discussion (18%), and cooperative learning (10%) as a delivery media of the training. On the other hand, novel technologies such as smart objects, interactive whiteboards, televisions, games, robots, and cameras were the media used

Figure 13. Word cloud extracted from the keywords of publications on creativity interventions for children. The size of the letters represents frequencies. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

least frequently, probably because they were non-existent at the time of the early interventions. However, these media have become more prominent in recent studies, denoting their potential to be included in the interventions with children. Regarding practice exercises, we can see that many interventions used imaginative exercises (19%), group exercises (15%), and art exercises (14%). While the least chosen interventions were domain-based performance, physical exercises, and field exercises. Other exercise types, such as play exercises, had a moderate presence in the interventions (6%).

Many interventions for creativity stimulated variables targeting the creative person (80%) while very few programs were dedicated to the creative process (10%) or product (10%). The majority of the interventions were conducted in the ambient of the school (92%). Unsurprisingly, the most prominent administrators of the interventions were teachers/professors (45%), researchers (17%), and facilitators (7%), while parents rarely served in that role (1%). It is important to note that many interventions were developed so that children could use them

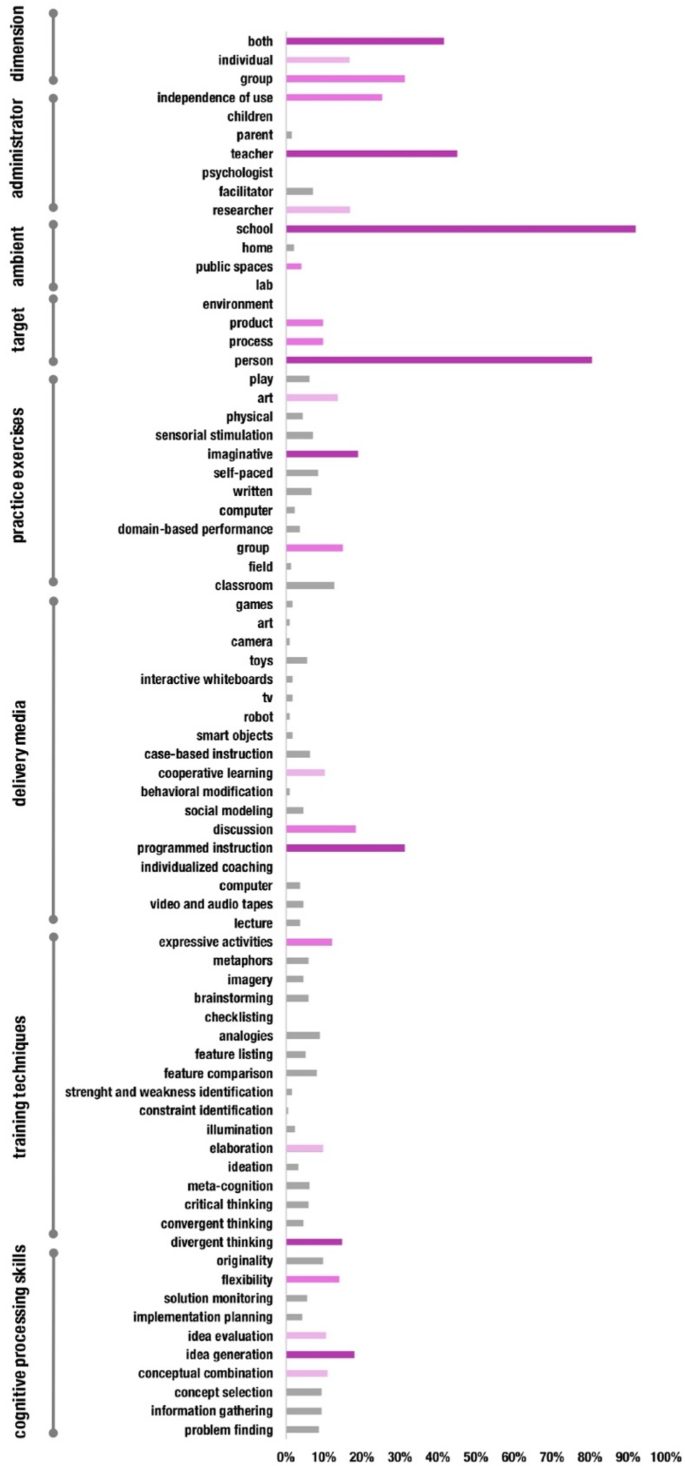

Figure 14. Percentage of the attributes of creativity. The color palette varies from deep to light pink to show the most used elements. Grey color evidences the least used elements. Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).

independently without the presence of external administrators (25%). Also, it can be seen that many of the programs used both an individual and a group component (42%), with few interventions being applied to a child individually (17%).

Design of Interventions for Creativity

We further analyzed the design of the interventions for creativity depending on their target and on their dimension of the intervention. The full table detailing the codification of each intervention for creativity can be seen in Table 1 in OSF[8].

Designing interventions for a specific target. We analyzed how the interventions were designed according to their target: the creative person (personal characteristics of individuals), the creative process (cognitive processes associated with creativity), or the creative product (creative products or outcome of the creative process). We elaborate on the design of interventions for each of these three targets.

Table 7 presents a comprehensive overview of the results, which showed that when the target is the creative person, many of the interventions stimulate the cognitive processing skills of idea generation, flexibility, and conceptual combination. Additionally, these studies most frequently used the training technique of divergent thinking, expressive activities, and elaboration. The media they most frequently implemented to deliver the training were programmed instruction, discussion, and cooperative learning. The interventions leveraged mostly imaginative, group, and classroom exercises; and were mainly performed in the school, with a teacher/professor as the administrator. Many interventions were applied to groups of

[8]Microsoft excel was used to compile Table 1 with the database codification due to its large size. For this reason, Table 1 can be accessed in Open Science Framework using the following weblink: https://osf.io/rufz2/

children or used a mixed context (having exercises for both groups of children and individual children), but they were rarely meant to be administered to an individual.

When the target is the creative process, the results showed that a wider variety of cognitive processing skills are being stimulated compared to interventions that target the creative person. Therefore, many interventions stimulated problem finding, concept selection, conceptual combination, idea generation, and idea evaluation, solution monitoring, information gathering, flexibility, and originality. Many interventions for the creative process used convergent thinking, critical thinking, feature comparison, divergent thinking, feature listing, analogies, meta-cognition, and expressive activities. These results also demonstrate the use of more training techniques in process-interventions than in person-targeted interventions. The media used to deliver the training in process-based interventions was also more diversified; relying on the usage of different media, such as programmed instruction, cooperative learning, toys, lectures, video and audio tapes, computer exercises, smart objects, robots, interactive whiteboards, and games. The types of practice exercises used were imaginative, group, written, classroom, computer exercises, play, sensory stimulation, and art exercises. A teacher or researcher usually performed the process-targeted interventions in the school, showing a high probability of being designed for children to use independently and showing the value of autonomous work in the creative process. Finally, most interventions were designed with both group and individual activities.

When the target was the creative product, the results show a similar pattern to process-targeted interventions, with a wider variety of creative attributes being used in comparison with person-targeted interventions. Despite this fact, the creative attributes used were not necessarily the same as the ones used in interventions focused on the creative process. Specifically, the cognitive processing skills most frequently targeted were idea generation, idea evaluation, flexibility, originality, concept selection, conceptual combination, information gathering, and implementation planning. As for the training techniques they were divergent thinking, elaboration, analogies, expressive activities, feature comparison, brainstorming, imagery, metaphors, and feature listing. Delivery media used by product-targeted interventions were programmed instruction, discussion, cooperative learning, computer exercises, interactive whiteboards, and handicrafts. Very frequently, the exercises used to deliver the training were group, imaginative, classroom, art, written, and self-paced exercises. All of these interventions were conducted in the school by a teacher and are designed for independence of use. Finally, and similarly to the other interventions, they were mostly applied in both groups and individually, or with groups of children.

Designing interventions according to the dimension of creativity. Interventions also seem to be designed differently depending on if they were applied to children in groups or individually. Therefore, we now elaborate on the design of the interventions according to the dimension in which they were applied to: groups, individual, or mixed. Table 7 presents a more comprehensive overview of the results, showing no extreme variations between programs delivered for an individual, group, or mixed applications. In fact, for all of these dimensions' idea generation and flexibility were stimulated the most of any of the cognitive skills. The training technique that many interventions used was divergent thinking stimulation and expressive activities. Programmed instruction was the delivery media used in all the dimensions. Regardless of the dimension of the intervention, the target tended to be the creative person. Also it was most common for a teacher or a researcher to perform the interventions in a school and they encouraged children to use the techniques independently.

Table 14. *Level of analysis of creativity interventions according to the target (person, process,* product) and the dimension (applied individually, in groups, or both). *Retrieved from Alves-Oliveira, Xavier, Arriaga, Hoffman, and Paiva (under review).*

Level of analysis	**Target**			**Dimension**		
	Person	**Process**	**Product**	**Individual**	**Group**	**Both**
Cognitive thinking skills						
Problem finding	9%	14%	3%	12%	5%	10%
Information gathering	10%	7%	6%	4%	11%	9%
Concept selection	9%	14%	12%	15%	7%	10%
Conceptual combination	11%	14%	12%	12%	12%	11%
Idea generation	19%	14%	15%	31%	16%	16%
Idea evaluation	10%	14%	15%	8%	9%	12%
Implementation planning	4%	0%	6%	4%	6%	3%
Solution monitoring	5%	10%	3%	4%	6%	5%
Flexibility	15%	7%	15%	8%	16%	15%
Originality	9%	7%	15%	4%	12%	10%
Training techniques						
Divergent thinking	15%	9%	11%	21%	13%	14%
Convergent thinking	4%	13%	2%	6%	3%	5%
Critical thinking	6%	13%	2%	9%	5%	6%
Meta-cognition	7%	6%	2%	6%	7%	7%
Ideation	3%	3%	2%	3%	3%	2%
Elaboration	10%	6%	11%	12%	11%	8%
Illumination	2%	3%	2%	3%	3%	1%

Constraint identification	1%	0%	0%	3%	0%	1%
Strength and weakness identification	2%	0%	2%	0%	2%	2%
Feature comparison	8%	13%	9%	9%	7%	9%
Feature listing	5%	9%	7%	6%	6%	5%
Analogies	9%	9%	11%	3%	9%	11%
Check listing	0%	0%	0%	0%	0%	0%
Brainstorming	6%	3%	9%	0%	8%	4%
Imagery	4%	3%	9%	3%	3%	7%
Metaphors	6%	3%	9%	0%	8%	6%
Expressive activities	13%	6%	11%	15%	12%	12%
Delivery media						
Lecture	3%	7%	0%	0%	6%	4%
Video and audio tapes	4%	7%	0%	7%	0%	4%
Computer exercises	2%	7%	7%	0%	3%	6%
Individualized coaching	0%	0%	0%	0%	0%	0%
Programmed instruction	31%	21%	36%	29%	31%	28%
Discussion	20%	0%	21%	7%	19%	22%
Social modeling	6%	0%	0%	7%	8%	2%
Behavioral modification	1%	0%	0%	0%	3%	0%
Cooperative learning	9%	14%	21%	0%	22%	6%
Case-based instruction	8%	0%	0%	7%	6%	6%

Smart objects	2%	7%	0%	7%	0%	2%
Robot	1%	7%	0%	7%	0%	0%
TV	2%	0%	0%	0%	0%	0%
Interactive whiteboards	1%	7%	7%	0%	0%	4%
Toys	4%	14%	0%	21%	0%	6%
Camera	1%	0%	0%	0%	0%	2%
Arts and crafts	0%	0%	7%	0%	0%	2%
Games	1%	7%	0%	0%	3%	2%
N/A	1%	0%	0%	7%	0%	0%
Practice exercises						
Classroom exercises	13%	9%	14%	12%	11%	12%
Field exercises	2%	0%	0%	0%	1%	2%
Group exercises	15%	14%	18%	0%	20%	18%
Domain-based performance exercises	3%	0%	7%	9%	0%	3%
Computer exercises	2%	9%	4%	3%	1%	3%
Written exercises	6%	14%	11%	3%	4%	9%
Self-paced exercises	8%	5%	11%	18%	7%	8%
Imaginative exercises	19%	18%	18%	21%	19%	18%
Sensorial stimulation	8%	9%	0%	12%	4%	8%
Physical exercises	5%	0%	0%	0%	9%	2%
Art exercises	14%	9%	14%	9%	17%	13%
Play	6%	14%	4%	12%	7%	5%
Target						
Person	100%	0%	0%	89%	88%	67%
Process	0%	100%	0%	11%	0%	19%

Product	0%	0%	100%	0%	13%	14%
Press or environment	0%	0%	0%	0%	0%	0%
Ambient						
Laboratory or university	0%	0%	0%	0%	0%	0%
Public spaces	5%	0%	0%	0%	7%	5%
Home	2%	0%	0%	0%	0%	5%
School	91%	80%	100%	88%	93%	91%
N/A	2%	20%	0%	13%	0%	0%
Administrator						
Researcher	18%	14%	13%	25%	5%	19%
Facilitator	8%	0%	0%	0%	16%	6%
Psychologist	0%	0%	0%	0%	0%	0%
Teacher/professor	43%	43%	63%	25%	63%	44%
Parent	2%	0%	0%	0%	0%	3%
Children	0%	0%	0%	0%	0%	0%
Independence of use	23%	43%	25%	50%	16%	25%
N/A	5%	0%	0%	0%	0%	3%
Dimension						
Group	34%	0%	40%	0%	100%	0%
Individual	20%	20%	0%	100%	0%	0%
Both	34%	80%	60%	0%	0%	100%
N/A	12%	0%	0%	0%	0%	0%

Discussion

In this work, we contributed with the design, development, and validation of a coding scheme due to the need to systematize levels of analysis of creativity interventions. Our coding scheme provides a basic nomenclature to ground the structure of the desired intervention for creativity and therefore has the potential to inform the design, development, and validation of new interventions/programs. In this sense, designers of creativity interventions can choose between different levels of analysis according to what attribute of creativity is meant to be stimulated, what technique to use, which media to apply, etc. This enables the development of interventions that have a clear target and goal. It also supports the understanding of existing intervention programs and guides practitioners in the choice of the most appropriate program to apply. Furthermore, the classification of interventions based on their level of analysis facilitates replication and reproducibility of programs. However, this also means that caution should be used when comparing the efficacy of interventions that stimulate different attributes of creativity. Despite this reservation this coding scheme facilitates cross-validation of effectiveness between programs.

An additional advantage of the coding scheme relates with the easiness of interpreting the results and placing them in the current state of the art in creativity research. For example, we can see that most of the interventions for creativity have been targeting divergent thinking and idea generation while less has been dedicated to convergent thinking and implementation planning training. While the term "creativity" shares the same root as create, it implies something beyond the creation of new ideas but also a synthesis into a useful solution; that is generating ideas and then culling and converging those ideas into a viable, useful solution. As such, it seems that more interventions that blend convergent and divergent thinking are needed. As Kaufman (2018b) puts it, "most empirical studies emphasize how to increase creativity rather than explore its possible benefits." (pp. 734).

This coding scheme included different emergent levels of analysis that are being brought from the field of technology to the field of creativity, e.g., robots, smart objects, computers. Although these examples were not the most common ones, mainly because our search includes a broad range of years and in early years some of the technology was non-existing, we can see there is a trend in the use of novel technologies for stimulating creativity. Moreover, they are associated with positive effects in the creativity levels of children (Pires, Alves-Oliveira, Arriaga, & Martinho, 2017).

Implications for Practice and Policymaking in Creativity Research

First, social interactions are beneficial for creativity stimulation in children. Our findings revealed that most interventions and programs for creativity were conducted within groups of children or have a mixed dimension (including both individual and group tasks). This seems to show the importance of stimulating the social dimension of creativity in children in which creations are made during interactions, collaborations, and exchange of ideas (Paulus & Nijstad, 2003; Tadmor, Satterstrom, Jang, & Polzer, 2012).

Second, school is the primary locus for creativity training. Indeed, the most common ambient or environment where interventions are conducted in the school setting. This means that an intervention in a location that is familiar to children helps them to express their creative potential. Safe and natural environments appear connected with positive creative work, such as divergent thinking stimulation and mental transformations (Jones, 2013).

Third, teachers are a cornerstone for developing creativity in children. In almost all of the interventions, teachers or professors were the most common administrators of creative training. However, as our results demonstrate, teachers and professors frequently lack proper training in delivering creativity interventions (see the limitations column in Table 4). This leads to inconsistencies in delivering the training and thus, results are hindered. Furthermore, Collard and Looney (2014) systematized a list of barriers in creativity education, mentioning the importance of teacher training and curricula accommodation for creativity tasks.

Fourth, the personalization of creativity interventions seems to matter. When interventions or programs are designed to target the creative process or the creative product, they are richer in their structure. That is, the training is more diversified, compared with interventions that target the creative person. For example, they include the stimulation of more types of cognitive processing skills and use more training techniques. The drawback of this diversity implies that it can be harder to understand what attributes of creativity if being responsible for the effectiveness of the program. In this sense, programs targeting the creative person are more focused and might a good option to demonstrate the efficacy of a given program.

Fifth, creativity interventions should go beyond test-like activities. As shown by our results, programmed instruction is the delivery media more frequently used in all interventions and programs. This means that the intervention is highly based on concrete instructions for children, which translates into programs that resemble evaluation tests rather than creative activities that can inspire creativity in children. Given the importance of play in children's development, alternative programs with playful attributes should be considered (Davies et al., 2013). For this, additional ways to measure creativity such as behavioral and verbal analysis (with a validated coding scheme that defines what creative behaviors can be coded), are particularly useful when the target group of the intervention are young children (Said-Metwaly, Van den Noortgate, & Kyndt, 2017) and should be explored further.

Sixth, opportunities for autonomy are opportunities for creativity. One of the most surprising results that emerged was the discovery of multiple interventions that placed children as independent users of the training, not needing external administrators. Given that autonomy and independence are two variables highly associated with creative individuals it is not surprising that these lead to behaviors of exploration, curiosity, and experimentation in children (Feist, 1999; Rejskind, 1982). Therefore, providing programs that empower children in their autonomy is beneficial for creativity outcomes. We believe that new technological media, such as robots, computers, and smart objects, can facilitate autonomy in creativity. This can be achieved by having tasks focused on children, such as the assembly of a robot with child-friendly instructions (e.g., LEGO Mindstorms) or the use of a computer to program a robot (e.g., LOGO programming environment developed by Papert (1980)). Additionally, our results show that interventions focused on autonomy were mostly group-based interventions, demonstrating how beneficial group interactions are for collective creativity.

Conclusion

At some point in life everyone can be creative. Creativity is an ability that seems to benefit personal growth, as well as to be a boon to society (Sternberg & Lubart, 1996). However, there seems to be a decline in creative abilities in some key-developmental stages (such as during childhood). To bridge this gap with existing efforts for creativity development, this systematic review had two main contributions: collect and summarize evidence of interventions and programs for creativity dedicated to children, and the proposal of an extended coding scheme that can be used to understand different levels of analysis of creativity interventions.

Our systematic review of programs for creativity spams 68 years of research. We have started our search with a poll of 3613 articles, and our final list of included studies includes 48 of these articles, selected using the PRISMA-P guidelines for systematic reviews (Moher et al., 2015). Our results include the description of the studies included, as well as a detailed analysis of the intervention programs for children. We concluded that although efforts are being made to develop new programs for children, showing promising levels of effectiveness, more research is required and new programs for creativity should be designed and validated given current limitations.

To evaluate the interventions, we have developed a coding scheme with different levels of analysis of creativity interventions. These levels of analysis include a detailed description of which cognitive processing skills are being stimulated by the interventions, what training techniques are applied, which media is being used, what exercises are being practiced, what is the target and the administrator of the intervention, in which ambient the training takes places, and in which social dimension training is being applied. Each of these concepts was associated with a definition, thus facilitating clarity in creativity nomenclature. This coding scheme is therefore called “Taxonomy of Creativity Interventions” and is meant to be broadly used to either design new creativity programs, apply existing ones, or compare efficacy between interventions.

Limitations and Recommendation for Future Research

“Nurturing young children’s creative potential is not frivolous. It stands at the center of preparing children for life” (Kemple & Nissenberg, 2000). Although this was an extensive systematic review that covered many years of research in the field of creativity, there are some limitations that need to be addressed.

As demonstrated by the results, the majority of the programs included in this systematic review had a positive impact on creativity. This means that little is known about programs and interventions that did not impact creativity work. This occurred mainly due to the file drawer problem (Rosenthal, 1979) that we have tried to address by contacting several authors and experts in the field. However, overall, we did not find enough supporting results for programs that are hindering creativity. That said, having a repository of knowledge about elements that hinder creativity allows curriculum designers to have a list of what not to include (Kaufman, 2018c). All in all, additional programs or interventions for creativity seem to be welcome. As Mumford (2003) stated, there is still space for the developments that focuses on practical innovation that takes into account cross-field differences in the nature of creative thought, and that combines the effects of creativity on people and social systems.

Domain differences, such as mathematical-logical and verbal-symbolic, among others, also play a role in differences in creativity expression (Baer, 2015; Baer & Kaufman, 2005; Kaufman & Baer, 2004, 2005; Lubart & Guignard, 2004; Plucker & Beghetto, 2004; Silvia, Kaufman, & Pretz, 2009). While this work did not analyze domains differences in creativity interventions, future work should describe programs in terms of the domain that is being stimulated. Additionally, a large number of interventions considered no intervention for a control condition in a randomized, controlled trial to avoid the Hawthorne effect (McCarney et al., 2007).

Finally, this work does not include articles that only provided qualitative results. In this sense, we viewed creativity as an end-goal. However, to fully understand the benefits of creativity it should be more closely examined in light of qualitative results. Also, more emphasis should be placed on the creative process and creative meanings (Kaufman, 2018a). In future work, broadening the scope of the search could provide a more holistic overview of other efforts being made in this field of research.

Highlights

- Review of evidence about the effectiveness of interventions for creativity dedicated to children.
- Transferability of knowledge by using the Taxonomy of Creative Interventions to other creativity efforts.
- Understanding about the enduring impact of current interventions to inform the design of new interventions.

Implications for this thesis

This systematic review was a steppingstone into the state of the art in creativity research. It enabled us to better understand what the current limitations are and how we can robotic technology as a tool for creativity-provoking interventions. Specifically, one of the main limitations in current interventions is the lack of personalization among the activities developed to stimulate creativity in children. Most of the activities miss essential elements of children's world, such as fun, imagination, and play. We took this as an opportunity to use robots for fun and decided to create a toy-like robot that children could play and *through the interaction with the robot*, creative abilities would be nurtured. To date, there is no study whose main goal is to design a child-robot interaction that praises play as a form of unleashing creativity. In Chapter 5 we detail how we have designed, fabricated, and programmed a robot that can support this intervention model.

This systematic review also sheds light on best practices among existing creativity interventions. There is an emphasis on the benefits of conducting these interventions in familiar places for children. Indeed, creative places are safe places as they honor explorations and empower new experimentations without fear (Ross, 2010). This led us to conduct our studies across different child places, such as schools, summer camps, and children's museums. An additional insight from this systematic review was the positive gains in developing interventions that children could take ownership, as autonomy is positively correlated with creativity. Towards this end, instead of imposing a new activity for children to learn, we integrated the intervention in activities that children already practice and enjoy. We have therefore chosen to focus on unstructured play and storytelling.

Chapter 4. Activities with robots to unlock creative potentials

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Alves-Oliveira, P., Arriaga, P., Hoffman, G., Paiva, A. (Manuscript in preparation). Designing and Coding Robots to Unlock Creative Potentials. International Journal of Child-Computer Interaction.

Abstract

Robots have massively been introduced in children's lives, showing promising effects on education and learning. Parallel to this, children's creative levels show a decline related to different factors, including the standardized teaching and learning dynamics present in traditional school systems. This work aims to investigate if the activities with robots introduced in school have an effect on children's creativity levels. To study this, we compared creative levels of children across three study conditions: (1) Experimental condition 1: Children performed STEAM activities in school by learning how to code robots; (2) Experimental condition 2: children performed STEAM activities by learning how to design robots; (3) Control condition: Children engaged in a music class. We applied the Test for Creative Thinking-Drawing Production (TCT-DP), a validated test that measures creative potential, before and after the intervention. Our results showed that creativity levels of children increased from pre- to post-testing, showing the effect of all intervention groups in potentiating creativity. Additionally, results showed that creative levels were significantly higher in the control condition. This result was expected since this condition consisted of an artistic musical intervention where creativity is foreseen to be stimulated. When analyzing the effects of the interventions on the two dimensions of TCT-DP (i.e., adaptiveness and innovativeness), results showed that both the control and the coding condition stimulated innovativeness, with moderate effect size for code condition and small effect size for control. This result seems to show the strong relationship between this intervention and the stimulation of non-conventional ways of thinking. This study contributes to understanding the effects of using robots for children.

Keywords: creativity, social robots, STEM, art

Theoretical Background

We now review the literature on activities with robots for children that are already being used in schools and how they relate to creativity expression.

Robotic Activities for Children

Digital competence, a skill highly related to STEM activities and robotics, was elected one of the eight basic competences of the European Reference Framework of key competences for lifelong learning (European Communities, 2007). Digital competence is defined as an awareness and a capacity of people to properly use digital tools to identify, access, integrate, manage or evaluate digital resources (Martin, 2005b). It is a competence that has been therefore included in the school curriculum in many countries, especially developing countries. This meant also that teachers had to include in their preparation didactic activities in which digital technologies are used to teach children to learn about other curricular concepts. It has been extensively recognized that experiential, hands-on educational activities provide higher motivation for learning new material, by providing real-world meaning to the otherwise abstract knowledge (Donohue, 2014; Mataric, Koenig, & Feil-Seifer, 2007). To contribute to this hands-on learning and growing, robotics has been shown to be a novel but promising tool to generate interest, motivation, and learning in topics of Science, Technology, Engineering, and Math (STEM).

This ability to learn concepts about curricular topics (e.g., math) through the use of robotics, was coined by Seymour Papert (Papert, 1980). The main idea was to teach children to learn how the computer thinks so they could learn about their thinking. Towards his goal, he developed LOGO, one of the earliest programming languages for children (Papert, 1999). To enable children to see the product of their coding, he developed the LOGO Turtle, a robot that would respond to children's commands and that would enable children to see the impact of their understanding about concepts by viewing it reflected on the robot (Solomon, & Papert, 1976) Education, like other social sectors, is rapidly adopting electronic means (Martin, 2005b). As this was a successful teaching technique, the programming language continued to be improved and gave origin to Scratch, a programming language of building blocks pervasively present in robotic kits for children so they learn how to code (Resnick, Martin, Sargent, & Silverman, 1996).

Robotics Activities and Creativity

Given the success of robotics in learning acquisitions, education started to rapidly adopt technology to bring new ways of learning in school (Ibáñez, & Delgado-Kloos, 2018). During STEM activities, children are active builders of their learning. Usually, these activities have an interpersonal nature and children are organized in small groups to solve a problem and lean with each other. By looking at the cognitive processes that are involved in STEM activities, one could say they incorporate processes that are relevant for creative thinking (Harms, Kennel, & Reiter-Palmon, 2017). Researchers have recognized this connection and several studies already evaluated if creativity levels increase with STEM activities, showing promising results (e.g., Conradty, & Bogner, 2018). However, little is known on how children perform in STEM-like activities (such as coding and designing robots) compared to artistic classes which are known to stimulate creativity with certainty (Liikanen, 1975). As such, a study performed by Ritter and Ferguson (2017) showed that listening to music, especially happy music, increases levels of both convergent and divergent thinking. Songwriting is an activity that also appears to be related to creativity reasoning in both teenagers (Arbuthnott, & Sutter, 2019) and children (Sarrazin, 2016). Additionally, being playing an instrument is also associated with an increase in creativity levels of children (Kokotsaki, 2016).

Our Contribution

STEM activities place clearly defined problems for children to solve. While children become efficient in acquiring a mindset for solving clear problems, they can have a harder time solving problems that are ill-defined (Moreau, & Engeset, 2016). Some literature exists on the influence of STEM activities in children's creative thinking (e.g., (Ibáñez, & Delgado-Kloos, 2018). In this work, we aim to expand this line of research by incorporating activities whose goal is not so clear but is still related to robotics learning. Therefore, in this work, we extend the line of research about STEM and creativity by studying how the impact of children designing a robot on their creative levels. Designing a robot, without actually needing to code it, can stimulate fantasy thinking. Additionally, there are infinite ways that children can use to design a robot, all of them equally correct, which makes this a more open-ended task than the ones presented during STEM. Therefore, the main contribution of this work is to assess, using validated measures of creativity, the impact that coding and designing a robot has on children's creative thinking. Additionally, we provide comparisons with a control group that consisted of a creative musical class, providing a fair comparison in terms of the impact on creativity levels.

Goal, Hypothesis, and Research Question

The main goal of this study was to investigate if existing activities for children that include robots (either real robots or designing a future robot) increase the creativity levels of children in comparison with artistic activities. Given this goal, the specific hypothesis for this study is that coding a robot (traditional STEM) and having musical classes will provide increases in the creativity of children. We consider that designing a robot an exploratory condition as little is known about the effects of design in children's creativity.

Therefore, we considered the following experimental conditions: i) *experimental condition of coding robots*: children learned how to code robots according to pre-defined activities; ii) *experimental condition of designing robots*: children learned how to design behaviors for robot prototypes without needing to code the behaviors; iii) *control condition*: children engaged in a music class. As such, the research question for this study is *can activities with robots increase children's creative abilities compared to artistic activities of music?*

Method

Participants

To estimate the sample size required for this study, an a priori power analysis was conducted using G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007). We considered the comparison of three independent groups using an Analysis of Variance (ANOVA) with repeated measures (pre-posttest), a medium effect size (f = 0.25), alpha of .05, power of .70, and a strong correlation between variables (r = .80). This power analysis showed that a total sample of 114 participants would be required.

A total sample of 150 children were involved in this study. The distribution of the participants across conditions was the following: eight participants were involved in the pilot testing, 43 were allocated in the code condition, 43 in the design condition, and 56 in the control condition. Three participants were excluded: one participant was excluded as he was diagnosed with autism spectrum disorder; however, the participant was involved in the experimental activities to avoid feelings of exclusion as the study was conducted in an inclusive school where children with special needs learn and play together with typically developing children. Two participants did not fill in the post-test, which made it impossible to analyze the effects of the intervention. Three different schools were involved in this study and each study condition was

Table 8. *Sample demographics, including gender, age, and grade distribution across conditions.*

	Total (N = 140)	**Code condition (*N* = 41)**	**Design condition (*N* = 43)**	**Control condition (*N* = 56)**	**Tests**
Gender	75F, 73M	18F, 23M	22F, 21M	32F, 24M	$\mathcal{X}^{2}$(2, *N* = 140) = 1.66, *p* = .435
Female	75	18	22	32	
Male	73	23	21	24	
Age (*M, SD*; Min-Max)	7.89, 1.51; 6-10	7.63, 1.34; 6-10	7.87, 1.26; 6-10	8.05, .80; 7-9	*F*(2,133) = 1.661, *p* = .194
Grade					$\mathcal{X}^{2}$(2, *N* = 140) = 31.85, *p* < .001
Moderate/Good	86	12	26	48	
Very Good/ Excellent	54	29	17	8	

performed in a different school.

A detailed description containing the demographics for each group is presented in Table 8. This table includes the distribution of children by condition, taking into account their gender, age, and grade. We used the grading system for Portuguese schools in which children are evaluated at the end of the semester with Poor, Moderate/Good, and Very Good/Excellent. Excluded participants and participants involved in the pilot testing were not included in the main analysis for this study.

Measures

We used the Test for Creative Thinking-Drawing Production (TCT-DP) to measure creativity at pre- and post-test levels using Forms A and B. TCT-DP is a well-established test in the field of creativity, applicable to persons of a broad age range, including children; it is culture-fair and helps to identify high creative potentials as well as low creative, neglected, and poorly developed ones (Jellen, & Urban,1986,1989; Urban, 2005. This test has been validated for the Portuguese adult population (Almeida, & Nogueira, 2010) and normative values were calculated for the young population (Nogueira, Almeida, & Lima, 2017c).

The TCT-DP test consists of a sheet of paper with six graphic elements of a circle, a dot, a dashed line, a 90-degree angle, a curved line, and a small open square, that are placed at fixed and pre-established locations on the page. All of the elements, except for the small open square, are enclosed in a large rectangular frame, and this forms a short of an incomplete drawing. The locations of the graphic elements are mirrored in the Form B compared to the Form A. Participants are instructed to *"complete the drawing that an artist started but has not finished"* (see the full transcription of the instructions in Appendix A). Collected drawings were coded according to a 14-point scoring system explained below (Urban & Jellen, 1996).

1. **Continuations -** Number of graphic elements used among the initial elements proposed;
2. **Completions -** Number of graphic elements used in a meaningful way;
3. **New Elements -** Number of new items added to the composition;
4. **Connections with lines -** Number of contacts established between the initial graphic elements;
5. **Connections made that contribute to a theme -** Degree to which the elements were connected thematically;
6. **Boundary-breaking being fragment-dependent -** Use of the element outside the frame;
7. **Boundary-breaking being fragment-independent -** Use of added elements outside the frame;

8. **Perspective -** Use of three-dimensional drawing techniques;
9. **Humor, affectivity/emotionality/expressive power of the drawing -** Creation of a humorist or emotional atmosphere;
10. **Unconventionality A -** Unconventional manipulation of the paper;
11. **Unconventionality B -** Use of abstract, surrealistic, fictional and/or symbolic themes;
12. **Unconventionality C -** Use of words, numbers, and/or cartoon-like elements;
13. **Unconventionality D -** Non-stereotypical utilization of fragments of figures.
14. **Speed -** Time for completion of the drawing. Speed response time is recorded; this was not possible for this sample because it was administered to a large group at one time. This procedure occurred in previous application of the TCT-DP, including applications made by the developers of this scale, suggesting that speed might not be a required variable to assess creative potential using TCT-DP (Dollinger, Urban, & James, 2004).

We started by exploring the presence of extreme values at baseline (pre-test values of TCT-DP). Results showed no extreme value and thus, no presence of outliers. TCT-DP test was also analyzed taking into account the two dimensions of Adaptiveness and Innovativeness (Nogueira, Almeida, & Lima, 2017a,b). Internal consistency of Adaptiveness and Innovativeness revealed to be good (α = .80 and .78, respectively). Internal consistency was also calculated at the pre- and post-test. Reliability was shown to have adequate values, indicating that our items are related and contribute to unique information (Streiner, 2003). We performed independent Analyses of Variance (ANOVAs), instead of one-way Multivariate Analysis of Variance (MANOVA) since these two dimensions are strongly correlated (pretest), $r(140) = .63$, $p < .001$. Moreover, ANOVA is considered to be robust for normality assumption violations, especially in the cases of large sample sizes, $p > 100$, and similarly sized groups (Blanca, Alarcón, Arnau, Bono, & Bendayan, 2017).

Two coders coded independently 30% of the data to establish an inter-coder agreement. Data was selected by using a website for randomizing lists[9] and coders were blinded to the study condition. Cohen's *k* was run to determine if the agreement after reconciliation between two coders on the analysis of Adaptiveness and Innovativeness of TCT-DP at pre- and post-test levels. There was a strong agreement on adaptiveness at both pre-teste, $k = .89$ (95% CI, 1.03, -0.75), $p < .001$, and post-test, $k = .85$ (95% CI, 1.01, -.69), $p < .001$. There was agreement on innovativeness at pre-test, $k = .617$ (95% CI, .82, - 0.41), $p < .001$, and a fair agreement at post-test, $k = .329$ (95% CI, .53, -.11), $p < .001$ (Altman, 1990; Landis & Koch, 1977).

Procedure

Participants whose parents had signed the consent form to participate in this study were invited to fill in a brief sociodemographic questionnaire that contained a question about their age and gender. Note that the grades of children, also collected in the scope of this study, were provided by the schoolteachers at the end of the study. Afterward, the TCT-DP Form A was handed to children. We initiated the intervention when all children filled in the test.

Children included in the experimental condition of coding a robot had the main task of learning to use Scratch language (Resnick et al., 2009) to give commands to the Dash and Dot robot[10] (see Figure 15). Children worked in small groups of 3-4 and were instructed to program a mail-delivery robot. This task consisted of writing lines of code to make the robot go from point A to point B, which were pre-defined in locations of the classroom (see Figure 15). Children

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[9] Randomizer website: https://www.random.org/

[10] Dash and Dot robots by Ardozia: https://ardozia.com/robots/

Figure 15. On the left: Close up on the Dash robot used in the code condition. On the right: Children using a tablet with Scratch programming language to code the Dash robot.

developed knowledge of geometric and mathematics since they had to make the robot turn (and thus, understand angles and distances). The activity lasted 45min and is a typical STEM task included in schools.

Children included in the experimental condition of designing a robot were instructed to think about different personalities for the robot, without needing to code the robot. To develop a personality for a robot, we relied on the Big Five Model of Personality, also entitled as the Five Factor Model developed by McCrae and Costa (McCrae, & Costa Jr, 1997), and on the correspondent NEO Personality Inventory Revised (NEO PI-R). In this model, personality is described according to five factors (Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to experience), each of these factors is a continuum with an opposing pole (Costa, & McCrae, 2010) encompassing several traits. Thus, Extraversion corresponds to a dimension that includes traits such as sociable, talkative, assertive, energetic; Agreeableness relates with good-natured, cooperative and trustful characteristics; Conscientiousness concerns with a disposition for control, self-discipline, and responsible;

Table 9. *Personality dimensions according to the Big Five Model of Personality (left column). Adaptation of the terminology for children (right column).*

Personality dimensions (and opposing poles)	**Adaptation of terminology for children**
Neuroticism (vs. Emotional stability)	Not used in this study
Extraversion (vs. Introversion)	Social (vs. Shy)
Openness (vs. Closedness to experience)	Imaginative (vs. Flat)
Agreeableness (vs. Antagonism)	Kind (vs. Grumpy)
Conscientiousness (vs. Lack of direction)	Not used in this study

Neuroticism includes traits such as nervous, unstable, and insecure; and Openness to experience with intellectual, imaginative, insightful, and curious traits (John, & Srivastava, 1999). The dimensions chosen for this activity with children were Extraversion and Agreeableness because they are the ones that are more related to the social facets of personality and, therefore, the ones that could be better captured in a social interaction with a robot. Also, we also selected Openness to experience because it includes traits related to creativity and we aimed to explore how children designed for this trait. As this terminology is very unfamiliar to children and used more technically within psychology, we adapted the trait concepts by using adjectives that were understandable for children. Therefore, Social and Shy to represented Extraversion and Introversion, Kind and Grumpy represented Agreeableness and Antagonism, and Imaginative and Flat represented Openness and Closeness to experience, and (see Table 9). This was the terminology used with children. Children were then assigned to produce movements for the personality dimensions using a low fidelity robot prototype in the form of a cube (see Figure 16). Children worked in small groups of 3-4 and were responsible for producing the movement for each personality trait together (see Figure 16).

Figure 16. On the left: Paper prototypes of robots used in the design condition were made using origami techniques and each cube was built with a mechanism that integrates a crayon inside so that children could represent the movements of the robot by drawing them in large paper sheets. We embed a crayon in one of the cube faces was a design methodology that motivated children to represent the robot's movements in a 2D space, avoiding movements in a 3D plane (such as flying and jumping) as real robots are not able to do so. On the right: Example of a trajectory performed by a child.

Children included in the control condition took a music class where they were invited to learn a new song and sing it. Additionally, children played instruments, such as the flute and performed musical rhythms using their bodies as instruments. The control condition for this study consisted of a creative activity to provide a fair baseline to the other two experimental conditions. When the activities were finished, children were invited to complete Form B of the TCT-DP with a similar instruction as the one provided for Form A.

Results

Effects of Group Conditions on Creativity

To compare the three group conditions (code, design, and control) on creativity (global, adaptiveness, and innovation) as a function of the phase (pre- and post-test), three independent two-way mixed analyses of variance (ANOVAs) 3 (groups: Code, Design, Control) X 2 (phase: pre-test, post-test) were conducted.

Results for the overall creativity scores showed a main effect of the phase, $F(1, 137) = 11.89$, $p < .001$, $\eta_p^2 = .08$, indicating that creativity increased from the pre-test

Table 10. *Values of TCT-DP according to study conditions at the pre- and post-test, compared to normative values for the Portuguese population (Nogueira, Almeida, & Lima, 2017c).*

	Code	**Design**	**Control**	**Normative values 7-8 years old**	**Normative values 8-9 years old**
TCT-DP pre-test (*M*, *SD*)	16.05, 9.68	16.23, 9.16	22.36, 11.66	23.3, 9.90	18.4, 8.00
TCT-DP post-test (*M*, *SD*)	21.39, 9.01	16.74, 9.05	25.14, 11.60	23.3, 9.90	18.4, 8.00

($M = 18.26$, $SE = 0.88$) to the post-test ($M = 20.92$, $SE = 0.86$). Additionally, the results showed a main effect of the group, $F(2, 137) = 7.91$, $p < .001$, $\eta_p^2 = .10$, indicating that participants in the control condition presented higher creativity scores ($M = 23.59$, $SE = 1.22$) than participants in the design condition ($M = 16.49$, $SE = 1.39$), p < .001, and in the code condition ($M = 18.68$, $SE = 1.43$), $p = .01$. No significant differences were found between the code and the design conditions, $p = .273$. Additionally, we compared the mean values of the TCT-DP test to the normative values for this population. As we can see by looking at Table 10, the values are in line with the norm for the Portuguese population (Nogueira, Almeida, & Lima, 2017c).

Results also showed that the difference between groups was present at baseline, suggesting that the control group was already higher in creativity potential before the intervention. Moreover, the interaction between the group condition and phase, $F(1, 137) = 3.08$, $p = .049$, $\eta_p^2 = .04$, indicated that the statistically significant increase in post-test from baseline was only found for the code group, $F(1, 137) = 14.21$, $p < .001$, $\eta_p^2 = .09$. For the other groups, the scores after the intervention were relatively similar to the baseline, *ps* > .05. Given the imbalance between groups in the creativity scores at pre-test, an additional one-way ANOVA was conducted to adjust for this baseline difference, by using a change score between the post- and the pre-test scores (higher scores correspond to higher increase from baseline). The overall

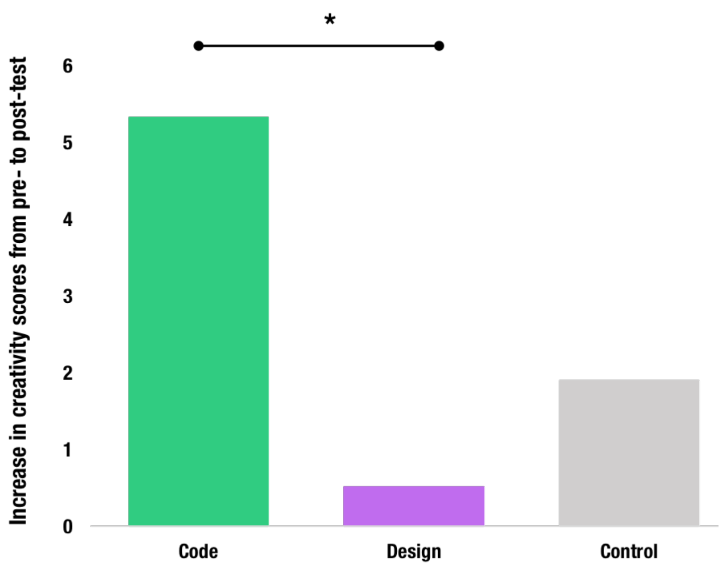

Figure 17. Changes of TCT-DP global scores from baseline to post-intervention as a function of group condition, *$p < .05$.

results of the one-way ANOVA was significant, $F(2, 137) = 3.08$, $p = .049$, $\eta_p^2 = .04$. The comparison between each level revealed that the creativity increase in the code group was significantly higher ($\Delta M = 5.32$; $\Delta SE = 1.41$) than the increase in the design group ($\Delta M = 0.51$; $\Delta SE = 1.38$), $t(137) = 2.44$, $p = .016$, but no statistical differences were found between these groups and the control condition (ΔM = 2.14; ΔSE = 1.21), *p*s > .05 (see Figure 17).

To better understand this decrease, we computed the means for each item of the TCT-DP considering the change in the scores between the pre- and post-tests. Results showed that the design group decreased creativity performance compared to baseline on the items CTH, PE, HU, and UCD and maintained the performance on the UCC item; the code group decreased creativity performance only on the HU item and maintained the performance on the BFI item; while the control group decreased creativity performance on the CM, UCB, and UCD items (see Figure 18 for a visual on these means).

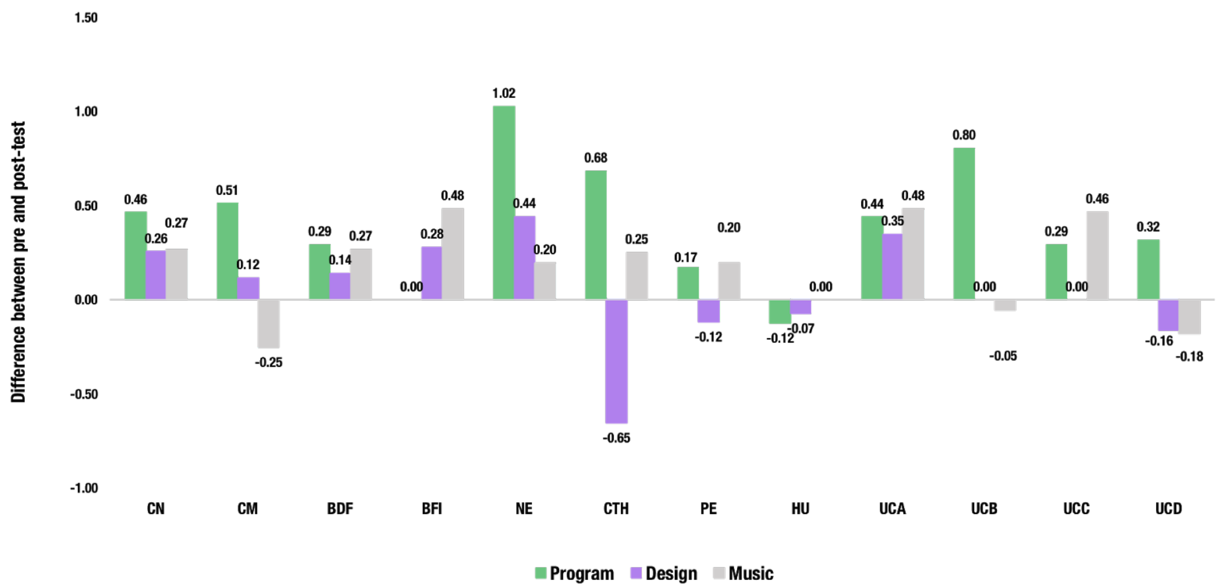

Figure 18. Difference between pre- and post-testing for each TCT-DP item. Items detail: CN - Continuations, CM - Completions, BFD - Boundary breaking being fragment dependent, BFI - Boundary breaking being fragment independent, NE - New elements, CTH - Connections made that contribute to a theme, PE - Perspective, HU - Humor, UCA - Unconventional manipulations, UCB - Symbolic, abstract, fictional, UCC - Symbol-figure combinations, UCD - Non-stereotypical utilization of fragments/figures.

The ANOVA 3 X 2 results for adaptiveness also showed a main effect of phase, indicating an increase in the adaptiveness scores from pre-test (M = 8.85, SE = 0.39) to the post-tests (M = 9.70, SE = 0.42), $F(1, 137) = 5.52$, $p = .02$, $\eta_p^2 = .04$. Again, we found higher scores on creativity in the control group compared to the other two groups. However, because these results were also found at baseline, we adjusted for this baseline imbalance, by using a change score between the post from the pre-test scores and running an additional one-way ANOVA. The results from this analysis revealed that the three groups were relatively similar in the increase in adaptiveness after the intervention, $F(2, 137) = 0.48$, $p = .621$, $\eta_p^2 = .01$ (see Table 11).

Table 11. *Mean values of TCT-DP dimensions adaptiveness and innovativeness across groups.*

	Code	**Design**	**Control**
TCT-DP Adaptiveness pre-test (*M*, *SD*)	7.78, 4.48	7.86, 3.88	10.91, 5.15
TCT-DP Adaptiveness post-test (*M*, *SD*)	9.07, 4.17	8.65, 4.24	11.36, 5.78
TCT-DP innovativeness pre-test (*M*, *SD*)	8.24, 6.77	8.37, 6.77	11.61, 7.99
TCT-DP Innovativeness post-test (*M*, *SD*)	12.27, 7.48	8.09, 6.47	13.48, 7.98

Regarding innovativeness, results also showed an increase from the pre-test ($M = 9.41$, $SE = 0.62$) to the post-test ($M = 11.28$, $SE = 0.63$), $F(1, 137) = 11.28$, $p = .001$, $\eta_p^2 = .08$. The interaction between phase and group showed a significant increase from baseline in both the control, $F(1, 137) = 4.60$, $p = .034$, $\eta_p^2 = .03$, and the code conditions, $F(1, 137) = 15.53$, $p < .001$, $\eta_p^2 = .10$. Similar to the results on adaptiveness, we found higher baseline scores on creativity in the control group compared to the other two groups. Thus, we adjusted for this imbalance by using a change score between the post from the pre-test. An additional one-way ANOVA using this change score in creativity levels revealed differences between conditions, $F(2, 137) = 4.55$, $p = .012$, $\eta_p^2 = .06$, and in particular between the code group ($\Delta M = 4.02$; $\Delta SE = 1.02$) and the design group ($\Delta M = -0.28$; $\Delta SE = 1.00$), $t(137) = 3.02$, $p = .003$. No statistical differences were found between these two groups and the control condition ($\Delta M = 1.88$; $\Delta SE = 0.87$), *p*s > .05 (see Figure 19).

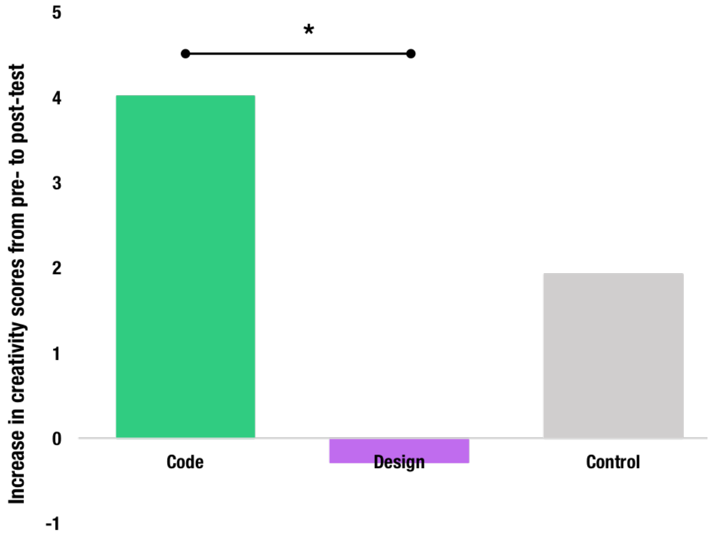

Figure 19. Changes of TCT-DP innovativeness scores from baseline to post-intervention as a function of group condition, $*p < .05$.

Discussion

The main aim of this study was to examine if creativity increased when children performed activities using robots (designing and coding robots) compared to an artistic music class. Children's creativity was measured using the TCT-DP test, which measures graphic-figural creativity in two dimensions of the creative thought: adaptiveness (related to conventional thinking) and innovativeness (related to non-conventional thinking). Results were analyzed taking into account the global score of TCT-DP and each dimension.

Regarding the global score of creativity, results showed an increase from pre- to post-test in all conditions. This result indicates a positive effect of interventions on rising creativity levels of children. By comparing our results with the normative values for this test in the Portuguese population (see Table 1), we can see that the values for all of our study conditions are somewhat aligned with the normative ones, with some values exceeding the normative mean, while others are inferior.

Results also showed that children in the control condition already had higher scores of creativity at the baseline level. After controlling for this unbalance by analyzing change scores, the results indicated that the increase in creativity was significantly higher in the code condition compared to the design condition. By looking at Figure 18 we can also see that the increase in the code condition is driven by an increase in TCT-DP items related to unconventional ways of thinking (namely the items NE, CTH, and UCs). This means that being involved in STEM activities that involve coding robots increases children's creativity levels related with unconventional thinking (or divergent thinking) which is important, since learning how to code have been massively incorporated in schools as part of their curriculum with the main aim of teaching children new ways to interact with technology. Our results thus suggest that such activities potentiate creativity levels in children, which can be considered a positive side effect of STEM.

When considering the two creativity dimensions of TCT-DP, adaptiveness and innovativeness, results showed that both adaptiveness and innovativeness increased from pre- to post-test, demonstrating that these two dimensions of creativity were stimulated in all groups. Given the multiple levels of analysis for this test, we have simplified these results in Table 2. When considering the interaction effect of the groups and phase on innovativeness, results showed a significant increase in control and coding conditions. However, the effect size for the coding condition appeared as higher than the effect size of the control condition. This seems to show a high magnitude effect of coding robots has on children's creativity. Moreover, since the control condition had higher creativity scores for both dimensions at baseline, we again performed analysis considering the variance of scores. Results showed a higher variance of scores in the coding condition compared to the design condition for the innovativeness dimension. No significant difference was found for adaptiveness. Therefore, the main gain in global creativity scores seems to be led by a gain in the innovativeness dimension. We recall that innovativeness is related to breaking limits, having humor, and the ability to think in perspective, contrasting with adaptiveness that is related to conventional thinking and manipulations (Nogueira, Almeida, & Lima, 2017).

It is thus interesting to see that coding robots stimulates innovativeness in children, more than designing robots. We associate this result to the nature of the coding task, in which children had to experiment by trial and error multiple ways of completing the coding activities, which in turn, stimulated aspects of non-conventional thinking. Despite the coding condition having higher creativity scores than control, this difference was not deemed significant. This seems to show that despite no difference was found, creativity levels were still high. Therefore, being involved in art-related activities (control condition) continues to be an effective way to potentiate creativity in children. This result was foreseen for the control condition, making it a fair benchmarking comparison to the experimental conditions.

Limitations

This study had several limitations that we would like to acknowledge. The first limitation concerns the experimental design of the study, which consisted of a quasi-experimental design study, as each condition was conducted in a different school. The reasoning behind this choice concerned the guidelines for ethics towards children when different interventions are involved in a study (e.g., to avoid participants that are included in the control condition to feel disappointed if they learn that their colleagues were involved in an experimental condition that is perceived as more interesting) (Lohan et al., 2017). The involved schools were private schools from the region of Lisbon and were comparable in terms of size (i.e., the number of classes per school year and the number of children in each class was similar) and tuition (i.e., similarly priced schools). Although we have tried to control for the school variables as well as children's variables, namely age, gender, and grades, there are still inherent differences between schools, such as the school culture, that could be influencing the results.

Another limitation of this study consisted of the nature of the activities between the experimental and control conditions. Children were organized in small groups in both experimental conditions, however, the control condition was performed in the context of a music class (thus, including the classroom as a whole and not dividing into smaller groups). As group effects are extensively documented in the literature (e.g., Karau, & Hart, 1998), large differences in group size as the one present in our study, could be influencing the results. Therefore, despite all the conditions were performed with groups of children, the groups were of different sizes and the interpretation of results should take this limitation into account.

Highlights

- STEM-like activities, such as coding and designing robots, impacts the creative potential of children.
- Activities with robots' impact children's innovativeness thought responsible for or non-conventional ways of thinking.
- This study shows the potential to use robots to nurture creativity.

Implications for this Thesis

This was our initial study to assess the potential to use robots as tools to be included in a creativity intervention. EE relied on pre-existing activities with robots, namely STEM activities in which children program and design a robot, to understand how their creativity levels vary. Our results showed the creativity levels of children increase and that the innovativeness way of thinking, which is related to non-conventional thinking patterns, was the most stimulated during the robot activities. This result per se gave us a solid indication that integrating robots in creativity practices could provide effects om children's creativity. With this result in mind, we decided to then build our robotic character. Details about the design, fabrication, and development of the robot are present in the next Chapter of this thesis.

Chapter 5. Designing, building, and programing YOLO, a robot for creativity

This chapter is based on the following papers:

Alves-Oliveira, P., Arriaga, P., Paiva, A., & Hoffman, G. (2019). Guide to build YOLO, a creativity-stimulating robot for children. *HardwareX*, *6*, e00074. doi:10.1016/j.ohx.2019.e00074

Alves-Oliveira, P., Gomes, S., Chandak, A., Arriaga, P., Hoffman, G., & Paiva, A. (2020). Software architecture for YOLO, a creativity-stimulating robot. SoftwareX (accepted)

Alves-Oliveira, P., Arriaga, P., Paiva, A., & Hoffman, G. (Under review). Children as Robot Designers (submitted to CoDesign Journal).

Abstract

Intending to stimulate creativity in children using a robot, we have designed, programmed, and fabricated YOLO. YOLO is a non-anthropomorphic social robot for children specifically developed for storytelling activities, in which the robot acts as a character. To stimulate creativity, YOLO makes use of creativity techniques that promote the creation of new storylines that would not emerge otherwise. Therefore, it is during the interaction between children and the robot that creativity can be stimulated. Particularly, YOLO can stimulate divergent and convergent thinking for story creations. In addition to YOLO's creativity techniques, this robot shows different personalities, providing it with a rich landscape of behaviors for immersive play and character-building. The design of the appearance and behaviors of YOLO was informed by: (1) psychological theories and models on creativity and personality, (2) design research including user-centered design practices with children, (3) interviews with creativity experts that work with children in improvisation. The end product was a robot that interacts with children using minimalistic social signals to communicate intentions during story creations. The non-verbal expressive modalities of YOLO consist in the expression of lights and movements. The timing in which these behaviors are expressed have the potential of increasing divergent or convergent thinking during story creations. In this Chapter, we detail on the software and hardware of YOLO.

Keywords: Robot, design, hardware, software

Introduction

Children are avid explorers, using objects to play and learn about the world (Piaget, 2013; Smith, 2017; Vygotsky, 1967). Toys play are essential objects in children's lives since they are always present during their favorite plays, being this especially true for pretend play (e.g., storytelling) (Sutton-Smith, 1986). The usage of toys during play have shown to be related to healthy cognitive, emotional, and physical development (Healey & Mendelsohn, 2019; Singer, 2009). A child who does not explore and play is often identified by parents and childhood professionals as a child at risk (Cecil, Gray, Thornburg, & ISPA, 1985). As play involves the transformation of people, actions, and scenes, into objects (or toys), *creativity arises within interaction and representation of toys as characters in play*; demonstrating how the concepts of *play*, *toys*, and *creativity* is intricately intertwined (Schwartzman, 2012).Indeed, it is in the alignment of toys and play that creative narratives emerge (Sutton-Smith, 1992). As toys are used as artifacts for children's imagination, they serve as stimuli whose intent is to *trigger creativity* and other cognitive skills important to be stimulated at this young age (Berlyne, 1960; Piaget, 2013).

Different types of play behavior are reported in the literature (Rubin & Howe, 1985; Whitebread et al., 2017). These are *physical play* (the earliest type of play that includes rhythmic stereotypies, exercise play, and is often called "rough-and-tumble" play) (Bjorklund & Brown, 1998; Brussoni et al., 2015; Pellegrini & Bohn, 2005; Pellegrini, & Smith, 1998; Pellis & Pellis, 2013), *play with objects* (or sensorimotor play; starts when children learn how to grasp objects and include mouthing/biting and later on making and constructing behaviors emerge) (Stroud, 1995), *symbolic play* (or semiotic play; usage of various symbolic representational systems we use to make and communicate meaning, such as making sounds and drawing) (Christie, &

Roskos, 2006), *pretend play* (include activities characterized by “as-if” moments, or a “pretense” is layered over reality during play) (Lillard et al., 2013), and *games with rules* (describes more organized forms of play in which there is some clear and publicly expressed goal) (DeVries, 2006; Boyle et al., 2016; Hassinger-Das et al., 2017). From these types of play, pretend play is the one most associated with creativity expansion (Mottweiler, & Taylor, 2014; Wallace & Russ, 2015; Hoffmann & Russ, 2016). In this work, we will use storytelling with children as the main activity for creativity stimulation, therefore, contributing to research on pretend play styles.

A new generation of technological objects is joining the more traditional set of toys, including smart-phones, tablets, virtual and augmented reality devices. Research shows that children are using smartphones, tablets, and computers as their toys as they are immersive and playful elements that engage children (Lee, 2012). Additionally, virtual reality is another effective playful media for children, offering a 3D interactive environment to play, learn, and potentially develop skills (Harris, & Reid, 2005). Virtual reality has been extensively used to explore new contexts of play as children literally feel placed in the scene and become actively engaged with the surrounding environment. In line with this, augmented reality has been used as a medium for promoting pretend play (Bai, Blackwell, & Coulouris, 2012), enrich gaming experiences (Tan & Soh, 2010), and as a new asset for contexts of learning (Akçayır & Akçayır, 2017; Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014; Ibáñez & Delgado-Kloos, 2018; Phon, Ali, & Halim, 2014; Radu, 2014). Taken together, the opportunities offered by digital devices to children allow for moments of fun and relaxation, to share materials with friends, and are a pleasurable way to pass the time when children are by themselves (Livingstone, Marsh, Plowman, Ottovordemgentschenfelde, & Fletcher-Watson, 2014).

Despite the positive experiences associated with these technologies, research reports that children are engaging in excessive screen-time (Bucksch et al., 2016), which means they are spending too much time in sedentary activities, such as being seated in front of the tv, tablet, computer, or smartphones (Inchley et al., 2016). However, physical activity is one of the most important activities at all ages, especially during childhood, providing benefits in health (Janssen & LeBlanc, 2010; Mnich, Weyland, Jekauc, & Schipperijn, 2019) and learning (Sneck et al., 2019). Although some digital games have been designed to afford some degree of physical activity, such as movements of the upper/lower body (Biddiss, & Irwin, 2010), children are still restricted to a small and limited space and perform activities that are somewhat unnatural (e.g., raise your arms to fetch an apple in the tree, although neither the apple nor the tree exists in reality. Robots enter as a new type of technological artifact that co-exists in our physical space and is guided by the same laws of physics and time. These shared experiences make robots a special type of technology that can be used in physical activity promotion. While some robots have been developed as physical exercises coaches these target older populations and not children (Lotfi, Langensiepen, & Yahaya, 2018); robots for children are usually stationary as they are power-outlet dependent, or due to their sensitive hardware which does not allow for unrestrained manipulations that happen during playtimes. The potential of using robots as tools for unrestrained play appears to be scarce or non-existent. In this Chapter, we will present the design, fabrication, and programming of a robot meant to be used by children during unrestricted storytelling spaces.

Figure 20. Roadmap of the work performed to develop YOLO included designing, building, and programming (coding) the robot. This was a two-year long iterative process that included a total of 134 children at all stages.

Our contribution

This Chapter presents the development of a social robot that can benefit children's creativity during playtime. It is divided into three main sections, which correspond with the tree main stages of the robot development. These are the *design*, *building*, and *programming* of YOLO robot (see Figure 20). Children were included at all stages of the development of YOLO, from co-design partners, to testers and users of the robot. This consisted of a two-year-long field design research, involving 134 children, and adopting a multidisciplinary approach in which a team of psychologists, computer scientists, mechanical and electrical engineers, designed a robot together. During this time, the robot was refined on its hardware and software according to the results from studies with children, but also taking into account theoretical models from psychology and design research. In particular, we relied on models of creativity and personality to develop YOLO. A third input for the robot's design came from experts and practitioners of creativity activities with children, who detain functional knowledge about strategies of interaction with children that can foster their creativity levels.

The challenge here was to accommodate the different knowledge sources into the design of a robot. To do so, we have developed novel methodologies of participatory design that would accommodate children. This meant that interviews or open questions in written formats were taken aside as they were not well suited for 7-year-old children as a form of data collection. We, therefore, created new forms of participatory design practices, based on playful interaction modes, to bring children at the heart of design and robot testing. The end result of this effort was a creativity-provoking robot called YOLO that is both robust and playful for children to play with. We now detail on the design, building, and programming of this robot.

Designing YOLO

In this section, we detail the process of designing a social robot *for* and *with* children. During the design process, children were placed at the heart of all the design stages as informants, users, experts, and design partners (Druin, 2002). We have adopted User-Centered Design (UCD) practices as these give voice to human needs, capabilities and behaviors, and can lead to increasingly usable and valuable products (Norman, 2013). Designers of social robots are often hard-pressed to include users in meaningful ways in the design process yet bring them in only during later stages of evaluation, when most of the design choices have been implemented (Tsvyatkova & Storni, 2019). At this moment, a few aspects of the robot design can be changed as major design decisions have already been taken without the users' input. The reasons behind including users so late in the design process related with the following: (1) working through a *long iterative process within a multidisciplinary team* presents challenges, e.g., each field has their own technical language which can make understanding between different teams hard to accomplish; (2) the *novelty of the robot* device can provoke modes of interaction that will change over time. This means that the novelty effect that users feel when testing a type of technology they are interacting with for the first time on their lives (such as social robots) does not provide a fair representation of a long-term interaction, which leaves designers with biased data; (3) there is a *hard-to-strike balance between engineering development and user experience research*, as methods for eliciting informative feedback from users over robot prototypes are scarce. This is especially true for certain populations, such as children. This means that, e.g., asking users what they want it not always the most informative feedback for technology improvement; (4) it can be *challenging to have representative users* and frequently the technology is tested with users that do not map the end-users for which the technology was developed for, e.g., adults test technologies that are meant to be used by children (Damodaran, 1996; Gulliksen, Lantz, & Boivie, 1999; Grudin, 2017; Schuler & Namioka, 1993). With children, there are additional challenges in finding user-centered methods that account for their developmental stages and that can empower their expressive and communicative abilities within the design process. This reveals a need to develop new methods and tools for involving children in the design process, especially when designing social robots that are meant for them. The major contributions of this work are the *description of the design process* of a robot for creativity stimulation according to specific *design principles* that were used according to the Double-Diamond Design process Model (Council, 2013). Taking into account our design experience with children we have derived *design guidelines* for designers that aim to include children in the design of social robots.

The resulting product was a small, lightweight, and non-anthropomorphic robot. It affords free play due to its internal power system not constraining interactions to be stationary as the robot is not power-outlet dependent. An optical sensor placed at the robot's base tracks play movements, and a capacitive sensor around the robot's body determines if children are touching it. According to the movement generated by children during the story, the robot can provide new storylines using movement and lights (see Figure 1).

Background

Robots for children. Research on social robotics for children can be divided into three major design categories: off-the-shelf robots, robotic design kits, and robots that emerged from design research. Off-the-shelf robots are used as pre-designed research platforms (often designed for adults) that can be programmed for a particular research goal. Examples of research that used commercial robots for children, included the NAO (Serholt, 2018) and Pepper robots (Tanaka et al., 2015), Jibo (Kory-Westlund & Breazeal, 2019), Cozmo (Druga, Williams, Park, & Breazeal, 2018), Zeno (Cameron et al., 2015), KASPAR (Wood, Zaraki, Robins, & Dautenhahn, 2019). Keepon (Shen, Slovak, & Jung, 2018), etc.

Robotic design kits are used as tools to foster learning in different knowledge domains. This category falls into Digital Manipulatives (Papert, 1980), defined as computationally enhanced versions of traditional toys for children, used as new tools for learning and growing (Resnick, 1998; Resnick et al., 1998). Examples are LEGO® Mindstorms, a commercially available design kit that derived from research. It includes concepts from Programmable Bricks (Resnick, Martin, Sargent, & Silverman, 1996) Magix (Ackermann, Strohecker, & Agarwala, 1997; Ackermann & Strohecker, 1999), Block Jam (Newton-Dunn, Nakano, & Gibson, 2003), Topobo (Raffle, Parkes, & Ishii, 2004), Smart Tiles (Elumeze & Eisenberg, 2005), Digital MiMs (Zuckerman, Arida, & Resnick, 2005,), Boda Blocks (Buechley & Eisenberg, 2007), Thymio (Vitanza, Rossetti, Mondada, & Trianni, 2019), and others (Schweikardt & Gross, 2007). The overarching idea is that through the process of building these kits, they become instruments for children to think and understand the world.

Robots derived from design research include children in some edges of the design process. For example, with Shybo robot, children (and their parents) were involved from early stages in the design process, informing the application scenario for this robot through the use of surveys. In addition to this, children were also testers of the final prototype participating in field studies in school to investigate if the robot met the initially established design requirements. While storyboard sketching, low-functioning, and low-fidelity prototypes of Shybo were developed, children were not included in these design stages (Lupetti, 2017; Lupetti, Yao, Mi, & Germak, 2017). Another example is the involvement of children in the design process of Ranger (Fink et al., 2014) and Cellulo (Özgür et al., 2017; Özgür, 2018). In these cases, researchers used the Wizard-of-Oz (WoZ) technique to inform interaction between children and robots. WoZ is a technique often used in HRI in which a human is hidden and controlling the robot, while the robot us interacting with users without their awareness that a human is “behind the curtain” (Riek, 2012). With the design of Curlybot, children were invited as testers of the final technology to study learning-oriented acquisitions (Frei, Su, Mikhak, & Ishii, 2000). Overall, despite children being included in some stages of the design process, robots designed to be used by children are still very much in the hands of researchers. As mentioned earlier, one of the reasons behind this relates to the gap of acceptable design research methods between different fields of research that is required to co-exist for a positive design outcome (Luria, Zimmerman, & Forlizzi, 2019). In the case of our robot, it was developed using design research as many of the implemented methodologies come from UCD.

Additionally, robots vary in their appearance and behaviors, depending on the application scenario for which they were developed. While Erica robot was designed to have human-like features such as eyelashes and lips (Glas, Minato, Ishi, Kawahara, & Ishiguro, 2016), other robots can have cartoon-like features with exaggerated eyes and expressions, such as Kismet (Breazeal, 2003), or have abstract shapes such as Kip (Anderson-Bashan et al., 2018; Zuckerman et al., 2016) Their behaviors can incorporate natural language speech (Kahn Jr et al., 2012), emotional expression (Paiva, Leite, Boukricha, & Wachsmuth, 2017), and artificial communication modalities using lights (Baraka & Veloso, 2018), motion (Knight & Simmons, 2016) sound (Moore, Tennent, Martelaro, & Ju, 2017; Tennent, Moore, Jung, & Ju, 2017), multi-modal displays (Löffler, Schmidt, & Tscharn, 2018), among other additional non-verbal behaviors (for a survey see Cha, Kim, Fong, & Mataric, 2018). Social robots for children have been used within a variety of application scenarios, from learning (Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018; Benitti, 2012; Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013; Spolaôr & Benitti, 2017; Toh, Causo, Tzuo, Chen, & Yeo, 2016), assistance and rehabilitation (Boucenna et al., 2014; Diehl, Schmitt, Villano, & Crowell, 2012; Pennisi et al., 2016; Rabbitt, Kazdin, & Scassellati, 2015; Scassellati, Admoni, & Matarić, 2012; Tejima, 2001), and play (Leite et al., 2010; Lupetti, Yao, Mi, & Germak, 2017; Robins et al., 2010; Robins et al., 2012; Short et al., 2014; Zaga, Moreno, & Evers, 2017). They have been used in different contexts, such as at home (Scassellati et al., 2018), in school (Alves-Oliveira, Sequeira, Melo, Castellano, & Paiva, 2019; Kanda, Hirano, Eaton, & Ishiguro, 2004) and within organized activities in the format of outreach (Ruiz-del-Solar, 2009) and workshops (Magnenat, Riedo, Bonani, & Mondada, 2012) for children. The interaction can occur individually or within groups (Correia et al., 2019), and can range from a short-term to interactions that last extended periods of time (Leite, Martinho, & Paiva, 2013; Westlund, Park, Williams, & Breazeal, 2018). In the case of our robot, it was designed with an abstract shape and uses corresponding minimal behaviors with lights and movements to interact with children.

Design process of social robots. The design process of social robots oftentimes is an iterative process that takes into account the robot's context of use, application scenarios, physical embodiment, and interactive behavior (Mast et al., 2012; Šabanović, Reeder, & Kechavarzi, 2014). These variables deeply influence and inform the design process and are described below.

1. **Context of use -** Designers usually evaluate the which needs are not met by observing interactions or daily routines taking place in real-world contexts. This technique is known as *need-finding* (Patnaik & Becker, 1999). To assess the users' needs, techniques such as direct observation, in-situ interviews, and focus groups, are used to explore the design space for a robot (Martelaro & Ju, 2019; Mutlu & Forlizzi, 2008; Pantofaru & Takayama, 2011). The findings from this stage enable meaningful and effective robot design by highlighting the needs of users in real-world contexts.
2. **Application Scenario -**Given the knowledge gathered about the users' needs, specific scenarios are proposed and developed. Robot designers perform brainstorming sessions to generate creative solutions that meet users' needs (Byrne & Barlow, 1993). Story-boarding and sketching help to narrow down solutions, providing a way to visualize and understand the interactive behavior between a user and a robot (Azenkot, Feng, & Cakmak, 2016; Kuo, Jayawardena, Broadbent, & MacDonald, 2011; Lupetti, 2017; Truong, Hayes, & Abowd, 2006).
3. **Physical Embodiment -** Different techniques have also been used to explore the two most important features of a social robot's identity: embodiment and movement. Sketching is one of the techniques used (Diana & Thomaz, 2011; Gomez, Szapiro, Galindo, & Nakamura, 2018; Hoffman, Zuckerman, Hirschberger, Luria, & Shani Sherman, 2015; Luria, Hoffman, Megidish, Zuckerman, & Park, 2016; Obaid, Barendregt, Alves-Oliveira, Paiva, & Fjeld, 2015), along with 3D animation studies (Hoffman & Ju, 2014; Ribeiro & Paiva, 2012) and rapid prototyping techniques (Lee et

al., 2009), to explore shape and movement design. At the end of this stage, robot designers have a clear idea about the embodiment of the robot and possible interaction scenarios.

4. **Interactive Behaviors -** To guide the algorithm design for the artificial intelligence of a social robot the WoZ technique is often used to simulate social interactive behaviors between a human and a robot and discover which behaviors are beneficial and thus worth exploring (Hoffman, 2016; Martelaro, 2016; Martelaro, & Ju, 2017; Sequeira et al., 2016; Wang, Sibi, Mok, & Ju, 2017). These are joined by different techniques, such as embodied improvisation, storyboarding, puppeteering, video prototyping (Hoffman et al., 2015; Hoffman, & Shamir, 2015; Sirkin & Ju, 2015; Slyper, Sirkin et al., 2016; Spadafora, Chahuneau, Martelaro, Sirkin, & Ju, 2016; Tennent, Moore, & Ju, 2018), and develop interaction patterns (Sirkin, Mok, Yang, & Ju, 2015).
5. **Evaluation –** The last stage of a robot design process finishes with a final evaluation and final testing of the robot, sometimes including end-users of the technology. The testing of robots designed for children has been performed at university labs (Kahn Jr et al., 2012) and in real-world contexts (Kanda, Hirano, Eaton, & Ishiguro, 2004), with this latter increasing the external validity of the evaluation results (Baxter, Kennedy, Senft, Lemaignan, & Belpaeme, 2016).

As mentioned before, despite this wide range of design approaches for social robots, users are not systematically included in all design stages. In the majority of the cases, users collaborate only during the evaluation stage, rarely prevailing for the entire process of design process (Jensen & Skov, 2005). Including users in the design process aligns with critical design principles intended to engage them into thinking, exploring ideas, and challenging assumptions, leading to user empowerment (Bardzell, Bardzell, Forlizzi, Zimmerman, & Antanitis, 2012; Bardzell, & Bardzell, 2013). However, critical design research is scarce when considering designing social robots. The novelty of this work lies in the dedication of the design process to children by considering their ideas and views at all design stages. Additionally, most of the methods for designing robots primarily rely on character-building-professionals, such as actors (Knight, 2011) and dancers (Ros & Demiris, 2013), or include adult populations during the design process. This leaves children with fewer opportunities to participate in the design process of a robot that is actually meant to be for them (Fails, Guha, & Druin, 2013). Our work lies on UCD practices for a full design process of a social robot, by systematically and directly involving children in all design stages through participatory design methods. This methodology gives children voice during the design, which is aligning with critical design (Bardzell, & Bardzell, 2013).

Participatory design and children. Participatory design (PD) is a method from user-centered design (UCD) research that empowers users during a design process (Schuler & Namioka, 1993; Simonsen & Robertson, 2012; Veale, 2005), leading to meaningful, approachable, and joyful products or experiences (Norman, 2013). Most PD methods applied with children grew out of or built on ideas from PD practices for adults (Fails, Guha, & Druin, 2013). However, children have different cognitive, motor, emotional, and communication abilities (Gruber & Vonèche, 1977; Thompson & Goodvin, 2005), requiring adaptation of PD methods. Traditional media used in PD, such as interviews and questionnaires, are usually not the best approach with children (Druin, Stewart, Proft, Bederson, & Hollan, 1997), even when these assessment metrics were deliberately developed for this young age group (Fuchs, 2008). Drawbacks associated with these metrics relate with characteristics of children (e.g., cognitive abilities vary considerably across age-related children), characteristics of the questionnaire (e.g., complexity and length of the question, and the number of response categories), and interview characteristics (e.g., richness of children's vocabulary to properly articulate responses) (Borgers & Hox, 2000; Fuchs, 2008). Other methods, such as brainstorming, can be used both with adults and children, but the cognitive level of a child may mean that abstract concepts need to be explained in a concrete manner. This is why brainstorming sessions with children benefit from tangible objects for ideation. In the literature, children have been included in PD practices for interactive technologies design under a few different roles, such *as user, tester, informant, and design partner* (Druin, 2012) and more recently as *co-researchers* (Van Doorn, 2016), and *protagonists* (Iversen, Smith, and Dindler, 2017). For the development of our robot, we involved children in the majority of these roles, such as informant, user, tester, and design partner.

Design principles

Based on prior work in the constructivism school of thought, in creativity and design research, we identified a set of principles that guided the design of YOLO robot.

- ***Design principle 1: Low floor, wide walls.*** Technology is considered to have "low floor and wide walls" when it is easy for novices to get started without requiring an entirely new skill set to perform the task (low floor), and when it supports the exploration of a wide variety of projects (wide walls) (Resnick & Silverman, 2005). This can be achieved by designing few and specific behaviors for the robot that promote quick understanding and engagement; this encourages positive first interactions with the robot that lead to further explorations.
- ***Design principle 2: Creativity provocations.*** Prior work has shown that divergent thinking, together with convergent thinking, are essential forms of the creative thought,

and that more studies on convergent thinking should be encouraged since convergence can lead to tangible solutions (Cropley, 2006). Using robots to provoke higher levels of creativity requires implementing validated techniques or programs from the psychology literature whose effectiveness has been proven (e.g., Smith, 1998).

- ***Design principle 3: Open-ended playfulness.*** According to Piaget, "play is the work of children" (Piaget, 1971), as this constitutes their central daily activity used to learn, explore, and connect with the world around them and with others. Open-ended play are environments specifically supportive of creativity as they trigger fantasy, imagination, and make-believe (Krafft & Berk, 1998; van Hoeve, De Valk, & Bekker, 2013).
- ***Design principle 4: Abstraction as disappointment avoidance.*** When human expectations of social robot capabilities are not met, they tend to feel the robot let them down (Cha, Dragan, & Srinivasa, 2015; Kaplan, 2005;). Disappointment is especially evident when interacting with anthropomorphic robot whose physical appearance does not match its social capabilities, e.g., the robot has eyes but cannot "see" (Choi & Kim, 2009). Designing for abstraction mean that the abstract physical appearance of the robot does not compromise its social abilities, which are instead discovered in the process of interacting with the robot.

Building in these four principles, the YOLO robot was designed as follows: To create a low floor, we designed a robot has a limited number of features, which are simple and specific, and that enable children without any previous experience with it to create a story. To create wide walls, we designed the behaviors for the robot that are non-directional and that allow for the creation of varying story topics and content. To provoke creativity, we focused on two techniques that allow for the stimulation of divergent and convergent thinking used by the

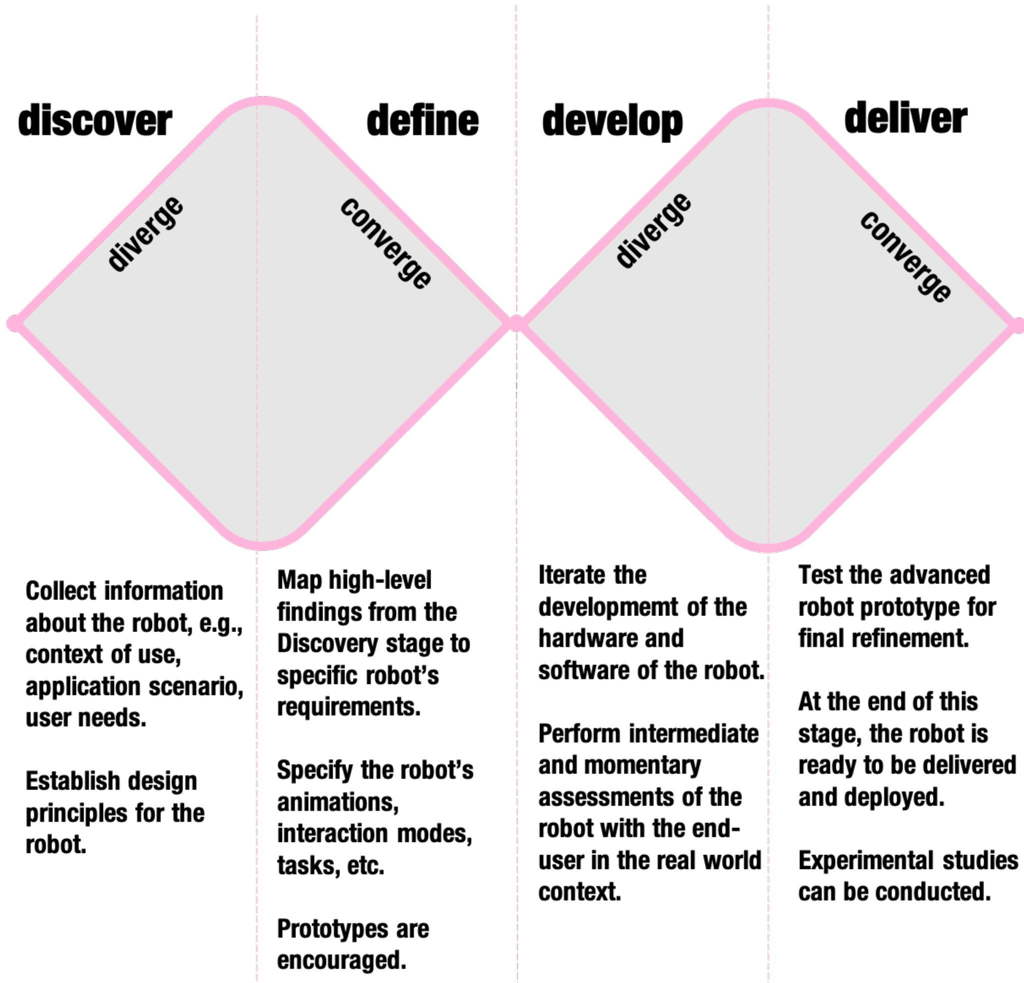

Figure 21. Design process applied to Human-Robot Interaction, based on the Double-Diamond Design Process Model that incorporates four main iterative stages: discover, define, develop, and deliver (Council, 2005; Norman, 2013). The design process used formative research, in which intermediate assessments with end-users in real-world context of interaction are conducted. Experimental controlled studies to validate the effectiveness of the robot are optional and when included can complement the Deliver stage. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).

robot at specific stages of the storytelling; this enables the elaboration of a given story idea (convergent thinking) or moving towards a plot twist (divergent thinking). Open-ended play was ensured for the storytelling activity as children were allowed to create a story about any theme they desired and had no time limits. The openness of the story theme was possible as children are familiar with the structure of stories, which provided them with some structure to for creativity and imagination. To avoid disappointment when interacting with the robot, it was designed with physical affordances that would map its actual capabilities.

Additionally, to design our robot, we evoked several participatory design practices that involve children as active contributors from early design stages to the final consumption of the robot as users. The use of a child-centered approach rests on several identified design principles that made the design process successful: *object choice*, *playfulness*, *child spaces*, and *child policies*. We used objects appropriated to children, such as toys and craft materials, to create our design tools. Playfulness was at the core of all activities to stimulate children's expression and communication. Familiar spaces, such as school playgrounds and schoolyards, were the stage where the design process unfolded. Child policies related to ethical, legal, and administrative aspects, were considered from the beginning as influential factors for method and tools choice during studies. Our child-centered design practices proved to be efficient in improving the design of a robot given children's feedback, having also been an empowering process for children as the design decisions reflect their needs and desires.

Design Process of YOLO, a Robot for Creativity Enhancement in Children

Our design approach for the YOLO robot is based on the Double-Diamond Design Process Model (Council, 2005; Norman, 2013) which maps the UCD onto four stages: *Discover, Define, Develop,* and *Deliver*. Table 12 shows how children's design roles map onto the established Double-Diamond Design Process Model, and how it relates to the various research activities that children undertook. Figure 21 presents the same model but generalized for the field of HRI. We now detail on each of these four design stages.

Discovery with Experts, Theory, and Observation. The first stage of the Double-Diamond Design Process was "Discover", where basic insights about the problem are collected.

In our work, the goal of this stage was to investigate how creativity unfolds and what practices can be applied to stimulate it. We used a three-fold approach, which included interviews with creativity education experts, an extensive literature review of theories of creativity, and direct observation of children during playtime, described below.

- **Expert Interviews and Observations -** We conducted semi-structured interviews and direct observation of two creativity education experts that teach dance and theatre improvisation classes to children. Our goal was to understand the methods they use to stimulate creativity during these activities. We discovered that creativity occurs through structured but open-ended activities framed with playfulness (Zaporah, 1995). A common aspect of every creative activity was the emergence of stories to facilitate the creative process of children. The design decision for this stage was the choice of a creative storytelling as the activity to include a robot in children's playtime;
- **Literature Review -** We conducted a systematic review of validated techniques for creativity training with children (see Chapter 2). The design decision for this stage concerned the adoption of two techniques for creativity stimulation to be implemented as part of the behavior of the robot. The techniques chosen were the *Contrasting* and *Mirroring* techniques (Smith, 1998). Both of these techniques relate to idea generation, a core aspect of story creation. While the Contrast technique stimulates divergent thinking, the Mirror technique is responsible for the development of convergent thinking. Both are required to establish the emergence of creativity (Lubart, 2001), rather than the more basic act of unregulated self-expression (Cropley, 2006).

Table 12. *Design Process of the robot according to the Double-Diamond Model of Design (Council, 2005), describing the roles of children (Druin, 2002), study goal and type, methods and tools used (Fails, Guha, & Druin, 2013), and major outcomes of the user-centered design with children. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).*

	Stage I: Discover	**Stage II: Define**	**Stage III: Develop**	**Stage IV: Deliver**
Role of children	Informants	Design partners	Testers	Users
Study goal	Investigate the emergence of creativity and how it can be stimulated.	Involve children in the design of the social behaviors during storytelling.	Improve and refine the robot's AI and physical shape.	Final evaluation of a creativity stimulation robot for playtimes.
Study type	- Expert interviews and observation; - Literature review; - Observation.	- Co-design with children	- Refinement of the robot Software; - Refinement of the robot physical embodiment.	- Validation of social behaviors for storytelling; - Validation of creativity techniques for story creations.
Methods and techniques	- Interviews; - Systematic review; - Behavioral observation.	- Sketching; - Puppeteering; - Body-storming.	- Co-discovery; - Direct observation; - Active involvement.	- Cards; - Drawing; - Behavior observation.

Outcome	- Storytelling as the activity for creativity stimulation; - Contrast and Mirror as the creativity training techniques for the robot; - Personality as the basis for the robot's social behaviour to increase story narratives.	- Identification of behaviour patterns designed by children as input for the design of the robot's behaviour.	- Selection and refinement of behaviors for the robot to improve the software; - Adaptation of the robot's physical shape to children's play manipulations.	- Preliminary results show the positive effect of the robot in stimulating creativity during play; - Drawing; - Behavior observation.
Design decisions	An affordance for grabbing in the form of an asymmetric concavity was added to the initial cube shape of robot.	Children used personality characteristics to animate their characters, thus personality was used as the basis for the interactive behavior of the robot.	The robot's size was ergonomically molded to children's hand size; a selection of efficient interactive behaviors for the robot was made based on children's play.	Preliminary results suggest the robot was used by children as a character for their stories, and that this may increase their creativity levels.

Figure 1. Iterative prototypes of the robot designed developed during the design process. *Left to right:* (1) early hand-ketches capturing movement analysis; (2) paper prototype to explore the size and mechanisms; (3) first actuated prototype; (4) second actuated prototype; (5) three different passive robot stand-ins for size and grasp studies; (6) final version of the robot. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).

- **Direct observation of children during playtime -** We conducted a field study in a school setting using direct observation with video recordings for post-observation, to understand how small groups of children create ideas together in a storytelling context. 13 children (4 female, 7-10 years old) organized in 4 groups (three groups of 3 children and one group of 4) participated in this study. Hand-made toys with the geometric shape of a cube were chosen as story characters due to their abstractness and to ensure uniformity in the children's experience (see Figure 22). We observed each group for about 30 minutes, with a total observation time in school of 2 hours. This study provided two outcomes. The first outcome concerned the unstructured nature of storytelling play, for which children oscillated between highly creative moments of divergent thinking showing thunderstorms of ideas, to creative moments of convergent thinking, translated by meaning making where ideas for their story were selected and narrowed down. This led to the design decision of having an open-ended story as the playful activity for

Figure 2. On the left: children using cube-toys as stand-ins for group storytelling creation during a free play activity. This study was part of the observation of children's playful behavior in which groups of children used the cube-toys as their characters during stories. On the right: body-storming session in which children expressed different personalities traits using only their bodies and refraining from using words. This primed them to use motion to illustrate their ideas, e.g., they enacted personality traits, such as "grumpy", as can be seen in the figure. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).

children and the robot. The second outcome related with the usage of personality attributes as the basis to design the social behavior for the robot. When creating new narratives for their story, children continued using personality traits to animate their cube-toys. To provoke more storylines when children play with the robot, we took the design decision of implementing a more extrovert or introvert personality into the robot as an expression of its social behavior. This finding goes in line with theory about creativity stimulation, in which creativity and personality are known to be interconnected variables when facing a creative situation (Batey & Furnham, 2006; Feist, 1998).

Definition through Body-Storming, Puppeteering, and Drawing. The second stage of the Double-Diamond Design Process is "Define", which focuses on specifying details of the design requirements. In our work, the goal of this stage was to translate the high-level findings from the discovery stage into specific requirements for the development of the first robot prototype. We involved children as partners in the design process, adapting PD methods such as body-storming, puppeteering, and sketching for children as co-designers. A study was conducted in a school with

44 children (25 female, 6-9 years old) participating in the design of the robot's social behaviors. Based on the previous phrase, we focused on personality traits within story-line creation. Children performed the activity in groups of 3-5, with each session lasting 1 hour and the total time of all sessions being 13 hours. The procedure used in the study is detailed below.

- **Body-Storming -** Body-storming is a form of PD to enact experiential awareness (Schleicher, Jones, & Kachur, 2010) and an embodied ideation method for movement-based interaction design (Segura, Vidal, & Rostami, 2016). We used body-storming to prime children towards understanding personality traits through enactment, so that later they would imbue in the robot. We used the Big Five Model of Personality (Costa Jr & McCrae, 2008), adapting the terminology of personality traits for children. As such, we used the adjectives "social and shy" instead of "extrovert/introvert", "imaginative and without ideas" instead of "openness/closedness to experience", and "kind and grumpy" instead of "agreeableness/antagonism" to represent the positive and negative poles inherent to each personality trait. The three personality traits chosen to represent the ones more closely related to social relationships and thus, more relevant to implement in the robot. During the body-storming activity, precise instructions related to personality expression were given to children, e.g., children were instructed to only use body movements, instead of natural language, to express themselves. The goal of this rule was to expand children's vocabulary for movement expression to match the robot's expression modalities. Figure 22 shows children in our study engaged in the body-storming process.
- **Drawing and Puppeteering** - The next stage was to use puppeteering and drawing techniques to develop and elaborate on the social behavior of the robot. We built a paper

Figure 3. *On the left:* paper-cubes used during the co-design study with children fabricated with paper and including a built-in drawing mechanism; these cubes enabled: (1) children to have a visual feedback for the created motions, (2) data collection of the drawn trajectories for later implementation in the robot, (3) a constraint for children to represent the movements in a 2D plane and avoiding 3D movements that are impossible to model and replicate in a real robot. *On the right:* example of a child expressing movement of a paper-cube by puppeteering it. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).

cube that included a built-in drawing mechanism and invited children to act out how this cube would behave according to different personality traits (see Figure 23). This mechanism enabled children to represent the movements of the robot by drawing them in large paper sheets of paper while puppeteering it (see Figure 23). In addition to movement design, children were invited to attribute a color to each personality of the robot. We collected the resulting drawings, in addition to video and audio recordings, to support the analysis of the results (see Figure 23). We relied on the Laban Movement Analysis, a method and language for describing, visualizing, interpreting and documenting movement, to analyze the movements produced by children using the robot prototype (von Laban, 1975) and discovered that children created consistent movement shapes according to the different personality types. Negative poles of personality traits, such as grumpy, were associated with fast and spike-like movements accompanied by

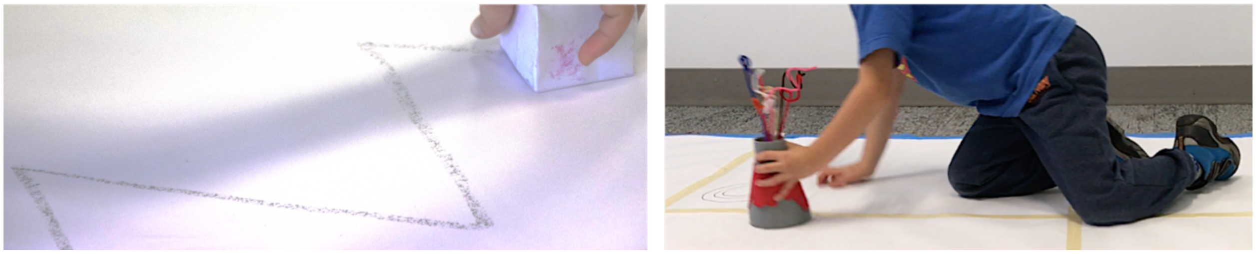

Figure 4. On the left: example of a sketch produced by a child using paper-cube. *On the right:* manipulation of a robot prototype for the study of the size of the robot and children's grasping behavior. The robot is covered with red play-doh to collect data about the location where children grab the robot. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).

cold colors (as green); and positive poles of personality, such as kind, with slower and curly-like movements accompanied by warm colors (as yellow).

The major design outcome of this study was the generation of specific motion and color patters to be implemented in the robot derived from children's input. Therefore, three sets of personality traits were created. The creativity behaviors for the robot were also defined in two domains: *convergent-stimulating behaviors* consisted of mimicking the same play patterns created by children during play. This would trigger the elaborations over the same storylines and thus provoking convergence over a given topic (we called this the Mirror technique). Divergent thinking behavior consisted in creating different behaviors than those that children create during play. This would trigger plot twists in the story, provoking divergence of the plot (we called this the Contrast technique).

Development through Iterative Prototyping. The third stage of the Double-Diamond Design Process is "Develop", the iterative development of prototypes. The goal of this stage was to develop both the AI software and the physical embodiment of the robot (hardware), including children as testers during the design process. We developed a prototype based on the insights from the previous two stages and used it as a reference for the studies described below.

- **Refinement of the robot software -** We conducted a study in a Science Museum for children located in Ithaca, NY, USA, to test the first iteration of interactive behaviors, using a low-fidelity mechanically actuated robot prototypes (see Figure 20-3,4) for children to play with. The total time of the study was 4 hours and a total of 20 children (7-9 years old) played with the robot freely. The robot acted autonomously, which meant that no human was controlling the robot's behaviors and displayed a set of behaviors inspired by the co-design study, including colored lights and movements. Additionally, we implemented novel behaviors inspired by results from previous studies to enrich the experience of interaction. For example, we implemented a rack and pinion mechanism that retracts the robot head inside its shell, and then shows it back again. We relied on *co-discovery* and *active intervention* methods to elicit feedback from children (Van Kesteren, Bekker, Vermeeren, & Lloyd, 2003). During Co-discovery, children consult each other to understand how the robot works. In our study, children were organized in small groups and were prompted to tell each other how they were playing with the robot. The researcher would ask questions such as "can you show to your friend what the robot can do?" This provided insights about the interpretation of the robot's behaviors by children and their explanations. For example, a child said that "[the robot] is happy because it is moving in circles." Or "[the robot] is angry because he has red lights." During Active Intervention, the researcher asked questions about the storytelling task and also about desired behaviors that children would like to see in the robot. For example, after being asked what was the game he was playing with the robot, a participant replied that he was "playing hide-and-seek and showing the robot other things" (participant that carried the robot around in different exhibitions at the museum, while describing to the robot what he was seeing). In addition to these techniques, we used direct observation of children free play with the robot to gather additional design requirements. The major outcome of this study was the selection and refinement of behaviors for the robot. For example, colors and motion were a major drive in storytelling. This result led us to explore richer ways to use these modalities by coupling light brightness and motion speed for behavior combinations. We removed of some features in the robot that did not support interaction towards storytelling and creation, such as sounds, that children paid little attention compared to other features.

- **Refinement of the robot hardware -** We conducted a laboratory study with non-actuated prototypes of the robot to gather design requirements for the physical shape of the robot. We used direct observation to discover the best suitable size for the robot, and to study how children grabbed the robot to inform ergonomic modifications in the shell for more natural playing behaviors. A total of 3 children (1 female, 7 years old participated by individually playing with different prototypes of the robot in sessions of 30 minutes. We used 3D printed robot prototypes with abstract and minimal shapes of three different sizes - Small, Medium, and Large (see Figure 23), to test for the best size. Additionally, we covered the robots' shell with clay to get data about where children place their hands to hold and manipulate the robot (see Figure 23). Individually, children were invited to trace a path on the floor with the robot by navigating the robot between three different key-points placed on the playground. We relied on the same method principle as the one used for the co-design study, by creating a playful activity that kept the robot grounded on the floor (a 2D plane). This created a familiar activity for children that enabled observations about how they would use the robot in its final context of use.

Figure 5. On the left: children playing with the robot and picking cards (in the middle) to guess what personality trait was expressed by the robot. *On the right*: children playing with the robot and creating a story together. The activity finished with children draw in their story to collect data about the themes that emerged. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (under review).

Our measure of analysis was the number of instances of grabbing behavior displayed by children during play. Therefore, n = 40 instances were analyzed, revealing that: (1) children had difficulties in grasping the large-sized robot because the shell was too large to be ergonomically grasped by their hands; (2) children did not treat the small-sized robot as a character during play, possibly because its small shell did not evoke this affordance; (3) children grasped the medium-sized robot comfortably. Data collection ceased at an early stage due to saturation, a method commonly used in qualitative studies. Saturation occurs when the data keeps showing the same results no matter how many participants are recruited (Glaser, Strauss, & Strutzel, 1968; Morse, 1995). Therefore, when children were giving the same behavioral responses during the study, we stopped data collection and progressed in the design process, representing the small sample size for this study. Results from this study showed three major design requirements: First, children have no orientation commitment when manipulating an abstract robot. We observed that children did not attribute a fixed “front” or “back” side to the robot; second, children consistently used the same area on the robot for manipulating it, suggesting an ideal design space for grabbing; third, children manipulated the medium-sized robot easily, making this the preferred size considering their hands size and playing behavior. These results informed mechanical decisions, e.g. choice if smaller sensors and actuators that fit the reduced size robot model.

Delivery through Testing and Refinement. The fourth and final stage of the Double-Diamond Design Process is “Deliver”, where a more developed prototype is taken through testing and further refinement. This stage can be considered a preliminary testing stage as children were involved as users of the robot. We implemented the final prototype of the robot and refined features of the based on insights from these evaluations.

- **Social behaviors for storytelling -** We conducted a study to investigate if children decoded the social behaviors implemented in the robot (see Figure 24). Decoding different behaviors in the robot was an important stage of the design process as it enables children to use the robot as many different characters for their story, providing opportunities for new narratives. This study was performed in a school setting and involved 22 children (6-8 years old) that individually played with the final version of an autonomous robot for 30 minutes (see Figure 20-6), with a total study time of 11 hours. We used a guessing game, similar to the classic game “Guess Who” in which children had to guess what the robot was expressing by choosing cards from a set of cards that we designed for this purpose (see Figure 24). Children were individually presented with three behaviors of the robot, each lasting 3 minutes, and presented in a randomized sequence. This was the “exploring stage” as children were incited to play with the robot by exploring its different behaviors. If children questioned the researcher about what the robot was doing, the researcher would always reply “what do you think?” This created a reflective mode in children, preparing them for the next stage. After being familiar with the personalities, the researcher distributed cards that displayed a word and an image about each personality trait (see Figure 24). Children picked a card for each personality trait and during this time it was explained to them that there were no right or wrong answers to avoid engaging children in test-like atmospheres. Afterward, the researcher engaged in a dialogue to understand the reason behind their choice for each matching personality card and behavior of the robot. For example, children said "I think he is grumpy because he is moving too fast, like I do when someone punishes me. And the one with the red lights is really upset." This led to an elaborated understanding of how children perceived the robot, and informed further refinements in its behavior. The major outcome of this study was the usage of children's feedback to improve the behaviors of the robot by adjusting some parameters, such as lights and speed of movement to make each personality trait more obvious.

- **Creativity techniques for story creations -** We conducted a preliminary field study to investigate if children were able to create new storylines by using the robot as a character. The robot acted autonomously, by using the two creativity techniques of Mirroring and Contrasting to stimulate new story narratives. This study lasted 4 hours and was performed in an outreach activity for children in which a total of 32 children were organized in small groups and played with the robot. While children interacted with the robot, we prompted them to think about possible stories for the robot. Data was collected by asking children to draw the story they imagined with the robot in a sheet of paper using crayons (see Figure 24). Additionally, direct observation was conducted by a researcher. This was a fast-speed storytelling preliminary study by the nature of the outreach activity, which lead each group of children with about 5min to play with the robot. The outcome of this study concerned a preliminary investigation of using the robot as a tool to stimulate creativity during storytelling in children. Results from direct observation have shown that children were able to accommodate the behavior of the robot in their story, underlying the capacity to integrate external stimuli into a pre-existing story mindset. This ability relates to problem solving, an important attribute of creative thought (Maier, 1970). Additionally, results from the drawing analysis have shown different types of stories created by children, some related to the school setting (translating a story based on daily routines), others related with higher levels of originality, such as stories about other worlds and species.

Guidelines for Child-Robot Design

This section described a two-year-long process that adapted PD methods and techniques to involve children in the design process of a social robot. Throughout this process, we identified several design principles that support the inclusion of children in the social robotic design process.

- ***Guideline 1.*** **Playfulness, a central mode of communication for children, should be at the core of all design activities.** Play, especially social play, is a key part of child development (Vygotsky, 1967). Play is defined as a minimally scripted, open-ended exploration where children are absorbed in the spontaneity of the experience (Ortlieb, 2010). In our work, we have imbued all design activities with playful elements to encourage children's expression during the design process of the robot. We relied on playful activities such as acting, sketching, body-storming, and traditional games, to ground the activities that invite children to the design. By honoring children's activities and ways of expression through play, we created a design process of a robot that did not impose an extra load of learning a new activity while at the same time providing essential data to design YOLO robot.

- *Guideline 2.* **Toys and craft materials are used by children daily and should be used as tools in the design process.** According to their developmental stage, children engage in different types of play where objects, such as toys, are an integral part (Piaget, 2013). Toys emerge as tools that are approachable and safe to play with, fostering the development of children. Froebel's gifts (Brosterman & Togashi, 1997) and Montessori's view on the "education of the senses" (Montessori, 1917) are examples of how manipulatives can be used to empower children's growth and development. In our work, we have incorporated toys and materials that are part of a child's world in all design activities during the robot design and creation. To this end, we opted for paper, crayons, cards, and play-doh, as the tools that children relied on for the robot design. Using these materials keep the design process playful and elicited natural responses from children.
- *Guideline 3.* **Child spaces, such as playgrounds, should be the stage on which the design process unfolds.** "Playscapes" are environments that are natural and in which children find joy and safety to play (Frost, 1992). Research on playground designs have brought to light qualities that lead to the most playful behaviors in children (Brown & Burger, 1984). Effective playscapes support a range of social scales, allowing for solitary and social play; effective playgrounds embrace emotional requirements, such as emotional relief spaces, including privacy and breakaway points for quiet play (Moore, & Cohen, 1978). In our work, we have used interior school playgrounds as they evoke playfulness and put our children co-designers in the right mindset for creative

exploration. Our work is based on design-research for which we have relied on theoretically inspired methods applied to a local design problem that has the potential to impact innovations within the design of social robots (Barab, 2006).

- ***Guideline 4.*** **Using child-appropriate protocols and materials.** Consider a narrative of briefing and debriefing that children can understand in order to explain the goal of the research. One example of a briefing protocol is the CHECk Tool (Read et al., 2013 commonly used during PD sessions with children (Van Mechelen et al., 2014). This will enable an ethical and informed participation of children, empowering them to decide if they want to enroll in the study. Consider data collection methods that are child-friendly, such as the Fun Toolkit that uses a Smilyometer instead of Likert scales (Read, 2008) before jumping into the actual activity add an ice-breaking activity with children that can be as simple as sharing hobbies or implementing other techniques, such as Vignettes (Hazel, 1995); this will result in more relaxed environment with children being more expressive and honest in their opinions towards the technology being tested (Gibson, 2007).
- ***Guideline 5.*** **Designing with children requires a multidisciplinary team.** Experts from a variety of backgrounds are a requisite when working with children. For example, when performing a study with children in a school, an expert in children's dynamics (such a psychologist that is trained to interact with children in study contexts) is required, as well as an expert in robotics (such as an engineer that can intervene when a problem with the robot arises). Multidisciplinary teamwork enables focus on different aspects during a study. In teams made up of experts in different backgrounds, however, special care needs to be given to develop a common language to support mutual understanding during

different design stages. Team members should be trained together in the lab before heading to a study with children. should meet regularly to provide updates about design stages and make sure that their individual tasks converge toward the intended project goal.

- ***Guideline 6.*** **Prepare to spend time on legal and ethical policies that concern child studies.** In particular, note that these policies are very localized and thus differ per institution, e.g., school district, university, specific school policies. Safety standards require that the methods and materials employed in studies with children are certified or are adapted for the child's developmental stage. Privacy and confidentiality require the adoption of alternative methods for data collection that protect a child's identity. All of this can cause restrictions on the study conducted and may, therefore, require exploring alternatives to originally conceived methods, e.g., using direct observation instead of video recordings. Having a long preparation time, and being open to change, is key to conducting design studies with children.
- ***Guideline 7.*** **Conduct pre- and post-activities with your study partners, such as schools and museums.** Visit the place where the study will be performed beforehand to understand the resources you have available, as this might define the conditions for your study. This includes understanding the physical (e.g., spaces in the school that you can use to conduct the sessions, location of power outlets) and administrative conditions (e.g., understanding who you will be coordinating with to have children coming in an organized way to the sessions). Consider performing clarification sessions with teachers and parents before the study begins as a strategy to have the institution on board during your study and parents signing consent forms in an informed way. At the end of the study

thank the school for the time, space, and coordination that enabled the study to be performed. This can be accomplished by performing a debriefing session about preliminary results at the end of the study, or by sending materials of interest to the school such as articles that describe your results. This is not only a way to thank your partners, but also assures a good connection to institutions and provide a return place in case additional sessions are needed.

Discussion

This work demonstrates the full design process of a social robot for creativity development. The design process of this robot relied on specific design principles applied to the Double-Diamond Design Process Model (Council, 2005), and brought children into each stage the design process. Children participated in the design of the robot under different design roles, such as *informants, partners, testers, and users*. The inclusion of children required adapting existing methods of UCD and PC practices to match how children experience the world and how they express themselves. We found that designing and testing technologies with children is useful to develop robots that accommodate their needs and that are understandable for them. We summarized a set of guidelines that can inform the design of robots for children. Additionally, we provided insights on how to use this design process in the field of HRI in general, thus creating robots that are aligned with human needs. Despite the richness of this design process, there are a few limitations that we would like to acknowledge. A major limitation of this work is that we have not compared to other processes of robot design. For future work, it would be interesting to compare different approaches in robot design (with different levels of user engagement) and conduct usability studies that would reflect which design process led to better results. We highlight again that this section was about the design process of the robot, and that the evaluation of the effectiveness of using this robot in creativity interventions is detailed in Chapter 6. In the next section, we will detail on the hardware fabrication for YOLO robot.

Building YOLO

In this section, we detail the process of building the physical body, or the hardware, of YOLO (see Figure 26). The source file repository with all materials and instructions necessary to build YOLO were made available in open-access in Open Science Framework[11]. This constitutes our second stage of developing this social robot (see Figure 20). As mentioned, HRI is a field of research dedicated to the design and evaluation of robotic systems that interact with humans (Goodrich & Schultz, 2008). These robots have been designed with the ability to “communicate and interact with us, understand and even relate to us, in a personal way” (Breazeal, 2004). They have been designed with different embodiments, using a rich taxonomy of expressive behaviors (Fong, Nourbakhsh, & Dautenhahn, 2003), classified according to the environment in which they operate, and to the intended application field (Ben-Ari & Mondada, 2018). Additionally, their interaction modalities range from emotional expression (Paiva, Mascarenhas, Petisca, Correia, & Alves-Oliveira, 2018) - including empathy (Paiva, Leite, Boukricha, & Wachsmuth, 2017), body gestures (Salem, Eyssel, Rohlfing, Kopp, & Joublin, 2013; Salem, Kopp, Wachsmuth, Rohlfing, & Joublin, 2012), and expressive lights (Baraka, 2018) - to color, motion, and sound (Löffler, Schmidt, & Tscharn, 2018). Highly successful interactions with humans tend to occur when the interactive and expressive modalities of robots match their physical embodiment (Mori, 1970). When a mismatch is perceived between the physical appearance of a human-like robot and its behavior, feelings of eeriness and revulsion may arise, denoting the so-called Uncanny Valley Effect that robot designers want to avoid (Mori, 1970). To counter this effect, we chose to

[11] Open Science Framework weblink for all materials and instructions to build YOLO: https://osf.io/kwrft/

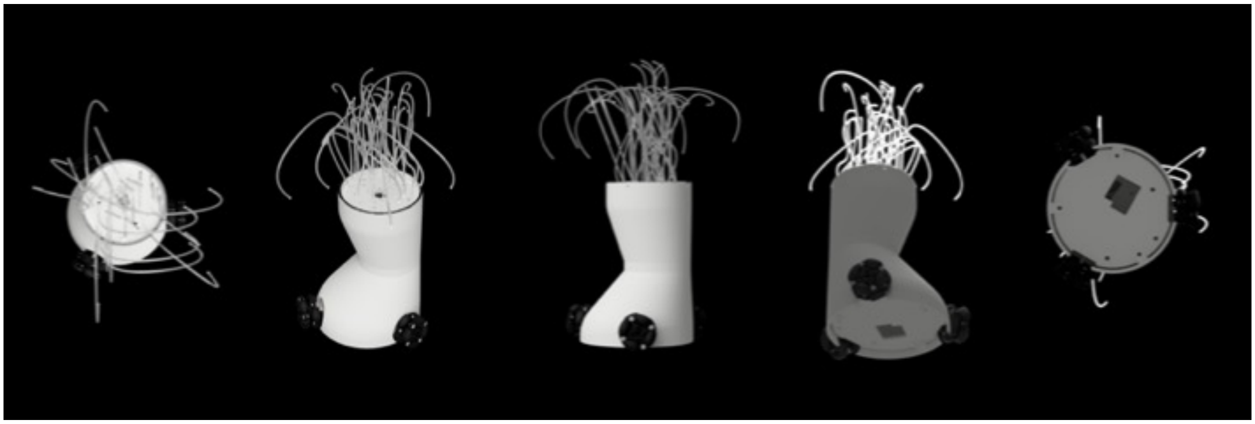

Figure 6. Perspective views of YOLO from left to right: top, top-side, side, bottom-side, and bottom. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

develop a non-anthropomorphic robot using non-verbal elements, such as colors and movement, to communicate with children (see Figure 27).

Interaction Elements of YOLO

To sustain playful and creative interactions with children, YOLO makes use of implicit interaction modalities, such as movements and lights, to communicate with children (Ju, 2015). YOLO's interactive elements are described below.

Lights and Movement as Interaction Modalities. Lights and movement were chosen as the main interaction modalities between the robot and children as this combination was recognized as one of the most efficient nonverbal multi-modal communication for non-anthropomorphic robots (Löffler, Schmidt, & Tscharn, 2018). YOLO interacts with children by making use of lights that display different colors creating different emotional expressions by using different scales of brightness levels that create a so-called "blinking" or "breathing" behavior. For example, when the robot exhibits more introvert traits, it would use less light-

Figure 7. Detailed views on YOLO robot. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

blinking behaviors with smooth transitions between them; when exhibiting an extrovert trait, the light-blinking behavior would happen with more frequency and at faster speeds of transition. Additionally, movement is used for interaction with YOLO performing different navigation patterns at varying speeds. In this sense, the robot senses how children move it (the robot can recognize the manipulation patterns of children while grabbing it) and reacts to these behaviors. For example, if children perform angular movements patterns with the robot (pretending, e.g., that the robot is avoiding obstacles, similarly to what children do when they play with car toys), the robot detects these and can react to them either by imitating them or by doing a different movement. In this case, the robot is reacting to a movement previously performed by children, in what we called “reactive behavior”. On the other hand, the robot can initiate an autonomous behavior to stimulate new ideas during playtime, in what we called “proactive behavior”, which means that the robot, without being previously manipulated by children, can start moving around to call their attention for playing.

Abstract Shape as Imagination Trigger. YOLO has a minimal abstract body shape as an invitation to children's imagination. Literature states that conceiving states of fantasy in which reality constraints have been dropped serve as a technique to increase idea generation (Smith, 1998). Therefore, by designing an embodiment that does not resemble previously known objects, YOLO can serve as any character that children wish for their stories, increasing idea generation (which is part of the divergent thinking in creative thought). The abstractness of the robot is envisioned to amplify imagination possibilities for children's stories, inciting them into creating a wide range of storylines that contribute to their creative thinking.

Touch for Shared Control. Children are usually in full control of their toys. However, this is not the case when they interact with autonomous robots, as interactive technology performs actions that are not controllable by children due to their autonomous nature. During an interaction, this can lead to positive effects, such as engagement due to novelty, but can also create frustration and sometimes even fear in children, possibly leading to interaction breakdowns with robots (Serholt, 2018). To address this aspect, YOLO has a shared control option that gives control over the interaction back control to children, similarly to what occurs during interactions with their traditional toys. This was made possible by using capacitive touch sensors in the robot's shell. When children touch the robot, the capacitive touch sensor is activated and the robot refrains from performing any autonomous behavior. During this deactivated time, children can play with it as they do with traditional toys. When children release the robot, which means that the capacitive sensor does not recognize touch, the robot returns to its fully autonomous mode. This shared control enables children to have the control they are used to with their traditional toys at certain levels of the interaction, and at the same time enables the robot to perform autonomously.

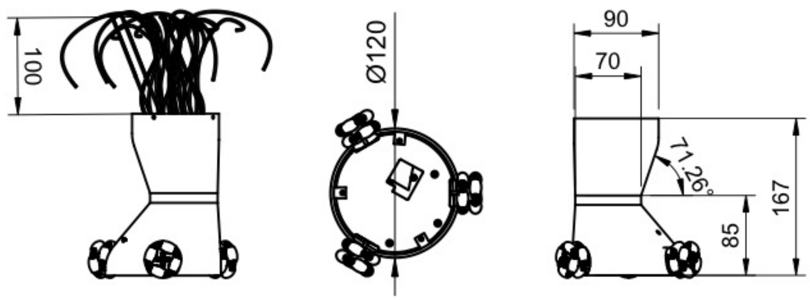

Figure 8. YOLO's drawing with main dimensions in mm. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

Technical Elements

In this section, we detail YOLO's technical elements related to its hardware design.

Small-Scale and Light-Weight Design. YOLO is a 167 x 120 mm robot with three omni-wheels that enable navigation and manipulation in any direction (see Figure 28). It was designed to be a small-scale and light-weight robot meant for children's hands' size and easy manipulation. With most robots, the space required by electronic circuits, wires, and power, make small-size and light-weight designs hard to achieve. Most off-the-shelf robots for children are heavy to hold, e.g., the NAO robot (Gouaillier, et al., 2009) weights 5.4 Kg. In its final version, YOLO weights approximately 0.5 Kg, the equivalent of a basketball, and its half-hourglass shape enables an easy grabbing for children's hand size (see Figures 27 and 28).

Child-Proof Design. YOLO's shell was fabricated using 3D printing material, with options for laser cutting. The robot's interior components (such as screws and standoffs) are made of nylon to avoid shorts between electrical boards. The circuitry and electronic boards were assembled in a compact and robust layered design to be safely manipulated by children

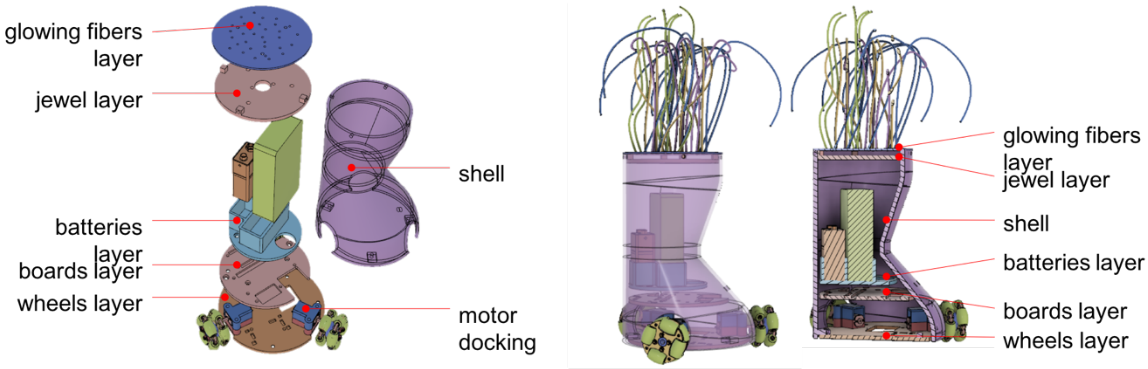

Figure 9. YOLO's exploded view (on the left) and section analysis with component coloring (on the right). Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

(see Figure 29).These materials and assembly processes make YOLO child-proof, accommodating for unrestricted and uncertain manipulations of the robot during play.

Grab-and-Go Play. YOLO was designed as a standalone and portable robot for a playful grab-and-go mindset. To enable portability, the robot has a robust internal power system, providing energy to all internal components. Compact power designs for robots are hard to achieve due to the large size of commercially available batteries, commonly presenting non-ergonomic shapes. Most robots for children are mostly stationary and dependent on power outlets to function, e.g., MyKeepon is a small and light-weighted robot for children (Kozima, Michalowski, & Nakagawa, 2009), however, it is a power outlet dependent robot. YOLO's portability enables free play both indoors and outdoors, not constraining it to pre-determined spaces. This is similar to what happens when children play with their traditional toys.

Table 13. *Design files to build YOLO. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).*

Design file name	File type	License	Location of the file
Shell	CAD file in STL	CC BY 4.0	https://osf.io/xdgf5/
Batteries layer	CAD file in STL	CC BY 4.0	https://osf.io/3dgyb/
Boards layer	CAD file in STL	CC BY 4.0	https://osf.io/4gj65/
Wheels layer	CAD file in STL	CC BY 4.0	https://osf.io/hyb56/
Glowing fibers layer	CAD file in STL	CC BY 4.0	https://osf.io/bqg4f/
Washer	CAD file in STL	CC BY 4.0	https://osf.io/5pdwj/
Motor docking (1)	CAD file in STL	CC BY 4.0	https://osf.io/crz7j/
Motor docking (2)	CAD file in STL	CC BY 4.0	https://osf.io/eruac/

Design Files

YOLO can be build using the design files included in Table 13 and represented in Figure 30. The design files are in STL format and ready to be 3D printed. Some of these files can be converted to a DXF format, adding a laser cutting option for faster and cheaper opportunities to fabricate YOLO. If opting to laser cut some of the components, note that the thickness of the laser cutting material should correspond to the CAD model dimensions. We suggest choosing a material for the laser cutter work that protects electronic boards, such as acrylic. Below is a summary of the design files presented in Table 10.

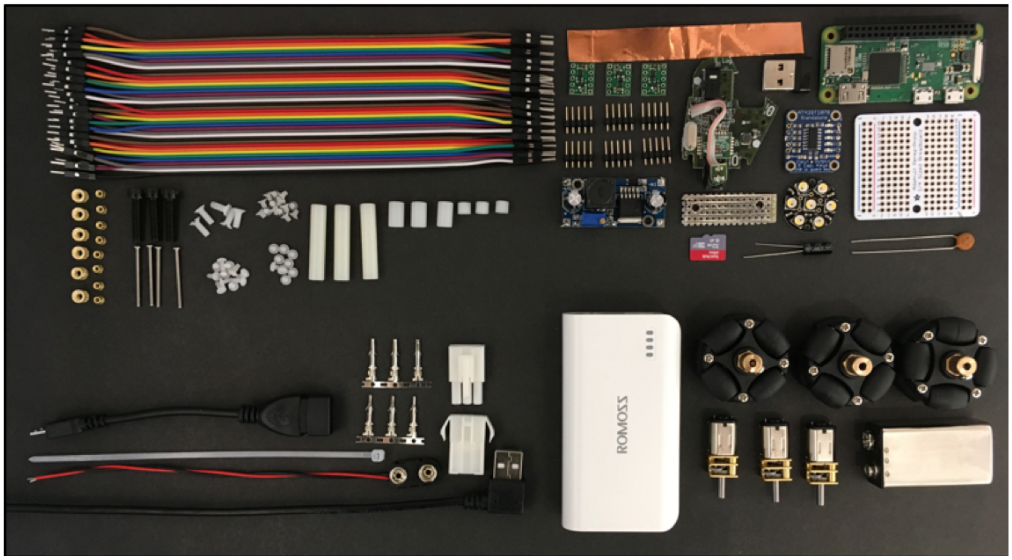

Figure 10. YOLO parts lineup. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

- **Shell -** File with the cover of the robot. This is the largest 3D printing file and requires a 3D printer capable of operating at large dimensions - at least 120 x 200 x 200 mm of printing capability. Use a vertical bottom-up position for printing the shell. Support material should be added on the faces of the three tabs. This design file does not present a laser cutting option as it is made of 3D organic shapes not ideal for laser cutting work.
- **Batteries, boards, and wheel layers -** These design files are composed of three circular platforms that should be placed on the interior of the shell to hold all the electronic components in place (see Figure 29). Print the layers horizontally. Support material is needed only on the face of the counter-bore holes of the larger platform. The laser cutting option is valid for this design file.
- **Jewel layer -** This file contains the design that serves to nest the LED jewel that will be attached from the top of the shell (see Figure 29). Print the LED nest horizontally with

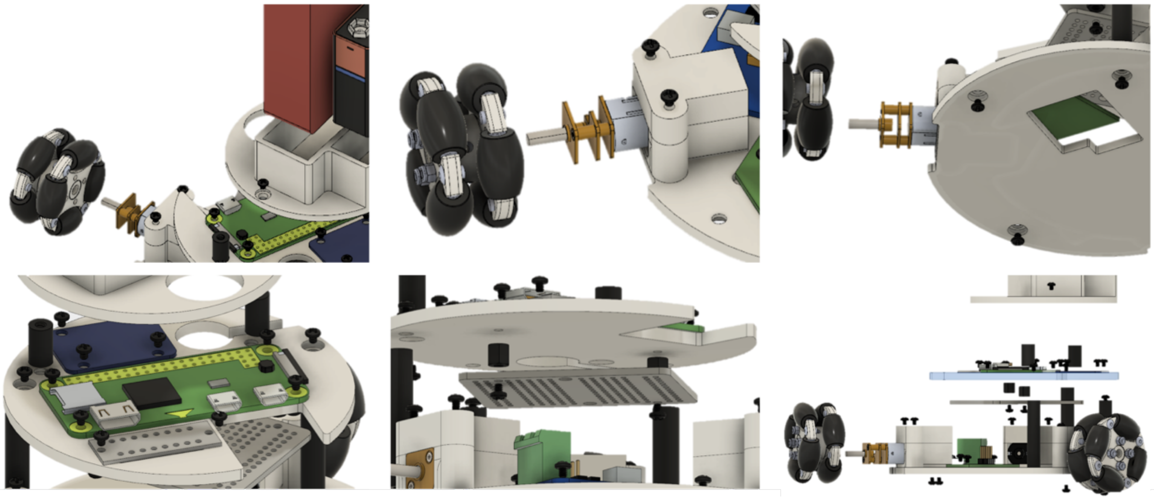

Figure 11. Close-ups on YOLO's inside. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

support material. This file does not support a laser cutting option due to its 3D design requirement.

- **Glowing fibers layer -** This design file contains the plate where the optical fibers should be glued (see Figure 29). Print the LED nest horizontally with support material. The laser cutting option is valid for this design file.
- **Washer -** Washers should be placed between the "Jewel layer" and the "glowing fibers layer" to secure this connection (see Figure 29). YOLO uses three washers to support this connection, so consider printing 3 parts. The laser cutting option is valid for this design file.
- **Motor docking (1) and (2) -** Composed of two files that together provide docking for the motors. Support material is not needed for 3D printing. The laser cutting option is valid for "Motor docking (2)".

Bill of Materials

The total estimated expenses for building YOLO is approximately $200. Although this cost might strike as expensive for a home-made robot, the total estimated price includes purchases of items that come in large packs, such as battery clips and wire zip ties, or that come with extra material quantities, such as wires and screws. A concrete example is the battery clips that come in packs of 10, while YOLO requires only 1; wires have an extension of 25ft and YOLO requires short extensions due to its compact design. The total estimated price can be reduced if YOLO is built in a laboratory or a maker space that already has some of the tools and materials for building and assembling. A description of the total bill of materials is presented in Appendix B.

Assembly

We now provide instructions for the robot's assembly process.

Assembly Preparation. The assembly requires the following tools: hacksaw, utility knife, screwdriver set, calipers, scissors, soldering kit (including solder spool, soldering station, wire stripper, diagonal cutters, solder wick for solder removal, soldering vise with a magnifying glass, and a panavise), and glue. 3D print and laser cut the required materials in present in Appendix B and Figure 30. Before assembly, configure the voltage transformer with an input of 5.0V and step down the buck converter output for 1.5V. Additionally, follow the steps described below:

1. Hack mouse sensor that will serve as an in-built system for motion detection of the robot[12];
2. Place brass inserts in the dedicated places using a soldering iron (Figure 32. steps 1-3)[13];

[12] A tutorial video on how to hack a mouse can be found using this weblink: https://youtu.be/Jz-cXqAwu4o
[13] A tutorial video on how to heat brass inserts can be found using this weblink: https://youtu.be/HB2Q_Wywl1s

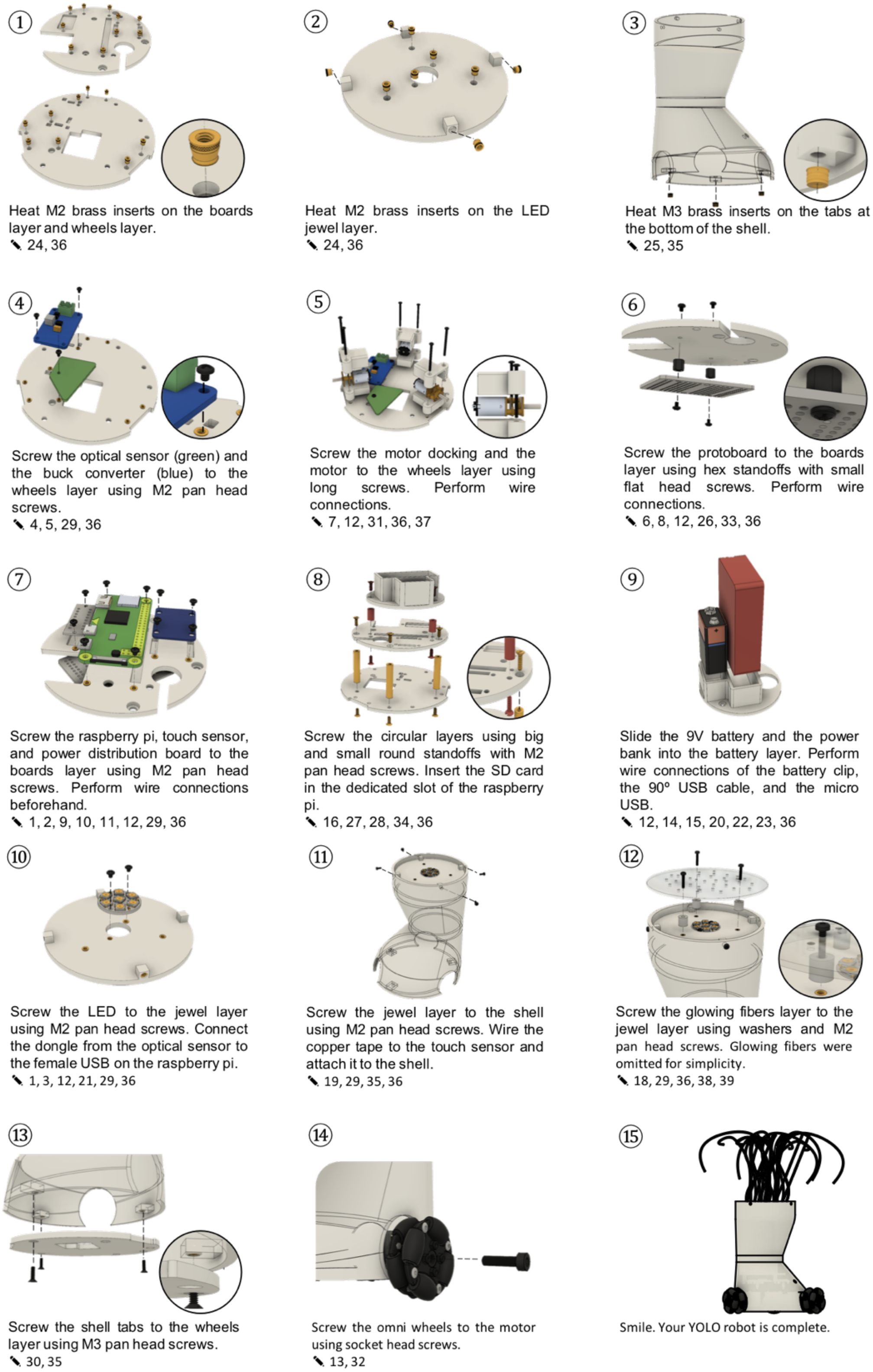

Figure 12. YOLO's assembly flow. Numbering accompanied by the symbol "✎" correspond to materials on Appendix B. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

3. Cut the circboard and drill two 2.10 in clearance holes for attachment[14];

4. Cut glowing fibers and attach them to the glowing fibers layer by using a hot glue gun or other effective glue. The length of the size of the glowing fibers can be selected by personal preference. We used lengths between 140-170 mm[15].

Assembly Flow. A step-by-step assembly flow with an action Diagram (Agrawala et al., 2003) is present in Figure 32. Follow each step and complement the assembly flow with the wiring instructions in Figure 33. An exploded view of YOLO that supports the understanding of the final robot configuration is present in Figure 29, with close-up views on 1. When the robot is fully assembled, attach a batch of copper tape to the shell of the robot to connect the wire that comes from the capacitive touch sensor. This will enable the robot to respond to touch.

Assembly Safeguards. Assembling YOLO is a process that involves interacting with mechanical tools and machinery for which safety guards are required. To the best of our knowledge, no safety guidelines for personal fabrication have been formally established, and misuses have been considered users' responsibility (Mota, 2011). As such, we strongly advise YOLO makers to follow our recommended safeguards.

It is advisable to assemble the robot under expert adult supervision at all times. Additionally, assembling this robot requires knowledge over some mechanical engineering procedures, such as soldering. We recommend a tutorial about soldering by Mitch Altman, Andie Nordgren, and Jeff Keyzer, "Soldering is Easy"[16]. We advise to train the art of soldering using a training board, and only after mastering this art, start soldering YOLO. The physical presence of an expert person

[14] A tutorial video on how to cut a circuit board can be found using this weblink: https://youtu.be/ummbqeoAhJY
[15] A tutorial vídeo on how to cut and attach glowing fibers can be found using this weblink: https://youtu.be/7TzWtuXsoN8
[16] A free online version of the tutorial "Soldering is Easy" by Mitch Altman, Andie Nordgren, and Jeff Keyzer, https://mightyohm.com/files/soldercomic/FullSolderComic_EN.pdf

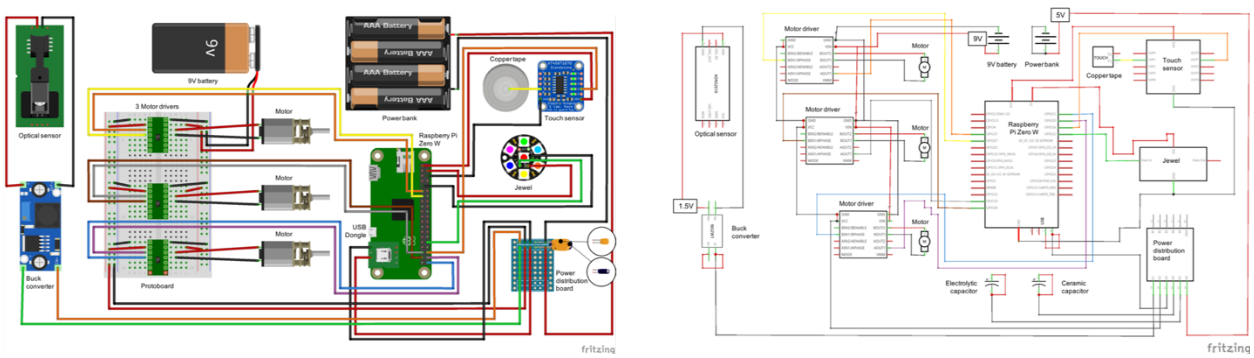

Figure 13. Wiring schematics of YOLO with visual components (on the left) and circuit schema (on the right). Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

during soldering, wiring, and 3D printing or laser cutting is recommended.

Operation Instructions

To operate YOLO, consider the schematics present in Figure 34. YOLO can display different social behaviors. Therefore, it can be used as a creativity-stimulating robot for children's playtime[17]. In this case, YOLO will be interacting with children playfully, while seeking to stimulate their creativity. Another way is to develop a software to operate YOLO. This can be performed by any person with some knowledge of programming. In this case, YOLO's software can be developed and personalized according to the needs and goals of the developers. To develop software for YOLO use a Python script-based language and Raspberry-Pi's specifications which will be explained further ahead in this Chapter when we explain the software of YOLO.

[17] Download an available version of the software with pre-sets that we have developed available at https://github.com/patricialvesoliveira/YOLO-Software

Table 14. *Materials and their usages required to initialize YOLO. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).*

Material	**Usage**
YOLO robot	Artifact that will be operated.
Router	To connect the Raspberry Pi and to the software program via wi-fi.
Computer/laptop	To initialize YOLO's software program.

To start operating YOLO, combine the materials required to initialize the robot present in Table 14 with the operating instructions in Figure 34. It is important to note that the performance of the robot is dependent on battery life, router range, and strong wiring connections. Regarding the battery, the average life is between 5-7 hours. This average can fluctuate depending on the playing behavior of children, i.e., if children interact more with YOLO, the battery life will decrease as the robot is prompt to perform more behaviors. If one or more omni-wheels start to not move, substitute the 9V battery, as there might be a power shortage. For full performance, YOLO's batteries need to be properly charged. Therefore, if the robot is non-responsive, recharge the power bank and try again when it is full. If YOLO continues non-responsive, check the wiring connections as they might need extra soldering as the unrestricted movements during children's play can weaken the connections. As the router range is wide, children can play with YOLO both indoors and outdoors. If YOLO starts being non-responsive, consider a smaller distance between the robot and the router.

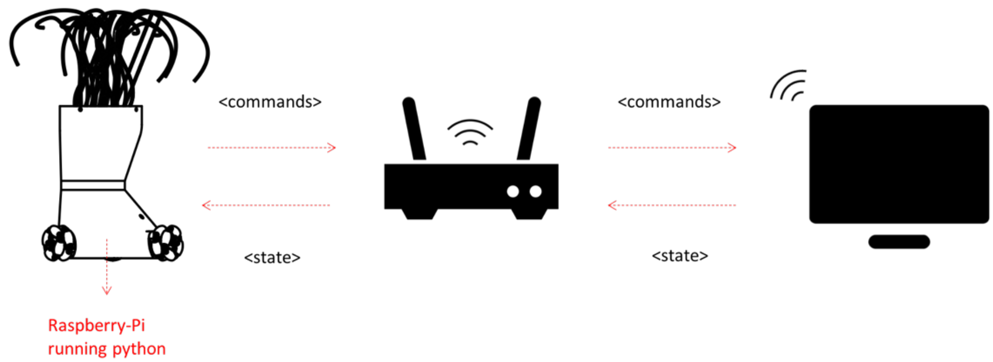

Figure 14. Operating instructions for YOLO. Retrieved from Alves-Oliveira, Arriaga, Paiva, and Hoffman (2019).

Operation Safeguards. YOLO is a robot made for children. Due to its target group and playful application nature, there are no major hazards when operating and playing with it. However, like any other technological toy, children should be supervised by an adult at all times. Additionally, a responsible adult should be in charge of initializing YOLO.

Discussion

YOLO presents as a low-cost-purchase and low-cost-maintenance cost robot, that can be used as a tool for research studies with children. The open-source hardware of YOLO thus provides opportunities for researchers with and without engineering background to build this robot and further use it targeting their own research goals, without depending upon complex robotic platforms. To demonstrate how this robot can be applied to academia, researchers can use it as a platform to explore the design of behaviors for a robot aimed at interacting with children. Another example is the usage of this robot by the social and cognitive sciences field as a controllable and programmable tool, to study the developmental aspects of children when interacting with robots. Predominantly, the scientific community relies on the usage of off-the-shelf robots as their research platforms when performing studies. Nonetheless, off-the-shelf robotics platforms are generally expensive (with purchase prices ranging from $5.000 to $20.000, or more) and associated with high maintenance costs. Also, the majority of these robots require special transportation services to be used during field studies, due to their robust size and heavyweight, placing additional costs for academic laboratories. YOLO offers a less expensive yet interesting solution for research. In the next section, we detail the software development for YOLO robot.

Programming YOLO

In this section, we detail the artificial intelligence of the software that gives life to the social robot YOLO. This constitutes our third and last stage of developing this social robot. We released in open access YOLO's code in GitHub[18]. The code is accompanied by a step-by-step tutorial that can be used by a novice user. Additionally, we developed an Application Programming Interface (API), which is an interface or a communication protocol between different parts of the program intended to facilitate the implementation of new behaviors for YOLO. This API is provided in GitHub in open access.

Software Description

YOLO's software is composed of creativity and social behaviors whose design was grounded on creativity research (Smith, 1998) the Big Five personality model (Costa Jr & McCrae, 2008; John, & Srivastava, 1999), and co-design sessions with children (Alves-Oliveira, Arriaga, Paiva, & Hoffman, 2017; see also the section "Designing YOLO" in the Chapter). We detail on the description of the robot's behaviors and how they compose the architecture of the software below.

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[18]GitHub weblink with the code to program YOLO: https://github.com/patricialvesoliveira/YOLO-Software

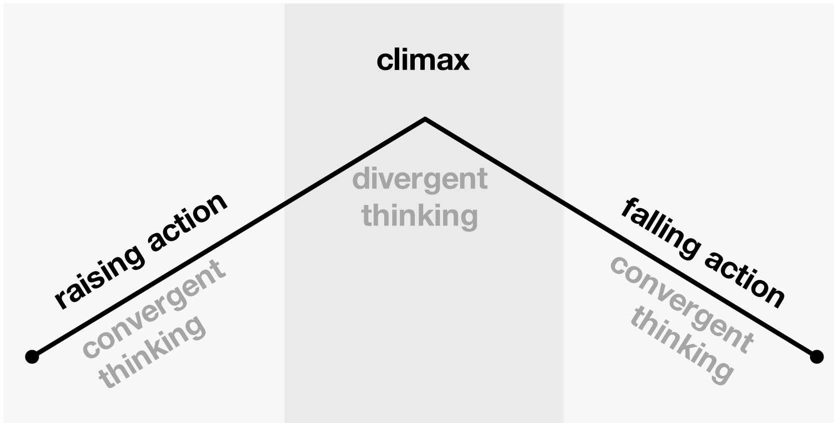

Figure 15. Storytelling arcs associated with creativity techniques: convergent thinking is stimulated during rising and falling action phases by using the mirror technique; divergent thinking is stimulated during climax by using the contrast technique. Retrieved from Alves-Oliveira, Gomes, Chandak, Arriaga, Hoffman, and Paiva (2019).

Creativity Behavior. In our specific application scenario, YOLO acts as a character that can trigger new directions in children's stories that otherwise would not emerge. During story creation, a combination of divergent (i.e., broad gathering of multiple ideas) and convergent thinking (i.e., narrowing down possibilities to create a coherent story plot) is required (Brenner, Uebernickel, & Abrell, 2016; Elbow, 1983, Alrutz, 2015). This constituted our theoretical foundation to design the creativity-stimulating behavior in YOLO. As mentioned earlier, we choose two techniques to stimulate creativity, named "contrast" and "mirror" derived from co-designing sessions with children, from the literature review, and considering the feedback collected with creative experts that work with children (see Section Designing YOLO in this Chapter). These techniques are described below. (see Figure 35).

- **Contrast -** This technique is used to stimulate divergent thinking (Rickards, 1975). In the Contrast technique, YOLO provides stimuli unrelated to the storyline that children are exploring at the moment, producing an opportunity to explore new directions in the plot. This leads to heightened action and interesting plot twists in the stories of children;

- **Mirror -** This technique is used to stimulate convergent thinking (Vangundy, 1988). When using the Mirror technique, YOLO provides stimuli that are connected with the storyline that children are exploring, leading to the elaboration and convergence of story ideas. This leads to the emergence of interesting details about a character, a scenario, or an action in the story.

YOLO chooses which technique to use according to the storytelling arc of the story.

Storytelling Arc. Successful and satisfying stories follow a storytelling arc (Freytag, 1872, 1896). According to the Theory of Dramatic Structure, each story has five acts: exposition, rising action, climax, falling action, and dénouement. These five acts can be modified and adapted to the dramatic structure of short stories, fables, or fairytales. In our software, we considered a short-story format similar to what is used in children's stories (Wright, 1995). Therefore, we divide the narrative of a story in the following phases:

- **Rising action -** Characters are introduced, a context is given to the story, and the story builds. During this stage, YOLO stimulates convergent thinking by using the mirror creativity technique;
- **Climax -** The story reaches the point of greatest tension. During this stage, YOLO stimulates divergent thinking by applying the contrast creativity technique;
- **Falling action -** The story shifts to an action that happens because of the climax, which means that the conflict is resolved, and the story reaches its end. During this stage, YOLO stimulates convergent thinking by using the mirror creativity technique.

YOLO was designed to display social behaviors, increasing its richness as a character in children's stories.

Social Behavior. YOLO expresses different social profiles to exhibit social behaviors. The profiles are named Exuberant, Aloof, and Harmonious. These social behaviors appear as pre-sets when YOLO is turned on and can be used interchangeably, making the robot a flexible character in the children's stories. An explanation for the robot's social behaviors is provided below.

- **Exuberant -** YOLO reacts to every social interaction in an "enthusiastic" manner. Movements are fast and have a high amplitude. It displays vibrant colors such as purple and red with high brightness levels. As Exuberant, YOLO is proactive and seeks out social interaction. This is a vibrant, frenetic, and daring social profile;
- **Aloof -** YOLO is less "socially reactive" and is a "shy robot". In this mode, the robot exhibits low amplitude, slow movements and displays cold colors such as green and blue with low brightness levels. As Aloof, YOLO is not proactive; does not seek interactions. This profile could also be described as a loner, contemplative, or reclusive;
- **Harmonious -** YOLO acts in a moderated fashion, presenting behaviors that are in-between the extreme versions of Exuberant and Aloof. As Harmonious, YOLO exhibits medium speed, movements with medium amplitude, and displays warm colors such as yellow and orange at medium brightness levels. This is a balanced and moderate profile.

Software Functionalities

A primary function of this software is to serve as an API that enables any user the opportunity to design personalized behaviors for YOLO, consequently providing the possibility to generate new behaviors and interaction modes[19]. The robot can receive information from the environment (input) and express different interactive behaviors towards (output). Table 15 lists pre-sets that were developed for YOLO to act as a social robot that can stimulate creativity in

[19]Guide for YOLO's API: https://github.com/patricialvesoliveira/YOLO-Software/wiki/API-Documentation

children. Examples of the behaviors that can be parameterized are colors, sequence, and brightness of the LED lights. Additionally, the movements produced by the robot can be changed concerning the patterns, amplitude, and speed of the movements. Simple behaviors can be composed into complex robot behaviors. These complex behaviors aggregate several simple allowing for high level control of several behaviors of the robot.

Since each aspect of the robot is controllable and parameterizable, behaviors can be tweaked, created and mixed. To demonstrate the API functionality, we conducted pilot testing sessions in which we asked two participants unfamiliar with YOLO software to create different behaviors for the robot. One of the participants had a background in Computer Science and the other in Psychology. The participants were instructed to choose beloved characters from animation movies and to create a behavior for the robot that would resemble the behavior of those characters. The examples created by the participants were Mickey, Barbie, Bugs Bunny, and Genie from Aladdin[20].

Software Architecture

The architecture of our software includes several modules that manipulate data at different levels of abstraction from the low-level sensors and actuators to high-level behaviors. Figure 36 shows the scheme of these modules and how they interact. Each module, namely Control, Behaviors, and Planning, are explained below.

Control. This module has two main functions: first, it extracts data associated with the robots' sensors and translates into a programmable format. Second, it instructs the actuators what to do based on the software calls.

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[20]Examples created by the participants using the API: https://github.com/patricialvesoliveira/YOLO-Software/wiki/Examples

Table 15. Software functionalities considering the sensors used, the input collected, the actuators in place, and the output provided. Retrieved from Alves-Oliveira, et al (2019).

Sensor	**Input**	**Actuator**	**Output**
Touch sensor	Ability to recognize when the robot is being touched.	LED lights.	The robot displays white lights while being touched, refrains from performing any behavior. When not sensing touch, the robot displays colors associated with its different social behaviors.
Optical sensor	Recognition of play patterns of children while manipulating the robot.	Omni wheels.	Imitating the collected movement patterns.
Time	Stage of the storytelling that children are currently engaged in.	Omni wheels and LED lights.	The robot performs a creativity technique according to the storytelling arc.

The *touch sensor* of YOLO indicates the robot is recognizing physical contact, and the *optical sensor* observes the differences in position to detect the direction of movement. The sensors record movement at each moment. The *shape recognizer* dynamically identifies and characterizes each movement using Machine Learning. The pre-trained K-Nearest-Neighbor (KNN) algorithm determines a shape using the robot motion sensors which capture coordinates in 3 seconds intervals (Altman, 1992). Figure 37 depicts the Machine Learning (ML) workflow. We trained the model by collecting raw coordinates and converting these coordinates into a feature vector using the convex hull algorithm (Barber, Dobkin, Dobkin, & Huhdanpaa, 1996)[21].

[21]More details about the shape recognizer algorithm are present at this link: https://github.com/patricialvesoliveira/YOLO-Software/wiki/Algorithm

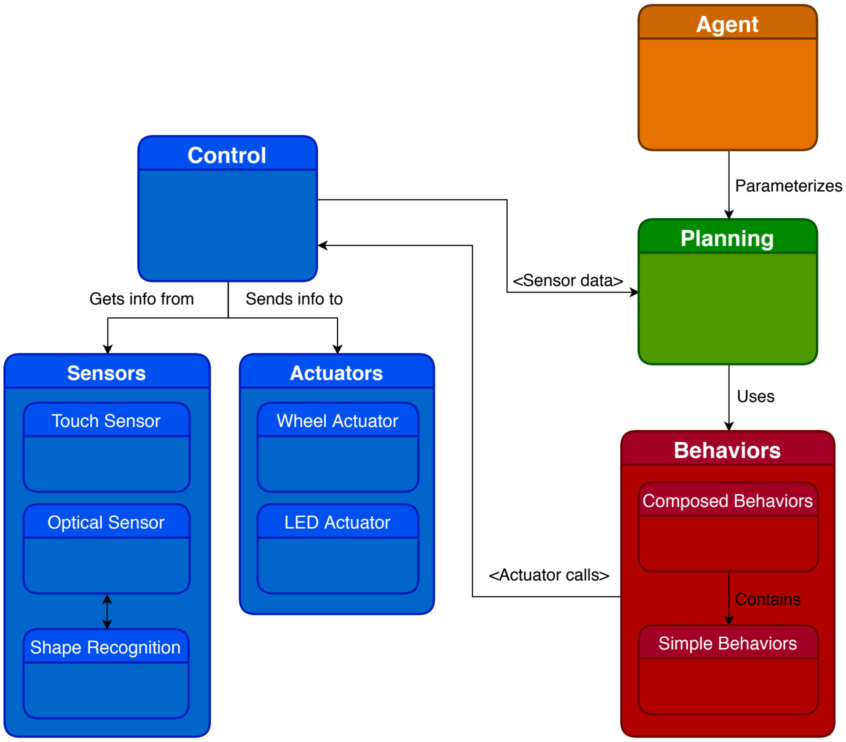

Figure 16. Architecture of the modules that compose YOLO software. Retrieved from Alves-Oliveira, et al (2019).

Every time a movement is detected, KNN is used to determine the closest matching shape from the training data. Simulations with a computer mouse showed us that with $n = 3$, KNN provided high accuracy (94%). Therefore, we used this parameterization. The current ML model was trained with the physical robot and can recognize with an 80% success rate the following shapes: circle, rectangles, loops, curls, spikes, and a straight line (see Figure 38).

YOLO actuators include the *Wheel Actuator* and the *LED Actuator*. While the *Wheel Actuator* receives direction and speed values and moves the wheels' motors accordingly, the *LED Actuator* receives a color and brightness level and displays it in the robot's jewel LEDs.

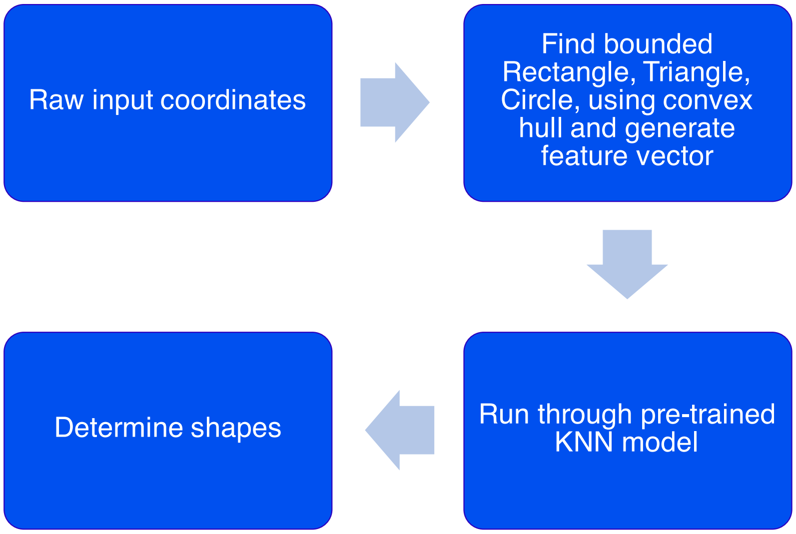

Figure 17. Workflow of the ML algorithm for shape recognition used by YOLO. Retrieved from Alves-Oliveira, et al (2019).

Behaviors. The *Behaviors* module coordinates the simultaneous execution of different actuators based on given parameters. The intended behavior arises from the simultaneous execution of different actuators. To simplify the development process, we divided behaviors into more concrete *Simple Behaviors*, which directly use the actuator data and *Composed Behaviors*, which unite several simple behaviors. *Simple behaviors* directly call the *Control* module. These behaviors consist of assigning different light behaviors (different colors, animations, and brightness) to different movement configurations (different movement patterns at varying speed)[22]. *Composed behaviors* can be used to define the social behaviors which YOLO exhibits, such as Exuberant, Aloof, and Harmonious[23].

[22]Examples of simple behaviors are detailed at this link: https://github.com/patricialvesoliveira/YOLO-Software/wiki/SimpleBehavior-Hierarchy
[23]Composed behaviors are further explained at this link: https://github.com/patricialvesoliveira/YOLO-Software/wiki/ComposedBehavior

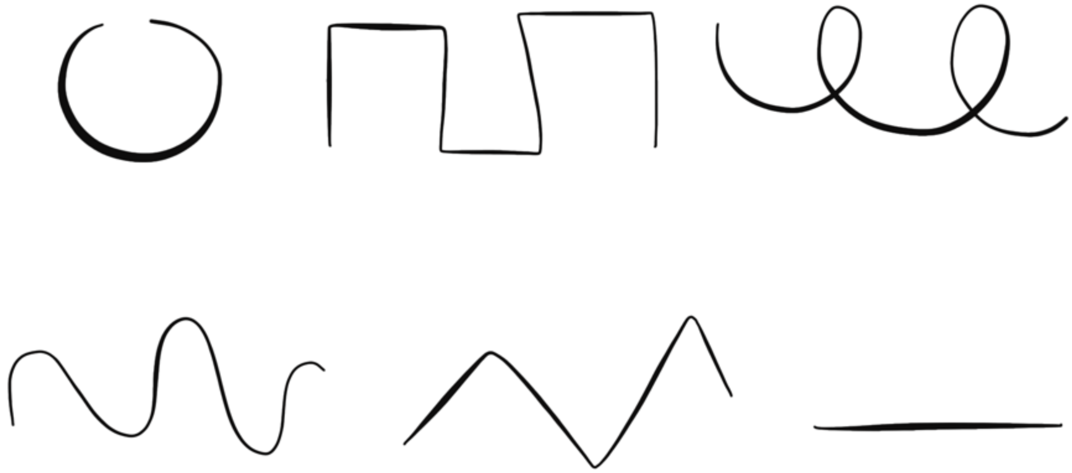

Figure 18. The lines illustrate the movement shapes performed by YOLO that are recognized by our algorithm. Illustrated shapes are: circle, rects, loops, curls, spikes, and straight line. Retrieved from Alves-Oliveira, et al (2019).

Planning. The *Planning* module schedules the behaviors in each moment of the interaction, executing specific ones based on the current interaction state. In order to trigger new interaction states, *Planning* module uses the data extracted from the sensors which the *Control* module provides. A flowchart illustrating the *Planning* module's is depicted in Figure 39.

Illustrative Example

To exemplify our software, we present a case-interaction between a child and the robot, as an example of how the artificial intelligence performs. The child was instructed to create a story, using the robot as a character. In the box below, we transcribed part of the interaction (see complementary Figure 40). In this example, it is visible how the robot makes use of its interaction profiles to stimulate convergent and divergent thinking and how this relates to the different stages of the storytelling.

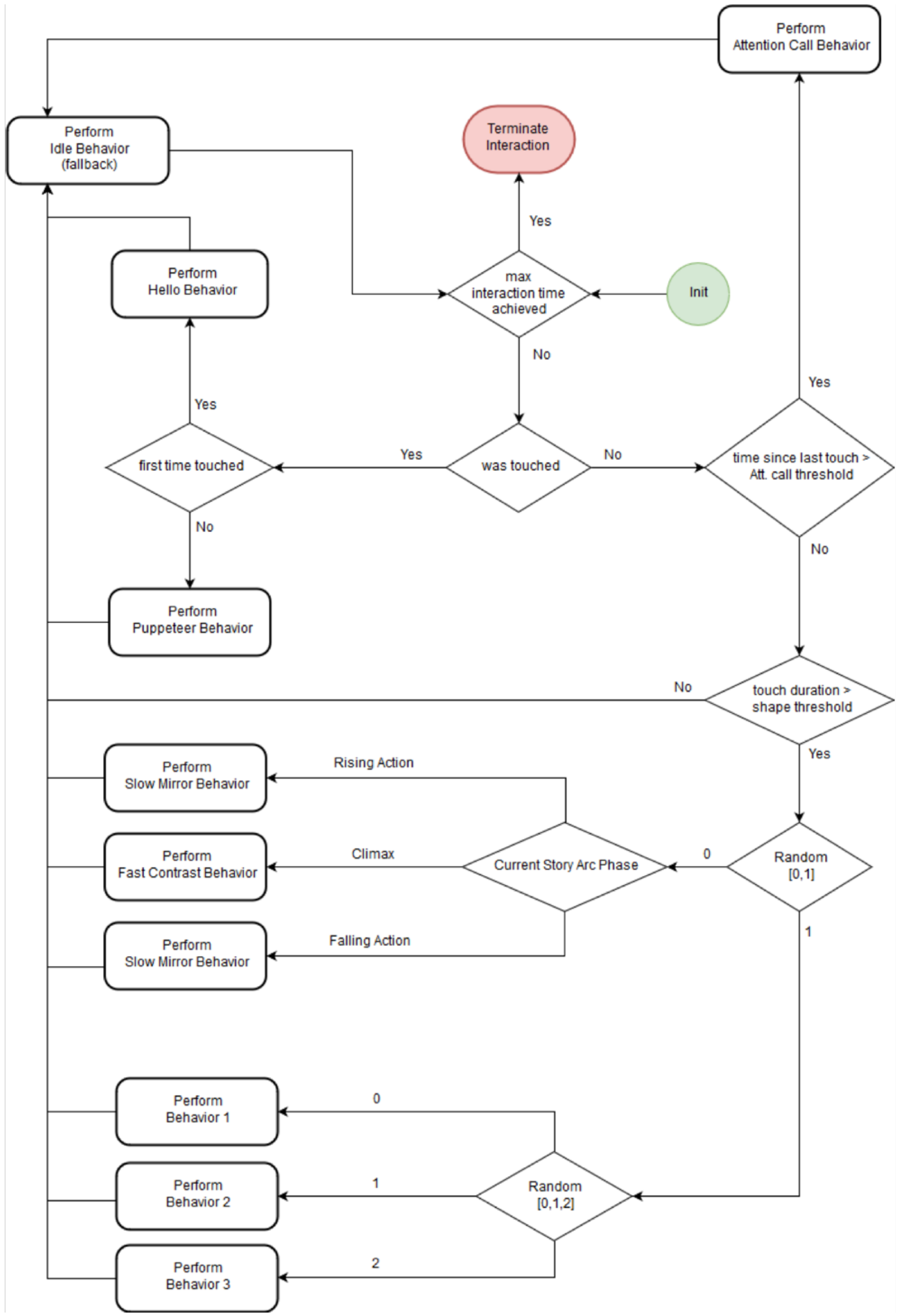

Figure 19. State machine diagram representing the schedule of the procedures executed in the *Planning* module. Retrieved from Alves-Oliveira, et al (2019).

Figure 20. Use-case example of a child using YOLO as a character for the creativity-stimulating storytelling scenario. Retrieved from Alves-Oliveira, et al (2019).

The child is on the floor playing with YOLO.

Child: **"***This is a football field and YOLO is from the Benfica team, so we are going to win!"*

The child manipulates YOLO in the imaginary football field, imitating the robot running after an imaginary ball and deviating from imaginary team adversaries. Because YOLO is still in the first part of the storytelling arc, i.e., in the Raising Action stage, the robot will stimulate convergent thinking abilities. Therefore, the robot imitates the last movement that the child performed. The child looks at the robot while it is moving.

Child: **"***Yes! Go for it, Cádiz, score!"* (Cádiz is the name of a Benfica team player that the child gave to the robot).

The child imitates scoring a goal and then grabs YOLO and celebrates.

Child: *"Ok Cádiz, but we have to continue doing well. These other guys are good too."*

The child continues manipulating YOLO through the adversaries. At this point in time, YOLO entered the next storytelling arc which is the Climax. During climax, divergent thinking is stimulated so the robot will perform a movement that is different from the last movement that the child has performed. The child manipulates the robot straight ahead towards the soccer goal, but the robot goes the opposite direction.

Child: *"What happened? Oh no, the other guys hit you in the knee. Assistance is needed here!"*

The game continues.

Discussion

We detailed on the software which allows the YOLO robot to encourage creativity stimulation in children. Specifically, we have detailed on the creativity and social behavior programming, as well as the underlying architecture of the software that relies on the storytelling arc and the play movements performed by children. We also presented how the software connects with the hardware.

The impact of this software is broad. By being an easy-to-use tool, children's stakeholders such as educators and parents, have access to a robot that is easy to prepare by using our API (e.g., STEAM-related activities), contrasting with other existing technological tools that can be cumbersome for non-experts to prepare (Chan & Yuen, 2014). Additionally, this software serves as a solid platform in academic studies, where researchers can use YOLO's API to study child-robot interaction.

Conclusion

This Chapter detailed the full process of designing, building, and programming YOLO. To create a tool for creativity that children will easily adopt in their lives, we used UCD procedures and applied PD methods from design research. With this, we developed and adapted methods to support children's involvement in the design of robots. This created a research tool developed in turn of user-centered values. Since robots have been mainly developed without including its end-users in the process, our work in one of the first to involve children during all the stages of the robot design throughout its final conception, influencing the design decisions about the shape and behavior of the robot.

To support the development of this robot we relied in formative research methods and performed intermediate studies of the robot at different design and fabrication stages. These studied provided immediate data towards what was led to the desired interaction, with specific requirements of open-ended playfulness for creativity provocations. It also provided data towards elements that needed refinement in the robot design. The result was an abstract-like robot that uses lights and movements as its interactive modalities. These interaction modes are non-intrusive in children's play providing at the same time necessary elements to provoke creativity. See Chapter 6 for an experimental study of the effectiveness of YOLO as a tool for creativity enhancement).

Limitations and Recommendations for Future Research

We would like to acknowledge improvements for future research, derived from the limitations of this work. As mentioned earlier, we have not empirically compared our design process with other design methods, therefore, we cannot say it is the best design procedure for robot development. As future work, it would be important to formalize each of the developed methodologies and procedures by comparing the effectiveness of a social robot for creativity across developed under different design methodologies. This will enable a deeper evaluation of the design process of robots with children, specifically describing what aspects of the process made the outcome better in terms of creativity stimulation; however, this was beyond the scope of this thesis.

Highlights

- Description of the design process of a robot for creativity, involving its end-users (children) at the heart of the design process, influencing design decisions
- Description of the fabrication of YOLO, including the development of a tutorial for novice users to build YOLO;
- Description of the programming architecture used for this robot, including a tutorial for novice users to program YOLO;
- Released in open access all the materials for developing this robot, which can serve as a research tool and as an object for the community.

Implications for this Thesis

The major implication of this work was the development of a social robot for empirical studies about creativity. In this thesis, we made a deliberate decision to refrain from using existing general-purpose robots and develop our own robotic tool specifically for creativity enhancement. The development of this robot implied learning about mechanical design as well as basic programming skills. The design process of this robot also enabled a deeper understanding of the application scenario for this robot, which consisted of a storytelling activity with children. In the next Chapter, we describe an experimental study with YOLO being used as a creativity-enhancing research tool.

Chapter 6. Experimental evidence of robots as tools for creativity stimulation

This chapter was based on the following papers:

Alves-Oliveira, P., Arriaga, P., Cronin, M. A., & Paiva, A. (2020, March). Creativity Encounters Between Children and Robots. In *Proceedings of the International Conference on Human-Robot Interaction* (pp 379-388). ACM/IEEE. doi:10.1145/3319502.3374817

Correia, F., Petisca, S., Alves-Oliveira, P., Ribeiro, T., Melo, F. S., & Paiva, A. (2017). Groups of humans and robots: Understanding membership preferences and team formation. In *Robotics: Science and Systems*.

Theoretical Background

We revise literature on variables related to creativity, namely personality and motivation; as well as provide an overview of the state of the art about using robots that interact with humans in the context of creativity stimulation.

Variables Related with Creativity

Creativity is an ability that can be influenced by other variables, such as personality and motivation. Some personality traits are associated with more creative success. Previous work suggests that people with high levels of autonomy, with ambition, that are confident, extravert, and open to new experiences were more creative (Feist, 1998). Individuals that have a high extraversion trait are generally more effective in divergent thinking tasks (Furnham, & Bachtiar, 2008). Additionally, motivation, namely intrinsic motivation also appears to be highly related to creativity (Hennessey, 2016). The high motivation of intrinsically motivated individuals has the effect of engaging them in the task (Tan, Lau, Kung, & Kailsan, 2019). However, activities that have external constrains can also undermine intrinsic motivation even in individuals that are usually highly intrinsically motivated. Thus, creativity depends on many factors related to the individual and the task itself (Koestner, Ryan, Bernieri, & Holt, 1984).

Group dynamics also play a role in creativity, as collective emerge occurs which is denoted by the unpredictability of the other creations and the need for one's to adapt and keep up with the creative emergence (Sawyer, 2010). Additionally, the characteristics of every person in the group also bring richness top the creative context that in individual creations is not possible to attain (Paulus, & Nijstad, 2003). Thus, despite finding on individual creativity being more extensively reported in the literature, group creativity seems to bring a new layer to creations.

Interventions for Creativity with Robots

Children's play has undergone a shift since the rise of the digital era where computers and video-games are substituting traditional play formats, such as physical and unstructured play in sandboxes and playgrounds. One of the reasons pointed out for this change relates with the willingness of children to interact with technology (Salonius-Pasternak, & Gelfond, 2005), associated with controversial effects on their development if overused (Gillespie, 2002; Greitemeyer, & Mügge, 2014; Sublette, & Mullan, 2012). However, when used with caution and care (Hutchby, & Moran-Ellis, 2013; Shields, & Behrman, 2000), technology can have positive effects in children across various aspects such as creativity expression and other transferable skills (Druin, & Solomon, 1996; Lewis, 2009; Papert, 1980; Pires, Alves-Oliveira, Arriaga, & Martinho, 2017).

Robots have been programmed with a deep variety of socially intelligent behaviors and affective states; thus, permitting robots to be perceived as social actors (Reeves, & Nass, 1996; Breazeal, 2004a). Additionally, due to their physical and interactive nature, they become a technology that can uniquely impact creativity stimulation. Ali, Moroso, and Breazeal (2019), demonstrated that a robot displaying creative behaviors positively influenced the creativity of children. The authors found that children who interacted with a creative robot generated more ideas, explored more themes, and were more original, than children who interacted with a non-creative robot. Additionally, Gordon, Breazeal, and Engel, (2015) demonstrated that children became more curious, with curiosity viewed as an important creativity trait when interacting with a curious robot. The authors found that these children posed more questions and become avid explores, compared to children who interacted with a non-curious robot. Additional studies with the adult population also show how robots can exert influence on creative abilities in the older population (Kahn Jr, 2016).

Our Contribution

These studies convey evidence regarding the potential of social robots as tools for creativity stimulation in children. However, none of them used validated techniques for creativity development in the design of the behavior for the robot. Our research designed behaviors for the robot that were grounded on effective techniques for creativity established in the literature. Additionally, the physical shape of the robot used within our creativity interventions emerged from extensive co-design sessions with children thus making the shape, form, and feel of the robot adapted and accepted by children. Indeed, our robot enables free play as it can be carried around like a traditional toy. In contrast, existing studies used off-the-shelf robotic platforms that are outlet dependent and do not afford the free play dynamic.

Additionally, our research incorporates a robot in a storytelling context which is a familiar play activity in children’s lives. This aligns with the Product Design Framework in which a product is developed taking into account existing dynamics between users and their environment (Forlizzi, 2008; Netting, 1986). By using storytelling as the main intervention activity, we do not place an extra cognitive load on children, and they can be focused on interacting with the robot in the context of their stories. Using an activity that is already part of children’s lives to develop an intervention is an additional contribution of this work since most interventions for children resemble test-like formats. Previously developed interventions that include robots are were tailored to the capabilities/limitations if the robotic technology to develop the activity and not taking children’s activities as their main design drive.

Figure 41. Play sequence between a child and the YOLO robot.

Goals, Hypothesis, and Research Question

The goal of this study is to investigate the impact of using a robotic intervention for creativity in children's verbal and figural creativity levels (see Figure 41). For that, we have designed five study conditions: i) an *Individual experimental condition* in which children interact with a robot that displays behaviors based on two creativity techniques (mirroring and contrasting, explained in Chapter 5); ii) an *Enhanced experimental condition* in which children interact with a robot that displays behaviors based on two creativity techniques plus social behaviors (social behaviors are described in Chapter 5); iii) a *Group experimental condition* in which groups of three children interact with a robot that displays behaviors based on two creativity techniques (in this condition the robot exhibited the same behaviors as in the individual condition); iv) a *Comparison condition* in which children interact with the same robot but the robot is turned off, thus no displaying any behaviors, and v) a *Control condition* in which children watch a short documentary movie about animals.

Given the literature on group effects, we expect creativity levels of children to be higher in this condition. We also expect the experimental conditions to outperform comparison and control, as the robot was designed inspired in techniques from creativity research. We expect that the individual and enhanced conditions lead to an increase in children's creative abilities compared to the comparison and control conditions. Finally, we expect that children in the comparison condition present higher creativity levels than children in the control. The research question for this study is the following: *Can YOLO, a robot designed as a creativity intervention tool, stimulate creativity in children during s storytelling activity?*

Method

Participants

A total of 130 participants were involved in this study from 54 different schools. Four participants were involved in the pilot testing and four participants were excluded. The reasons for exclusion concerned three participants that were unable either to fill in the questionnaires of performing the intervention activity, and one participant was excluded due to special needs. Therefore, the main analysis consisted of 122 participants. Details about the sample demographics can be found in Table 16 and include children's gender, age, number of siblings, nationality, and ethnicity. Despite having children from different nationalities and ethnicities, all children involved in the study were proficient in written and spoken Portuguese according to their developmental stage. This study was performed in school summer camps in the region of Lisbon.

We applied the Pictorial Personality Traits Questionnaire for Children at pre-test, the Intrinsic Motivation Index (dimensions Interest/Enjoyment and Perceived effort/Usefulness) at post-test, and two questions that evaluated the researcher's warmth and competence at post-test. Results from these controlled factors are detailed in Table 16. The analysis showed no significant differences between groups.

Table 16. *Sample demographics of eligible participants as a function of conditions.*

Demographics	**Total (N = 122)**	**Conditions**					**Tests**
		Control (N = 20)	**Comparison (N = 25)**	**Individual (N = 24)**	**Enhanced (N = 24)**	**Group (N = 29)**	
Gender (*N*)	50F, 72M	8F, 12M	12F, 13M	6F, 18M	10F, 14M	14F, 15M	$\mathcal{X}^2(4, N = 122) = 3.69, p = .449$
Age (*M* ± *SD*; Min-Max)	8.05 ± 0.89; 6-10	8.15 ± 0.99; 7-10	7.80 ± 0.76; 6-9	8.25 ± 0.85; 7-9	7.79± 0.98; 6-10	8.24 ± 0.83; 7-10	$F(4, 122) = 1.74, p = .145$
Sibling (*M, SD*; Min-Max)	0.86, 0.83; 0-4	0.75 ± 0.72; 0-3	1.12 ± 1.13; 0-4	0.96 ± 0.81; 0-3	0.83 ± 0.57; 0-2	0.66 ± 0.77; 0-3	$F(4, 122) = 1.254, p = .292$
Nationality (*N*)							$\mathcal{X}^2(16, N = 122) = 16.10, p = .446$
Portuguese	117	20	23	23	22	29	
Swiss	1	0	0	1	0	0	
Brazilian	1	0	0	0	1	0	
Italian	1	0	1	0	0	0	
Romanian	1	0	1	0	0	0	

Ethnicity (*N*)							$\chi^2(8, N = 122) = 7.54, p = .480$
Caucasian	115	19	24	22	22	28	
Indian	3	1	1	0	1	0	
African	3	0	0	2	0	1	

Measures

We applied two different measures to evaluate creativity in children: CREA (Corbalán et al., 2003) and TCT-DP (Jellen, & Urban, 1986). Additionally, we interpreted the time that children spent on the task as an indicator of creativity exploration. Time was measured in minutes thought the audio recordings f children. We also applied the Pictorial Personality Traits Questionnaire for Children (PPTQ-C; Maćkiewicz, & Cieciuch, 2016), the Intrinsic Motivation Index, (IMI; McAuley, Duncan, & Tammen, 1989), and the Researcher Warmth and Competence. We describe each of these measures below.

CREA is a test was used to measure verbal creative intelligence using a cognitive evaluation of an individual's creativity by considering questions generation (Corbalán Berná, et al., 2003). As our main intervention is verbal, i.e., children *verbally* create a story with a robot, CREA was the fittest test to use in our study. CREA consists of three illustrated pages (Forms A, B, and C) from which the subjects are asked to generate as many questions as he/she can think of that are related with the drawings. Two of these drawings (Forms A and C) can be applied in young children and were used in the scope of this study, Form A was applied at pre-test level and Form C at the post-test level. The questions asked by children were audio-recorded, transcribed, and evaluated taking into account CREA's manual for verbal creativity measurement and a single score is attributed at the end. Therefore, each question received 1 point per cognitive scheme. For example, the question "Is this a rabbit?" would receive one point, whereas the question "Is this a rabbit or a dog?" would receive two points, and so on. Generally, all questions were considered correct including questions that are similar, such as *"What age are they?" and "When were they born"?* were included, as well as questions that represent distance *"Is this related with the History of Portugal?",* or questions that are more general *"What happened* *here?"*. Questions were excluded if they were repeated o if the questions did not contain formulation (e.g., *"What?")*. The single score computed for creativity verbal intelligence consisted of the sum of scores that followed a formula. In this formula, the scores for each question were summed and the scores of excluded questions were subtracted. We explored the presence of extreme values at baseline (pre-test values of CREA). Results showed five extreme values with higher levels of creativity. We transformed data using logarithmic transformation (LOG10+1) to deal with negative numbers. With this logarithmic transformation, no extreme values were found, and data is normally distributed at pre- and post-tests, $p > .05$ (Field, 2009).

TCT-DP is a test that measures the graphic-figural creative potential of children. For this study, we used TCT-DP Form A at the post-test level. No pre-test was applied since the intervention had a verbal content superior to the graphic-figural content. TCT-DP was applied and analyzed similarly to what was described in Chapter 4 (see Appendix A for the instructions used).

The Pictorial Personality Traits Questionnaire for Children (called Personality Test from now on for simplicity; Maćkiewicz, & Cieciuch, 2016) measures the creativity traits of young children. The main idea of this instrument is that the personality traits are indicated by pictures that represent behaviors. The character presented in each picture was designed to be unisex and is performing different actions (e.g., cleaning the room, playing in school). Children are presented with 14 questions and have to in a 3-point type-Likert scale that is accompanied by an image to facilitate their understanding. Their goal is to choose the behavior that they perform more. In case none of the images represent their behavior, they can choose the answer *"it depends"*. This measure was translated into Portuguese by the researchers due to the inexistence of the questionnaire validation for the Portuguese population. However, the authors of this questionnaire were contacted, and the full questionnaire was shared with us. We applied this questionnaire at the pre-test level.

The intrinsic motivation of children to perform the storytelling task was measured using the Intrinsic Motivation Inventory (IMI; McAuley, Duncan, & Tammen, 1989). This inventory is a multidimensional measurement intended to assess participants' subjective experiences related to a target activity. The instrument assesses participants' intrinsic motivation across the 6 subscales of (1) interest/enjoyment, (2) perceived competence, (3) effort, (4) value/usefulness, (5) felt pressure and tension, (6) and perceived choice, thus yielding six subscale scores. For this study, the subscales of Interest-Enjoyment and Effort-Usefulness were chosen. Children used a 5-point type-Likert scale in the form of a Smilyometer to answer this questionnaire by asking children to tick one face (or emoji) (Read, 2008). The key attributes of the Smilyometer are that it is easy to complete, quick to complete, requires limited reading ability, and requires no writing. This measure was applied in the post-test.

Evaluation of the researcher was performed by asking children to answer two questions referring to the researcher's warmth and competence during the intervention task. We included questions targeting the warmth and competence of the researcher that performed the intervention (R1) as these are two fundamental dimensions of social perception defined by the Stereotype Content Model (Cuddy, Fiske, & Glick, 2008; Fiske, Cuddy, Glick, & Xu, 2002). The two questions are the following: *"How nice was the researcher with you?"* (warmth item) and *"How well did the researcher explain the activity to you?"* (competence item). Children were invited to answer these questions using a 5-point type-Likert scale in the form of a Smilyometer (Read, 2008). To ensure additional anonymity in answering these questions, a secret box was provided to the participant who placed their answer in the box. This measure was at a posttest stage and signaled the closure of the activity.

Additionally, we measured the time that children were engaged in the storytelling by analyzing each audio recording of the session. Time is an important variable in creativity findings and time pressure is associated with creativity increase under certain and very specific conditions, such as a deadline to “get a job done”. Therefore, time constraints can be useful for tasks that have a closed end-goal but also come with drawbacks, such as increased anxiety levels (Amabile, Hadley, & Kramer, 2002; Amabile, Mueller, Simpson, Hadley, Kramer, & Fleming, 2002). Given the playful nature of our intervention related with open-ended stories of children, we opted to not limit children’s storytelling in terms of time, but rather to analyze time as a measure of exploration behaviors, which are related to creativity (Cecil, Gray, Thornburg, & ISPA, 1985). Therefore, we measure the total duration of the narrative of storytelling by considering the time difference between the first and the last idea generated for the story. Additionally, latency response time was also measured by analyzing the audio recordings of children. Latency time was defined as the time lapse between the presentation of the stimuli to the children (YOLO robot) and the beginning of the generation of the first idea for the story. Latency response is associated with the generation of new ideas (Benedek, Jauk, Fink, Koschutnig, Reishofer, Ebner, & Neubauer, 2014) and specifically to divergent thinking processes (Acar, & Runco, 2017). Latency time was thus measured from the stimulus onset (presentation of YOLO robot to the children) until the first idea related to the story was generated (see Figure 45).

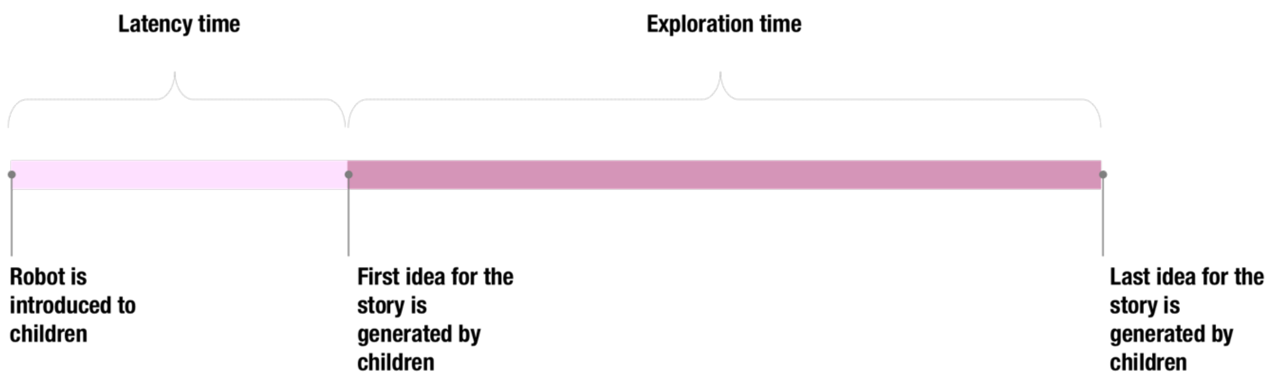

Figure 42. Time measurements included Latency and Exploration time.

Procedure

Data collection will include the following stages: recruitment of summer camps, recruitment of children participants, perform study sessions (including pretest, treatment, posttest), and debriefing. We described these stages in detail below. Additionally, this study followed the ethical and professional standards of the code of conduct of research in Portugal, which requires a commitment to protect the fundamental right to privacy and personal data protection, being subject to the requirements of the General Data Protection Regulation and associated legislation. No monetary or symbolic reward is provided to children who participated in this study. However, children benefited from the study by being exposed to cutting-edge robotic technology.

Recruitment of summer camps. Summer camps in the region of Lisbon, Portugal, were contacted via email. Upon gathering which summer camps are interested in being involved in the study, a visit to the summer camp was performed to assure that the requirements for the study are met (e.g., having access to a private classroom for the study). During this first visit, the study was be presented to the summer camp staff which consisted of teachers and additional relevant personnel. A presentation session with parents was held in some cases to clarify potential doubts depending on the summer camp requests.

Recruitment of participants. Since the participants are children, the written consent of legal guardians was required as well as children's verbal assent to engage in the study at the time of the intervention session. The recruitment process was held jointly with summer camps. A consent form was delivered to the summer camps that have declared interested in being involved in the study. The consent form was then delivered to the legal guardians of children through summer camps and only children whose informed consent was returned and signed were included in the study. This consent form contained: a summary about the study including estimated time per session and the activities that will be performed, an explanation about the voluntary nature of participation detailing the need for children's verbal assent at the time of the session, an explanation about how data will be collected, treated and stored, and that collected data is anonymized and kept private. The main goal of the study was not explicit in the consent form to ensure internal validity. However, a detailed debriefing was provided to children at the end of the study session. Email contact of the researchers was provided in the consent form to enable the legal guardians the possibility of contacting the researcher for clarifying additional questions.

Intervention. The study was be performed in a reserved room ensuring a controlled environment with no interruptions. Three researchers (named R1 and R2, for simplicity) with psychology training were responsible for conducting the study. One of the researchers was responsible for administering the intervention (R1) and two different researchers delivered the pre and posttests measures (R2 and R3). R2 and R3 alternated their presence in the study. They had a similar psychology background and equivalent experience in working with children. This requirement was performed to control for possible experimenter bias.

Before the beginning of the study, R1 coordinated with the summer camp teachers to select one child at the time to perform the session. The child was briefed about the general activities to be performed and gave a verbal assent in participating. It was emphasized that there were no right or wrong answers for any question, and the child was encouraged to ask questions in case some clarification was needed. It was emphasized that there are no consequences in case the child refused to participate. The study was composed of three moments with an estimated total duration of 30-45 min in total:

The pretest took between 10-15min and R2/R3 delivered the following questionnaires: demographic information (e.g., age, number of siblings); Pictorial Personality Traits Questionnaire for Children (Maćkiewicz, & Cieciuch, 2016) translated to Portuguese by the researchers; measure for verbal creativity CREA Form A (Corbalán Berná et al., 2003).

Activity had no time limit and took place on the floor of the room to replicate a natural setting where children play with their toys. R1 explained the activity to the child according to the allocated condition:

Experimental and comparison conditions: It was explained to the participant that he/she will play and create a story of their choice using the YOLO robot as a character. The instructions are delivered by R1 and the participant seated on the floor next to each other to set an informal environment. When the activity started, R1 remained nearby but with minimum interventions. This task had no time-limit and ends when the participant says that the story has come to an end. Pilot testing revealed that story creation takes between 2-10min.

Control condition: Children watched a short documentary movie about animals. Original documentary translated to Portuguese: https://www.youtube.com/watch?v=Ls7WOGcE9Oo. The selected part of the documentary starts at 44:45min until 51:45min, having the same medium time of treatment conditions. This part was chosen as it contained the least emotionally arousing part while still containing enough story content to engage children. At the end of the session, children in this group were given equal opportunity to be exposed to the robot by being invited to play with it.

The post-test took between 10-15min and R2/R3 administered the following questionnaires: Graphic-figural creativity was measured using the TCT-DP Form A (Jellen, & Urban, 1986); verbal creativity was measured using the CREA Form C (Corbalán Berná, et al. 2003); Intrinsic Motivation Inventory (IMI; Dimensions Interest-enjoyment and Effort-usefulness, McAuley, Duncan, & Tammen, 1989); and evaluation of R1 warmth and competence levels (Cuddy, Fiske, & Glick, 2008; Fiske, Cuddy, Glick, & Xu, 2002).

The debriefing was made to the child directly, and the way the information was delivered was adapted to the child's level of language and cognition. This meant that researchers were available to answer any questions that the child might have about the study and the procedures in an understandable way. In case children did not ask direct questions at the end of the study, the researcher voluntarily debriefed children by explaining that the goal of this study was to investigate how children play with toys and how these can affect their creativity (debriefing for the experimental condition). In the case of the control condition, it was explained that we investigated the impact of watching a short documentary movie on children's creativity. Additionally, summer camps involved in this study will have access to the study results.

Results

Group Comparison on Individual Differences (Personality), Evaluation of Researcher (warmth and competence) and Motivation for the Task (Intrinsic Motivation)

We started by analyzing differences between groups regarding personality differences, the motivation for the task, and how children evaluated the researcher in terms of warmth and competence (see Table 17). Results have shown that there were no significant differences across conditions in terms of the personality traits Agreeableness, $F(4, 122) = 2.32$, $p = .061$, Openness to experience, $F(4, 122) = 0.71$, $p = .585$, Neuroticism, $F(4, 122) = 0.80$, $p = .525$, Consciousness, $F(4, 122) = 0.07$, $p = .992$, and Extraversion, $F(4, 122) = 1.14$, $p = .342$. Additionally, we can see that the overall sample scored high on Agreeableness ($M = 2.76$, $SD = 0.39$) and the lowest trait was Neuroticism ($M = 1.37$, $SD = 0.41$). Similarly, results showed no differences between conditions on the level of intrinsic motivation of children to perform the task. This can be seen in as the dimensions of Interest-Enjoyment, $F(4, 122) = 1.51$, $p = .205$, and Effort-Usefulness, $F(4, 122) = 2.22$, $p = .071$ did not differ between conditions. Additionally, children reported to have greatly enjoyed the task ($M = 4.57$, $SD = 0.70$) and have placed effort in it ($M = 4.50$, $SD = 0.66$). In terms of the researcher evaluation, there were also no differences across condition on the perceived researcher warmth, $F(4, 97) = 1.40$, $p = .240$, and competence, $F(4, 97) = .17$, $p = .953$, with these levels being rated high (M = 4.96, SD = 0.20; M = 4.93, SD = 0.20, for warmth and competence, respectively.

Table 17. *Comparison of conditions as a function of children's intrinsic motivation, personality, and evaluation of researcher (warmth and competence).*

Variables	Total	Conditions					Tests
		Control	**Comparison**	**Individual**	**Enhanced**	**Group**	
	M* ± *SD	***M* ± *SD***	***M* ± *SD***	***M* ± *SD***	***M* ± *SD***	***M* ± *SD***	
Intrinsic Motivation (range 1-5)							
Interest-enjoyment	4.57 ± 0.70	4.55 ±0.79	4.48 ± 0.59	4.44 ± 0.90	4.47 ± 0.79	4.83 ± 0.31	*F*(4, 122) = 1.51, *p* = .205
Perceived effort-usefulness	4.50 ± 0.66	4.20 ± 0.83	4.57 ±0.43	4.51 ± 0.75	4.38 ± 0.83	4.72 ± 0.36	*F*(4, 122) = 2.22, *p* = .071
Personality (range 1-3)							
Agreeableness	2.76 ± 0.39	2.88 ± 0.25	2.87 ± 0.25	2.58 ± 0.55	2.75 ± 0.38	2.74 ± 0.38	*F*(4, 122) = 2.32, *p* = .061
Openness to experience	2.61 ± 0.39	2.63 ± 0.39	2.68 ± 0.30	2.54 ± 0.44	2.67 ± 0.34	2.55 ± 0.46	*F*(4, 122) = 0.71, *p* = .585
Neuroticism	1.37 ± 0.41	1.32 ± 0.48	1.39 ± 0.44	1.43 ± 0.44	1.46 ± 0.39	1.29 ± 0.32	*F*(4, 122) = 0.80, *p* = .525
Consciousness	2.58 ±0.48	2.57 ± 0.47	2.61 ± 0.42	2.55 ± 0.54	2.57 ± 0.57	2.60 ± 0.45	*F*(4, 122) = 0.07, *p* = .992
Extraversion	2.54 ± 0.46	2.67, 0.43	2.61 ± 0.56	2.49 ± 0.39	2.40 ± 0.45	2.54 ± 0.44	*F*(4, 122) = 1.14, *p* = .342
Evaluation of Researchers (range 1-5)							
Warmth	4.96 ±, 0.20	4.90 ±, 0.31	5.00 ± 0.0	4.92 ± 0.28	5.00 ± 0.0	5.00 ± 0.0	*F*(4, 97) = 1.40, *p* = .240
Competence	4.93 ±, 0.20	4.90 ±, 0.45	4.92 ± 0.29	4.92 ± 0.28	4.95 ± 0.23	4.96 ± 0.19	*F*(4, 97) = .17, *p* = .953

Table 18. *Zero-order correlations between creativity outcomes (verbal and figural) with children's baseline levels of verbal creativity, intrinsic motivation (interest-enjoyment and perceived effort-usefulness) and personality (openness to experience, neuroticism, extraversion, conscientiousness, and agreeableness).*

	Creativity outcomes			
Baseline verbal creativity measures & motivation	Verbal	Figural global	Figural: Innovativeness	Figural: Adaptiveness
Baseline Verbal creativity	.60**	.18	.14	.17
Interest/enjoyment	.09	.06	-.01	.20*
Perceived effort-usefulness	.02	-.05	-.09	.09
Openness to experience	-.03	.08	.07	.04
Neuroticism	.01	-.04	.05	-.01
Extraversion	.04	.11	.08	.11
Conscientiousness	-.05	-.12	-.17	.07
Agreeableness	-.06	-.08	-.10	.01

Note. * $p < .05$; ** $p < .001$

We analyzed the correlations between the creativity outcomes measured with CREA and TCT-DP (verbal and figural-graphic creativity) with children's baseline levels for the creativity tests, their personality traits, and intrinsic motivation (see Table 18). Results showed a positive and moderate correlation between the verbal creativity at baseline and at the post-test level, $r = .60$, $p < .001$. We also found a correlation although with a lower value, between the dimension of Interest-Enjoyment of the IMI and the Adaptiveness dimension of TCT-DP, $r = .20$, $p < .05$.

Effects of Conditions on Figural Creativity

We started by analyzing the effect of the Group conditions on the figural creativity of children. To compare the five conditions (Control, Comparison, Individual, Enhanced, and Group) on figural creativity (TCT-DP global, and the two dimensions of adaptiveness and innovation) using CREA pre-test as a covariate, analyses of covariance (ANCOVAs) were conducted. Results for the global creativity, $F(4,112) = .41$, $p = .80$, $\eta_p^2 = .01$, and for each dimension, i.e., adaptiveness, $F(4,112) = .41$, $p = .80$, $\eta_p^2 = .01$, and innovativeness, $F(4,112) = .46$, $p = .77$, $\eta_p^2 = .02$, did not present significant results.

Additionally, in the same ANCOVAs, we performed two planned contrasts of interest. The first planned contrast compared the effect of the four conditions that used a robot (Comparison, Individual, Enhanced, and Group) to the control condition. However, the analyses also revealed no significant result, $F(1, 112) = 1.33$, $p = .25$, $\eta_p^2 = .01$. The second planned contrast compared the effect of the three conditions that used the no static version of the robot (Individual, Enhanced, and Group) to the control condition, but the results were also non-significant, $F(1, 112) = 1.41$, $p = .24$, $\eta_p^2 = .01$.

Effect of Conditions on Verbal Creativity

To compare the five conditions (Control, Comparison, Individual, Enhanced, and Group) on verbal creativity (CREA), a one-way ANOVA was conducted using a change score between the post- and the pre-tests scores (higher scores correspond to higher increase in verbal creativity from baseline). The overall results were not significant, $F(4, 111)$, $p = .08$, $\eta_p^2 = .07$. However, the comparison between each level revealed that verbal creativity increased more in the Group ($\Delta M = 6.56$; $\Delta SE = 1.22$) compared to the Enhanced ($\Delta M = 1.50$; $\Delta SE = 1.31$, $p = .006$) and the Comparison conditions ($\Delta M = 2.96$; $\Delta SE = 1.30$, $p = .45$). No significant differences were found between the Individual ($\Delta M = 4.17$; $\Delta SE = 1.32$, and the Control conditions ($\Delta M = 3.90$; $\Delta SE = 1.42$), $p > .05$ (see Figure 43).

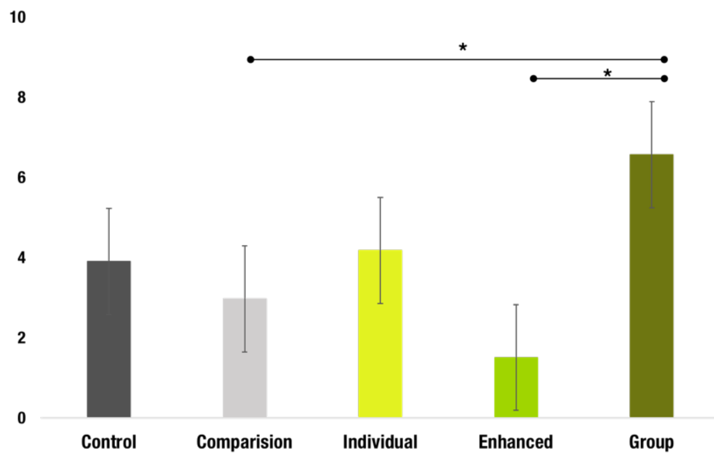

Figure 43. Increase in verbal creativity (CREA) from pre to post-test, *$p < .05$.

Effects of Conditions on Exploration and Latency Times

The effect of the conditions on the creativity process of story creation while children were interacting with the robot were additionally tested by considering the time spent creating the story; and the latency (i.e., the amount of delay it took to create the first idea for the story), both measured in minutes. For these analyses we did not consider the Control condition, since these processes could not be analyzed in a condition where children were only watching a movie. Therefore, to compare the four conditions (Comparison, Individual, Enhanced, and Group) on exploration using CREA pre-test as a covariate, two ANCOVAs were conducted.

Results for the time children spent creating the story showed an effect of the condition, $F(3, 91) = 29.03$, $p < .001$, $\eta_p^2 = .49$, indicating that the children spend more time creating the story in the Group, ($M = 8.92$, $SE = .43$), than in the Enhanced ($M = 4.74$, $SE = .49$, $p < .001$), Individual ($M = 4.59$, $SE = .51$, $p < .001$), and Comparison conditions ($M = 2.62$, $SE = 48$, $p < .001$). Results also indicated that in the Comparison children spend the lowest time creating the

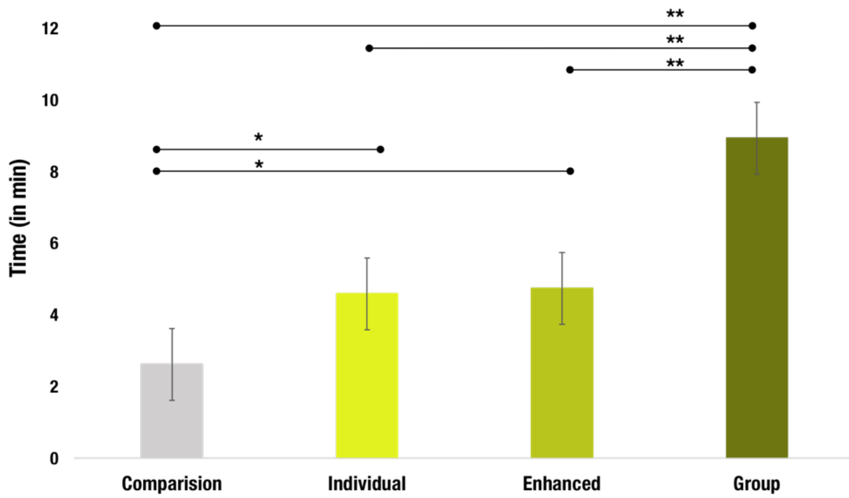

Figure 44. Duration of story creation as a function of conditions in which children played with the robot. *$p < .05$, **$p < .001$.

story compared to the Individual and the Enhanced conditions, $p = .006$ and $p = .002$, respectively. No significant differences were found between the Individual and the Enhanced conditions, $p > .05$ (see Figure 44).

The ANCOVA results for the latency time also showed an effect of the condition, $F(3, 91) = 13.73$, $p < .001$, $\eta_p^2 = .31$, indicating that the highest latency time occurred in the Group, ($M = 2.25$, $SE = .15$), compared to the Enhanced ($M = 1.74$, $SE = .15$, $p = .018$), Individual ($M = 1.63$, $SE = .16$, $p = .006$), and Comparison ($M = .91$, $SE = 15$, $p < .001$). In addition, the results indicated that latency time in the Comparison condition was the lowest compared to the Individual and the Enhanced conditions, $p = .001$ and $p < .001$, respectively. No significant differences were found between the Individual and the Enhanced conditions, $p > .05$ (see Figure 45).

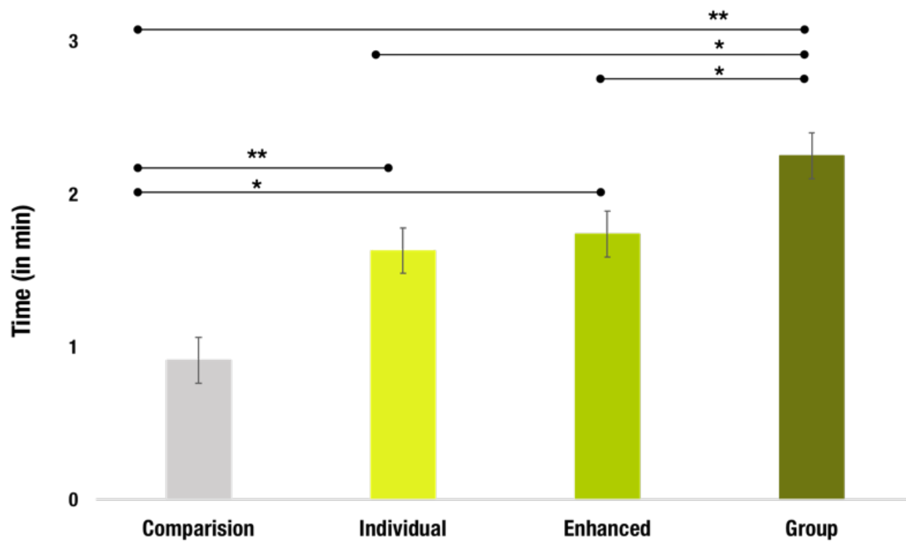

Figure 45. Latency time to generate ideas as a function of conditions in which children played with the robot *$p < .05$, **$p < .001$.

Discussion

This study aimed at providing evidence for the use of a robot in creativity interventions with children for creativity fostering. This robot was co-designed with children and its behaviors were grounded in literature research in creativity. Additionally, the context of the intervention was a playful task of storytelling in which children used the robot as a character for their stories. We evaluated creativity increase in terms of verbal and figural creativity stimulation. Our results showed that the Group condition outperformed the Individual conditions, including the Experimental, Comparison, and Control conditions. Particularly, children's creativity increased comparing the Group condition with the Individual condition, in which the robot was generating the same types of behaviors. This result seems to show that group effects play an important role in creativity stimulation.

Additionally, we have measured how long children were engaged in the storytelling task and results showed that children are engaged for a longer period in the Group condition compared to the other conditions. Additionally, results also showed that children have a significantly lower exploration time in the Control condition, which means they are engaged in creativity processes of storytelling for significantly lower periods of time. An interesting result is the fact that children in the Control condition had a lower latency time and in the Group condition they had a higher latency time. Therefore, while children took more time to generate ideas for the story in a group context, they then seem to stay engaged in the task for longer periods. Similarly, to the previous result group effects seem to be strong in creativity in the context of an open-ended task. We hypothesize that children are discussing more between until reaching an agreement in the Group condition, therefore also taking more time for the story creation. Taken together, these confirm our hypothesis and seem to be in line with previous work on adult group creativity which shows that while it is possible for one person to take multiple perspectives on a problem or task, a wider range of perspectives is more likely when several people are brought together and approach an issue or problem from different angles or backgrounds (Paulus, & Nijstad, 2003).

Research on group creativity has also shown that the group dynamics influence creativity processes, especially in groups that hold different perspectives over a problem or situation. Indeed, products generated in these groups are more original (Van Dyne, & Saavedra, 1996), innovative (De Dreu, & West, 2001), complex (Gruenfeld, 1995), and with higher value (Nemeth, Brown, & Rogers, 2001). Additionally, the cognitive mechanisms by which groups exchange ideas to generate decisions or products, can be considered to require creative processes. In our case, to create a cohesive story children had to debate ideas with each other until a consensus was reached. Taking into account this literature and the fact that we have collected audio recordings of children creating a story for all the conditions, new hypothesis can be generated *a posteri*. Namely, we hypothesize that the creative process of children differs across conditions. This hypothesis can yield additional understandings about interventions for creativity using robots and the group dynamics behind them. Therefore, it would be interesting to study this hypothesis as future work; however, it is currently outside the objectives of this thesis[24].

Limitations

This study contains limitations that we would like to acknowledge. Firstly, to study the effects of a creativity intervention we used a test that evaluated creativity potential traits. Although the results are informative and important, they do not account for influences in creativity states in children. Creativity is reported to changes over the lifespan demonstrating that creative states are not stable, instead they can have fluctuations (Palmiero, Di Giacomo, & Passafiume, 2014). Despite creativity being dependent on individual traits, such as personality (Puryear, Kettler, & Rinn, 2017) and motivation (Conti, Collins, & Picariello, 2001), it should also be looked at from a state perspective, which is not present in the study. Additionally, CREA, was our main creativity measure since it evaluates verbal creativity mapped to the verbal nature of the task. As mentioned before, CREA, provides a sum score for creativity outcomes. However, this score has no maximum or minimum value, which can introduce problematic unbalances in when it comes to analyzing the results of this test.

Authors in the field of creativity have pointed out several limitations for the existing creativity tests. Firstly, creativity is a multifaced concept and a domain-dependent construct; therefore, instruments for measuring creativity may vary as a function of the domain-components

[24] We collaborated with an animation artist to bring one of the stories created by children come to live. This story is called "The Medal" and was created in the context of the individual condition: https://www.youtube.com/watch?v=yJwv-IatUcw&feature=youtu.be

being stimulated or evaluated (Barbot, Besançon, & Lubart, 2011). Secondly, there are a varying number of definitions for what creativity means, which suggests that creativity measures vary depending on which concept of creativity was used on the scale validation (Houtz, & Krug, 1995). As a consequence, most of the knowledge about creativity is based on different assumptions of what creativity is, introducing a variability bias that hinders understanding about intervention, which is the case of our study. Thirdly and most importantly for the understanding of our results, is the fact that there are very few data evidencing the stability, factor complexity and predictive validity of creativity measures. This leads many authors in the field of creativity to develop new scales and lament the failure of existing measurement methods (Barbot, Besançon, & Lubart, 2011; Haensly Torrance, 1990; Houtz, & Krug, 1995). Therefore, analyzing the creative process of children could provide new results about the understanding of the effects of the different interventions. This could be achieved by relying on a traditional scoring system for the cognitive dimensions of creativity comprised of Fluency (number of ideas generated), Flexibility (number of ideas that belong to a different category), Elaboration (number of details introduced), and Originality (rarity of ideas) (Guilford, 1967; Sternberg, 2005; Torrance, 1966).

Highlights

- Experimental testing of the effects of a novel intervention tool, a social robot, in creativity training.
- Analysis of group versus individual effects on creativity stimulation with robots.
  Pre-registration of this research in the Open Science Framework, ensuring a planned research plan and data analysis, according to pre-defined hypothesis

Chapter 7. General discussion

This thesis sheds light on the effects of a creativity intervention that uses an autonomous robot to stimulate creativity during the interaction with children in the context of free play. This work includes a literature a review of interventions for creativity, studies to investigate the potentials of robotic technology in creativity stimulation, and on the development of a fully autonomous robot. The main contributions of this thesis are represented in Figure 46.

This work came from the need to nurture creativity in children given its current importance in society. As previously mentioned, Bloom's Taxonomy was upgraded and now includes creativity as the most complex of the cognitive processes (Hanna, 2007). The New Skills Agenda for Europe delivered by the European Commission considered creativity as one of the Key Competences for Lifelong Learning (Cachia, Ferrari, Ala-Mutka, & Punie, 2010; European Comission, 2006;), and UNESCO's Sustainable Developmental Goals highlighted the importance of creativity and innovation to develop societies and economies (UNESCO, 2017). Therefore, this work has the potential to contribute to the field of creativity research, design, and HRI.

In terms of psychology, and specifically focusing on the creativity research field, this work contributed with an extensive literature review spanning 68 years of research on creativity programs for children. During the systematic review of the literature, there was a need identified during this thesis to code the existing programs. With the fuzziness of literature in the field of creativity, in which many concepts are being used under different terms lacking a general agreement not only on the concept of "creativity" but also on its various related concepts (Runco, Nemiro, & Walberg, 1998; Sternberg, 1999), we have developed a coding scheme for coding creativity interventions.

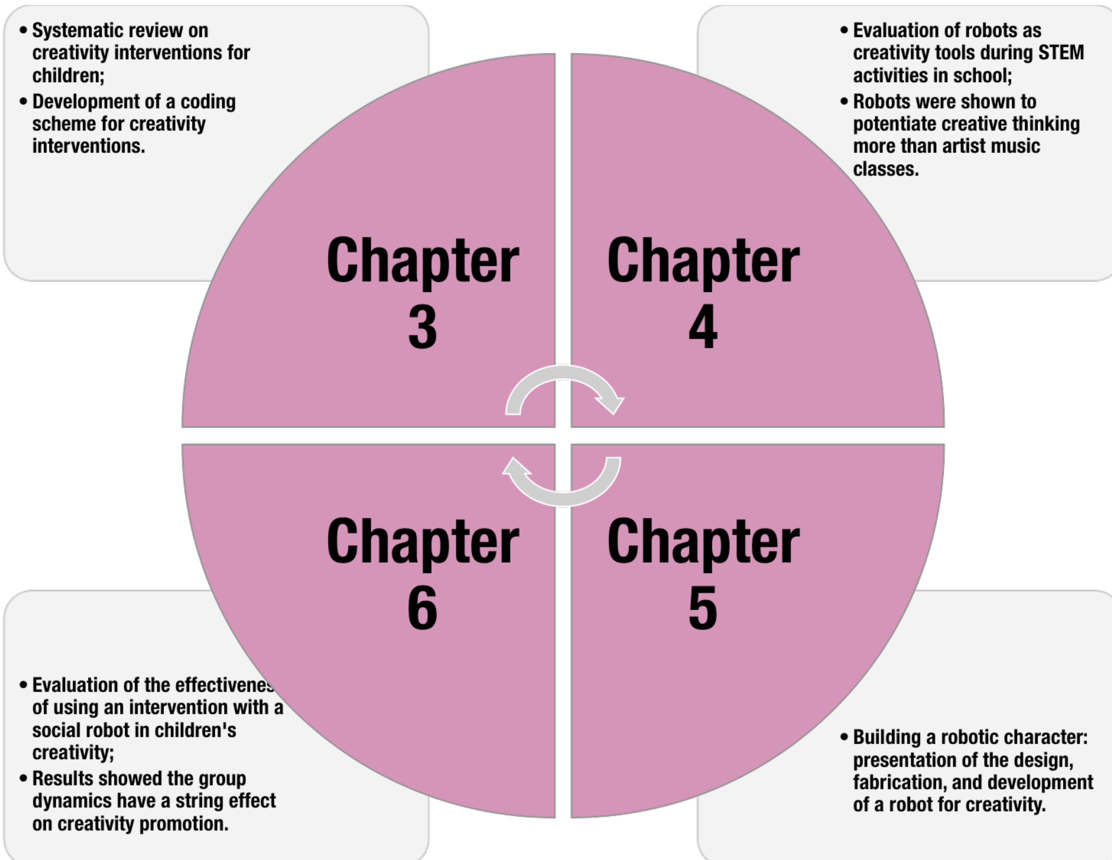

Figure 46. Main contributions of this thesis organized by chapters.

This coding scheme was extensively based on previous literature (Scott, Leritz, & Mumford, 2004a) and included different levels of analysis for which a creativity intervention can be classified for (see Chapter 3 for more details).

Also, we demonstrated that existing activities performed in schools using robots, such as coding and designing robots, have the potential to increase creativity (see Chapter 4). This introduces a turning point for classroom activities, as not only children learn new concepts of geometry, math, physics during STEM education, as their creativity gets stimulated at the same time as a positive side-effect. Up to now, school systems have been looked at conservatively when it comes to stimulating creativity, being the main reasons related with homework overload and the passive role of children while learning (Gardner & Gardner, 2008; Nash, 1974; Runco, Acar, & Cayirdag, 2017; Runco & Cayirdag, 2006; Torrance, 1968). Given that creativity has been considering one of the most important qualities to have (Bloom, 1956, Hanna, 2007) this constitutes an important result as schools should incorporate similar activities to develop creativity in children.

Within this work, we also demonstrated the design and fabrication of our own robot for creativity. The motivation behind building a robot relates to the fact that existing robots presented several limitations in the context of a creativity intervention for children. For example, existing robots are usually heavy, hard to manipulate, and children are cautious when it comes to the interaction with fear of damaging it. On top of this, existing robots are outlet dependent, which constrains children in being seated at the table or confined to a place during an interaction. Overall, our main contribution was the development of a robot whose interaction with children enables creativity development as this robot was designed according to creativity research principles. Additionally, this robot enables free play, physical touch, and unrestricted movements through space. An additional and equally important contribution was the fact that this robot was co-designed with children, given them the possibility of expressing their wishes, desires, and wants for a technology that is meant to be used by them. Through the interaction with children, we envisioned this robot as a catalyzer of their creative thought. During the process of design and fabrication of this robot, new knowledge was acquired. Concepts from related fields of research, such as mechanical engineering, computer science, and robotics were learned to enable us to build this robotic artifact.

This research demonstrates how social robots can become tools for psychological interventions. Social robots have already been used as an intervention tool or a stimulus in interventions (Cangelosi, & Schlesinger, 2018). We have leveraged on robot's controllability, namely the possibility to code any behavior into a robot, making it a tool in creativity interventions. We conducted an intervention task that can facilitate creative processes due to its open-ended nature (storytelling) but also due to the familiarity of children with telling stories, not imposing an extra cognitive load on children during the intervention (see Chapter 6). This approach goes in line with the Product Design Framework in which a product is developed taking into account existing dynamics between users and their context and environment (Netting, 1986; Forlizzi2008). Having robots as tools also introduces new benefits for the field of psychology as they easy the replication process of studies. Researchers can share the code of their robots with other researchers to reproduce the same behaviors for the robot in a different lab. We believe that this will enable transparent research paradigms and contribute to the advancement and innovation in the field (Ishiyama, 2014).

Reflections for Future Studies in Child-Robot Interaction for Creativity

We would like to take a chance to share deeper reflections that emerged from findings that this thesis originated and how they relate to the interdisciplinary nature of this research. Our main goal with this work was to use robots as creativity interventions with children whose purpose was to stimulate their creative abilities. To achieve this, we build on a combination of three main research fields: Psychology, Design Research, and HRI. We started by performing a literature review that provided a deeper understanding of the various training programs for creativity. While this literature review was eliciting in many aspects of creativity research, it also proved to be limited in its essence. The main limitation we found was that the term "creativity" is not well defined in the literature. We found not many different and sometimes opposing views of the term "creativity", but we also found that the different skills that can be developed under creativity training lack consensus. We, therefore, had difficulty in categorizing the different creativity skills that training programs were promoting and to choose what creativity skills we could promote in children within our research. To face this, we developed a coding scheme that we hope can initiate further consensus on this field and have chosen to stimulate divergent and convergent thinking skills. However, this decision still has its problems as, for example, it was difficult to determine when divergent thinking turns into convergent thinking. Therefore, we acknowledge that more work is needed to define creativity concepts.

An additional limitation that we have found related to measuring creativity. While several tests that measure creativity traits and potentials, there is a need to develop measures that account for analyzing creativity states. What this means is that while pre- and post-test measures are available to measure impacts/effects on creativity, there is a lack of measures that account for analyzing the *creativity process*, which is an extremely rich part of creativity research. Although some coding schemes can be available in the literature, these are not sustained by studies that can inform benchmarks on the creative process. This means that although we can quantify the creative process, we are unable to tell if the resulting creativity score corresponds to high/low creativity. Furthermore, there is no benchmark for different demographics, which prevents understand about the creative process across different populations such as children vs adults. There is thus a need to deepen the research in creativity processes.

Taken together, this had several implications for our work. Firstly, we found it difficult to understand how to *design* a robot for creativity. While we did our best to motivate our design decisions, there is a corresponding uncertainty since concepts in creativity are poorly defined and confusing at times. We envision that further studies with the YOLO robot in which the behavior of the robot is programmed with different degrees of creativity interventions can lead to a more accurate understanding of the effects of the interaction in children's creativity levels and dimensions.

Secondly, we would like to acknowledge that previous work on creativity and robots is scarce, which resulted in very few works that could inform our own. Despite this, we were still able to build an autonomous robot that can influence the creativity of children up to a certain level. This research-case furthers the usage of social robots as it presents a groundbreaking deployment of a robot for creativity interventions, which has never been done before. This sets new goals for the field of HRI where robots can be used to improve human skills and empower their lives, rather than just performing repetitive tasks and help-behaviors. YOLO physical look (or embodiment) is non-humanoid, showing that we do not necessarily need robots that resemble the human body to create engaging interactions that have effects on creativity. Instead, minimalistic interactions with abstract robots such as YOLO can be efficient in affecting human behavior. This also sets a different vision for the field of robots that goes beyond the traditional sci-fi looking robots to enter more creative robot's designs. Additionally, the fact that robots impacted the creativity of children also demonstrates (shows in the studies of Chapters 4 and 6) demonstrates that psychology can benefit from an additional research tool – the robots themselves.

Thirdly, During the process of designing YOLO, as considering this was a UCD process in which children were active participants in each design stage, we were able to contribute to several contributions to the field of design research. A major contribution was the abstraction in our design process of YOLO to the UCD process of *any* social robot. We achieved this by generalizing the different stages of the Double Diamond-Design Process Model that we have used with children, to the design of any robot. More on this can be seen in Figure 21. We intended to provide to any researcher with a starting point for designing a robot that is inclusive of the end-users throughout the entire design process. While users have been included in the design of social robots in the past, they are usually called in late in the design stages when all the major design decisions were made. Especially in the case of children, who are a more challenging group when it comes to collecting design requirements, there is a lack of research in this regard. Therefore, our contribution to both field of HRI and Design Research concerns the adaption of the Double Diamond-Design Process Model to design social robots under a UCD approach.

I would like to finish this thesis by acknowledging the different learning acquisitions that were present since the beginning of this work: from studying mechanical engineering and computer science to studying design research and trying to combine it with psychology. While this thesis demonstrates the research implications of the work, it does not make justice to all the challenges I came across and to the sense of bliss I felt when I was immersed in the learning process.

References

Note: References marked with an asterisk symbol, "*", indicate studies included for analysis in the systematic review of Chapter 3.

Abbas, R., Tootell, H., Freeman, M., & Ellmers, G. (2018). Engaging Young Children as Application Design Partners: A Stakeholder-Inclusive Methodological Approach. *IEEE Technology and Society Magazine*, *37*(3), 38-47. doi:10.1109/MTS.2018.2857584.

Abdulla, A. M., & Cramond, B. (2018). The creative problem finding hierarchy: A suggested model for understanding problem finding. Creativity: Theories – Research – Applications(5), 197-229.

Abras, C., Maloney-Krichmar, D., & Preece, J. (2004). User-centered design. Bainbridge, W. *Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications, 37*(4), 445-456.

Ackermann, E., & Strohecker, C. (1999). Build, launch, convene: Sketches for constructive-dialogic play kits. In *TR99-30, Mitsubishi Electric Research Lab*.

Ackermann, E., Strohecker, C., & Agarwala, A. (1997). The Magix series of playful learning environments. *Paper TR97–24, MERL–Mitsubishi Electric Research Laboratory*.

Admoni, H., & Scassellati, B. (2017). Social eye gaze in human-robot interaction: A review. *Journal of Human-Robot Interaction, 6(*1), 25-63. doi:10.5898/JHRI.6.1.Admoni.

Africano, D., Berg, S., Lindbergh, K., Lundholm, P., Nilbrink, F., & Persson, A. (2004, April). Designing tangible interfaces for children's collaboration. In *CHI'04 Extended Abstracts on Human Factors in Computing Systems* (pp. 853-868). ACM. doi:10.1145/985921.985945.

Agrawala, M., Phan, D., Heiser, J., Haymaker, J., Klingner, J., Hanrahan, P., & Tversky, B. (2003, July). Designing effective step-by-step assembly instructions. In *ACM Transactions on Graphics (TOG)* (Vol. 22, No. 3, pp. 828-837). ACM. doi:10.1145/1201775.882352.

*Akar, I., Sengil-Akar, S. (2013). The effectiveness of the creative reversal act (CREACT) on student's creative thinking: Further evidence from Turkey. *Turkish Online Journal of Educational Technology, 12*(4), 188-191.

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1-11. doi:10.1016/j.edurev.2016.11.002.

Albert, R. S., & Runco, M. A. (1999). A history of research on creativity. In R. Sternberg, *Handbook of Creativity* (pp. 16-31). Cambridge, UK: Cambridge University Press.

*Alencar, E., Feldhusen, J. F., Widlak, F. W. (1999). Creativity training in elementary schools in Brazil. *The Journal of Experimental Education, 44*(4), 42-40. doi:10.1080/00220973.1976.11011544.

*Alfonso-Benlliure, V., Meléndez, J. C., & García-Ballesteros, M. (2013). Evaluation of a creativity intervention program for preschoolers. *Thinking Skills and Creativity, 10*, 112-120. doi:10.1016/j.tsc.2013.07.005.

Ali, S., Moroso, T., & Breazeal, C. (2019, June). Can Children Learn Creativity from a Social Robot?. In *Proceedings of the 2019 on Creativity and Cognition* (pp. 359-368). ACM. doi: 10.1145/3325480.3325499.

Almeida, L., & Nogueira, S. I. (2010). Estudo preliminar do teste Test for Creative Thinking-Drawing Production (TCT-DP). *Psychologica, (52-I),* 193-210.

Alrutz, M. (2015). Digital storytelling and youth: Toward critically engaged praxis. *Youth Theatre Journal*, *29*(1), 1-14. doi:10.1080/08929092.2015.1020184.

Als, B. S., Jensen, J. J., & Skov, M. B. (2005, June). Comparison of think-aloud and constructive interaction in usability testing with children. In *Proceedings of the 2005 Conference on Interaction Design and Children* (pp. 9-16). ACM. doi:10.1145/1109540.1109542.

Altman, D. G. (1990). *Practical Statistics for Medical Research*. London, UK: Chapman & Hall Press.

Altman, N. S. (1992). An introduction to kernel and nearest-neighbor nonparametric regression. *The American Statistician*, *46*(3), 175-185.

Alves-Oliveira, P., Arriaga, P., Nogueira, S. I., Hoffman, G., & Paiva, A. (2016) Landscapes of creativity. *PROSPERO: International Prospective Register of Systematic Reviews*. Available from: https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=52101

Alves-Oliveira, P., Arriaga, P., Paiva, A., & Hoffman, G. (2017, June). YOLO, a Robot for Creativity: A Co-Design Study with Children. In *Proceedings of the 2017 Conference on Interaction Design and Children* (pp. 423-429). ACM. doi:10.1145/3078072.3084304.

Alves-Oliveira, P., Arriaga, P., Paiva, A., & Hoffman, G. (2019). Guide to build YOLO, a creativity-stimulating robot for children. *HardwareX*, *6*, e00074. doi:10.1016/j.ohx.2019.e00074

Alves-Oliveira, P., Arriaga, P., Paiva, A., & Hoffman, G. (2020). YOLO-Your Own Living Object. In *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 638-638). doi:10.1145/3371382.3378395.

Alves-Oliveira, P., Arriaga, P., Paiva, A., & Hoffman, G. (under review). Children as Robot Designers. *CoDesign Journal.*

Alves-Oliveira, P., Gomes, S., Chandak, A., Arriaga, P., Hoffman, G., & Paiva, A. (2020). Software architecture for YOLO, a creativity-stimulating robot. *arXiv preprint arXiv:1909.10823*. (Decision: Revise and re-submit to SoftwareX Journal).

Alves-Oliveira, P., Küster, D., Kappas, A., & Paiva, A. (2016, September). Psychological science in hri: Striving for a more integrated field of research. In *2016 AAAI Fall Symposium Series.* Technical Reports.

Alves-Oliveira, P., Sequeira, P., Melo, F. S., Castellano, G., & Paiva, A. (2019). Empathic robot for group learning: A field study. *ACM Transactions on Human-Robot Interaction (THRI)*, *8*(1), 3. doi:10.1145/3300188.

Alves-Oliveira, P., Xavier, C., Arriaga, P., Hoffman, G., & Paiva, A. (under review). Creativity Landscapes: Systematic Review Spanning 68 Years of Creativity Interventions for Children. *Journal of Creativity Research*.

Amabile, T. M. (1989). *Growing up creative: Nurturing a lifetime of creativity.* Norwalk, CT, US: Crown House Publishing Limited.

Amabile, T. M. (1996). *Creativity in Context: Update to the Social Psychology of Creativity.* Boulder, CO, US: WestviewPress.

Anderson-Bashan, L., Megidish, B., Erel, H., Wald, I., Hoffman, G., Zuckerman, O., & Grishko, A. (2018, August). The Greeting Machine: An Abstract Robotic Object for Opening Encounters. In *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (pp. 595-602). IEEE. doi:10.1109/ROMAN.2018.8525516.

*Antonietti, A. (2000). Enhancing creative analogies in primary school children. *North American Journal of Psychology, 2*(1), 75-84.

Arbuthnott, K. D., & Sutter, G. C. (2019). Songwriting for nature: increasing nature connection and well-being through musical creativity. *Environmental Education Research, 1*-19. doi:10.1080/13504622.2019.1608425.

Armbruster, B. B. (1989). Metacognition in creativity. In Glover, J. A., Royce, R. R., & Reynolds, C. R., *Handbook of creativity* (pp. 177-182). Boston, MA, USA: Springer.

Axtell, J. (1966). Discontinuities in the perception of curiosity in gifted preadolescents. *Gifted Child Quarterly, 10*(2), 78-82.

Ayman-Nolley, S. (1992). Vygotsky's perspective on the development of imagination and creativity. *Creativity Research Journal, 5*(1), 77-85.

Azenkot, S., Feng, C., & Cakmak, M. (2016, March). Enabling building service robots to guide blind people a participatory design approach. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 3-10). IEEE. doi:10.1109/HRI.2016.7451727.

*Azevedo, I., Morais, M. F., & Martins, F. (2017). Educação para a criatividade em adolescentes: Uma experiência com Future Problem Solving Program Internacional. *REICE. Revista Electrónica Iberoamericana sobre Calidad, Eficacia y Cambio en Educación, 15*(2), 75-87. doi:10.1080/10400419209534424.

Babineu, J. (2014). Product review: Covidence (Systematic Review Software). *Journal of the Canadian Health Libraries Association, 35*(2), 68-71.

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented Reality Trends in Education: A Systematic Review of Research and Applications. *Educational Technology & Society, 17* (4), 133–149.

*Baer, J. (1996). The effects of task-specific divergent-thinking training. *The Journal of Creative Behavior, 30*(3), 183-187. doi:10.1002/j.2162-6057.1996.tb00767.x.

Baer, J., (1998). The case for domain specificity of creativity. *Creativity Research Journal, 11*(2), 173-177. doi:10.1207/s15326934crj1102_7.

Baer, J. (2015). The importance of domain-specific expertise in creativity. *Roeper Review, 37*(3), 165-178. doi:10.1080/02783193.2015.1047480.

Baer, J. (2017). Content Matters: Why Nurturing Creativity Is So Different in Different Domains. In R. Beghetto, & B. Sriraman, *Creative Contradictions in Education. Creativity Theory and Action in Education* (Vol. 1, pp. 129-140). Springer, Cham.

Baer, J., & Kaufman, J. C. (2005). Bridging generality and specificity: The amusement park theoretical (APT) model of creativity. *Roeper Review, 27*(3), 158-163.

*Baer Jr, J. M. (1988). Long-term effects of creativity training with middle school students. *The Journal of Early Adolescence, 8*(2), 183-193. doi:10.1177/0272431688082006.

Baer, M. (2010). The strength-of-weak-ties perspective on creativity: A comprehensive examination and extension. *Journal of Applied Psychology, 95*(3), 592-601. doi:10.1037/a0018761.

Bai, Z., Blackwell, A. F., & Coulouris, G. (2012, November). Making Pretense Visible and Graspable: An augmented reality approach to promote pretend play. In *2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (pp. 267-268). IEEE. doi:10.1109/ISMAR.2012.6402567.

Bakeman, R., & Quera, V. (2011). *Sequential analysis and observational methods for the behavioral sciences*. Cambridge University Press.

Bandura, A. (1971). *Social Learning Theory*. Morristown, NJ: General Learning Press.

Barab, S. (2006). *Design-Based Research: A Methodological Toolkit for the Learning Scientist*. Cambridge University Press.

Baraka, K., Alves-Oliveira, P., & Ribeiro, T. (2020). An extended framework for characterizing social robots. *arXiv preprint arXiv:1907.09873*. (Chapter submitted to the Evaluation Methods Standardization in Human-Robot Interaction Book, Springer.).

Baraka, K., & Veloso, M. M. (2018). Mobile service robot state revealing through expressive lights: formalism, design, and evaluation. *International Journal of Social Robotics*, *10*(1), 65-92. doi:10.1007/s12369-017-0431-x.

Barber, C. B., Dobkin, D. P., Dobkin, D. P., & Huhdanpaa, H. (1996). The quickhull algorithm for convex hulls. *ACM Transactions on Mathematical Software (TOMS)*, *22*(4), 469-483. doi: 10.1145/235815.235821.

Bardzell, J., & Bardzell, S. (2013, April). What is critical about critical design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3297-3306). ACM. doi:10.1145/2470654.2466451.

Bardzell, S., Bardzell, J., Forlizzi, J., Zimmerman, J., & Antanitis, J. (2012, June). Critical design and critical theory: the challenge of designing for provocation. In *Proceedings of the Designing Interactive Systems Conference* (pp. 288-297). ACM. doi:10.1145/2317956.2318001.

Barbot, B., Besançon, M., & I Lubart, T. (2011). Assessing creativity in the classroom. *The Open Education Journal, 4(*1).

Barbot, B., & Heuser, B. (2017). Creativity and identity formation in adolescence: A developmental perspective. In M. Karwowski, & J. C. Kaufman, *The Creative Self.* London, UK: Academic Press.

Barbot, B., & Reiter-Palmon, R. (2019). Creativity assessment: Pitfalls, solutions, and standards. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 131. doi:10.1037/aca0000251.

Batey, M., & Furnham, A. (2006). Creativity, intelligence, and personality: A critical review of the scattered literature. *Genetic, Social, and General Psychology Monographs*, *132*(4), 355-429. doi:10.3200/MONO.132.4.355-430.

Bartneck, C., Kulić, D., Croft, E., & Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International Journal of Social Robotics, 1*(1), 71-81. doi:10.1007/s12369-008-0001-3.

Bhattacharjee, T., Cabrera, M. E., Caspi, A., Cakmak, M., & Srinivasa, S. S. (2019, October). A Community-Centered Design Framework for Robot-Assisted Feeding Systems. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility* (pp. 482-494). ACM. doi:10.1145/3308561.3353803.

Baughman, W. A., & Mumford, M. D. (1995). Process-analytic models of creative capacities: Operations influencing the combination-and-reorganization process. *Creativity Research Journal, 8*(1), 37-62. doi:10.1207/s15326934crj0801_4.

Baxter, P., Kennedy, J., Senft, E., Lemaignan, S., & Belpaeme, T. (2016, March). From characterising three years of HRI to methodology and reporting recommendations.

In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 391-398). IEEE. doi:10.1109/HRI.2016.7451777.

Becker, H. J. (2000). Who's wired and who's not: Children's access to and use of computer technology. *The Future of Children*, 44-75. doi:10.2307/1602689.

Beelmann, A. (2006). Systematic Reviews in the Social Sciences: A Practical Guide. *European Psychologist, 11*(3), 244-245.

Beer, J. M., Fisk, A. D., & Rogers, W. A. (2014). Toward a framework for levels of robot autonomy in human-robot interaction. *Journal of Human-Robot Interaction, 3*(2), 74-99. doi:10.5898/JHRI.3.2.Beer.

Beghetto, R. A., & Kaufman, J. C. (2010). *Nurturing Creativity in the Classroom.* New York, NY, US: Cambridge University Press.

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for education: A review. *Science robotics*, *3*(21), eaat5954. doi:10.1126/scirobotics.aat5954.

Ben-Ari, M., & Mondada, F. (2018). *Elements of robotics*. Lausanne: Switzerland. Springer International Publishing.

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education*, *58*(3), 978-988. doi:10.1016/j.compedu.2011.10.006.

Bereczki, E. O., & Kárpáti, A. (2018). Teachers' beliefs about creativity and its nurture: A systematic review of the recent research literature. *Educational Research Review, 23*. 25-56. doi:10.1016/j.edurev.2017.10.003.

Berlyne, D. E. (1960). Conflict, arousal, and curiosity. New York, NY, US: McGraw-Hill Book Company. doi:10.1037/11164-000.

Bethel, C. L., & Murphy, R. R. (2006). Auditory and Other Non-verbal Expressions of Affect for Robots. In *AAAI Fall Symposium: Aurally Informed Performance* (pp. 1-5).

Biddiss, E., & Irwin, J. (2010). Active video games to promote physical activity in children and youth: a systematic review. *Archives of Pediatrics & Adolescent Medicine*, *164*(7), 664-672. doi:10.1001/archpediatrics.2010.104.

Billard, A., Robins, B., Nadel, J., & Dautenhahn, K. (2007). Building Robota, a mini-humanoid robot for the rehabilitation of children with autism. *Assistive Technology, 19*(1), 37-49. doi:10.1080/10400435.2007.10131864.

Birdi, K. (2016). Creativity training. In H. Shipton, P. Budhwar, & A. Brown, *Human Resource Management, Innovation and Performance* (pp. 298-312). London, UK: Palgrave Macmillan.

Björgvinsson, E., Ehn, P., & Hillgren, P. A. (2010, November). Participatory design and democratizing innovation. In *Proceedings of the 11th Biennial Participatory Design Conference (*pp. 41-50). ACM. doi:10.1145/1900441.1900448.

Bjorklund, D. F., & Brown, R. D. (1998). Physical play and cognitive development: Integrating activity, cognition, and education. *Child development*, *69*(3), 604-606. doi:10.1111/j.1467-8624.1998.tb06229.x.

Blanca, M., Alarcón, R., Arnau, J., Bono, R., & Bendayan, R. (2017). Non-normal data: Is ANOVA still a valid option? *Psicothema*, *29*(4), 552-557. doi:10.7334/psicothema2016.383

Bloom, B. S. (1956). *Taxonomy of Educational Objectives. Vol. 1: Cognitive Domain.* New York: McKay.

Boden, M. A. (2004). *The Creative Mind: Myths and Mechanisms.* London, UK: Routledge.

Borgers, N., & Hox, J. J. (2000, October). Reliability of responses in questionnaire research with children. In *fifth international conference on logic and methodology, Cologne, Germany*.

Bose, M., Anne Garretson Folse, J., & Burton, S. (2013). The role of contextual factors in eliciting creativity: primes, cognitive load and expectation of performance feedback. *Journal of Consumer Marketing*, *30*(5), 400-414. doi:10.1108/JCM-02-2013-0475.

Boucenna, S., Narzisi, A., Tilmont, E., Muratori, F., Pioggia, G., Cohen, D., & Chetouani, M. (2014). Interactive technologies for autistic children: A review. *Cognitive Computation*, *6*(4), 722-740. doi:10.1007/s12559-014-9276-x.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., Ribeiro, C., & Pereira, J. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education*, *94*, 178-192. doi:10.1016/j.compedu.2015.11.003.

Bramer, W. M., Giustini, D., de Jonge, G. B., Holland, L., & Bekhuis, T. (2016) De-duplication of database search results for systematic reviews in EndNote. *Journal of the Medical Library Association, 104*(3), 240-243. doi:10.3163/1536-5050.104.3.014.

Breazeal, C. (2003). Toward sociable robots. *Robotics and autonomous systems*, *42*(3-4), 167-175. doi:10.1016/S0921-8890(02)00373-1.

Breazeal, C. (2004a). *Designing sociable robots*. Cambridge, MA, US: MIT press.

Breazeal, C. (2004b). Social interactions in HRI: the robot view. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 34*(2), 181-186. doi: 10.1109/TSMCC.2004.826268.

Breazeal, C., Hoffman, G., & Lockerd, A. (2004, July). Teaching and working with robots as a collaboration. In *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems-Volume 3* (pp. 1030-1037). IEEE Computer Society.

Brenner, W., Uebernickel, F., & Abrell, T. (2016). Design thinking as mindset, process, and toolbox. In *Design thinking for innovation* (pp. 3-21). Springer, Cham. doi:10.1007/978-3-319-26100-3_1.

Brey, P. (2018). The strategic role of technology in a good society. *Technology in Society*, 52, 39-45.

Broekens, J., Heerink, M., & Rosendal, H. (2009). Assistive social robots in elderly care: a review. *Gerontechnology, 8*(2), 94-103.

Brosterman, N., & Togashi, K. (1997). *Inventing kindergarten*. Harry N. Abrams.

Brown, A. R., & Sorensen, A. (2009). Interacting with generative music through live coding. *Contemporary Music Review*, *28*(1), 17-29. doi:10.1080/07494460802663991.

Brown, J. G., & Burger, C. (1984). Playground designs and preschool children's behaviors. *Environment and Behavior*, *16*(5), 599-626. doi:10.1177/0013916584165004.

Brussoni, M., Gibbons, R., Gray, C., Ishikawa, T., Sandseter, E. B. H., Bienenstock, A., Chabot, G., Fuselli, P., Herrington, S., Janssen, I., Pickett, W., Power, M., Stranger, N., Sampson, M., & Tremblay, M. S. (2015). What is the relationship between risky outdoor play and health in children? A systematic review. *International Journal of Environmental Research and Public Health*, *12*(6), 6423-6454. doi:10.3390/ijerph120606423.

Buechley, L., & Eisenberg, M. (2007, July). Boda blocks: A collaborative tool for exploring tangible three-dimensional cellular automata. In *Proceedings of the 8th International*

Conference on Computer Supported Collaborative Learning (pp. 102-104). International Society of the Learning Sciences.

*Burke, L. A., & Williams, J. M. (2008). Developing young thinkers: An intervention aimed to enhance children's thinking skills. *Thinking skills and Creativity, 3*(2). 104-124. doi:10.1016/j.tsc.2008.01.001.

Burnett, C. A., & Haydon, K. P. (2017). Do We need a revolutionary approach to bring creativity into education? In R. Beghetto, & B. Sriraman, *Creative Contradictions in Education* (pp. 201-220). Switzerland: Springer Cham.

Byrne, J. G., & Barlow, T. (1993, October). Structured brainstorming: A method for collecting user requirements. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 37, No. 5, pp. 427-431). Sage CA: Los Angeles, CA: SAGE Publications. doi:10.1177/154193129303700507.

Byron, K., Khazanchi, S., & Nazarian, D. (2010). The relationship between stressors and creativity: A meta-analysis examining competing theoretical models. *Journal of Applied Psychology, 95*(1). 201-212. doi:10.1037/a0017868.

Cachia, R., Ferrari, A., Ala-Mutka, K., & Punie, Y. (2010). *JRC Working Papers JRC62370.* Retrieved 10 2019, from Joint Research Centre (Seville site): https://ideas.repec.org/p/ipt/iptwpa/jrc62370.html

Cakmak, M., & Takayama, L. (2013, March). Towards a comprehensive chore list for domestic robots. In *2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 93-94). IEEE. doi:10.1109/HRI.2013.6483517.

Callahan, C. M., & Renzulli, J. S. (1977). The effectiveness of a creativity training program in the language arts. *Gifted Child Quarterly*, *21*(4), 538-545. doi:10.1177/001698627702100412.

Cameron, D., Fernando, S., Collins, E., Millings, A., Moore, R., Sharkey, A., Evers, V., & Prescott, T. (2015, January). Presence of life-like robot expressions influences children's enjoyment of human-robot interactions in the field. In *Proceedings of the AISB Convention 2015*. The Society for the Study of Artificial Intelligence and Simulation of Behaviour.

Campa, R. (2016). The rise of social robots: a review of the recent literature. *Journal of Evolution and Technology, 26*(1).

Camurri, A., Lagerlöf, I., & Volpe, G. (2003). Recognizing emotion from dance movement: comparison of spectator recognition and automated techniques. *International Journal of Human-Computer Studies*, *59*(1-2), 213-225. doi:10.1016/S1071-5819(03)00050-8.

Cangelosi, A., & Schlesinger, M. (2018). From babies to robots: the contribution of developmental robotics to developmental psychology. *Child Development Perspectives, 12(*3), 183-188. doi:10.1111/cdep.12282.

Cecil, L. M., Gray, M. M., Thornburg, K. R., & ISPA, J. (1985). Curiosity-exploration-play-creativity: The early childhood mosaic. *Early Child Development and Care*, *19*(3), 199-217. doi:10.1080/0300443850190305.

Cha, E., Dragan, A. D., & Srinivasa, S. S. (2015). Perceived robot capability. In *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (pp. 541-548). IEEE. doi:10.1109/ROMAN.2015.7333656.

Cha, E., Kim, Y., Fong, T., & Mataric, M. J. (2018). A survey of nonverbal signaling methods for non-humanoid robots. *Foundations and Trends® in Robotics*, *6*(4), 211-323. doi:10.1561/2300000057.

Chadha, D. (2006). A curriculum model for transferable skills development. engineering education, 1(1), 19-24. doi:10.11120/ened.2006.01010019.

Chan, S., & Yuen, M. (2014). Personal and environmental factors affecting teachers' creativity-fostering practices in Hong Kong. *Thinking Skills and Creativity*, *12*, 69-77. Doi: 10.1016/j.tsc.2014.02.003

Chan, Zenobia C. Y. (2013). A systematic review of creative thinking/creativity in nursing education. *Nurse Education Today, 33*(11), 1382-1387. doi:10.1016/j.nedt.2012.09.005.

Chao, C., Cakmak, M., & Thomaz, A. L. (2010, March). Transparent active learning for robots. In *2010 5th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 317-324)*. IEEE. doi:10.1109/HRI.2010.5453178.

*Cheung, R. H. P. (2010). Designing movement activities to develop children's creativity in early childhood education. *Early Child Development and Care, 180*(3), 377-385. doi:10.1080/03004430801931196.

Choi, J. G., & Kim, M. (2009). The usage and evaluation of anthropomorphic form in robot design. *Undisciplined! Design Research Society Conference 2008*, Sheffield Hallam University, Sheffield, UK, 16-19 July 2008.

Christie, J. F., & Roskos, K. A. (2006). Standards, Science, and the Role of Play in Literacy Education. In Singer, D. G., Golinkoff, R. M., Hirsh-Pasek, K. *Play = Learning: How Play Motivates and Enhances Children's Cognitive and Social-Emotional Growth: How*

Play Motivates and Enhances Children's Cognitive and Social-Emotional Growth. New York, NY, US: Oxford University Press.

Claxton, A. F., Pannells, T. C., & Rhoads, P. A. (2005). Developmental trends in the creativity of school-age children. *Creativity Research Journal, 17*(4), 327-335.

*Cliatt, M. J. P., Shaw, J. M., & Sherwood, J. M. (1980). Effects of training on the divergent-thinking abilities of kindergarten children. *Child Development, 51*(4), 1061-1064. doi:10.2307/1129544.

Collard, P., & Looney, J. (2014). Nurturing creativity in education. *European Journal of Education, 49*(3), 348-364.

Collins, N., McLean, A., Rohrhuber, J., & Ward, A. (2003). Live coding in laptop performance. *Organised sound*, *8*(3), 321-330. doi:10.1017/S135577180300030X.

Colton, S. (2012). The painting fool: Stories from building an automated painter. In *Computers and creativity* (pp. 3-38). Springer, Berlin, Heidelberg. doi:10.1007/978-3-642-31727-9_1.

Colton, S., Halskov, J., Ventura, D., Gouldstone, I., Cook, M., & Ferrer, B. P. (2015, June). The Painting Fool Sees! New Projects with the Automated Painter. In *ICCC* (pp. 189-196).

Conradty, C., & Bogner, F. X. (2018). From STEM to STEAM: How to Monitor Creativity. *Creativity Research Journal, 30*(3), 233-240. doi:10.1080/10400419.2018.1488195.

Conti, R., Collins, M. A., & Picariello, M. L. (2001). The impact of competition on intrinsic motivation and creativity: considering gender, gender segregation and gender role orientation. *Personality and Individual Differences, 31*(8), 1273-1289. doi:10.1016/S0191-8869(00)00217-8.

Corbalán J., Martínez F., Donolo, D., Alonso, C., Tejerina, M. Limiñana (2003). CREA. Inteligencia Creativa. Una medida cognitiva de la creatividad.

Correia, F., Petisca, S., Alves-Oliveira, P., Ribeiro, T., Melo, F. S., & Paiva, A. (2019). “I Choose... YOU!” Membership preferences in human–robot teams. *Autonomous Robots*, *43*(2), 359-373. doi:10.1007/s10514-018-9767-9.

Costa Jr, P. T., & McCrae, R. R. (2008). The Revised NEO Personality Inventory (NEO-PI-R). In Boyle, G. B., Matthews, G., & Saklofske, D. H. (Eds.) *The SAGE Handbook of Personality Theory and Assessment: Volume 2 - Personality Measurement and Testing.* SAGE Publications Ltd.

Costa, P. T., & McCrae, R. R. (2010). *NEO-PI-3*. London: Sigma Assessment Systems.

Council, B. D. (2005). The Design Process: The ‘Double Diamond’ Design Process Model. Retrieved 27 November from: http://www. designcouncil. org. uk/about-design/how-designers-work/the-design-process/.

Cronin, M. A., & Loewenstein, J. (2018). *The Craft of Creativity.* Stanford, CA, US: Stanford University Press.

Cropley, A. J. (1997). Fostering creativity in the classroom: General principals. In M. A. Runco, *The Creativity Research Handbook* (Vol. 1). Norwood, NJ, US: Ablex.

Cropley, A. J. (2006). In praise of convergent thinking. *Creativity research journal, 18*(3), 391-404. doi:10.1207/s15326934crj1803_13.

Csikszentmihalyi, M. (1997). Flow and the psychology of discovery and invention. *Harper Perennial, New York*, *56*.

Csikszentmihalyi, M. (1999). 16 implications of a systems perspective for the study of creativity. In R. J. Sternberg, *Handbook of Creativity.* Cambridge, UK: Cambridge University Press.

Cuddy, A. J., Fiske, S. T., & Glick, P. (2008). Warmth and competence as universal dimensions of social perception: The stereotype content model and the BIAS map. *Advances in Experimental Social Psychology, 40*, 61-149. doi:10.1016/S0065-2601(07)00002-0

Dacey, J. S. (1989). Peak periods of creative growth across the lifespan. *The Journal of Creative Behavior, 23*(4), 224-247.

Damodaran, L. (1996). User involvement in the systems design process-a practical guide for users. *Behaviour & information technology*, *15*(6), 363-377. doi:10.1080/014492996120049.

*Dansky, J. L. (1980). Make-believe: A mediator of the relationship between play and associative fluency. *Child Development, 51*(2), 576-579. doi:10.2307/1129296.

*Dansky, J. L., & Silverman, I. W. (1973). Effects of play on associative fluency in preschool-aged children. *Developmental Psychology, 9*(1), 38-43. doi:10.1037/h0035076.

Derks, P., & Hervas, D. (1988). Creativity in humor production: Quantity and quality in divergent thinking. *Bulletin of the Psychonomic Society*, *26*(1), 37-39. doi:10.3758/BF03334854.

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education — A systematic literature review. *Thinking Skills and Creativity, 8*, 80-91.

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Howe, A., Collier, C., & Hay, P. (2014). The roles and development needs of teachers to promote creativity: A systematic review of literature. *Teaching and Teacher Education, 41*, 34-41. doi:10.1016/j.tate.2014.03.003

Davies, T. (2006). Creative teaching and learning in Europe: Promoting a new paradigm. *The Curriculum Journal, 17*(1), 37-57.

Dautenhahn, K., & Billard, A. (1999, September). Studying robot social cognition within a developmental psychology framework. In *1999 Third European Workshop on Advanced Mobile Robots (Eurobot'99). Proceedings (Cat. No. 99EX355)* (pp. 187-194). IEEE. doi:10.1109/EURBOT.1999.827639.

Dautenhahn, K., Woods, S., Kaouri, C., Walters, M. L., Koay, K. L., & Werry, I. (2005, August). What is a robot companion-friend, assistant or butler?. In *2005 IEEE/RSJ international conference on intelligent robots and systems* (pp. 1192-1197). doi:10.1109/IROS.2005.1545189.

De Dreu, C. K., Baas, M., & Nijstad, B. A. (2008). Hedonic tone and activation level in the mood-creativity link: toward a dual pathway to creativity model. *Journal of Personality and Social Psychology*, *94*(5), 739. doi:10.1037/0022-3514.94.5.739.

De Dreu, C. K., & West, M. A. (2001). Minority dissent and team innovation: The importance of participation in decision making. *Journal of Applied Psychology, 86*(6), 1191. doi:10.1037/0021-9010.86.6.1191.

de Jesus, S. N., Rus, C. L., Lens, W., & Imaginário, S. (2013). Intrinsic motivation and creativity related to product: A meta-analysis of the studies published between 1990-2010. *Creativity Research Journal, 25*(1), 80-84. doi:10.1080/10400419.2013.752235.

de Rooij, A., Vromans, R. D., & Dekker, M. (2018). Noradrenergic modulation of creativity: evidence from pupillometry. *Creativity Research Journal*, *30*(4), 339-351. doi:10.1080/10400419.2018.1530533.

DeVries, R. (2006). Games with Rules. In D.P. Fromberg & D. Bergen (Eds) *Play from Birth to Twelve*, 2nd Ed. Abingdon, Oxon: Routledge.

Diana, C., & Thomaz, A. L. (2011, May). The shape of Simon: Creative design of a humanoid robot shell. In *CHI'11 Extended Abstracts on Human Factors in Computing Systems* (pp. 283-298). ACM. doi:10.1145/1979742.1979648.

Di Blas, N., Paolini, P., & Sabiescu, A. (2010, June). Collective digital storytelling at school as a whole-class interaction. In *Proceedings of the 9th International Conference on interaction Design and Children* (pp. 11-19). ACM. Doi:10.1145/1810543.1810546.

Diehl, J. J., Schmitt, L. M., Villano, M., & Crowell, C. R. (2012). The clinical use of robots for individuals with autism spectrum disorders: A critical review. *Research in Autism Spectrum Disorders*, *6*(1), 249-262. doi:10.1016/j.rasd.2011.05.006.

DiSalvo, C., & Gemperle, F. (2003, June). From seduction to fulfillment: the use of anthropomorphic form in design. In *Proceedings of the 2003 International Conference on Designing Pleasurable Products and Interfaces* (pp. 67-72). ACM.

Dollinger, S. J., Urban, K. K., & James, T. A. (2004). Creativity and openness: Further validation of two creative product measures. *Creativity Research Journal, 16*(1), 35-47. doi: /10.1207/s15326934crj1601_4.

Donohue, C. (Ed.). (2014). *Technology and digital media in the early years: Tools for teaching and learning.* Routledge.

Dougherty, D. (2012). The maker movement. *Innovations: Technology, Governance, Globalization*, 7(3), 11-14.

Dougherty, D. (2013). *The maker mindset*. In Design, make, play (pp. 25-29). Routledge.

Donker, A., & Reitsma, P. (2004, June). Usability testing with young children. In *Proceedings of the 2004 Conference on Interaction Design and Children: Building a Community* (pp. 43-48). ACM. doi:10.1145/1017833.1017839.

*Doron, E. (2016). Short term intervention model for enhancing divergent thinking among school aged children. *Creativity Research Journal, 28*(3), 372-378. doi:10.1080/10400419.2016.1195616.

Dragan, A. D., Lee, K. C., & Srinivasa, S. S. (2013, March). Legibility and predictability of robot motion. In *Proceedings of the 8th ACM/IEEE International Conference on Human-Robot Interaction* (pp. 301-308). IEEE Press.

Druga, S., Williams, R., Park, H. W., & Breazeal, C. (2018, June). How smart are the smart toys?: children and parents' agent interaction and intelligence attribution. In *Proceedings of the 17th ACM Conference on Interaction Design and Children* (pp. 231-240). ACM. doi:10.1145/3202185.3202741.

Druin, A. (2002). The role of children in the design of new technology. *Behaviour and Information Technology*, *21*(1), 1-25.

Druin, A., & Solomon, C. (1996). Designing Multimedia Environments for Children: Computers, Creativity, and Kids. *Wiley Computer Publishing, John Wiley and Sons, Inc., One Wiley Drive, Somerset,* NJ 08875.

Druin, A., Stewart, J., Proft, D., Bederson, B., & Hollan, J. (1997, March). KidPad: a design collaboration between children, technologists, and educators. In *CHI* (Vol. 97, pp. 463-470).

Dubina, I. M., Carayannis, E. G., & Campbell, D. F. (2012). Creativity economy and a crisis of the economy? Coevolution of knowledge, innovation, and creativity, and of the knowledge economy and knowledge society. *Journal of the Knowledge Economy, 3*(1), 1-24.

*Dziedziewicz, D., Gajda, A., & Karwowski, M. (2014). Developing children's intercultural competence and creativity. *Thinking Skills and Creativity,139*, 32-42. doi: 10.1016/j.tsc.2014.02.006.

*Dziedziewicz, D., Oledzka, D., & Karwowski, M. (2013). Developing 4-to 6-year-old children's figural creativity using a doodle-book program. *Thinking Skills and Creativity, 9*, 85-95. doi:10.1016/j.tsc.2012.09.004.

Ekman, P. (1992). An argument for basic emotions. *Cognition & emotion, 6*(3-4), 169-200. doi:10.1080/02699939208411068.

Ekman, P., Friesen, W. V., & Ellsworth, P. (2013). *Emotion in the human face: Guidelines for research and an integration of findings* (Vol. 11). Elsevier.

Elbow, P. (1983). Teaching thinking by teaching writing. *Change: The Magazine of Higher Learning*, *15*(6), 37-40. doi:10.1080/00091383.1983.10570005.

Elkind, D. (2008). The Power of Play: Learning What Comes Naturally. *American Journal of Play*, *1*(1), 1-6.

Elumeze, N., & Eisenberg, M. (2005, November). SmartTiles: mobility and wireless programmability in children's construction and crafts. In *IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'05)* (pp. 8-pp). IEEE. doi:10.1109/WMTE.2005.58.

Ennis, R. H. (1962). A concept of critical thinking. *Harvard Educational Review, 32*(1), 81-111.

Epley, N., Waytz, A., & Cacioppo, J. T. (2007). On seeing human: A three-factor theory of anthropomorphism. *Psychological review, 114*(4), 864. doi:10.1037/0033-295X.114.4.864.

Erat, S., & Gneezy, U. (2016). Incentives for creativity. *Experimental Economics, 19*(2), 269-280.

European Comission. (2006, 12 18). *Publications Office of the European Union.* Retrieved 10 2019, from Europa: https://publications.europa.eu/en/publication-detail/-/publication/0259ec35-9594-4648-b5a4-fb2b23218096

European Communities (2007). Key competences for lifelong learning – A European framework. Annex of a Recommendation of the European Parliament and of the Council of 18 December 2006 published in the Official

Journal of the European Union on 30 December 2006/L394. Retrieved from http://eurlex.europa.eu/LexUriServ/site/en/oj/2006/l_394/l_39420061230en00100018.pdf.

Eysenck, H. J. (2003). Creativity, personality and the convergent-divergent continuum. In Runco, M. A. *Critical Creative Processes: Perspectives on Creativity Research* (pp. 95-114). Cresskill, NJ, US: Hampton Press.

Eyssel, F. (2017). An experimental psychological perspective on social robotics. *Robotics and Autonomous Systems, 87*, 363-371. doi:10.1016/j.robot.2016.08.029.

Fails, J. A., Guha, M. L., & Druin, A. (2013). Methods and techniques for involving children in the design of new technology for children. *Foundations and Trends® in Human–Computer Interaction*, *6*(2), 85-166. doi:10.1561/1100000018.

Fasola, J., & Mataric, M. (2011). Comparing physical and virtual embodiment in a socially assistive robot exercise coach for the elderly. Center for Robotics and Embedded Systems, Los Angeles, CA.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191. doi:10.3758/BF03193146.

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review*, *2*(4), 290-309. doi:10.1207/s15327957pspr0204_5.

Feist, G. J. (1999). Autonomy and independence. In Runco, M. A., & Pritzker, S. R., *Encyclopedia of Creativity* (pp. 151-163). San Diego, CA, USA: Academic Press.

*Feldhusen, J. F., Bahlke, S. J., & Treffinger, D. J. (1969). Teaching creative thinking. *The Elementary School Journal, 70*(1), 48-53. doi:10.1086/460544

Feldman, D. H. (1999). The development of creativity. In R. J. Sternberg, *Handbook of Creativity* (pp. 169-188). Cambridge, UK: Cambridge University Press.

Field, A. (2009). Discovering Statistics Using SPSS, *Third Edition.*

Fink, A., Grabner, R. H., Gebauer, D., Reishofer, G., Koschutnig, K., & Ebner, F. (2010). Enhancing creativity by means of cognitive stimulation: Evidence from an fMRI study. *NeuroImage, 52*(4), 1687-1695.

Fink, J., Lemaignan, S., Dillenbourg, P., Rétornaz, P., Vaussard, F., Berthoud, A., ondada, F., Wille, F., & Franinović, K. (2014, March). Which robot behavior can motivate children to tidy up their toys? Design and evaluation of ranger. In *Proceedings of the 2014 ACM/IEEE international Conference on Human-Robot Interaction* (pp. 439-446). ACM. doi:10.1145/2559636.2559659.

Fischer, G. (2005). *Social creativity: Making all voices heard*. University of Colorado Center for LifeLong Learning and Design Department of Computer Science.

Fischer, G. (2007, September). Meta-design and social creativity: making all voices heard. In *IFIP Conference on Human-Computer Interaction* (pp. 692-693). Springer, Berlin, Heidelberg. doi:10.1007/978-3-540-74800-7_86

Fischer, G., Giaccardi, E., Eden, H., Sugimoto, M., & Ye, Y. (2005). Beyond binary choices: Integrating individual and social creativity. *International Journal of Human-Computer Studies*, *63*(4-5), 482-512. doi:10.1016/j.ijhcs.2005.04.014.

Fiske, S. T., Cuddy, A. J. C., Glick, P., & Xu, J. (2002). A model of stereotype content as often mixed: Separate dimensions of competence and warmth respectively follow from status and competition. *Journal of Personality and Social Psychology, 82*(6), 878-902.

*Flaherty, M. A. (1992). The effects of a holistic creativity program on the self-concept and creativity of third graders. *The Journal of Creative Behavior, 26*(3), 186-198. doi:10.1002/j.2162-6057.1992.tb01173.x.

*Fleith, D. S., Renzulli, J. S., & Westberg, K. L. (2002). Effects of a creativity training program on divergent thinking abilities and self-concept in monolingual and bilingual classrooms. *Creativity Research Journal, 14*(3-4), 373-386. doi:10.1207/S15326934CRJ1434_8.

Friedman, B. (1996). Value sensitive design. Interactions, 3(6), 16-23. *ACM*

Friedman, B., & Hendry, D. G. (2019). Value sensitive design: Shaping technology with moral imagination. *Mit Press.*

Florida, R. (2005). *Cities and the creative class*. New York: Harper Business.

Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and Autonomous Systems*, *42*(3-4), 143-166. doi:10.1016/S0921-8890(02)00372-X.

Ford, D. Y., & Harris III, J. J. (1992). The elusive definition of creativity. *The Journal of Creative Behavior, 26*(3), 186-198.

Forlizzi, J. (2008). The product ecology: Understanding social product use and supporting design culture. *International Journal of Design, 2*(1).

*Franklin, B. S., & Richards, P. N. (1977). Effects on children's divergent thinking abilities of a period of direct teaching for divergent production. *British Journal of Educational Psychology, 47*(1), 66-70. doi:10.1111/j.2044-8279.1977.tb03002.x.

Frei, P., Su, V., Mikhak, B., & Ishii, H. (2000, April). Curlybot: Designing a new class of computational toys. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 129-136). ACM.

Freud, S. (1959). *Creative Writers and Day-dreaming.* London, UK: Hogarth Press.

Freytag, G. (1872). *Die technik des dramas*. Hirzel.

Freytag, G. (1896). *Freytag's technique of the drama: an exposition of dramatic composition and art*. Scholarly Press.

Frich, J., MacDonald Vermeulen, L., Remy, C., Biskjaer, M. M., & Dalsgaard, P. (2019, April). Mapping the landscape of creativity support tools in HCI. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (p. 389). ACM. doi:10.1145/3290605.3300619.

Frith, U., & Frith, C. (2010). The social brain: allowing humans to boldly go where no other species has been. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1537), 165-176. doi:10.1098/rstb.2009.0160.

Frost, J. L. (1992). *Play and Playscapes: Instructor's Guide*. Delmar Publishers.

Fuchs, M. (2008). The reliability of children's survey responses: the impact of cognitive functioning on respondent behavior. In *Proceedings of Statistics Canada Symposium*.

Furnham, A., & Bachtiar, V. (2008). Personality and intelligence as predictors of creativity. *Personality and individual differences, 45*(7), 613-617.doi: 10.1016/j.paid.2008.06.023.

Gajda, A., Karwowski, M., & Beghetto, R. A. (2017). Creativity and academic achievement: A meta-analysis. *Journal of Educational Psychology, 109*(2), 269-299. doi:10.1037/edu0000133

Gabe, T., Florida, R., & Mellander, C. (2012). The creative class and the crisis. *Cambridge Journal of Regions, Economy and Society, 6*(1), 37-53.

*Garaigordobil Landazabal, M. (2005). Prosocial and creative play: Effects of a programme on the verbal and nonverbal intelligence of children aged 10-11 years. *International Journal of Psychology, 40*(3), 176-188. doi:10.1080/00207590444000276.

*Garaigordobil, M. (2006). Intervention in creativity with children aged 10 and 11 years: Impact of a play program on verbal and graphic-figural creativity. *Creativity Research Journal, 18*(3), 329-345. doi:10.1207/s15326934crj1803_8.

*Garaigordobil, M. & Berrueco, L. (2011). Effects of a play program on creative thinking of preschool children. *The Spanish Journal of Psychology, 14*(2), 608-618. doi:10.5209/rev_SJOP.2011.v14.n2.9.

Gardner, H. (1982). Giftedness: Speculations from a biological perspective. *New Directions for Child and Adolescent Development, 17*, 47-60.

Gardner, H., & Gardner, E. (2008). *Art, mind, and brain: A cognitive approach to creativity.* New York, NY, US: Basic Books.

Gardner, H., Kornhaber, M. L., & Wake, W. K. (1996). *Intelligence: Multiple Perspectives*. Harcourt Brace College Publishers.

Garrison, D. R., Cleveland-Innes, M., Koole, M., & Kappelman, J. (2006). Revisiting methodological issues in transcript analysis: Negotiated coding and reliability. *The Internet and Higher Education*, *9*(1), 1-8. doi:10.1016/j.iheduc.2005.11.001.

Gervás, P. (2001). An expert system for the composition of formal spanish poetry. In *Applications and Innovations in Intelligent Systems VIII* (pp. 19-32). Springer, London. doi:10.1007/978-1-4471-0275-5_2.

Gibson, F. (2007). Conducting focus groups with children and young people: strategies for success. *Journal of Research in Nursing*, *12*(5), 473-483. doi:10.1177/1744987107079791.

Gilbert, A. N., Fridlund, A. J., & Lucchina, L. A. (2016). The color of emotion: A metric for implicit color associations. *Food Quality and Preference*, *52*, 203-210. doi:10.1016/j.foodqual.2016.04.007.

Gillespie, R. M. (2002). The physical impact of computers and electronic game use on children and adolescents, a review of current literature. *Work, 18*(3), 249-259.

Glas, D. F., Minato, T., Ishi, C. T., Kawahara, T., & Ishiguro, H. (2016, August). Erica: The erato intelligent conversational android. In *2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (pp. 22-29). IEEE. doi:10.1109/ROMAN.2016.7745086.

Glaser, B. G., Strauss, A. L., & Strutzel, E. (1968). The discovery of grounded theory; strategies for qualitative research. *Nursing Research*, *17*(4), 364.

Glaveanu, V. (2018). Creativity in and for Society. *Creativity: Theories-Research-Applications, 5*(2), 155-158.

Gomez, R., Szapiro, D., Galindo, K., & Nakamura, K. (2018, February). Haru: Hardware design of an experimental tabletop robot assistant. In *Proceedings of the 2018 ACM/IEEE international conference on human-robot interaction* (pp. 233-240). ACM. doi:10.1145/3171221.3171288.

Goodrich, M. A., & Schultz, A. C. (2008). Human-robot interaction: a survey. *Foundations and Trends® in Human–Computer Interaction*, *1*(3), 203-275. doi:10.1561/1100000005.

*Goor, A., & Rapoport, T. (1977). Enhancing creativity in an informal educational framework. *Journal of Educational Psychology, 69*(5), 636-643. doi:10.1037/0022-0663.69.5.636.

Gopnik, A., Griffiths, T. L., & Lucas, C. G. (2015). When younger learners can be better (or at least more open-minded) than older ones. *Current Directions in Psychological Science*, 24(2), 87-92. doi:10.1177/0963721414556653.

*Gordon, G., Breazeal, C., & Engel, S. (2015, March). *Can children catch curiosity from a social robot?* Paper presented at the 10th ACM/IEEE International Conference on Human-Robot Interaction, 91-98, Portland, Oregon, USA. doi:10.1037/0022-0663.69.5.636.

Gouaillier, D., Hugel, V., Blazevic, P., Kilner, C., Monceaux, J., Lafourcade, P., Marnier, B., Serre, J., & Maisonnier, B. (2009, May). Mechatronic design of NAO humanoid. In *2009 IEEE International Conference on Robotics and Automation* (pp. 769-774). IEEE. doi:10.1109/ROBOT.2009.5152516.

Graf, C., Härtl, A., Röfer, T., & Laue, T. (2009, December). A robust closed-loop gait for the standard platform league humanoid. In *Proceedings of the Fourth Workshop on Humanoid Soccer Robots* (pp. 30-37).

Greitemeyer, T., & Mügge, D. O. (2014). Video games do affect social outcomes: A meta-analytic review of the effects of violent and prosocial video game play. *Personality and social psychology bulletin, 40*(5), 578-589. doi:10.1177/0146167213520459.

Gruber, H. E., & Vonèche, J. J. (Eds.). (1977). *The Essential Piaget* (pp. 435-436). London: Routledge & Kegan Paul.

Grudin, J. (2017). Obstacles to participatory design in large product development organizations. In *Participatory Design* (pp. 99-119). CRC Press.

Gruenfeld, D. H. (1995). Status, ideology, and integrative complexity on the US Supreme Court: Rethinking the politics of political decision making. *Journal of Personality and Social Psychology, 68*(1), 5. doi:10.1037/0022-3514.68.1.5.

Guilford, J. P. (1950). Creativity. *American Psychologist, 5*(9), 444-454. doi:10.1037/h0063487

Guilford, J. P. (1967). *The nature of human intelligence.* New York, NY, US: McGraw-Hill.

Guilford, J. P. (1968). *Intelligence, creativity, and their educational implications*. Edits Pub.

Gulliksen, J., Lantz, A., & Boivie, I. (1999). User centered design in practice-problems and possibilities. *Sweden: Royal Institute of Technology*, *315*, 433.

Gunderson, J. P., & Gunderson, L. F. (2004). Intelligence, autonomy, capability. *Performance Metrics for Intelligent Systems, PERMIS.*

Haensly PA, Torrance EP. *Assessment of creativity in children and adolescents*. In: Reynolds CR, Kamphaus RW, Eds. Handbook of Psychological and Educational Assessment of Children: Intelligence and achievement New York: Guilford Press 1990; pp.697-722.

*Haley, G. L. (1984). Creative response styles: The effects of socioeconomic status and problem-solving training. *Journal of Creative Behavior, 18*(1), 25-40. doi:10.1002/j.2162-6057.1984.tb00987.x.

Hall, E. T. (1966). *The hidden dimension* (Vol. 609). Garden City, NY: Doubleday.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), 495-504. doi:10.17763/haer.84.4.34j1g68140382063.

Hampton, J. A. (1987). Inheritance of attributes in natural concept conjunctions. *Memory & Cognition*, *15*(1), 55-71. doi:10.3758/BF03197712.

Hanna, W. (2007). The new Bloom's taxonomy: Implications for music education. *Arts Education Policy Review, 108*(4), 7-16.

Harms, M., Kennel, V., & Reiter-Palmon, R. (2017). Team creativity: Cognitive processes underlying problem solving. In *Team creativity and innovation* (pp. 61-86). Oxford University Press. doi:10.1093/oso/9780190222093.003.0004.

Harris, K., & Reid, D. (2005). The influence of virtual reality play on children's motivation. *Canadian journal of occupational therapy*, *72*(1), 21-29. doi:10.1177/000841740507200107.

Hart, J. P. (2008). *Art of the Storyboard*. Elsevier Science & Technology.

Hassinger-Das, B., Toub, T. S., Zosh, J. M., Michnick, J., Golinkoff, R., & Hirsh-Pasek, K. (2017). More than just fun: a place for games in playful learning/Más que diversión: el lugar de los juegos reglados en el aprendizaje lúdico. *Infancia y Aprendizaje*, *40*(2), 191-218. doi:10.1080/02103702.2017.1292684.

Hazel, N. (1995). Elicitation techniques with young people. *Social Research Update*, *12*(4), 1-8.

Healey, A., & Mendelsohn, A. (2019). Selecting appropriate toys for young children in the digital era. *Pediatrics*, *143*(1), e20183348. doi:10.1542/peds.2018-3348.

Hemphill, M. (1996). A note on adults' color–emotion associations. *The Journal of Genetic Psychology*, *157*(3), 275-280. doi:10.1080/00221325.1996.9914865.

Hennessey, B. A., Amabile, T. M., & Mueller, J. S. (1999). Consensual assessment. *Encyclopedia of Creativity*, *1*, 346-359.

Hennessey, B. A. (2016). Intrinsic Motivation and Creativity in the Classroom. Nurturing creativity in the classroom.

Ho, W. C., Dautenhahn, K., Lim, M. Y., & Du Casse, K. (2010, August). *Modelling Human Memory in Robotic Companions for Personalisation and Long-term Adaptation in HRI*. In BICA (pp. 64-71).

Hoffman, G. (2016, March). Openwoz: A runtime-configurable wizard-of-oz framework for human-robot interaction. In *2016 AAAI Spring Symposium Series*.

Hoffman, G., & Ju, W. (2014). Designing robots with movement in mind. *Journal of Human-Robot Interaction*, *3*(1), 91-122. doi:10.5898/JHRI.3.1.Hoffman.

Hoffman, G., Zuckerman, O., Hirschberger, G., Luria, M., & Shani Sherman, T. (2015, March). Design and evaluation of a peripheral robotic conversation companion. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction* (pp. 3-10). ACM. doi:10.1145/2696454.2696495.

*Hoffmann, J. D., & Russ, S. W. (2016). Fostering pretend play skills and creativity in elementary school girls: A group play intervention. *Psychology of Aesthetics, Creativity, and the Arts, 10*(1), 114. doi:10.1037/aca0000039.

Homans, G. C. (1974). *Social Behavior: Its Elementary Forms*. Harcourt Brace Jovanovich

Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, make, play: Growing the next generation of STEM innovators*. Routledge.

Hopkins, E. J., Dore, R. A., & Lillard, A. S. (2015). Do children learn from pretense? *Journal of Experimental Child Psychology*, *130*, 1-18. doi:10.1016/j.jecp.2014.09.004.

*Houtz, J. C., & Feldhusen, J. F. (1976). The modification of fourth graders' problem solving abilities. *The Journal of Psychology, 93*(2), 229-237. doi:10.1080/00223980.1976.9915817.

Houtz, J. C., & Krug, D. (1995). Assessment of creativity: Resolving a mid-life crisis. *Educational Psychology Review, 7*(3), 269-300. doi:10.1007/BF02213374.

Hoyle, R. H., Harris, M. J., & Judd, C. M. (2002). *Research Methods in Social Relations*. US: Wadsworth/Thomson Learning.

Hsin, C. T., Li, M. C., & Tsai, C. C. (2014). The influence of young children's use of technology on their learning: A review. *Journal of Educational Technology & Society*, *17*(4), 85-99.

*Huber, J., Treffinger, D., Tracy, D., & Rand, D. (1979). Self-instructional use of programmed creativity-training materials with gifted and regular students. *Journal of Educational Psychology, 71*(3), 303-309. doi:10.1037/0022-0663.71.3.303.

*Hui, A., & Lau, S. (2006). Drama education: A touch of the creative mind and communicative-expressive ability of elementary school children in Hong Kong. *Thinking Skills and Creativity, 1*(1), 34-40. doi:10.1016/j.tsc.2005.06.001.

Hutchby, I., & Moran-Ellis, J. (2013). Children, technology and culture: The impacts of technologies in children's everyday lives. Routledge.

Hutton, E., & Sundar, S. S. (2010). Can video games enhance creativity? Effects of emotion generated by Dance Dance Revolution. *Creativity Research Journal*, *22*(3), 294-303. Doi: 10.1080/10400419.2010.503540.

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, *123*, 109-123. doi:10.1016/j.compedu.2018.05.002.

Irfan, B., Kennedy, J., Lemaignan, S., Papadopoulos, F., Senft, E., & Belpaeme, T. (2018, March). Social psychology and human-robot interaction: An uneasy marriage. In *Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 13-20). ACM. doi:10.1145/3173386.3173389.

Ishiyama, J. (2014). Replication, research transparency, and journal publications: Individualism, community models, and the future of replication studies. *PS: Political Science & Politics, 47*(1), 78-83. doi:10.1017/S1049096513001765.

Ivcevic, Z. (2009). Creativity map: Toward the next generation of theories of creativity. *Psychology of Aesthetics, Creativity, and the Arts, 3*(1), 17-21.

Iversen, O. S., Smith, R. C., & Dindler, C. (2017, June). Child as protagonist: Expanding the role of children in participatory design. In *Proceedings of the 2017 Conference on Interaction Design and Children* (pp. 27-37). ACM. doi:10.1145/3078072.3079725.

Jack, R. E., Garrod, O. G., & Schyns, P. G. (2014). Dynamic facial expressions of emotion transmit an evolving hierarchy of signals over time. *Current biology*, *24*(2), 187-192. doi:10.1016/j.cub.2013.11.064.

Jacq, A., Lemaignan, S., Garcia, F., Dillenbourg, P., & Paiva, A. (2016, March). Building successful long child-robot interactions in a learning context. *In 11th ACM/IEEE*

International Conference on Human-Robot Interaction (HRI) (pp. 239-246). IEEE. doi:10.1109/HRI.2016.7451758.

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, *7*(1), 40. doi:10.1186/1479-5868-7-40.

Jausovec, N. (1994). Can giftedness be taught? *Roeper Review, 16*(3), 210-214. doi:10.1080/02783199409553576.

Jellen, H. G., & Urban, K. K. (1986). The TCT-DP (Test for Creative Thinking-Drawing Production): An instrument that can be applied to most age and ability groups. *Creative Child & Adult Quarterly*.

Jellen, H. G., & Urban, K. K. (1989). Assessing creative potential world-wide: the first cross-cultural application of the test for creative thinking—drawing production (TCT-DP). *Gifted Education International*, *6*(2), 78-86. doi:10.1177/026142948900600204.

Jensen, J. J., & Skov, M. B. (2005, June). A review of research methods in children's technology design. In *Proceedings of the 2005 Conference on Interaction Design and Children* (pp. 80-87). ACM. doi:10.1145/1109540.1109551.

John, O. P., & Srivastava, S. (1999). The Big Five trait taxonomy: History, measurement, and theoretical perspectives. In Pervin, L. A., & John, O. P. (Eds). *Handbook of Personality: Theory and Research*, *2*(1999) (pp. 102-138). London, UK: The Guilford Press.

Johnson-Laird, P. N. (1988). Freedom and constraint in creativity. In Sternberg, R. J., *The Nature of Creativity: Contemporary Psychological Perspectives* (pp. 202-219). New York, NY, USA: Cambridge University Press.

Johnson-Laird, P. N. (1988). Analogy and the exercise of creativity. In Vosniadou, S., & Ortony, A., *Similarity and Analogical Reasoning* (pp. 313-331). New York, NY, USA: Cambridge University Press.

Jones, J. K. (2013). Re-discovering the arts: The impact of engagement in a natural environment upon pre-service teacher perceptions of creativity. *Thinking Skills and Creativity, 8*, 102-108. doi:10.1016/j.tsc.2012.08.001.

Jordan, P. W. (1998). Human factors for pleasure in product use. *Applied ergonomics, 29*(1), 25-33. doi:10.1016/S0003-6870(97)00022-7.

Ju, W. (2015). The design of implicit interactions. *Synthesis Lectures on Human-Centered Informatics*, *8*(2), 1-93. doi:10.2200/S00619ED1V01Y201412HCI028.

*Justo, C. F. (2008). Creative relaxation, motor creativity, self-concept in a sample of children from Early Childhood Education. *Electronic Journal of Research in Educational Psychology, 6*(1), 29-50.

Kahn, P. H., Freier, N. G., Kanda, T., Ishiguro, H., Ruckert, J. H., Severson, R. L., & Kane, S. K. (2008, March). Design patterns for sociality in human-robot interaction. In *Proceedings of the 3rd ACM/IEEE International Conference on Human-Robot Interaction* (pp. 97-104). ACM. doi:10.1145/1349822.1349836.

Kahn Jr, P. H., Kanda, T., Ishiguro, H., Freier, N. G., Severson, R. L., Gill, B. T., Ruck, J. H., & Shen, S. (2012). "Robovie, you'll have to go into the closet now": Children's social and moral relationships with a humanoid robot. *Developmental Psychology*, *48*(2), 303. doi:10.1037/a0027033.

Kahn Jr, P. H., Kanda, T., Ishiguro, H., Gill, B. T., Ruckert, J. H., Shen, S., Gary, H. E.., Reichert, A. L., Freier, N. G., & Severson, R. L. (2012, March). Do people hold a humanoid robot morally accountable for the harm it causes?. In *Proceedings of the seventh annual ACM/IEEE International Conference on Human-Robot Interaction* (pp. 33-40). ACM. doi:10.1145/2157689.2157696.

Kahn Jr, P. H., Kanda, T., Ishiguro, H., Gill, B. T., Shen, S., Ruckert, J. H., & Gary, H. E. (2016, March). Human creativity can be facilitated through interacting with a social robot. In *The Eleventh ACM/IEEE International Conference on Human Robot Interaction* (pp. 173-180). IEEE Press.

Kampylis, P. G., & Valtanen, J. (2010). Redefining creativity - Analyzing definitions, collocations, and consequences. *The Journal of Creative Behavior, 44*(3), 191-214.

Kanda, T., Hirano, T., Eaton, D., & Ishiguro, H. (2004). Interactive robots as social partners and peer tutors for children: A field trial. *Human–Computer Interaction*, *19*(1-2), 61-84.

Kanda, T., Sato, R., Saiwaki, N., & Ishiguro, H. (2007). A two-month field trial in an elementary school for long-term human–robot interaction. *IEEE Transactions on robotics, 23*(5), 962-971. doi:10.1109/TRO.2007.904904.

Kaplan, F. (2005, October). Everyday robotics: robots as everyday objects. In *Proceedings of the 2005 Joint Conference on Smart Objects and Ambient Intelligence: Innovative Context-aware Services: Usages and Technologies* (pp. 59-64). ACM. doi:10.1145/1107548.1107570.

*Kara, N., Aydin, C. C., & Cagiltay, K. (2013). Investigating the activities of children toward a smart storytelling toy. *Journal of Educational Technology & Society, 16*(1), 28-43. doi:10.1002/j.2162-6057.2010.tb01333.x

Karau, S. J., & Hart, J. W. (1998). Group cohesiveness and social loafing: Effects of a social interaction manipulation on individual motivation within groups. *Group Dynamics: Theory, Research, and Practice, 2*(3), 185. doi:10.1037/1089-2699.2.3.185.

Kaufman, J. (2018a). Finding meaning with creativity in the past, present, and future. *Perspectives on Psychological Science, 13*(6), 734-749. doi:10.1177/1745691618771981

Kaufman, J. (2018b). Creativity as a stepping stone toward a brighter future. *Journal of Intelligence, 6*(2), 1-7.

Kaufman, J. (2018c). Uniquely creative: Developing a new outline for positive outcomes. Creativity: *Theories-Research-Applications*, *5*(2), 188-196. doi:10.1515/ctra-2018-0018.

Kaufman, J. C., & Baer, J. (2005). *Creativity Across Domains: Faces of the Muse*. New Jersey, NY, USA: Lawrence Erlbaum Associates.

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four C model of creativity. *Review of General Psychology, 13*(1), 1-13.

Kaufman, J. C., & Sternberg, R. J. (2010). *The Cambridge Handbook of Creativity.* New York, NY, US: Cambridge University Press.

Keltner, D., & Ekman, P. (2015). The Science of 'Inside Out'. *New York Times*, *3*.

Kemple, K. M., & Nissenberg, S. A. (2000). Nurturing creativity in early childhood education: *Families are part of it. Early Childhood Education Journal, 28*(1), 67-71. doi:10.1023/A:1009555805909.

Kennedy, J., Baxter, P., & Belpaeme, T. (2015). Comparing robot embodiments in a guided discovery learning interaction with children. *International Journal of Social Robotics, 7*(2), 293-308. doi:10.1007/s12369-014-0277-4.

Kim, K. H. (2005). Can only intelligent people be creative? A meta-analysis. *Journal of Secondary Gifted Education, 16*(2-3), 57-66. doi:10.4219/jsge-2005-473

Kim, K. H. (2008). Meta-analyses of the relationship of creative achievement to both IQ and divergent thinking test scores. *The Journal of Creative Behavior42*(2), 106-130. doi:10.1002/j.2162-6057.2008.tb01290.x

Kim, K. (2011). The creativity crisis: The decrease in creative thinking scores on the Torrance Tests of Creative Thinking. *Creativity Research Journal, 23*(4), 285-295.

Knight, H. (2011, November). Eight lessons learned about non-verbal interactions through robot theater. In *International Conference on Social Robotics* (pp. 42-51). Springer, Berlin, Heidelberg. doi: 10.1007/978-3-642-25504-5_5.

Knight, H., & Simmons, R. (2016, May). Laban head-motions convey robot state: A call for robot body language. In *2016 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 2881-2888). IEEE. doi:10.1109/ICRA.2016.7487451.

Koestner, R., Ryan, R. M., Bernieri, F., & Holt, K. (1984). Setting limits on children's behavior: The differential effects of controlling vs. informational styles on intrinsic motivation and creativity. *Journal of personality, 52*(3), 233-248.

Kogan, N. (1973). Creativity and Cognitive Style: A Life-Span Perspective. In P. B. Baltes, & W. K. Schaie, *Life-Span Developmental Psychology: Personality and Socialization.* Cambridge, MA, US: Academic Press.

Kohlberg, L. (1966). Moral education in the schools: A developmental view. *The School Review, 74*(1), 1-30.

Kokotsaki, D. (2016). Engagement and Creativity in Music Education. In *Trends in Music Information Seeking, Behavior, and Retrieval for Creativity* (pp. 295-309). IGI Global.

Kory-Westlund, J. M., & Breazeal, C. (2019). A long-term study of young children's rapport, social emulation, and language learning with a peer-like robot playmate in preschool. *Frontiers in Robotics and AI*, *6*, 81. doi:10.3389/frobt.2019.00081.

Kövecses, Z. (2010). Metaphor, creativity, and discourse. *DELTA: Documentação de Estudos em Linguística Teórica e Aplicada, 26,* 719-738. doi:10.1590/S0102-44502010000300016.

Kozbelt, A., Beghetto, R. A., & Runco, M. (2010). Theories of creativity. In J. C. Kaufman, & R. J. Sternberg, *The Cambridge Handbook of Creativity.* New York, NY, US: Cambridge University Press.

Kozima, H., Michalowski, M. P., & Nakagawa, C. (2009). Keepon. *International Journal of Social Robotics*, *1*(1), 3-18. doi:10.1007/s12369-008-0009-8.

Krafft, K. C., & Berk, L. E. (1998). Private speech in two preschools: Significance of open-ended activities and make-believe play for verbal self-regulation. *Early Childhood Research Quarterly*, *13*(4), 637-658. doi:10.1016/S0885-2006(99)80065-9.

*Krampen, G. (1997). Promotion of creativity (divergent productions) and convergent productions by systematic-relaxation exercises: Empirical evidence from five experimental studies with children, young adults, and elderly. *European Journal of Personality, 11*(2), 83-99. doi:10.1002/(SICI)1099-0984(199706)11:2%3C83::AID-PER280%3E3.0.CO;2-5.

Krathwohl, D. R., & Anderson, L. W. (2009). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Longman.

Krippendorff, K., & Bock, M. A. (2009). *The Content Analysis Reader*. New Delhi, India: SAGE Publications.

Kuo, I. H., Jayawardena, C., Broadbent, E., & MacDonald, B. A. (2011). Multidisciplinary design approach for implementation of interactive services. *International Journal of Social Robotics*, *3*(4), 443-456. doi:10.1007/s12369-011-0115-x.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 159-174. doi:10.2307/2529310.

Landoni, M., Rubegni, E., Nicol, E., & Read, J. (2016, June). How many roles can children play? In *Proceedings of the The 15th International Conference on Interaction Design and Children* (pp. 720-725). ACM. doi:10.1145/2930674.2932222.

Lee, K. Y. (2012). The study of factors in affecting the user's addictive behavior in using the smart phone applications. *Korean Journal of Business Education*, *27*(5), 183-208.

Lee, M. K., Forlizzi, J., Rybski, P. E., Crabbe, F., Chung, W., Finkle, J., Glaser, E., & Kiesler, S. (2009, March). The snackbot: documenting the design of a robot for long-term human-robot interaction. In *Proceedings of the 4th ACM/IEEE International Conference on Human Robot Interaction* (pp. 7-14). ACM. doi:10.1145/1514095.1514100.

Lee, K. M., Jung, Y., Kim, J., & Kim, S. R. (2006). Are physically embodied social agents better than disembodied social agents? The effects of physical embodiment, tactile interaction, and people's loneliness in human–robot interaction. *International Journal of Human-Computer Studies, 64*(10), 962-973. doi:10.1016/j.ijhcs.2006.05.002.

Leite, I., Martinho, C., & Paiva, A. (2013). Social robots for long-term interaction: a survey. *International Journal of Social Robotics*, *5*(2), 291-308. doi:10.1007/s12369-013-0178-y.

Leite, I., Mascarenhas, S., Pereira, A., Martinho, C., Prada, R., & Paiva, A. (2010, September). “Why Can’t We Be Friends?” An Empathic Game Companion for Long-Term

Interaction. In *International Conference on Intelligent Virtual Agents* (pp. 315-321). Springer, Berlin, Heidelberg. doi:10.1007/978-3-642-15892-6_32.

Lewis, T. (2009). Creativity in technology education: Providing children with glimpses of their inventive potential. *International Journal of Technology and Design Education, 19*(3), 255-268. doi:10.1007/s10798-008-9051-y.

Li, J. (2015). The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents. *International Journal of Human-Computer Studies, 77*, 23-37. doi:10.1016/j.ijhcs.2015.01.001.

Liikanen, P. (1975). Increasing creativity through art education among pre-school children. *Jyväskylä Studies in Education, Psychology & Social Research.*

Lillard, A. S., Lerner, M. D., Hopkins, E. J., Dore, R. A., Smith, E. D., & Palmquist, C. M. (2013). The impact of pretend play on children's development: A review of the evidence. *Psychological bulletin*, *139*(1), 1. doi:10.1037/a0029321.

Livingstone, S., Marsh, J., Plowman, L., Ottovordemgentschenfelde, S., & Fletcher-Watson, B. (2014). Young children (0-8) and digital technology: a qualitative exploratory study-national report-UK.

Löffler, D., Schmidt, N., & Tscharn, R. (2018, February). Multimodal expression of artificial emotion in social robots using color, motion and sound. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 334-343). ACM. doi:10.1145/3171221.3171261.

Lohan, M., Aventin, Á., Maguire, L., Curran, R., McDowell, C., Agus, A., Donaldson, C., Clarke, M., Linden, M., Kelly, C., McDaid, L., Dunne, L., & O'Halloran, P. (2017). Recruitment, randomisation, allocation and retention. In *Increasing boys' and girls'* *intentions to avoid teenage pregnancy: A cluster randomised controlled feasibility trial of an interactive video drama-based intervention in post-primary schools in Northern Ireland*. NIHR Journals Library.

Lotfi, A., Langensiepen, C., & Yahaya, S. (2018). Socially assistive robotics: Robot exercise trainer for older adults. *Technologies*, *6*(1), 32. doi:10.3390/technologies6010032.

Lubart, T. I. (2001). Models of the creative process: Past, present and future. *Creativity Research Journal, 13*(3-4), 295-308.

Lubart, T. (2005). How can computers be partners in the creative process: classification and commentary on the special issue. *International Journal of Human-Computer Studies*, *63*(4-5), 365-369. Doi: 10.1016/j.ijhcs.2005.04.002

Lubart, T. I., & Getz, I. (1997). Emotion, metaphor, and the creative process. Creativity Research Journal, 10(4), 285-301. doi:10.1207/s15326934crj1004_1.

Lubart, T. I., & Guignard, J. H. (2004). The generality-specificity of creativity: A multivariate approach. In Sternberg, R. J., Singer, J. L., & Grigorenko, E. L., *Creativity: From Potential to Realization* (pp. 43-56). Washington, DC, USA: American Psychological Association.

Lubart, T., Mouchiroud, C., Tordjman, S., & Zenasn, F. (2015). *Psychologie de la créativité* (Vol. 2). Paris: Armand Colin.

Lucas, P., & Martinho, C. (2017). Stay Awhile and Listen to 3Buddy, a Co-creative Level Design Support Tool. In *International Conference of Computational Creativity* (pp. 205-212).

*Luftig, R. L. (2000). An investigation of an arts infusion program on creative thinking, academic achievement, affective functioning, and arts appreciation of children at three grade levels. *Studies in Art Education, 41*(3), 208-227. doi:10.1080/00393541.2000.11651678.

Lungarella, M., & Metta, G. (2003). Beyond gazing, pointing, and reaching: A survey of developmental robotics.

Lungarella, M., Metta, G., Pfeifer, R., & Sandini, G. (2003). Developmental robotics: a survey. Connection science, 15(4), 151-190. doi:10.1080/09540090310001655110.

Lupetti, M. L. (2017). Shybo - Design of a research artefact for human-robot interaction studies. *Journal of Science and Technology of the Arts*, *9*(1), 57-69. doi:10.7559/citarj.v9i1.303.

Lupetti, M., Yao, Y., Mi, H., & Germak, C. (2017). Design for children's playful learning with robots. *Future Internet*, *9*(3), 52. doi:10.3390/fi9030052.

Luria, M., Hoffman, G., Megidish, B., Zuckerman, O., & Park, S. (2016, August). Designing Vyo, a robotic Smart Home assistant: Bridging the gap between device and social agent. In *2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (pp. 1019-1025). IEEE. doi:10.1109/ROMAN.2016.7745234.

Luria, M., Zimmerman, J., & Forlizzi, J. (2019). Championing Research through design in HRI. *arXiv preprint arXiv:1908.07572*.

Ma, H. H. (2009). The effect size of variables associated with creativity: A meta-analysis. *Creativity Research Journal, 21*(1), 30-42.

*MacDonald, W. S., Heinberg, P., Fruehling, R. T., & Meredith, C. G. (1976). Training of original responses and academic performance of fifth-grade students. *Psychological Reports, 38*(1), 67-72. doi:10.2466/pr0.1976.38.1.67.

Maćkiewicz, M., & Cieciuch, J. (2016). Pictorial Personality Traits Questionnaire for Children (PPTQ-C)—A New Measure of Children's Personality Traits. *Frontiers in psychology, 7*, 498. doi:10.3389/fpsyg.2016.00498.

Magnenat, S., Riedo, F., Bonani, M., & Mondada, F. (2012, May). A programming workshop using the robot "Thymio II": The effect on the understanding by children. In *2012 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)* (pp. 24-29). IEEE. doi:10.1109/ARSO.2012.6213393.

Magnusson, T. (2011). Algorithms as scores: Coding live music. *Leonardo Music Journal*, 19-23. doi:10.1162/LMJ_a_00056.

Maier, N. R. (1970). Problem Solving and Creativity; In Individuals and Groups. Brooks/Cole Pub. Co.

*Majid, D. A., Tan, A. G., & Soh, K. C. (2003). Enhancing children's creativity: An exploratory study on using the Internet and SCAMPER as creative writing tools. *Korean Journal of Thinking and Problem Solving, 13*(2), 67-82.

*Maker, C. J., Jo, S., & Muammar, O. M. (2008). Development of creativity: The influence of varying levels of implementation of the DISCOVER curriculum model, a non-traditional pedagogical approach. *Learning and Individual Differences, 18*(4), 402-417. doi:10.1016/j.lindif.2008.03.003.

Mansfield, R. S., Busse, T. V., & Krepelka, E. J. (1978). The effectiveness of creativity training. *Review of Educational Research, 48*(4), 517-536.

Martelaro, N. (2016, March). Wizard-of-oz interfaces as a step towards autonomous HRI. In *2016 AAAI Spring Symposium Series*.

Martelaro, N., & Ju, W. (2017, February). WoZ Way: Enabling real-time remote interaction prototyping & observation in on-road vehicles. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (pp. 169-182). ACM.

Martelaro, N., & Ju, W. (2019). The needfinding machine. In *Social internet of things* (pp. 51-84). Springer, Cham. doi:10.1007/978-3-319-94659-7_4.

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER)*, 5(1), 4. doi:10.7771/2157-9288.1099.

Martin, A. (2005b). DigEuLit – A European framework for digital literacy: A progress report. *Journal of eLiteracy, 2*(2), 130-136

Mast, M., Burmester, M., Krüger, K., Fatikow, S., Arbeiter, G., Graf, B., Kronreif, G., Pigini, L., Facal, D., & Qiu, R. (2012). User-centered design of a dynamic-autonomy remote interaction concept for manipulation-capable robots to assist elderly people in the home. *Journal of Human-Robot Interaction*, *1*(1), 96-118. doi:10.5898/JHRI.1.1.Mast.

Mataric, M. J., Koenig, N. P., & Feil-Seifer, D. (2007, March). Materials for Enabling Hands-On Robotics and STEM Education. In *AAAI spring symposium: Semantic scientific knowledge integration* (pp. 99-102).

Mavridis, N. (2015). A review of verbal and non-verbal human–robot interactive communication. *Robotics and Autonomous Systems, 63*, 22-35. doi:10.1016/j.robot.2014.09.031.

Mayer, R. E. (1999). Fifty years of creativity research. In R. K. Sternberg, *Handbook of Creativity.* New York, NY, US: Cambridge University Press.

Mayo, J. A. (2002). Case-based instruction: A technique for increasing conceptual application in introductory psychology. *Journal of Constructivist Psychology, 15*(1), 65-74. doi:10.1080/107205302753305728.

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. *Research quarterly for exercise and sport, 60(*1), 48-58. doi:10.1080/02701367.1989.10607413.

McCarney, R., Warner, J., Iliffe, S., Van Haselen, R., Griffin, M., & Fisher, P. (2007). The Hawthorne Effect: A randomised, controlled trial. *BMC Medical Research Methodology, 7*(1), 30(38). doi:10.1186/1471-2288-7-30.

McCrae, R. R., & Costa Jr, P. T. (1997). Personality trait structure as a human universal. *American Psychologist, 52*(5), 509. doi:10.1037/0003-066X.52.5.509.

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica: Biochemia Medica*, *22*(3), 276-282.

McKenney, S., & Voogt, J. (2010). Technology and young children: How 4-7 year olds perceive their own use of computers. *Computers in Human Behavior*, *26*(4), 656-664. doi:10.1016/j.chb.2010.01.002.

*Meador, K. S. (1995). The effect of synectics training on gifted and nongifted kindergarten students. *Journal for the Education of the Gifted*, 18(1), 55-73. doi:10.1177/016235329401800105.

Mellander, C., & Florida, R. (2013). *The Creative Class Goes Global.* Oxfordshire, UK.

Mellou, E. (1996). Can creativity be nurtured in young children? *Early Child Development and Care, 119*(1), 119-130.

Melonio, A., & Gennari, R. (2012). *Co-Design with children: The State of the Art*. Technical report, KRDB Research Centre Technical Report.

Meriçli, Ç., Veloso, M., & Akın, H. L. (2011). Task refinement for autonomous robots using complementary corrective human feedback. *International Journal of Advanced Robotic Systems, 8(*2), 16. doi:10.5772/10575.

Michinov, N., & Primois, C. (2005). Improving productivity and creativity in online groups through social comparison process: New evidence for asynchronous electronic brainstorming. *Computers in Human Behavior, 21*(1), 11-28. doi:10.1016/j.chb.2004.02.004.

Miller, B, & Gerard, D. (1979). Family influences on the development of creativity in children: An integrative review. *Family Coordinator, 28*(3), 295-312. doi:10.2307/581942

Miller, D. L. (2015). Cultivating creativity. *The English Journal, 104*(6), 25-30.

Mnich, C., Weyland, S., Jekauc, D., & Schipperijn, J. (2019). Psychosocial and Physiological Health Outcomes of Green Exercise in Children and Adolescents—A Systematic Review. *International Journal of Environmental Research and Public Health*, *16*(21), 4266. doi:10.3390/ijerph16214266.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic reviews, 4*(1), 1-9. doi: 10.1186/2046-4053-4-1.

Montessori, M. (1917). *The Advanced Montessori Method.* (Vol. 1). Frederick A. Stokes Company.

Moore, D., Tennent, H., Martelaro, N., & Ju, W. (2017, March). Making noise intentional: A study of servo sound perception. In *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 12-21). ACM. doi:10.1145/2909824.3020238.

Moore, G. T., & Cohen, U. (1978). Exceptional Education and the Physical Environment: Toward Behaviorally-Based Design Principles.

*Moore, M., & Russ, S. W. (2008). Follow-up of a pretend play intervention: Effects on play, creativity, and emotional processes in children. *Creativity Research Journal, 20*(4), 427-436. doi:10.1080/10400410802391892.

Moraveji, N., Li, J., Ding, J., O'Kelley, P., & Woolf, S. (2007, April). Comicboarding: using comics as proxies for participatory design with children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1371-1374). ACM. doi:10.1145/1240624.1240832.

*Moreno, J. M., & Hogan, J. D. (1976). The influence of race and social-class level on the training of creative thinking and problem-solving abilities. *The Journal of Educational Research, 70*(2), 91-95. doi:10.1080/00220671.1976.10884960.

Moran, S. (2010). The roles of creativity in society. In J. C. Kaufman, & R. J. Sternberg, *The Cambridge Handbook of Creativity* (pp. 74-90). New York, NY, US: Cambridge University Press.

Mordoch, E., Osterreicher, A., Guse, L., Roger, K., & Thompson, G. (2013). Use of social commitment robots in the care of elderly people with dementia: A literature review. *Maturitas, 74*(1), 14-20. doi:10.1016/j.maturitas.2012.10.015.

Mordvintsev, A., Olah, C., & Tyka, M. (2015a). Deep dream: A code example for visualizing neural networks. *Google Research*, *2*(5).

Mordvintsev, A., Olah, C., & Tyka, M. (2015b). Inceptionism: Going deeper into neural networks, 2015. Retrieved 11 2019, from Google AI 2005: https://research. googleblog. com/2015/06/inceptionism-going-deeper-into-neural.html.

Mori, M. (1970). On the uncanny valley. *Energy*, *7*(4), 33-35.

Morse. J. M. (1995). The significance of saturation. *Qualitative Health Research, 5*(2), 147-149.

Mota, C. (2011, November). The rise of personal fabrication. In *Proceedings of the 8th ACM conference on Creativity and cognition* (pp. 279-288). ACM. doi:10.1145/2069618.2069665.

Mottweiler, C. M., & Taylor, M. (2014). Elaborated role play and creativity in preschool age children. *Psychology of Aesthetics, Creativity, and the Arts*, *8*(3), 277.

Moura, L. (2007). A new kind of art: The robotic action painter. *X Generative Art Conferece, Politecnico di Milano University*.

Moura, L. (2018, September). Robot Art: An Interview with Leonel Moura. In *Arts* (Vol. 7, No. 3, p. 28). Multidisciplinary Digital Publishing Institute.

Moreau, C. P., & Engeset, M. G. (2016). The downstream consequences of problem-solving mindsets: How playing with LEGO influences creativity. *Journal of Marketing Research, 53*(1), 18-30.

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, *1*(209-0015), 13. doi:10.2316/Journal.209.2013.1.209-0015.

Mumford, M. D. (2003). Where have we been, where are we going? Taking stock in creativity research. *Creativity Research Journal, 15*(2-3), 107-120. doi:10.1080/10400419.2003.9651403.

Mumm, J., & Mutlu, B. (2011). Designing motivational agents: The role of praise, social comparison, and embodiment in computer feedback. *Computers in Human Behavior, 27*(5), 1643-1650. doi:10.1016/j.chb.2011.02.002.

Murphy, R. R., Nomura, T., Billard, A., & Burke, J. L. (2010). Human-Robot Interaction. *IEEE Robotics & Automation Magazine, 17*(2), 85-89. doi:10.1109/MRA.2010.936953.

Mutlu, B., & Forlizzi, J. (2008, March). Robots in organizations: the role of workflow, social, and environmental factors in human-robot interaction. In *Proceedings of the 3rd ACM/IEEE International Conference on Human Robot Interaction* (pp. 287-294). ACM. doi:10.1145/1349822.1349860.

Nash, W. R. (1974). The effects of a school for the gifted in averting the fourth grade slump in creativity. *Gifted Child Quarterly, 18*(3), 168-170.

Nass, C., Steuer, J., & Tauber, E. R. (1994, April). Computers are social actors. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 72-78). ACM.

*Nelson, A., & Lalemi, B. (1991). The role of imagery training on Tohono O'odham children's creativity scores. *Journal of American Indian Education, 30*(3), 24-32.

Netting, R. M. (1986). Cultural ecology (No. 304.2 N47).

Nemeth, C., Brown, K., & Rogers, J. (2001). Devil’s advocate versus authentic dissent: Stimulating quantity and quality. *European Journal of Social Psychology, 31*(6), 707-720. doi:10.1002/ejsp.58.

Newton-Dunn, H., Nakano, H., & Gibson, J. (2003, May). Block jam: a tangible interface for interactive music. In *Proceedings of the 2003 conference on New interfaces for musical expression* (pp. 170-177). National University of Singapore.

Nickerson, R. S. (1999). Enhancing creativity. In R. J. Sternberg, *Handbook of Creativity.* Cambridge, UK: Cambridge University Press.

Nijdam, N. A. (2009). Mapping emotion to color. *Book Mapping Emotion to Color*, 2-9.

Nogueira, S. I., Almeida, L. S., & Lima, T. S. (2017a). Two Tracks of Thought: A Structural Model of the Test for Creative Thinking-Drawing Production (TCT-DP). *Creativity Research Journal*, *29*(2), 206-211. doi:10.1080/10400419.2017.1303312.

Nogueira, S. I., Almeida, L. S., & Lima, T. S. (2017b, July). *In the path of Two Tracks of Thought: A Structural Model of the Test for Creative Thinking Drawing Production (TCT-DP), over the School Years in Portuguese Context*. Poster presented at the16th International Centre for Innovation in Education Conference (ICIE) on: Excellence, Innovation, & Creativity in Basic-Higher Education & Psychology, Paris, France.

Nogueira, S. I., Almeida, L. S., & Lima, T. S. (2017c, July). *Normative values for the Test for Creative Thinking-Drawing Production (TCT-DP), over the school years in Portuguese context.* Poster presented at the16th International Centre for Innovation in Education Conference (ICIE) on: Excellence, Innovation, & Creativity in Basic-Higher Education & Psychology, Paris, France.

Norman, D. (1986). *Cognitive engineering*. User Centered System Design, 31, 61. Encyclopedia of GIS. doi:10.1007/978-3-319-17885-1_100154.

Norman, D. (2013). *The design of everyday things: Revised and expanded edition*. New York, NY, US: Basic Books.

Nesset, V., & Large, A. (2004). Children in the information technology design process: A review of theories and their applications. Library & Information Science Research, 26(2), 140-161. doi:10.1016/j.lisr.2003.12.002.

Obaid, M., Barendregt, W., Alves-Oliveira, P., Paiva, A., & Fjeld, M. (2015, October). Designing robotic teaching assistants: interaction design students' and children's views. In *International conference on social robotics* (pp. 502-511). Springer, Cham. doi:10.1007/978-3-319-25554-5_50.

Oden, S., & Asher, S. R. (1977). Coaching children in social skills for friendship making. *Child Development, 48*(2), 495-506. doi:10.2307/1128645.

Oliveira, H. (2009). Automatic generation of poetry: an overview. *Universidade de Coimbra*.

Oliveira, H. G., & Cardoso, A. (2015). Poetry generation with PoeTryMe. In *Computational Creativity Research: Towards Creative Machines* (pp. 243-266). Atlantis Press, Paris. doi:10.2991/978-94-6239-085-0_12.

Ortlieb, E. T. (2010). The Pursuit of Play within the Curriculum. *Journal of Instructional Psychology*, *37*(3).

Osborn, A. F. (1953). Applied imagination. Oxford, England: Scribner'S.

Osburn, H. K., & Mumford, M. D. (2006). Creativity and planning: Training interventions to develop creative problem-solving skills. *Creativity Research Journal, 18*(2), 173-190. doi:10.1207/s15326934crj1802_4.

Özgür, A. (2018). *Cellulo: Tangible Haptic Swarm Robots for Learning* (Doctoral dissertation, Ecole Polytechnique Fédérale de Lausanne).

Özgür, A., Lemaignan, S., Johal, W., Beltran, M., Briod, M., Pereyre, L., Mondada F., & Dillenbourg, P. (2017, March). Cellulo: Versatile handheld robots for education. In *2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI* (pp. 119-127). IEEE.

*Pagona, B., & Costas, M. (2008). The development of motor creativity in elementary school children and its retention. *Creativity Research Journal, 20*(1), 72-80. doi:10.1080/10400410701842078.

Paiva, A., Leite, I., Boukricha, H., & Wachsmuth, I. (2017). Empathy in virtual agents and robots: A survey. *ACM Transactions on Interactive Intelligent Systems (TiiS)*, *7*(3), 11. doi:10.1145/2912150.

Paiva, A., Mascarenhas, S., Petisca, S., Correia, F., & Alves-Oliveira, P. (2018). Towards more humane machines: Creating emotional social robots. In *New interdisciplinary landscapes in morality and emotion* (pp. 125-139). London, UK: Routledge.

Palmiero, M., Di Giacomo, D., & Passafiume, D. (2014). Divergent thinking and age-related changes. *Creativity Research Journal, 26*(4), 456-460. doi:10.1080/10400419.2014.961786.

Pantofaru, C., & Takayama, L. (2011). Need finding: A tool for directing robotics research and development. In *RSS 2011 Workshop on perspectives and contributions to robotics from the human sciences*.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY, US: Basic Books, Inc.

Papert, S. (1999). What is Logo? Who needs it. Logo philosophy and implementation.

Patnaik, D., & Becker, R. (1999). Needfinding: The why and how of uncovering people's needs. *Design Management Journal (Former Series)*, *10*(2), 37-43. doi:10.1111/j.1948-7169.1999.tb00250.x.

Park, H. W., Rosenberg-Kima, R., Rosenberg, M., Gordon, G., & Breazeal, C. (2017, March). Growing growth mindset with a social robot peer. In *2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI* (pp. 137-145). IEEE. doi:10.1145/2909824.3020213.

Parkhurst, H. B. (1999). Confusion, lack of consensus, and the definition of creativity as a construct. *The Journal of Creative Behavior, 33*(1), 1-21.

Paulus, P. B., & Nijstad, B. A. (2003). *Group Creativity: Innovation Through Collaboration*. New York, NY, USA: Oxford University Press.

Pellegrini, A. D., & Bohn, C. M. (2005). The role of recess in children's cognitive performance and school adjustment. *Educational Researcher*, *34*(1), 13-19. doi:10.3102/0013189X034001013.

Pellegrini, A. D., & Smith, P. K. (1998). Physical activity play: The nature and function of a neglected aspect of play. *Child Development*, *69*(3), 577-598. doi:10.1111/j.1467-8624.1998.tb06226.x.

Pellis, S., & Pellis, V. (2013). *The playful brain: venturing to the limits of neuroscience*. London, UK: Oneworld Publications.

Pennisi, P., Tonacci, A., Tartarisco, G., Billeci, L., Ruta, L., Gangemi, S., & Pioggia, G. (2016). Autism and social robotics: A systematic review. *Autism Research*, *9*(2), 165-183. doi:10.1002/aur.1527.

Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Delta Kappan*, 95(3), 22-27. doi:10.1177/003172171309500306.

Phon, D. N. E., Ali, M. B., & Halim, N. D. A. (2014, April). Collaborative augmented reality in education: A review. In *2014 International Conference on Teaching and Learning in Computing and Engineering* (pp. 78-83). IEEE. doi:10.1109/LaTiCE.2014.23.

Piaget, J. (1950). *The Psychology of Intelligence.* London, UK: Routledge.

Piaget, J. (1959). *The Language and Thought of the Child.* London, UK: Routledge Classics.

Piaget, J. (1971). The theory of stages in cognitive development. In D. R. Green, M. P. Ford, & G. Flamer, *Measurements and Piaget.* New York, NY, US: McGraw-Hill.

Piaget, J. (2013). Play, dreams and imitation in childhood. Routledge.

Piaget, J., & Cook, M. (1952). *The Origins of Intelligence in Children.* New York, NY, US: International Universities Press.

Pink, D. H., & Unwin, A. (2005). Why right-brainers will rule the future. In *A whole new mind: Moving from the information age to the conceptual age.* New York, NY, US.

Pires, A., Alves-Oliveira, P., Arriaga, P., & Martinho, C. (2017, August). *CUBUS: Autonomous embodied characters to stimulate creative idea generation in groups of children*. Paper presented at the 17th International Conference on Intelligent Virtual Agents, 360-373, Stockholm, Sweden. doi:10.1007/978-3-319-67401-8_46.

Pfeifer, R., & Scheier, C. (2001). *Understanding Intelligence*. MIT press.

Plowman, L., & McPake, J. (2013). Seven myths about young children and technology. *Childhood Education*, *89*(1), 27-33. doi:10.1080/00094056.2013.757490.

Plucker, J. A., & Beghetto, R. A. (2004). Why creativity is domain general, why it looks domain specific, and why the distinction does not matter. In Sternberg, R. J., Grigorenko, E. L.,

& Singer, J. L., *Creativity: From Potential to Realization* (pp. 153-167). Washington, DC, USA: American Psychological Association.

Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist, 39*(2), 83-96.

Poole, D. A., & Lamb, M. E. (1998). *Investigative interviews of children: A guide for helping professionals*. American Psychological Association.

Powers, A., Kiesler, S., Fussell, S., & Torrey, C. (2007, March). Comparing a computer agent with a humanoid robot. In *2nd ACM/IEEE International Conference on Human-Robot Interaction (HRI*) (pp. 145-152). IEEE. doi:10.1145/1228716.1228736.

Puryear, J. S., Kettler, T., & Rinn, A. N. (2017). Relationships of personality to differential conceptions of creativity: A systematic review. *Psychology of Aesthetics, Creativity, and the Arts, 11*(1), 59. doi:10.1037/aca0000079.

Rabbitt, S. M., Kazdin, A. E., & Scassellati, B. (2015). Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use. *Clinical Psychology Review*, *35*, 35-46. doi:10.1016/j.cpr.2014.07.001.

Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing*, *18*(6), 1533-1543. doi:10.1007/s00779-013-0747-y.

Raffle, H. S., Parkes, A. J., & Ishii, H. (2004, April). Topobo: a constructive assembly system with kinetic memory. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 647-654). ACM. doi:10.1145/985692.985774.

Raina, N. T. (1982). Sex differences in creativity in India: A second look. *Indian Educational Review, 17*(3), 122-128.

Ramesh, G., & Devadasan, S. R. (2007). Literature review on the agile manufacturing criteria. *Journal of Manufacturing Technology Management*, 18(2), 182-201.

Read, J. C. (2008). Validating the Fun Toolkit: an instrument for measuring children's opinions of technology. *Cognition, Technology & Work*, *10*(2), 119-128. doi:10.1007/s10111-007-0069-9.

Read, J. C., Horton, M., Sim, G., Gregory, P., Fitton, D., & Cassidy, B. (2013, April). CHECk: a tool to inform and encourage ethical practice in participatory design with children. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems* (pp. 187-192). ACM. doi:10.1145/2468356.2468391.

Reeves, B., & Nass, C. (1996). How people treat computers, television, and new media like real people and places.

Rejskind, F. G. (1982). Autonomy and creativity in children. *The Journal of Creative Behavior, 16*(1), 58-67. doi:10.1002/j.2162-6057.1982.tb00322.x.

Resnick, M. (1998). Technologies for lifelong kindergarten. *Educational Technology Research and Development*, *46*(4), 43-55. doi:10.1007/BF02299672.

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B., & Kafai, Y. B. (2009). Scratch: Programming for all. *Communinations of the Acm*, *52*(11), 60-67. doi:10.1145/1592761.1592779.

Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., & Silverman, B. (1998, January). Digital manipulatives: new toys to think with. In *Proceedings of the SIGCHI* *conference on Human factors in computing systems* (pp. 281-287). ACM Press/Addison-Wesley Publishing Co.

Resnick, M., Martin, F., Sargent, R., & Silverman, B. (1996). Programmable bricks: Toys to think with. *IBM Systems Journal*, *35*(3.4), 443-452. doi:10.1147/sj.353.0443.

Resnick, M., & Robinson, K. (2017). *Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play*. MIT press.

Resnick, M., & Silverman, B. (2005, June). Some reflections on designing construction kits for kids. In *Proceedings of the 2005 Conference on Interaction Design and Children* (pp. 117-122). ACM. doi:10.1145/1109540.1109556.

Rhodes, M. (1961). An analysis of creativity. *The Phi Delta Kappan*, *42*(7), 305-310.

Ribeiro, T., & Paiva, A. (2012, March). The illusion of robotic life: principles and practices of animation for robots. In *2012 7th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 383-390). IEEE. doi:10.1145/2157689.2157814.

Richardson, J. T. (2011). Eta squared and partial eta squared as measures of effect size in educational research. *Educational Research Review*, *6*(2), 135-147. doi:10.1016/j.edurev.2010.12.001.

Rickards, T. (1974). *Problem-solving through creative analysis*. Epping, England: Gower Press.

Riek, L. D. (2012). Wizard of oz studies in HRI: A systematic review and new reporting guidelines. *Journal of Human-Robot Interaction*, *1*(1), 119-136. doi:10.5898/JHRI.1.1.Riek.

Rietzschel, E. F., Nijstad, B. A., & Stroebe, W. (2010). The selection of creative ideas after individual idea generation: Choosing between creativity and impact. *British Journal of Psychology, 101*(1), 47-68. doi:10.1348/000712609X414204.

Rietzschel, E. F., Slijkhuis, J. M., & Van Yperen, N. W. (2014). Task structure, need for structure, and creativity. *European Journal of Social Psychology*, *44*(4), 386-399. doi:10.1002/ejsp.2024.

Ritter, S. M., & Ferguson, S. (2017). Happy creativity: Listening to happy music facilitates divergent thinking. *PloS one, 12*(9), e0182210. doi:10.1371/journal.pone.0182210.

Robert, L. (2018, December). Personality in the human robot interaction literature: A review and brief critique. In Robert, LP (2018). Personality in the Human Robot Interaction Literature: A Review and Brief Critique, Proceedings of the *24th Americas Conference on Information Systems,* Aug (pp. 16-18).

Robert, D., & Breazeal, C. (2012, March). Blended reality characters. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction* (pp. 359-366). ACM. doi:10.1145/2157689.2157810.

Roberts, B. W., & Mroczek, D. (2008). Personality trait change in adulthood. Current directions in psychological science, 17(1), 31-35. doi:10.1111/j.1467-8721.2008.00543.x.

Robins, B., Dautenhahn, K., Ferrari, E., Kronreif, G., Prazak-Aram, B., Marti, P., Iacono, I., Gelderblom, G. J., Bernd, T., Caprino, F., & Laudanna, E. (2012). Scenarios of robot-assisted play for children with cognitive and physical disabilities. *Interaction Studies*, *13*(2), 189-234. doi:10.1075/is.13.2.03rob.

Robins, B., Ferrari, E., Dautenhahn, K., Kronreif, G., Prazak-Aram, B., Gelderblom, G. J., Tanja, B., Caprino, B., Laudanna, E., & Marti, P. (2010). Human-centred design methods: Developing scenarios for robot assisted play informed by user panels and field trials. *International Journal of Human-Computer Studies*, *68*(12), 873-898. doi:10.1016/j.ijhcs.2010.08.001.

Robinson, K. (2011). *Out of our minds: Learning to be creative.* Mankato, MN, USA: Capstone.

Ros, R., & Demiris, Y. (2013, October). Creative dance: An approach for social interaction between robots and children. In *International Workshop on Human Behavior Understanding* (pp. 40-51). Springer, Cham. doi:10.1007/978-3-319-02714-2_4.

Rose, L. H., & Lin, H.-T. (1984). A meta-analysis of long-term creativity training programs. *The Journal of Creative Behavior, 18*(1), 11-22.

Rosenthal, R. (1979). The file drawer problem and tolerance for null result. *Psychological Bulletin, 86*(3), 638-641. doi:10.1037/0033-2909.86.3.638.

Roskos-Ewoldson, B., Intons-Peterson, M. J., & Anderson, R. E. (1993). Imagery, creativity, and discovery: Conclusions and implications. *Advances in Psychology, 93*, 313-328. doi:10.1016/S0166-4115(08)60147-8.

Ross, D. S. (2010). Improv ed: Changing thoughts about learning (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3415717).

Rossi, S., Ferland, F., & Tapus, A. (2017). User profiling and behavioral adaptation for HRI: a survey. *Pattern Recognition Letters, 99*, 3-12. doi:10.1016/j.patrec.2017.06.002.

Rubin, K. H., & Howe, N. (1985). Toys and play behaviors: An overview. *Topics in Early Childhood Special Education*, *5*(3), 1-9. doi:10.1177/027112148500500302.

Roussou, M. (2004). Learning by doing and learning through play: an exploration of interactivity in virtual environments for children. *Computers in Entertainment (CIE)*, *2*(1), 10-10. doi:10.1145/973801.973818.

Ryokai, K., Vaucelle, C., & Cassell, J. (2003). Virtual peers as partners in storytelling and literacy learning. *Journal of computer assisted learning*, *19*(2), 195-208. doi:10.1046/j.0266-4909.2003.00020.x.

Ruiz-del-Solar, J. (2009). Robotics-centered outreach activities: An integrated approach. *IEEE Transactions on Education*, *53*(1), 38-45. doi:10.1109/TE.2009.2022946.

Runco, M. A. (1999). Fourth grade slump. In M. A. Runco, & S. R. Pritzker, *Encyclopedia of Creativity* (pp. 743-744). San Diego, CA, US: Academic Press.

Runco, M. A., Acar, S., & Cayirdag, N. (2017). A closer look at the creativity gap and why students are less creative at school than outside of school. *Thinking Skills and Creativity, 24*, 242-249.

Runco, M. A., & Cayirdag, N. (2006). The development of children's creativity. In O. N. Saracho, & B. Spodek, *Handbook of Research on the Education of Young Children* (Vol. 2, pp. 102-110). New York, NY, US: Routledge: Taylor & Francis Group.

Runco, M. A., & Charles, R. E. (1993). Judgments of originality and appropriateness as predictors of creativity. *Personality and Individual Differences, 15*(5), 537-546.

Runco, M. A., & Laeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal, 24*(1), 92-96.

Runco, M. A., & Pritzker, S. (1999). *Encyclopedia of creativity* (Vol. 2). San Diego, CA, US: Academic Press.

Runco, M. A., Nemiro, J., & Walberg, H. (1998). Personal explicit theories of creativity. *The Journal of Creative Behavior, 32*(2), 1-17.

Russ, S. W. (2016). Pretend play: Antecedent of adult creativity. *New Directions for Child and Adolescent Development, 151*, 21-32. doi:10.1002/cad.20154.

Russ, S. W., Robins, A. L., & Christiano, B. A. (1999). Pretend play: Longitudinal prediction of creativity and affect in fantasy in children. Creativity Research Journal, 12(2), 129-139. doi:10.1207/s15326934crj1202_5.

Rybski, P. E., Yoon, K., Stolarz, J., & Veloso, M. M. (2007, March). Interactive robot task training through dialog and demonstration. In *Proceedings of the ACM/IEEE international conference on Human-robot interaction (pp. 49-56)*. ACM. doi:10.1145/1228716.1228724.

Šabanović, S. (2010). Robots in society, society in robots. *International Journal of Social Robotics*, *2*(4), 439-450. doi:10.1007/s12369-010-0066-7.

Šabanović, S., Reeder, S. M., & Kechavarzi, B. (2014). Designing robots in the wild: In situ prototype evaluation for a break management robot. *Journal of Human-Robot Interaction*, *3*(1), 70-88. doi:10.5898/JHRI.3.1.Sabanovic.

Said-Metwaly, S., Van den Noortgate, W., & Kyndt, E. (2017). Approaches to measuring creativity: A systematic literature review. *Creativity: Theories-Research-Applications, 4*(2), 238-275. doi:10.1515/ctra-2017-0013.

Salem, M., Eyssel, F., Rohlfing, K., Kopp, S., & Joublin, F. (2013). To err is human (-like): Effects of robot gesture on perceived anthropomorphism and likability. *International Journal of Social Robotics*, *5*(3), 313-323. doi:10.1007/s12369-013-0196-9.

Salem, M., Kopp, S., Wachsmuth, I., Rohlfing, K., & Joublin, F. (2012). Generation and evaluation of communicative robot gesture. *International Journal of Social Robotics*, *4*(2), 201-217. doi:10.1007/s12369-011-0124-9.

Salonius-Pasternak, D. E., & Gelfond, H. S. (2005). The next level of research on electronic play: Potential benefits and contextual influences for children and adolescents. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*.

Salvini, P., Laschi, C., & Dario, P. (2010). Design for acceptability: improving robots' coexistence in human society. *International Journal of Social Robotics*, *2*(4), 451-460. doi:10.1007/s12369-010-0079-2.

Santos, J. R. A. (1999). Cronbach's alpha: A tool for assessing the reliability of scales. *Journal of Extension*, *37*(2), 1-5.

Sarrazin, N. (2016). *Children's Musical Play: Musicality and Creativity*. Music and the Child.

Sarrica, M., Brondi, S., & Fortunati, L. (2019). How many facets does a "social robot" have? A review of scientific and popular definitions online. *Information Technology & People*. doi:10.1108/ITP-04-2018-0203

Streiner, D. L. (2003). Starting at the beginning: an introduction to coefficient alpha and internal consistency. *Journal of Oersonality Assessment*, *80*(1), 99-103. doi: 10.1207/S15327752JPA8001_18.

Sawicki, D. (2003). *The Rise of the Creative Class: And How it's Transforming Work, Leisure, Community and Everyday Life* (Vol. 69). Chicago, IL, US: Taylor & Francis Inc.

Sawyer, R. K. (2010). *Individual and Group Creativity*. The Cambridge handbook of creativity, 366-380.

Sawyer, K. R. (2017). *Group Genius: The Creative Power of Collaboration.* New York, NY, US: Basic Books.

Sawyer, K. R. (2017). Teaching creativity in art and design studio classes: A systematic literature review. *Educational Research Review, 22*, 99-113. doi:10.1016/j.edurev.2017.07.002

Sawyer, K. R. (2011). *Explaining Creativity: The Science of Human Innovation.* New York, NY, US: Oxford University Press.

Sawyer, R. K., & DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts*, *3*(2), 81. doi:10.1037/a0013282

Sawyer, R. K., John-Steiner, V., Moran, S., Sternberg, R. J., Feldman, D. H., Nakamura, J., & Csikszentmihalyi, M. (2003). *Creativity and Development.* New York, NY, US: Oxford University Press.

Scassellati, B. (2002). Theory of mind for a humanoid robot. *Autonomous Robots, 12*(1), 13-24. doi:10.1023/A:1013298507114.

Scassellati, B. (2003, July). Investigating models of social development using a humanoid robot. In *Proceedings of the International Joint Conference on Neural Networks,* 2003. (Vol. 4, pp. 2704-2709). IEEE. doi:10.1109/IJCNN.2003.1223995.

Scassellati, B., Admoni, H., & Matarić, M. (2012). Robots for use in autism research. *Annual Review of Biomedical Engineering*, *14*, 275-294. Doi: 10.1146/annurev-bioeng-071811-150036.

Scassellati, B., Boccanfuso, L., Huang, C. M., Mademtzi, M., Qin, M., Salomons, N., Ventola, P., & Shic, F. (2018). Improving social skills in children with ASD using a long-term, in-home social robot. *Science Robotics*, *3*(21), eaat7544. doi:10.1126/scirobotics.aat7544.

Schardt, C., Adams, M. B., Owens, T., Keitz, S., & Fontelo, P (2007). Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Medical Informatics and Decision Making, 7*(1), 1-6. doi: 10.1186/1472-6947-7-16.

Schleicher, D., Jones, P., & Kachur, O. (2010). Bodystorming as embodied designing. *Interactions*, *17*(6), 47-51.

Scholtz, J. (2003, January). Theory and evaluation of human robot interactions. In *36th Proceedings of the Annual Hawaii International Conference on System Sciences, 2003.* (pp. 10-pp). IEEE. doi:10.1109/HICSS.2003.1174284.

Schuler, D., & Namioka, A. (Eds.). (1993). *Participatory Design: Principles and Practices*. Hillsdale, New jersey, US: CRC Press.

Schweikardt, E., & Gross, M. D. (2007, March). A brief survey of distributed computational toys. In *2007 First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL'07)* (pp. 57-64). IEEE. doi:10.1109/DIGITEL.2007.4.

Scott, G., Leritz, L. E., & Mumford, M, M. D. (2004). Types of creativity training: Approaches and their effectiveness. *The Journal of Creative Behavior, 38*(3), 149-179.

Scott, G., Leritz, L. E., & Mumford, M. (2004). The effectiveness of creativity training: A quantitative review. *Creativity Research Journal, 16*(4), 361-388.

Segura, E. M., Vidal, L. T., & Rostami, A. (2016). Bodystorming for movement-based interaction design. *Human Technology*, *12*(2).

Sengers, P., Boehner, K., David, S., & Kaye, J. J. (2005, August). Reflective design. In *Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility* (pp. 49-58). ACM. doi:10.1145/1094562.1094569.

Serholt, S. (2018). Breakdowns in children’s interactions with a robotic tutor: A longitudinal study. *Computers in Human Behavior*, *81*, 250-264. doi:10.1016/j.chb.2017.12.030.

Sequeira, P., Alves-Oliveira, P., Ribeiro, T., Di Tullio, E., Petisca, S., Melo, F. S., Castellano, G., & Paiva, A. (2016, March). Discovering social interaction strategies for robots from restricted-perception Wizard-of-Oz studies. In *The eleventh ACM/IEEE international conference on human robot interaction* (pp. 197-204). IEEE Press.

Shamay-Tsoory, S. G., Adler, N., Aharon-Peretz, J., Perry, D., & Mayseless, N. (2011). The origins of originality: the neural bases of creative thinking and originality. *Neuropsychologia, 49*(2), 178-185. doi:10.1016/j.neuropsychologia.2010.11.020.

Shamsuddin, S., Yussof, H., Ismail, L., Hanapiah, F. A., Mohamed, S., Piah, H. A., & Zahari, N. I. (2012, March). Initial response of autistic children in human-robot interaction therapy with humanoid robot NAO. *In IEEE 8th International Colloquium on Signal Processing and its Applications* (pp. 188-193). IEEE. doi:10.1109/CSPA.2012.6194716.

Shen, S., Slovak, P., & Jung, M. F. (2018, February). Stop. I see a conflict happening.: A robot mediator for young children's interpersonal conflict resolution. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 69-77). ACM. doi:10.1145/3171221.3171248.

Shibata, T. (2004). An overview of human interactive robots for psychological enrichment. *Proceedings of the IEEE, 92*(11), 1749-1758. doi:10.1109/JPROC.2004.835383.

Shields, M. K., & Behrman, R. E. (2000). Children and computer technology: Analysis and recommendations. *The future of children, 4*-30.

*Shivley, J. E., Feldhusen, J. F., & Treffinger, D. J. (1972). Developing creativity and related attitudes. *The Journal of Experimental Education, 41*(2), 63-69. doi:10.1080/00220973.1972.11011395.

Short, E., Swift-Spong, K., Greczek, J., Ramachandran, A., Litoiu, A., Grigore, E. C., Feil-Seifer, ., Shuster, S., ee, J. J., Levonisova, S., Litz, J., Li, J., Spruijt-Metz, D., Matarić, M., & Scassellati, B. (2014, August). How to train your dragonbot: Socially assistive robots for teaching children about nutrition through play. In *The 23rd IEEE International*

Symposium on Robot and Human Interactive Communication (pp. 924-929). IEEE. doi:10.1109/ROMAN.2014.6926371.

Shuster, M. M., Mikels, J. A., & Camras, L. A. (2017). Adult age differences in the interpretation of surprised facial expressions. *Emotion*, *17*(2), 191. doi:10.1037/emo0000234.

Silvia, P. J. (2008). Creativity and intelligence revisited: A latent variable analysis of Wallach and Kogan. *Creativity Research Journal, 20*(1), 34-39. doi:10.1080/10400410701841807.

Silvia, P. J., Kaufman, J. C., & Pretz, J. E. (2009). Is creativity domain-specific? Latent class models of creative accomplishments and creative self-descriptions. *Psychology of Aesthetics, Creativity, and the Arts, 3*(3), 139-148. doi:10.1037/a0014940.

Simonsen, J., & Robertson, T. (Eds.). (2012). *Routledge international handbook of participatory design*. London and New York, UK and US: Routledge, Taylor and Francis Group.

Simonton, D. K. (2010). Creativity in highly eminent individuals. In J. C. Kaufman, & R. J. Sternberg, *The Cambridge Handbook of Creativity.* New York, NY, US: Cambridge University Press.

Simonton, D. K. (2018). Defining creativity: Don't we also need to define what is not creative? *The Journal of Creative Behavior, 52*(1), 80-90.

Singer, D. G., & Singer, J. L. (2009). *The house of make-believe: Children's play and the developing imagination*. Harvard, UK: University Press.

Sirkin, D., Baltodano, S., Mok, B., Rothenbücher, D., Gowda, N., Li, J., Martelaro, N., Miller, D., Sibi, S., & Ju, W. (2016). Embodied design improvisation for autonomous vehicles. In *Design Thinking Research* (pp. 125-143). Springer, Cham. doi:10.1007/978-3-319-40382-3_9.

Sirkin, D., & Ju, W. (2015). Embodied design improvisation: a method to make tacit design knowledge explicit and usable. In *Design Thinking Research* (pp. 195-209). Springer, Cham. doi:10.1007/978-3-319-06823-7_11.

Sirkin, D., Mok, B., Yang, S., & Ju, W. (2015, March). Mechanical ottoman: how robotic furniture offers and withdraws support. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction* (pp. 11-18). ACM. doi: 10.1145/2696454.2696461.

Slyper, R., Hoffman, G., & Shamir, A. (2015, January). Mirror puppeteering: Animating toy robots in front of a webcam. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 241-248). ACM. doi:10.1145/2677199.2680548.

Smith, G. F. (1998). Idea-generation techniques: A formulary of active ingredients. *The Journal of Creative Behavior*, *32*(2), 107-134. doi:10.1002/j.2162-6057.1998.tb00810.x.

Smith, G. J., & Carlsson, I. (1983). Creativity in early and middle school years. *International Journal of Behavioral Development, 6*(2), 167-195.

Smith, G., & Carlsson, I. (1985). Creativity in middle and late school years. *International Journal of Behavioral Development, 8*(3), 329-343.

Smith, P. K. (2017). *Children's play: Research developments and practical applications*. London and New York, UK and US: Routledge.

Smith, S. M. (1995). Fixation, incubation, and insight in memory and creative thinking. In Smith, S. M., Ward, T. B., & Finke, R. A., *The Creative Cognition Approach* (135-156). USA: MIT.

*Smogorzewska, J. (2012). Storyline and associations pyramid as methods of creativity enhancement: Comparison of effectiveness in 5-year-old children. *Thinking Skills and Creativity,7*(1), 28-37. doi:10.1016/j.tsc.2011.12.003.

*Smogorzewska, J. (2014). Developing children's language creativity through telling stories - An experimental study. *Thinking Skills and Creativity, 13*, 20-31. doi:10.1016/j.tsc.2014.02.005.

Sneck, S., Viholainen, H., Syväoja, H., Kankaapää, A., Hakonen, H., Poikkeus, A. M., & Tammelin, T. (2019). Effects of school-based physical activity on mathematics performance in children: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 109. doi:10.1186/s12966-019-0866-6.

Soh, K. (2017). Fostering student creativity through teacher behaviors. *Thinking Skills and Creativity, 23*, 58-66.

Solomon, C. J., & Papert, S. A. (1976). A case study of a young child doing Turtle Graphics in LOGO.

*Sowden, P. T., Clements, L., Redlich, C., & Lewis, C. (2015). Improvisation facilitates divergent thinking and creativity: Realizing a benefit of primary school arts education. *Psychology of Aesthetics, Creativity, and the Arts, 9*(2), 128-138. doi:10.1037/aca0000018.

Spadafora, M., Chahuneau, V., Martelaro, N., Sirkin, D., & Ju, W. (2016, February). Designing the behavior of interactive objects. In *Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 70-77). ACM. doi:10.1145/2839462.2839502.

Spodek, B., & Saracho, O. N. (2014). *Handbook of Research on the Education of Young Children.* New York, NY, US: Routledge: Taylor & Francis Group.

Spolaôr, N., & Benitti, F. B. V. (2017). Robotics applications grounded in learning theories on tertiary education: A systematic review. *Computers & Education*, *112*, 97-107. doi:10.1016/j.compedu.2017.05.001.

St-Louis, A. C., & Vallerand, R. J. (2015). A successful creative process: The role of passion and emotions. *Creativity Research Journal*, *27*(2), 175-187. doi:10.1080/10400419.2015.1030314.

Steinfeld, A., Jenkins, O. C., & Scassellati, B. (2009, March). The oz of wizard: simulating the human for interaction research. In *Proceedings of the 4th ACM/IEEE international conference on Human robot* interaction (pp. 101-108). ACM. doi:10.1145/1514095.1514115.

Sternber, R. J. (1988). *The nature of creativity: Contemporary psychological perspectives.* New York, NY, US: Cambridge University Press.

Sternberg, R. J. (1999). *Handbook of Creativity.* New York, NY, US: Cambridge University Press.

Sternberg, R. J. (2005). Creativity or creativities? *International Journal of Human-Computer Studies, 63*(4-5), 370-382. doi:10.1016/j.ijhcs.2005.04.003.

Sternberg, R. J., & Kaufman, J. C. (2018). *The Nature of Human Creativity.* New York, NY, US: Cambridge University Press.

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. *American Psychologist, 51*(7), 677-688.

Stroud, J. E. (1995). Block play: Building a foundation for literacy. *Early Childhood Education Journal*, *23*(1), 9-13. doi:10.1007/BF02353373.

Sublette, V. A., & Mullan, B. (2012). Consequences of play: A systematic review of the effects of online gaming. *International Journal of Mental Health and Addiction, 10*(1), 3-23. doi:10.1007/s11469-010-9304-3.

Sutton-Smith, B. (1986). *Toys as culture*. Gardner Press, Inc., 19 Union Square West, New York, NY 10003.

Sutton-Smith, B. (1992). The role of toys in the instigation of playful creativity. *Creativity Research Journal*, *5*(1), 3-11. doi:10.1080/10400419209534418.

Sutton, T. M., & Altarriba, J. (2016). Color associations to emotion and emotion-laden words: A collection of norms for stimulus construction and selection. *Behavior research methods*, *48*(2), 686-728. doi:10.3758/s13428-015-0598-8.

Schwartzman, H. (Ed.). (2012). *Transformations: The Anthropology of Children's Play*. Chicago: Illinois, US: Springer Science & Business Media.

Szafir, D., Mutlu, B., & Fong, T. (2015, March). Communicating directionality in flying robots. In *2015 10th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 19-26). IEEE.

Tadmor, C. T., Satterstrom, P., Jang, S., & Polzer, J. T. (2002). Beyond individual creativity: The superadditive benefits of multicultural experience for collective creativity in culturally diverse teams. *Journal of Cross-Cultural Psychology, 43*(3), 384-392. doi:10.1177/0022022111435259.

Tan, C. T., & Soh, D. (2010). Augmented reality games: A review. *Proceedings of Gameon-Arabia, Eurosis*.

Tan, C. S., Lau, X. S., Kung, Y. T., & Kailsan, R. A. L. (2019). Openness to experience enhances creativity: The mediating role of intrinsic motivation and the creative process engagement. The Journal of Creative Behavior, 53(1), 109-119.

Tanaka, F., Cicourel, A., & Movellan, J. R. (2007). Socialization between toddlers and robots at an early childhood education center. Proceedings *of the National Academy of Sciences, 104*(46), 17954-17958. doi:10.1073/pnas.0707769104.

Tanaka, F., Isshiki, K., Takahashi, F., Uekusa, M., Sei, R., & Hayashi, K. (2015, November). Pepper learns together with children: Development of an educational application. In *2015 IEEE-RAS 15th International Conference on Humanoid Robots (Humanoids)* (pp. 270-275). IEEE. doi:10.1109/HUMANOIDS.2015.7363546.

Taylor, C. W. (1988). Various approaches to and definitions of creativity. In R. J. Sternberg, *The Nature of Creativity: Contemporary Psychological Perspectives* (pp. 99-121). New York, NY, US: Cambridge University Press.

Tejima, N. (2001). Rehabilitation robotics: a review. *Advanced Robotics*, *14*(7), 551-564. doi: 10.1163/156855301742003.

Tennent, H., Moore, D., & Ju, W. (2018). Character actor: Design and evaluation of expressive robot car seat motion. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, *1*(4), 165. doi:10.1145/3161407.

Tennent, H., Moore, D., Jung, M., & Ju, W. (2017). Good vibrations: How consequential sounds affect perception of robotic arms. In *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (pp. 928-935). IEEE. doi:10.1109/ROMAN.2017.8172414.

Terada, K., Yamauchi, A., & Ito, A. (2012, September). Artificial emotion expression for a robot by dynamic color change. In *2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication* (pp. 314-321). IEEE. doi:10.1109/ROMAN.2012.6343772.

Terwogt, M. M., & Hoeksma, J. B. (1995). Colors and emotions: Preferences and combinations. *The Journal of General Psychology*, *122*(1), 5-17. doi:10.1080/00221309.1995.9921217.

Thomas, F., Johnston, O., & Thomas, F. (1995). *The illusion of life: Disney animation* (pp. 306-312). New York: Hyperion.

Thompson, R., & Goodvin, R. (2005). Concepts and theories of human development: Historical and contemporary dimensions. *Developmental Science: An Advanced Textbook*, *5*, 391-428.

Tinwell, A., Grimshaw, M., Nabi, D. A., & Williams, A. (2011). Facial expression of emotion and perception of the Uncanny Valley in virtual characters. *Computers in Human Behavior*, *27*(2), 741-749. doi:10.1016/j.chb.2010.10.018.

Toh, L. P. E., Causo, A., Tzuo, P. W., Chen, I. M., & Yeo, S. H. (2016). A review on the use of robots in education and young children. *Journal of Educational Technology & Society*, *19*(2), 148-163.

Torrance, E. P. (1966). Torrance tests of creative thinking: Norms-technical manual: Verbal tests, forms a and b: Figural tests, forms a and b. *Personal Press, Incorporated.*

Torrance, P. E. (1968). A longitudinal examination of the fourth grade slump in creativity. *Gifted Child Quarterly, 12*(4), 195-199.

Torrance, P. E. (1988). The nature of creativity as manifest in its testing. In R. J. Sternberg, Robert J., *The Nature of Creativity: Contemporary Psychological Perspectives.* New York, NY, US: Cambridge University Press.

Torrance, P. E., & Torrance, P. (1972). Combining creative problem-solving with creative expressive activities in the education of disadvantaged young people. *The Journal of Creative Behavior, 6*(1), 1-10. doi:10.1002/j.2162-6057.1972.tb00902.x.

Tottenham, N., Phuong, J., Flannery, J., Gabard-Durnam, L., & Goff, B. (2013). A negativity bias for ambiguous facial-expression valence during childhood: Converging evidence from behavior and facial corrugator muscle responses. *Emotion*, *13*(1), 92. doi:10.1037/a0029431.

Truong, K. N., Hayes, G. R., & Abowd, G. D. (2006, June). Storyboarding: an empirical determination of best practices and effective guidelines. In *Proceedings of the 6th Conference on Designing Interactive Systems* (pp. 12-21). ACM. doi:10.1145/1142405.1142410.

Tsvyatkova, D., & Storni, C. (2019). A review of selected methods, techniques and tools in Child-Computer Interaction (CCI) developed/adapted to support children's involvement in technology development. *International Journal of Child-Computer Interaction*. doi:10.1016/j.ijcci.2019.100148.

Turing, A. M. (2009). Computing machinery and intelligence. In *Parsing the Turing Test* (pp. 23-65). Springer, Dordrecht. doi:10.1007/978-1-4020-6710-5_3.

UNESCO. (2017). *Brussels: Official Journal of the European Union.* Retrieved 10 2019, from UNESCO moving forward the 2030 Agenda for Sustainable Development: https://en.unesco.org/creativity/files/unesco-moving-forward-2030-agenda-sustainable

Urban, K. K. (1991). On the development of creativity in children. *Creativity Research Journal, 4*(2), 177-191.

Urban, K. K. (2004). Assessing creativity: the test for creative thinking-drawing production (TCT-DP) the concept, application, evaluation, and international studies. *Psychology Science*, *46*(3), 387-397.

Urban, K. K. (2005). Assessing Creativity: The Test for Creative Thinking-Drawing Production (TCT-DP). *International Education Journal*, *6*(2), 272-280.

Urban, K. K., & Jellen, H. G. (1996). Manual of Test for Creative Thinking-Drawing Production (TCT-DP). *Amesterdam: Harcourt*.

Van den Akker, J. (1999). Principles and methods of development research. In *Design approaches and tools in education and training* (pp. 1-14). Springer, Dordrecht. doi:10.1007/978-94-011-4255-7_1.

Van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (Eds.). (2006). *Educational design research*. London and New York, UK, US: Routledge.

Van Doorn, F. (2016). Children as co-researchers in design: Enabling users to gather, share and enrich contextual data. *Manuscript. Delft University of Technology, Delft*. doi:10.4233/uuid:f16db80d-9f1a-4064-91be-decf8c805898.

Van Dyne, L., & Saavedra, R. (1996). A naturalistic minority influence experiment: Effects on divergent thinking, conflict and originality in work-groups. *British Journal of Social Psychology, 35*(1), 151-167. doi:10.1111/j.2044-8309.1996.tb01089.x.

VanGundy, A. B. (1988). *Techniques of structured problem solving*. Springer.

van Hoeve, B., De Valk, L., & Bekker, T. (2013, November). Toinggg: How changes in children's activity level influence creativity in open-ended play. In *International*

Conference on Advances in Computer Entertainment Technology (pp. 642-645). Springer, Cham. doi:10.1007/978-3-319-03161-3_72.

Van Kesteren, I. E., Bekker, M. M., Vermeeren, A. P., & Lloyd, P. A. (2003, July). Assessing usability evaluation methods on their effectiveness to elicit verbal comments from children subjects. In *Proceedings of the 2003 conference on Interaction design and children* (pp. 41-49). ACM. doi: 10.1145/953536.953544.

Van Mechelen, M., Sim, G., Zaman, B., Gregory, P., Slegers, K., & Horton, M. (2014, June). Applying the CHECk tool to participatory design sessions with children. In *Proceedings of the 2014 conference on Interaction design and children* (pp. 253-256). ACM. doi: 10.1145/2593968.2610465.

Vargas, E. A., & Vargas, J. S. (1991). Coaching children in social skills for friendship making. *Journal of Behavioral Education, 1*(2), 235-251. doi:10.1007/BF00957006.

Vatsal, V., & Hoffman, G. (2018, May). Design and Analysis of a Wearable Robotic Forearm. In *2018 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 1-8). IEEE. doi:10.1109/ICRA.2018.8461212.

Veale, A. (2005). Creative methodologies in participatory research with children. In Greene, G., & Hogan, D. (Eds.) *Researching Children's Experience: Approaches and Methods* (pp. 253-272). London, UK: SAGE Pulications Ltd.

Vitanza, A., Rossetti, P., Mondada, F., & Trianni, V. (2019). Robot swarms as an educational tool: The Thymio's way. *International Journal of Advanced Robotic Systems*, *16*(1). doi:10.1177/1729881418825186

Von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., & Vandenbroucke, J. P. (2007). The Strengthening the Reporting of Observational Studies in Epidemiology

(STROBE) statement: Guidelines for reporting observational studies. *Annals of Internal Medicine, 147*(8), 573-577. doi:10.7326/0003-4819-147-8-200710160-00010.

von Laban, R. (1975). *Modern Educational Dance*. London, UK: Princeton Book Co Pub.

Vygotsky, L. S. (1967). Play and its role in the mental development of the child. *Soviet Psychology*, *5*(3), 6-18. doi:10.2753/RPO1061-040505036.

Vygotsky, L. S. (1980). *Mind in Society: The Development of Higher Psychological Processes.* Cambridge, MA, US: Harvard university press.

Vygotsky, L. S. (1987). Imagination and its development in childhood. In R. W. Rieber, & A. S. Carton, *The Collected Works of LS Vygotsky* (pp. 339-350). Boston, MA, US: Springer.

Vygotsky, L. S. (1990). Imagination and creativity in childhood. *Soviet Psychology, 28*(1), 84-96.

Vygotsky, L. S. (2004). Imagination and creativity in childhood. *Journal of Russian & East European Psychology, 42*(1), 7-97.

Wainer, J., Feil-Seifer, D. J., Shell, D. A., & Mataric, M. J. (2007, August). Embodiment and human-robot interaction: A task-based perspective. In *RO-MAN 2007-The 16th IEEE International Symposium on Robot and Human Interactive Communication* (pp. 872-877). IEEE. doi:10.1109/ROMAN.2007.4415207.

Wallace, C. E., & Russ, S. W. (2015). Pretend play, divergent thinking, and math achievement in girls: A longitudinal study. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(3), 296. doi:10.1037/a0039006.

Wallas, G. (1926). *The Art of Thought*. London, UK: Jonathan Cape.

Wallbott, H. G. (1998). Bodily expression of emotion. *European Journal of Social Psychology*, *28*(6), 879-896. doi:10.1002/(SICI)1099-0992(1998110)28:6<879::AID-EJSP901>3.0.CO;2-W.

Wang, P., Sibi, S., Mok, B., & Ju, W. (2017, March). Marionette: Enabling on-road wizard-of-oz autonomous driving studies. In *2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI* (pp. 234-243). IEEE.

Walsh, G., Druin, A., Guha, M. L., Foss, E., Golub, E., Hatley, L., Bonsignore, E., & Franckel, S. (2010, April). Layered elaboration: a new technique for co-design with children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1237-1240). ACM. doi: 10.1145/1753326.1753512.

Ward, T. B. (2007). Creative cognition as a window on creativity. *Methods, 41*(1), 28-37. doi:10.1016/j.ymeth.2006.12.002.

Ware, C. (2012). *Information visualization: perception for design*. Elsevier.

Warren, T. F., & Davis, G. A. (1969). Techniques for creative thinking: An empirical comparison of three methods. *Psychological Reports, 21*(1), 207-214. doi:10.2466/pr0.1969.25.1.207.

Westlund, J. M. K., Park, H. W., Williams, R., & Breazeal, C. (2018, June). Measuring young children's long-term relationships with social robots. In *Proceedings of the 17th ACM Conference on Interaction Design and Children* (pp. 207-218). ACM. doi:10.1145/3202185.3202732.

Whitebread, D., Neale, D., Jensen, H., Liu, C., Solis, S. L., Hopkins, E., Hirsh-Pasek, K., & Zosh, J. (2017). *The role of play in children's development: a review of the evidence*. LEGO Fondation.

Whiting, C. S. (1958). *Creative Thinking*. New York, NY, USA: Reinhold.

Wierenga, B., & Van Bruggen, G. H. (1998). The dependent variable in research into the effects of creativity support systems: Quality and quantity of ideas. *MIS quarterly*, 81-87. doi:10.2307/249679.

Williams, T., Thames, D., Novakoff, J., & Scheutz, M. (2018, February). Thank you for sharing that interesting fact!: Effects of capability and context on indirect speech act use in task-based human-robot dialogue. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 298-306). ACM. doi:10.1145/3171221.3171246.

Winer, B. J., Brown, D. R., & Michels, K. M. (1971). *Statistical principles in experimental design* (Vol. 2). New York: McGraw-Hill.

Wood, L. J., Zaraki, A., Robins, B., & Dautenhahn, K. (2019). Developing Kaspar: a humanoid robot for children with autism. *International Journal of Social Robotics*, 1-18. doi:10.1007/s12369-019-00563-6.

World Economic Forum. (2018). *World Economic Forum, report.* Retrieved 10 2019, from The Future of Jobs Report 2018: http://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf

Wright, A. (1995). *Storytelling with Children*. Oxford, UK: Oxford University Press.

Yan, R. (2016, July). i, Poet: Automatic Poetry Composition through Recurrent Neural Networks with Iterative Polishing Schema. In *IJCAI* (pp. 2238-2244).

Yanco, H. A., & Drury, J. (2004, October). Classifying human-robot interaction: an updated taxonomy. In 2004 *IEEE International Conference on Systems, Man and Cybernetics*

(IEEE Cat. No. 04CH37583) (Vol. 3, pp. 2841-2846). IEEE. doi:10.1109/ICSMC.2004.1400763.

Zaga, C., Moreno, A., & Evers, V. (2017, February). Gotta Hatch'em All! Robot-Supported Cooperation in Interactive Playgrounds. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (pp. 347-350). ACM. doi:10.1145/3022198.3026355.

Zaporah, R. (1995). *Action theater: The Improvisation of Presence*. Berkley, CA, US: North Atlantic Books.

Zhou, J. and George, J. M. (2003). Awakening employee creativity: The role of leader emotional intelligence. *The Leadership Quarterly, 14*(4-5), 545-568. doi:10.1016/S1048-9843(03)00051-1

Zuckerman, O., Arida, S., & Resnick, M. (2005, April). Extending tangible interfaces for education: digital montessori-inspired manipulatives. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 859-868). ACM. doi:10.1145/1054972.1055093.

Zuckerman, O., Hoffman, G., Kopelman-Rubin, D., Klomek, A. B., Shitrit, N., Amsalem, Y., & Shlomi, Y. (2016, February). KIP3: robotic companion as an external cue to students with ADHD. In *Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 621-626). ACM. doi:10.1145/2839462.2856535.

Appendix

Appendix A

TCT-DP Instructions Script - Forms A and B (Urban & Jellen, 1996)

TCT-DP was applied under the instruction detailed below.

In front of you is an incomplete drawing.

The artist who started was interrupted before he knew what it was going to become.

Please continue this incomplete drawing.

You are allowed to draw whatever you want.

Nothing you draw will be wrong.

Everything you put on paper will be correct.

When you finish drawing, you can give it a title.

In case of the application of Form B, it was added:

This is not the same initial drawing that the artist did, although it looks similar.

After delivering the Form A/B to the participant, the researcher added:

You can draw whatever you feel like.

If there are questions from participants during the test, they will be answered only by saying:

You are allowed to draw whatever you want. Or *Everything is correct; there is no way to make mistakes.*

If there is any insistence from participants, they will be answered:

You can start drawing and don't worry about time, but hey, we don't have an hour to complete it.

When the participant finishes, it will be said:

If you know a name or title or theme for your drawing, write it above your drawing.

Appendix B – Bill of Materials for YOLO

	Designator	Component	Quantity	Cost per unit in USD	Total cost in USD	Supplier
1	Raspberry Pi	Raspberry Pi W Zero	1	10.00	10.00	https://www.adafruit.com/product/3400
2	Touch sensor	Standalone 5-pad capacitive touch sensor breakout	1	7.50	7.50	https://www.adafruit.com/product/1362
3	Jewel	NeoPixel jewel 7 x 5050 RGBW LED w/ integrated drivers natural white ~4500K	1	6.95	6.95	https://www.adafruit.com/product/2859
4	Voltage converter	LM 2596 DC-DC buck converter step down module power supply output 1.23V-30V	1	14.95	14.95	https://www.amazon.com/LM2596-Converter-Module-Supply-1-23V-30V/dp/B008BHBEE0
5	Optical sensor	Logitech wireless mouse M170	1	9.00	9.00	https://www.amazon.com/Logitech-M170-Wireless-USB-mouse/dp/B01EKKPI9S
6	Motor driver	DRV8838 single brushed DC motor driver	3	2.99	8.97	https://www.pololu.com/product/2990

7	Motor	Micrometal gear motor HP 6V	3	15.95	47.85	https://www.pololu.com/product/997
8	Protoboard	Adafruit perma-proto quarter-sized breadboard PCB	1	2.50	2.50	https://www.adafruit.com/product/1608
9	Power distribution board	Universal glass fiber PCB board	1	3.80	3.80	http://www.dx.com/p/universal-glass-fiber-pcb-board-for-diy-project-brown-139590#.WyEMNVMvw_U
10	Ceramic capacitor	Ceramic capacitor disc 0.047µF 25V +80% to -20%	1	0.25	0.25	https://www.jameco.com
11	Electrolytic capacitor	10uF 50V electrolytic capacitors	1	1.95	1.95	https://www.adafruit.com/product/2195
12	Wires	Hook-up wire spool set 22AWG solid core 6 x 25ft	1	15.95	15.95	https://www.adafruit.com/product/1311
13	Omni wheels	38mm by 3mm omni wheels	3	6.30	19.20	https://it.aliexpress.com/store/product/8mm-1-5inch-double-plastic-omni-wheel-with-3mm-mounting-hubs-couplings-k18436/1455619_32478938051.html
14	Power bank	USB battery pack 4000mAh, 5V, 1A	1	24.95	24.95	https://www.adafruit.com/product/1565

15	9V battery	EBL advanced 9V 1200 mAh lithium batteries	1	5.50	5.50	https://www.amazon.com/EBL-Advanced-1200mAh-Batteries-Non-Rechargeable/dp/B06Y64ZHF2
16	SD card	SanDisk ultra 32GB micro SDHC UHS-I card with adapter	1	12.96	12.96	https://www.amazon.com/SanDisk-microSDHC-Standard-Packaging-SDSQUNC-032G-GN6MA/dp/B010Q57T02
17	Router	TP-Link N300 wireless wi-fi router 2 x 5dBi high power antennas up to 300Mbps	1	19.99	19.99	https://www.amazon.com/TP-Link-N300-Wireless-Wi-Fi-Router-TL-WR841N/dp/B001FWYGJS
18	Glowing fibers	CHINLY roll PMMA plastic	1	8.44	8.44	https://www.amazon.com
19	Coper tape	Copper foil tape with conductive adhesive	1	5.95	5.95	https://www.adafruit.com/product/1128
20	Battery clip	Cable connection 9V plastic battery clip connector buckle	1	0.40	0.40	https://www.amazon.com
21	Female USB to micro USB	USB A female to micro USB B 5 pin male adapter cable	1	2.50	2.50	https://www.amazon.com

22	Micro USB	Micro USB plug to 5.5/2.1mm DC barrel jack adapter	1	1.95	1.95	https://www.adafruit.com/product/2727
23	90º USB	USB to right angle mini USB with 90º	1	6.99	6.99	https://www.amazon.com
24	M2 brass inserts	Heat-set inserts for plastics; M2 x 0.4mm thread; 2.9mm length	28	0.10	10.44	https://www.mcmaster.com/#catalog/124/3395/=1d96kgn
25	M3 brass inserts	Heat-set inserts for plastics; M3 x 0.5mm thread; 3.8mm length	3	0.12	12.30	https://www.mcmaster.com/#catalog/124/3395/=1d96lus
26	Hex standoff	Nylon 6/6 plastic hex standoff 3/16”; 3/16” long; 2-56 female thread	2	1.47	2.94	https://www.mcmaster.com/#92319A210
27	Small round standoff	Nylon 6/6 female threaded round standoff 1/4" OD; 13/32” length; 4-40 thread	2	1.40	2.80	https://www.mcmaster.com/#96110A070
28	Big round standoff	Nylon 6/6 female threaded round standoff 1/4” OD; 1-1/4” length; 4-40 thread	3	2.00	6.00	https://www.mcmaster.com/#96110A009

29	M2 pan head screw	Nylon pan head Philips screws M2 x 0.40mm thread 5mm	18	0.90	4.98	https://www.mcmaster.com/#92492A702
30	M3 pan head screw	Nylon pan head Philips screws M3 x 0.50mm thread 16mm	3	0.23	7.82	https://www.mcmaster.com/#92492a721/=1d9nrmo
31	Long screw	Passivated 18-8 stainless steel pan head Philips screw 1-72 thread 1" long	6	1.33	11.09	https://www.mcmaster.com/#91772A187
32	Socket head screw	Black-oxide alloy steel socket head screw M4 x 0.7mm thread 18mm long	3	0.34	11.31	https://www.mcmaster.com/#91290A164
33	Small flat head screw	Nylon slotted flat head screws; 100º countersink; 2-56 thread; 1/8" long	4	0.25	6.13	https://www.mcmaster.com/#92929A107
34	Big flat head screw	Nylon slotted flat head screws 100º countersink; 4-40 thread; 5/16" long	13	0.73	5.59	https://www.mcmaster.com/#92929A131
35	Shell	3D printed design in PLA	1	19.28	19.28	https://www.3dprintingbusiness.directory/company/ff3dm/
36	Circular layers	3D printed design in PLA	1	68.44	68.44	https://www.3dprintingbusiness.directory/company/ff3dm/

37	Motor docking	3D printed design in PLA	6	2.00	12.00	https://www.3dprintingbusiness.directory/company/ff3dm/
38	Washer	3D printed design in PLA	3	1.00	3.00	https://www.3dprintingbusiness.directory/company/ff3dm/
39	Glowing fibers layer	Laser cut design in clear acrylic with 1.50mm of material thickness	1	15.54	15.54	https://www.sculpteo.com/en/