Chapter 8
Emotional Design and Human-Robot Interaction

Magda Saraiva[1] and Hande Ayanoğlu[2,3], Beste Ozcan[4]

[1] Instituto Universitário de Lisboa (ISCTE-IUL), Centro de Investigação e Intervenção Social (CIS-IUL), Lisboa, Portugal
[2] Universidade Europeia, IADE, Av. D. Carlos I, 4, 1200-649 Lisboa, Portugal
[3] UNIDCOM / IADE – Unidade de Investigação em Design e Comunicação, Av. D. Carlos I, 4, 1200-649 Lisboa, Portugal
[4] Institute of Cognitive Sciences and Technologies, National Research Council of Italy, Rome

Abstract. Recent years have shown an increase in the importance of emotions applied to the Design field - Emotional Design. In this sense, the emotional design aims to elicit (e.g., pleasure) or prevent (e.g., displeasure) determined emotions, during human product interaction. That is, the emotional design regulates the emotional interaction between the individual and the product (e.g., robot). Robot design has been a growing area whereby robots are interacting directly with humans in which emotions are essential in the interaction. Therefore, this paper aims, through a non-systematic literature review, to explore the application of emotional design, particularly on Human-Robot Interaction. Robot design features (e.g., appearance, expressing emotions and spatial distance) that affect emotional design are introduced. The chapter ends with a discussion and a conclusion.

Keywords: Emotional Design, Human-Robot Interaction, emotion expressions, facial expressions, vocal expressions.

1. Introduction

Some products have positive traits (e.g., appealing, engaging, exciting, tempting) while others have negative traits (e.g., repulsive, displeasing, undesirable, unattractive), thus, products can evoke several different emotions. Although, studies on product design focused on more functionality and utility of the product than emotional factor (Khalid & Halander, 2006), for sustained interaction it is vital to make experiences pleasurable and enjoyable (Wensveen & Overbeeke, 2003). Pleasure can make the importance of emotions more apparent.

Tielman, Neerincx, Meyer and Looije (2014) indicate that expressive behavior (e.g., emotions) is a crucial aspect of human interaction. Emotions can allow humans to establish a relationship with others as well as the environment (e.g., objects, machines). In this sense, interaction with technology (i.e., robots) should be guided by the same principle (Valli, 2008). Currently, robots are designed to become a part of people's lives and creating emotional engagement with robots can shape the involvement of people during an interaction. In particular tasks (e.g., entertainment and playing), the robot will interact closely with people in their daily environment. Within this context, it is essential to create natural, engaging, pleasurable and intuitive communication between humans and robots.

Walter (2011) emphasizes that emotional experiences (positive or negative) make deep influences on people's long-term memory. Negative emotional experiences can cause unpleasant and unappealing interaction with the products whereas positive emotional experiences can cause pleasure and enjoyment. Pleasure and enjoyment have a critical role to make an appropriated bridge between people and robot's feature and characteristics which support a continuous interaction. The main concern during an interaction between a robot and a person is how the person feels about the experience which can be positive or negative. Is the person happy, satisfied, scared or stressed? Another concern is how the robot can reveal positive or negative experience by its appearance, behavior, expressions. In order to comprehend these concerns, first emotional design will be introduced followed by its applications in Human-Robot Interaction.

2. Emotional Design

Gorp and Adams (2012) explains emotional design as directing the attention of a person to create an emotional response to the right thing at the right time. Emotional design is mostly about creating positive emotions and preventing negative ones. According to Norman (2004), as aesthetics, attractiveness and beauty collaborate so do pleasure, and usability within emotional design. Designing emotionally meaningful products can change the experience with the products. Personal experiences and emotional meanings complete the appearance and functions of a product.

Walter (2011) indicates that emotional design captivates ordinary people, thus they would be ready to tell others about their positive experience.

There are also other terms which seek to build an emotional connection with people: affective design, pleasurable design, and hedonomics. Helander and Khalid (2012) define affect as the judgmental system and emotion as the conscious experience of affect. According to Demirbilek and Sener (2003), affect is the user's psychological response to product design.

According to Picard (1997), machines and robots, in particular, should associate intelligence with emotion, thus giving rise to affective computing. The field of artificial intelligence aims to study how machines (e.g., computers, robots) can process and express emotions. According to Norman

(2004), affective computing is an attempt to evolve machines which can sense the emotions of the people and respond accordingly. Hence, affective design arose from affective computing which endeavors to improve human-computer interaction with emotional information that is communicated by the users in a natural and comfortable way.

Jordan (2003) defined pleasure as the emotional, hedonic and practical benefits related with products where emotional benefit is how things related with a product affects people's emotions, hedonic benefits refer to the sensory and aesthetic appreciation whereas practical benefits are outcomes of tasks that the product is for.

Tiger (2000) proposed a framework that classifies positive emotions into four type types of pleasures. First, the physical pleasure derives from the five senses (e.g., touching a robot during interaction). Second is the social pleasure that is related to relationships (e.g., social interactions with a robot). The third one is the psychological pleasure which refers to people's cognitive and emotional reactions (e.g., robots stimulating interaction for a certain satisfaction). The last one is the ideological pleasure that expresses the values that a product represents (e.g., robot made of sustainable material). The four pleasures can be useful to design pleasurable robots, thereby, motivate people to enhance HRI.

Hancock, Pepe and Murphy (2005) defined hedonomics as the scientific study which is dedicated to promote pleasurable human-technology interaction. Mokdad and Abdel-Moniem (2017) noted that ergonomics was more focused on physical and cognitive aspects of a system, though later ergonomists became enthusiastic about making the human-machine system pleasurable. Helander (2002) denotes that hedonomics concerns with pleasurable products and tasks. Each product can evoke various emotions and depend on the emotions, a person can enjoy using/interacting with the product.

Desmet (2002) explained three characteristics concerning product emotions which are personal (i.e., people differ and consequently so does the emotional response toward the same product), temporal (i.e., a person can have different emotions independent of time toward the same product) and mixed (i.e., a person can have various emotions towards a product). Gorp and Adams (2012) state that emotions can be effective in inducing people to alter attention and change their behaviors. Also, experiences and realities are dominated by emotions and emotions play a role in human reasoning (Demasio, 1994).

3. Emotional Design in HRI

Changing emotional states of people can increase the possibility of performing the desired behavior (e.g., securely approaching a robot). Creating positive emotional states/experiences between people and robots would eventually influence the interaction between them.

Gorp and Adams (2012) supports that whatever the desired behavior, emotional design can be guide people's attention to the right place at the right time to initiate and extend the interaction into a relationship. A relationship can be created between people and robots for cogent interactions.

Emotional design is also relevant in the robot design process because people's needs must be taken into account and the most important features from their point of view, thus facilitating greater user acceptance of the robot (Hameed, Tan, Thomsen & Duan, 2016). Demirbilek and Sener (2003) state that for high-tech products (i.e., robots) emotional needs have been a basis. Moreover, Norman (2004) emphasizes the importance of robots to display emotions for successful interaction.

Helander and Khalid (2012) refer that there are two purposes to understand the emotions and affect. The first purpose is how to measure and analyze human reactions (i.e., emotions) to affective and pleasurable design. Limited studies (e.g., Rosenthal-von der Pütten, Krämer, Hoffmann, Sobieraj & Eimler, 2013) can be found dedicated to measure emotional reactions of people towards the design of robots though mainly behavior and attitudes towards robots. In Chapter 9, methods to measure people's emotions are detailed. The second purpose is how to produce affective design features of a product (e.g., robots). Constituting affective/pleasurable robots, besides appearance (e.g., human-like robots), is mostly fulfilled by making them capable of expressing emotions. Though emotions need to appear as natural and ordinary as human emotions or they look fake and will be more irritating than useful (Norman, 2004).

There are different interaction scenarios where in some cases, people need to touch robots (e.g., Nakata, Sato & Mori, 1998; McGlynn, Kemple, Mitzner, King & Rogers, 2017) which can influence emotional design in HRI. Emotional design can be affected by various characteristics of robots, i.e., in order to create positive emotions and experiences on a person, robot design features (e.g., appearance, expressing emotions and spatial distance) can be manipulated. Moreover, the robot's design features are crucial for attaining HRI.

3.1 Appearance

Emotional design can be affected by various components of the appearance of a robot. Leite, Martinho and Paiva (2013) emphasize that embodiment can play an important role in the first impressions and future expectations about a robot. Campa (2016) supports that the appearance is fundamentally important, due to interacting with humans on an emotional level, and this type of interaction is grounded in visual and tactile perception no less than in verbal communication.

Robots can appear in different forms, sizes, colors, and even genders, age, ethnicity and outfits due to having anthropomorphous (e.g., humanoids and androids) features. Mori (1970) states that when the appearance of a robot is similar to a human, emotional response to the robot becomes positive until a point in which the robot looks too much like a human. It is still desirable for natural interactions that robots share some physical characteristics with humans. The appearance of a robot is important to distinguish social expectations. Bartneck, Croft, and Kulic (2008) state that appearance can evoke expectations (e.g., human-like robots are expected to listen and talk) and that if the robot is not be able to fulfill those expectation it can cause disappointment.

Form of robots can be categorized into four classes: human-like, semi human-like (i.e., limited lower body movements), pet-like and character-like. Concerning the resemblance of characteristics of a human, social robots, mostly, have a torso, hands, and a head. On one hand, Dautenhahn (2004) indicates that anthropomorphism might create incorrect expectations related with the cognitive and social abilities that the robot cannot perform. On the other hand, several authors (e.g., Bartneck, Bleeker, Bun, Fens & Riet, 2010; Kanda & Ishiguro, 2013) point out that human brain does not react emotionally to artificial objects but reacts positively to resemblance to the human likeness. As such, robots should be designed taking into account their behavioral and social capabilities, as well as the robot's functions (Leite, Martinho & Paiva, 2013).

3.2 Expressing Emotions

Expression of emotions allows for the existence of a realistic HCI and/or HRI, and for this reason, HRI currently aims to provide robots with human characteristics. Some studies have revealed that the humans are able to establish an empathic relationship with human-like robots (Riek, Rabinowitch, Chakrabarti & Robinson, 2009) easier than with non-human-like robots (e.g., Bartneck, Bleeker, Bun, Fens & Riet, 2010). In HRI, it is effective and necessary that the robot, no matter what it looks like, is able to express emotions, and also recognize the emotions expressed by humans and respond to them appropriately (e.g., empathetically, complicit) (Picard, 2000).

A robot should be capable of interacting naturally with humans as a social partner and adapt its behavior according to the given states. Fong, Nourbakhsh, and Dautenhahn (2002) support that the robot must manifest believable behavior such as establishing appropriate social expectations, regulating social interaction (using dialogue and action), and following social convention and norms. Emotions are also an important factor in reflecting the given states. However, it should be noted that when referring to the robots that recognize emotions, this recognition is not the same as in humans. That is, a robot is unable to attribute meaning or analyze cognitively an experience or interaction as a human does (e.g., Blow, Dautenhahn, Appleby, Nehaniv & Lee, 2006). Thus, Picard and Klein (2002) defined two types of requirements for interaction between users and machines (which can refer to robots): (1) emotional needs (e.g., empathy); (2) emotional experience (e.g., frustration). It is at the level of emotional experience that machines play an important role. With its artificial intelligence and endowed with affective computing, machines help the user to have a positive experience while interacting, allowing the user to not have a negative experience and preventing frustrating situations (Klein, Moon & Picard, 2002).

Equipping machines with the ability to respond to emotions and to express them is a way to create intelligent machines (artificial intelligence) (Picard, 1997). Thus, the biggest challenge is to build machines (i.e., robots) that are able to infer emotional states through behaviors and emotional expressions of the user and respond to them appropriately. According to Picard (1997) there are four factors that explain the need for robots to present emotions: (1) the presence of emotions facilitates the communication (emotional communication) with the user; (2) the need to develop applications that control emotional information; (3) growing interest in developing robots with social and emotional skills, and; (4) the presence of emotions in robots makes the interaction with user, a more interesting experience and less frustrating for the user. These components are particularly important when referring to service robots. Service robots are autonomous systems equipped with artificial intelligence, which enable them to perform many of the daily activities carried out by humans (Khan, 1998). This type of robots which provide assistance are having an increased focus recently, due to uncertainties in the industrialized world (e.g., increasing number of the elderly, diseases). These robots are intended to help people in their daily tasks but also to be, for example, companion robots for the elderly without family. Currently, there are some robots which are able to express emotions and/or recognize emotions expressed by humans while doing their tasks.

From a design perspective, the emotion system would implement the style and the personality of a robot, encoding and conveying its attitudes and behavioral inclinations toward the events it counters (Breazeal & Brooks, 2005). Designing robots with personality may help provide people a good mental model (Breazeal & Brooks, 2005), similar to what occurs in the interaction between humans. Breazeal (2002) discusses an important and related aspect in HRI which is the readability of the behavior. The author supports the fact that the robot's behavior and manner of expression (facial expressions, shifts of gaze and posture, gestures, actions, etc.) should be well matched to the robot's cues and movements so that people would understand and predict its behavior (e.g., their theory-of-mind and empathy competencies). For better readability, the robot anthropomorphizes itself to make its behavior familiar and more understandable.

It is in this context that social robots appear and are able to express and recognize emotions and human behaviors. Adams, Breazeal, Brooks and Scassellati (2000) discuss that two skills are required for a social robot to have an emotional model that understands and manipulates the environment around it. First is the ability to attain social input to understand the cues which humans provide about their emotional state. Second is the ability to manipulate the environment which can be done by the robot expressing its own emotions. Therefore, expressing emotions can be the key to improved interaction.

Bartneck (2001) states that for humans one of the ways to express emotions is by using body language (i.e., facial expression, gesture and body movement). Picard (1997) also supports that emotions can be expressed through body movement, facial expressions, and physiological responses. Since some social robots' bodies are built to resemble human's, this allows more natural interactions while using their body language. Breazeal (2003) declares that robots should have a social interface which naturally employs human-like social cues and communication modalities. According to DiSalvo, Gemperle, Forlizzi and Kiesler (2002), the addition of a nose, eyelids, and a mouth gives a robot more human characteristics. On one hand, robots are expected to resemble human for natural interactions, on the other hand, it is also encouraged that robots should maintain as much of a robotic appearance feeling as possible while remaining human-friendly in order to avoid an uncanny valley effect (Mori, 1970).

Expressiveness of robots can be a key to keep natural interactions in HRI. Robots can use facial expressions, vocal expressions and body movements while expressing emotions similar to a human.

3.2.1 Facial Expressions

Facial expressions are particularly important in the communication between humans because it allows easily identifying emotions through small changes in the face (e.g., Russell, 1997; Plutchik, 1984; Woodworth, 1938). Facial expressions provide a basic means by which people can detect emotion (Ekman, Friesen and Ellsworth, 1972) and are used in nonverbal communication. There are distinctive clues of the face to each basic emotion though depending on the intensity and the meaning more areas can be involved and according to intensity signals are adapted (Ekman, 2003a, 2003b). Facial expressions can be reduced to changes in eyes, eyebrows, mouth, nose and so on.

Argyle (1994) specifies that facial expressions work better as a way of providing feedback on what the other person is saying. According to the author, the eyebrows provide a continuous running commentary; the mouth area adds to the running commentary by diversifying between turned up (i.e., pleasure) and turned down (i.e., displeasure); eye movements (e.g., eye contact, eye gaze, blinking, pupil size) have an important role in sustaining the flow of interaction between humans. While a person is in a conversation with another person, eye movements are a natural and important part of the communication process. Eye movements such as eye gaze, blinking, and pupil size can be implemented to robots as ocular behaviors to express emotions. Eye gaze is especially important while approaching a person and should be implemented to robots for natural interactions (e.g., Yamazaki *et al.*, 2008; Mutlu, 2009; Mohammad, Okada & Nishida, 2010).

Since, nonverbal emotional feedback plays a very important role in human interaction (Salichs *et al.*, 2006), it should be extended to HRI as well. If a similar type of human-human communication is anticipated to be interpreted by robots, the facial expressions and the corresponding emotions should be clearly defined so that they are recognized reliably. Usually, the programming of facial expressions in robots (e.g., Loza, Marcos Pablos, Zalama Casanova, Gómez García-Bermejo & González, 2013) is based on FACS (Ekman & Friesen, 1978), which is validated (in humans) for the six basic emotions. Instead of visualizing emotions in a static manner, dynamic methods and additional visualization methods (e.g., blinking, blushing) can be used to generate robot emotions. Some common features to include robot expressiveness can be making direct eye contact (e.g., prolonged eye contact can cause distress) or averting gaze (e.g., this might indicate distraction or discomfort), blinking (e.g., often or rarely, rapid or slow), or dilated pupils (e.g., highly dilated eyes can indicate interest or arousal).

3.2.2 Vocal expressions

Vocal expressions can be divided as linguistic (e.g., speech) and nonlinguistic vocalizations (e.g., laughing, crying, yawning, whispering sounds). Douglas-Cowie, Cowie and Schröder (2000) indicate that vocal expression is linked to facial expression, gestures and verbal content.

Speech is the most natural method of communication between human and the same method can apply to human and machine (Feil-Seifer & Mataric, 2005; El Ayadi, Kamel & Karray, 2011). Speech is also used as a way to transmit emotional state for humans (e.g., Engberg, Hansen, Andersen & Dalsgaard, 1997; Amir, Ron & Laor, 2000). According to Burkhardt, Paeschke, Rolfes, Sendlmeier and Weiss (2005), emotional cues in speech gained attention due to new developments with respect to human-machine interfaces that see applications of automatic recognition and simulation of emotional expression within reach. Moreover, speech emotion recognition is useful in human-machine interfaces (El Ayadi, Kamel & Karray, 2011). Feil-Seifer and Mataric (2005) suggest robots may use synthetic speech generation or pre-loaded human voice which is another factor to change the emotional design.

Darwin (1872) described various nonlinguistic vocalizations for specific emotions, such as deep sighs for grief, snorts for contempt and little coughs for embarrassment. Russell, Bachorowski and Fernández-Dols (2003) hypothesize that since there are different variations of laughter, different types of laughs correspond to different emotional states. Depending on the expressed emotion the sound can be slower/faster or have a lower/higher pitch. There are studies (e.g., Schröder, 2000; Sauter & Scott, 2007; Simon-Thomas, Keltner, Sauter, Sinicropi-Yao & Abramson, 2009) about vocal bursts (e.g., “yeeey” for amusement, “ahhh” for fear) while people are expressing emotions. These studies support the fact that most vocal expressions are accurately categorized for the intended emotion. Furthermore, Kraus (2017) found that hearing (i.e., voices) may be more reliable than sight (i.e., facial expressions) to accurately detect emotions.

For more natural interactions, robots are expected to mirror or mimic humans. Thus, during interactions, robots can use diverse vocal expressions with or without facial expressions to show their emotional states. Thereby, it would be easier to identify the emotions that the robot is representing and, people can react accordingly.

3.2.3 Body Movements

De Gelder, de Borst and Watson (2015) specify that historically the human body has been perceived primarily as a tool for actions, there is now increased understanding that the body is also an important medium for emotional expression. Montepare, Koff, Zaitchik and Albert (1999) emphasized that research on the communication of emotion has generally supposed that the perception of emotion is more engaged with facial or vocal expressions than with body movements. Bodily emotion communication is an old though neglected topic in emotion research regarding humans (Dael, Mortillaro & Scherer, 2012). Although movement of the body or its parts makes a considerable contribution to nonverbal communication for humans (e.g., Atkinson, Dittrich, Gemmell & Young, 2004; Zieber, Kangas, Hock & Bhatt, 2014), there is conclusive support that specific facial expressions exist for certain emotions (e.g., Ekman, Friesen & Ellsworth, 1972).

Atkinson, Dittrich, Gemmell and Young (2004) found that exaggerating body movements increase both the recognition of emotions and intensity. Wallbott (1998) denotes that there is evidence that specific body movements accompany specific emotions and, also, movements might be the indication of the intensity of emotion. Moreover, Aviezer, Trope and Todorov (2012) found that peak emotions are detected more accurately from body movements than facial expressions.

Body movements can be divided into two for robots: movements of parts of body and translocation. Compared to other machines, body movements are one of the most distinguishing features of robots. Hence, introducing body movements in robots could support the emotion that is indicated by facial expressions. Furthermore, it is necessary to understand robot abilities/limitations to use the movement information to distinguish different emotions.

Mobility (i.e., translocation) is an important feature for robots to execute tasks. Most of the social robots are mobile (e.g., Bonarini *et al.*, 2016). Robots can use location change as an additional component to reveal the emotional state, though, using only translocation to express emotions can be inefficient and strange. Hence, it should be introduced with other expression methods.

4. Spatial Distance

Hall (1966) categorized the distance people keep with each other in four: intimate, personal, social and public. According to Hall, the distance between people is determined depending on what they do, the relationship between them, mutual feelings, and culture. According to Gillespie and Leffler (1983), age, gender and place are also factors that affect the distance.

Feil-Seifer and Mataric (2012) suggested that if a robot is to be an effective socially, its actions, including interpersonal distance, must be appropriate for the given social situation. Van Oosterhout and Visser (2008) stated that when one interaction partner is a robot, it is not well known to what extent the different factors of human distances still apply and what new factors play a role. Though, robots should still follow similar distances to interact with people (Yamaji, Miyake, Yoshiike, De Silva & Okada, 2011) in order not to make people uncomfortable or disturbed and cause miscommunication. Walters *et al.* (2005) found out that when approaching a robot, or when being approached by a robot, prefer approach distances that are compatible with those expected for human-human interaction. Oosterhout and Visser (2008) defined possible factors that influence the spatial distance in HRI: robot type (i.e., to know the intention), person's height, gender and age, and occupancy of the interaction space (e.g., crowded). Therefore, the spatial distance would change according to the robot.

The spatial distance can have an impact on emotional design. Based on the distance between a robot and a person, people can have negative or positive emotions towards robots. Furthermore, the way and speed of approaching could also influence emotional design. Kato, Kanda and Ishiguro (2015) defined two types of approaches. The passive approach is when a robot waits until a person initiates interaction with the robot which can cause hesitation or uncertainty for the person. The proactive approach is when a robot seeks people to initiate conversation (e.g., Satake *et al.*, 2009) in which people can feel annoyed or disrespected.

The direction of approach can also be important in HRI. For instance, Dautenhahn *et al.* (2006) found out that when people are seated, they preferred a robot to approach from either the left or right side and they found frontal approach uncomfortable, impractical, and even threatening or confrontational. Moreover, sometimes, interactions require a robot to follow (approach behind) its human companion (e.g., Hüttenrauch, Eklundh, Green & Topp, 2006; Hu, Wang, & Ho, 2014). Sünderhauf *et al.* (2018) define person-following scenarios as the result of a common task in which a robot needs to follow a person. The spatial distance during the interaction should also be taken into account to perceive the emotions of the person followed.

Furthermore, if the spatial distance is too close between a robot and a person, this might end up with physical interaction. In most healthcare cases (e.g., Mukai *et al.*, 2010; Chen, King, Thomaz, & Kemp, 2011; McGlynn, Kemple, Mitzner, King & Rogers, 2017), physical contact is needed in which the robot is in the intimate space of a person. Physical contact can affect the emotional state of the people, though it depends on other variables such as whether the robot or the person initiates the contact, cause of the contact and forms of touch that Weiss (1992) referred, such as the location, intensity, modality, and duration of the touch. Additionally, psychological discomfort caused by any factors, as well as a robotic violation of social conventions and norms during an interaction, can also have serious negative effects on people over time (Lasota, Fong & Shah, 2017).

5. Related Studies

As mentioned, several theories on the existence and nature of basic and fundamental emotions have been proposed (e.g., James, 1884; Plutchik, 1980; Schachter & Singer, 1962). At the same time, robots are mainly expected to help and assist during activities of daily living and to achieve the outcome, personal robots should be capable of human-like emotion expressions (Endo, Momoki, Zecca, Itoh & Takanishi, 2008).

Different studies were performed to assess emotions in HRI. Studies about expressions of emotions by robots (e.g., Cañamero & Fredslund, 2000; Breazeal, 2003; Blow, Dautenhahn, Appleby, Nehaniv & Lee, 2006; Sosnowski, Bittermann, Kuhnlenz & Buss, 2006; Hashimoto, Hitramatsu, Tsuji & Kobayashi, 2006; Salichs *et al.*, 2006; Endo, Momoki, Zecca, Itoh & Takanishi, 2008; Zecca *et al.*, 2009; Beck, Cañamero & Bard, 2010; Oh and Kim, 2010; Cohen, Looije & Neerincx, 2011; Giambattista, Teixeira, Ayanoğlu, Saraiva & Duarte, 2016) and human reactions and attitudes toward robots (e.g., Bruce, Nourbakhsh & Simmons, 2002; Nomura, Kanda, Suzuki & Kato, 2004; Woods, Dautenhahn & Schulz, 2004; Ray, Mondada & Siegwart, 2008) are presented.

In this sense, the studies about the expression of robot emotions can be differentiated as follows: (a) form; (b) emotion stimuli; c) ways of emotion expression; (d) robot stimuli; (e) participants in the study; (f) measures; and (g) results revealed.

(a) Form. Human-like robot examples are Feelix (Cañamero & Fredslund, 2000), iCub (Beira *et al.*, 2006; Tanevska, Rea, Sandini & Sciutti, 2017), KASPAR (Blow, Dautenhahn, Appleby, Nehaniv & Lee, 2006), Kismet (Breazeal & Aryananda, 2002; Breazeal, 2003), Nao (Beck, Cañamero & Bard, 2010; Häring, Bee & André, 2011), Saya (Hashimoto, Hitramatsu, Tsuji & Kobayashi, 2006), Kobian (Zecca *et al.*, 2009), Tiro (Oh & Kim, 2010), Doldori (Kwon *et al.*, 2007; Lee, Park & Chung, 2007), Eddie (Sosnowski, Bittermann, Kuhnlenz & Buss, 2006).

Semi human-like robots examples are Ifbot (Kanoh, Iwata, Kato & Itoh, 2005), Maggie (Salichs *et al.*, 2006), Monarch (Giambattista, Teixeira, Ayanoğlu, Saraiva & Duarte, 2016; Ferreira & Sequeira, 2017), Pepper (Dignan, 2014), WE-4RII (Zecca *et al.*, 2004; Endo, Momoki, Zecca, Itoh & Takanishi, 2008)

iCat (Kessens, Neerincx, Looije, Kroes & Bloothooft, 2009; Cohen, Looije & Neerincx, 2011), Probo (Saldien, Goris, Vanderborght, Vanderfaeillie & Lefeber, 2010) and Sparky (Scheeff, Pinto, Rahardja, Snibbe & Tow, 2002) have a pet-like appearance while eMuu (Bartneck, 2002) is an example of character-like.

(b) Emotion Stimuli. The emotions that are implemented in many robots as stimuli (e.g., Ifbot, Eddie, Probo, Doldori) correspond to the ones known as the 6 basic emotions (Ekman, Friesen, & Ellsworth, 1972) which are joy, sadness, fear, surprise, anger and disgust. Furthermore, there are some robots that exclude the disgust emotion (e.g., Feelix, iCat) or used extra emotions such as calm, pride, excitement and perplexity (e.g., Saya, Kobian, Nao) or sorrow, interest, and curiosity (e.g., Tiro, Kismet, Monarch) additional to the 6 basic emotions. It is worth to mention that there is a common use of a neutral emotion in many studies.

(c) Ways of emotion expression. 4 different ways of emotional expression can be found which are implemented to a robot: (i) facial expressions; (ii) body movements; (iii) translocation; and, (iv) vocal expressions. These ways are used by themselves or simultaneously. The first and most common way is to manipulate facial expressions. Most of the robots use their eyes and mouth (e.g., Ifbot, eMuu) to express emotions. Changing color in facial features, such as eye color (see Chapter 10) or, cheek color (WE-4RII), is an extra feature for adapting different emotions.

Additionally, to these features, some robots use the eye brows (e.g., Feelix, iCat) or the eyelids (e.g., Saya, WE-4RII, Maggie). Nose (e.g., Probo) and ears (e.g., Kismet and Eddie) are used when the robots resemble a character. The second way of expression is by using body movements. Arm rotations are extensively used for several robots (e.g., Maggie, Kaspar), while, rotation of the head is also frequently applied (e.g., Doldori, Monarch). Even though many of the robots lack legs, some are using leg movements to express emotions (e.g., Kobian, Nao). Translocation is the third way in which robots express emotions, by changing their positions while expressing an emotion (e.g. Kobian, Monarch). Furthermore, some robots are also using tablets on their body (e.g. Monarch, Pepper) as an extra element to interact with people. Care-o-Bot 4's head is working as a touch screen besides expressing facial emotions (Kittmann *et al.*, 2015). While vocal expressions are not studied in detail, there are some robots which can talk to communicate (e.g., Breazeal & Aryananda, 2002; Salichs *et al.*, 2006); Dignan, 2014) or use various sounds (e.g., an animal or weather event) to express emotions (e.g., Wagner, 2015).

(d) Robot stimuli. In the studies about expressions of robot emotions, it is possible to verify that there are, at least, four different ways of presenting robots in tests with participants: (i) the robot itself - the real robot was used (e.g., Eddie, eMuu, Feelix, iCat, Ifbot, Nao, Probo) to express emotions; (ii) images - the robot's expressions were photographed (e.g., Kismet, Saya) and shown to participants; (iii) videos - the robots performed an expression and this video was recorded (Kaspar, Kismet, Kobian, Saya) and presented to participants; and (iv) virtual models - the robot was demonstrated as a computerized 3D model (e.g., Probo, Monarch).

Some of the studies (e.g., Tsui, Desai, Yanco, Cramer & Kemper, 2010) did not use any particular robot and focused on the idea of the robots specialized in different tasks (i.e., service robots, medical robots, military robots).

(e) Participants. The expressions of emotions in robots has been studied with participants of different ages, including children aged between 5-14 years old (e.g., iCat, Probo, Feelix, Kismet, Eddie, Tiro), adults aged 15-58 (e.g., Kaspar, Saya, Kobian, Nao), and elderly (e.g., Kobian). Moreover, some studies (e.g., Feelix, Eddie, Kismet) had two groups of participants, namely children and adults.

(f) Measures. There are essentially three forms of measure in the studies: (i) Free test in which the participants observe the robot's performance to express a sequence of emotions and then identify the emotions that were expressed (e.g., Feelix); (ii) Multiple choice in which participants are asked to label a sequence of expressions, but this time they are given a list of emotions (e.g., Feelix, Eddie, Kismet, Kobian, Nao, Probo, Saya); and (iii) Likert scale in which the participants rated, on a scale, the level of the emotion expressed by the robot (e.g., Kaspar).

(g) Results. Many of these studies (e.g., Kismet, eMuu, Eddie, Nao) were done in labs, though there are some studies (e.g., Tiro, Monarch) that took place in different contexts (e.g., school and hospital) or contexts that were given as stories (e.g., iCat). Results related to context revealed that emotions expressed in a specific context were significantly better recognized than emotions expressed without a context (e.g., iCat).

In terms of robot stimuli, the data showed that in studies with videos, participants using had an overall stronger recognition of emotions performance than with static images (e.g., Kismet, Saya). Another result (e.g., WE-4RII, Kobian) showed the importance of combining different cues (e.g., face and body) to promote the recognition of emotions expressed by the robot. The most recognized emotions are happiness, sadness and surprise (e.g., Saldien, Goris, Vanderborght, Vanderfaeillie & Lefeber, 2010; Giambattista, Teixeira, Ayanoğlu, Saraiva & Duarte, 2016) and fear is the least recognizable emotion for many robots (e.g., Breazeal, 2002; Zecca *et al.*, 2004; Kanoh, Iwata, Kato & Itoh, 2005). If disgust is included in the list of emotions expressed, it also has a lower rate (e.g., Kanoh, Iwata, Kato & Itoh, 2005; Saldien, Goris, Vanderborght, Vanderfaeillie & Lefeber, 2010). Furthermore, in some studies (e.g., Ifbot, Kismet, Monarch), there are some emotions that are confused with others. For instance, surprise was confused with fear or despair and fear was confused with disgust, anxiety or sadness.

As it was referred, many robots are expressing the emotions in their own ways. However, the interest should also focus on the emotions of the human towards robots. There are some studies that concern about human emotions which can be recognized by robots (e.g., Maggie, Pepper). Furthermore, studies concerning human reactions/attitudes towards robots can be found as well (e.g., Woods, Dautenhahn & Schulz, 2004; Nomura, Kanda, Suzuki & Kato, 2006; Syrdal, Dautenhahn, Koay & Walters, 2009). Nomura, Kanda, Suzuki and Kato (2004) created the NARS scale (Negative Attitudes Toward Robots) to measure human attitudes towards robots in various studies (e.g., Nomura, Yamada, Kanda, Suzuki & Kato, 2009; Wang, Rau, Evers, Robinson & Hinds, 2010; Riek & Robinson, 2011; Schaefer, Sanders, Yordon, Billings & Hancock, 2012; Nomura, 2017). The NARS scale consists of 3 subordinate scales, 5-point Likert scales, which are negative attitudes toward situations of interaction with robots, negative attitudes toward the social influence of robots, and negative attitudes toward emotions in interaction with robots. Besides the NARS scale, questionnaires were also used to collect data about attitudes towards robots (e.g., Khan, 1998; Fong, Nourbakhsh & Dautenhahn, 2003; Woods, Dautenhahn & Schulz, 2004; Ray, Mondada & Siegwart, 2008; Sanders *et al.*, 2017).

Discussion and Conclusion

The chapter provides information about emotional design and how it is applied to Human-Robot Interaction (HRI). Appearance, expressing emotions and spatial distance are defined factors that can influence emotional design. Displaying emotions is the most common and effective way to affect the emotional design, through facial expressions, vocal expressions, and body movements. Manipulating the expressiveness of a robot's emotions can lead to pleasurable and enjoyable experiences during HRI. Also, studies related to emotional design in HRI, namely, expressions of emotions by robots and human reactions and attitudes towards robots, are presented.

Spatial distance should be considered as another factor affecting emotional design. Mumm and Mutlu (2011) emphasize that robots must be designed to follow societal norms of physical and psychological distancing to seamlessly integrate into human environments. Also, Kim and Mutlu (2014) emphasize that robots which are deployed in a social setting should be aware of the social norms (i.e., social distance). Though, if the distance is not as expected, people may experience negative emotions (e.g., anxiety, annoyance, fear, frustration) which is another research branch to be considered/included in HRI concerning emotional design.

The expectations of people regarding robots are changing due to robots increasingly participating in daily life. Besides functionality, usability and safety, people would desire robots to enhance their lives and evoke emotions. Also, DiSalvo, Hannington and Forlizzi (2004) support the idea that people look for more dimensions that go beyond usability and the necessity to create an emotional resonance between people and products (i.e., robots) increases. In fact, in many products, designers are challenged to manipulate the emotional impact. Likewise, Cupchik (1999) claims that the emotional process begins with an initial impression (i.e., appearance) of a product and continues with experiences of usage and culminate with an emotional attachment to it. Hereby, appearance can be a very powerful affirmative approach and encourage experiences between people and robots. Bartneck, Croft and Kulic (2008) suggest that the emotional response becomes positive as the appearance and movements of robots become less distinguishable from those of a human. Moreover, Fong, Nourbakhsh and Dautenhahn (2003) state that the physical appearance biases interaction and most research in HRI is not focused on design of the robot. Additionally, Koay *et al.* (2007) revealed that humans let robots without human traits approach themselves more than humanoid robots. Therefore, the design of the robot is quite important to achieve a substantial emotional experience and it is essential to include design areas (e.g., product, graphics and interaction design) to the field of HRI.

Emotional design, creating positive emotions and pleasurable experience, is an important approach in HRI. Norman (2004) indicates that emotional expressions of robots would notify people about their motivations, desires, accomplishments, and frustrations which increase people’s satisfaction and appreciation. Desmet (2002) states that people are expert at interpreting emotional expressions. In this sense, introducing emotional design in HRI should, first, demonstrate the interpretation of expressed emotions by robots. One way to manipulate emotions elicited by the design of a robot is to implement emotions to robots. Generating emotions in robot design can be implemented by using facial expressions, vocal expressions, body movements, and spatial distance. Ekman, Friesen and Ellsworth (1972) denote that as sound and speech are intermittent, the face can be informative. The studies in the HRI field support that the most common way used to convey emotions is by manipulating facial expressions. Eyes and mouth are mainly studied due to the limitations of robots (i.e., not having more facial features). However, with more facial features to convey emotions, they could be easier for people to perceive (e.g., Kühnlenz, Sosnowski & Buss, 2010) and, accordingly, interaction becomes less effortful. The main issue is to find realistic and accepted combinations of modalities during emotional expression.

There are various robots functioning in diverse environments. Depending on the context and functions, robots may/should be designed to address specific emotions. Desmet, Porcelijn and van Dijk (2007) found that it was possible to design products that target specific types of emotions by measuring emotional responses. Moreover, understanding the context might enhance and stimulate the emotional experience and make the experience more pleasing, agreeable and favorable.

Emotions, obviously, play an important role in people's lives. Triberti, Chirico, La Rocca and Riva (2017) state that emotions are cognitive processes with a significant influence on the overall quality of interaction and accordingly new technologies (i.e., robots) can be treated as opportunities to manipulate, enhance and trigger different discrete, and even complex emotional states. Helander and Khalid (2012) denote that there is not a neutral design, thus any design will reveal emotions. Though, DiSalvo, Hannington and Forlizzi (2004) specify that products cannot be designed to generate specific emotional experiences and according to Desmet (2002) designers can only predict the emotional impact of a design. While many studies (e.g., Fong, Nourbakhsh and Dautenhahn, 2003; Dautenhahn, 2004) support that robots should behave in a socially acceptable manner to increase acceptance in human-occupied environments, the analysis of the impact of robot designs during HRI is a lacking area of HRI research. Hence, including people is essential when designing HRI trials (Koay, Syrdal, Walters & Dautenhahn, 2007) whereby it is essential to consider that accurately foreseeing emotional responses is difficult for various factors and emotions are not dependent on the instant perceptual situation (Helander and Khalid, 2012).

With advanced technology, it is easier to achieve usability as well as encourage pleasure for people. Designers are advised to thoughtfully address the link between emotions and HRI. This would facilitate communication and interaction with robots; consequently, it would lead to the desired experience. As HRI employs emotional design more effectively, better and more positive experiences will emerge, though, as Walter (2011) emphasizes the emotional design should never interfere with usability, functionality, or reliability.

References

Adams, B., Breazeal, C., Brooks, R. A., & Scassellati, B. (2000). Humanoid robots: A new kind of tool. IEEE Intelligent Systems and Their Applications, 15(4), 25-31.

Amir, N., Ron, S. and Laor, N. (2000). Analysis of an emotional speech corpus in Hebrew based on objective criteria. In *Proceedings of the ISCA Workshop on Speech and Emotion*, pp. 73–76.

Argyle, M. (1994). The psychology of interpersonal behaviour. Penguin UK.

Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., & Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. Perception, 33(6), 717-746. doi: 10.1068/p5096.

Aviezer, H., Trope, Y. and Todorov, A. (2012). Body cues, not facial expressions, discriminate between intense positive and negative emotions. *Science*, 338(6111), pp. 1225–1229. doi: 10.1126/science.1224313.

El Ayadi, M., Kamel, M. S. and Karray, F. (2011). Survey on speech emotion recognition: Features, classification schemes, and databases. *Pattern Recognition*. Elsevier, 44(3), pp. 572–587. doi: 10.1016/j.patcog.2010.09.020.

Bartneck, C. (2001). Affective expressions of machines, in *CHI2001 Conference on Human factors in*

computing systems, pp. 189–190. doi: 10.1145/634067.634181.
Bartneck, C. (2002). *eMuu -- An Embodied Emotional Character for the Ambient Intelligent Home*, *Technische Universiteit Eindhoven*.
Bartneck, C., Croft, E., & Kulic, D. (2008, March). Measuring the anthropomorphism, animacy, likeability, perceived intelligence and perceived safety of robots. In Metrics for HRI workshop, technical report (Vol. 471, pp. 37-44).
Bartneck, C., Bleeker, T., Bun, J., Fens, P., & Riet, L. (2010). The influence of robot anthropomorphism on the feelings of embarrassment when interacting with robots. Paladyn, Journal of Behavioral Robotics, 1(2), 109-115.
Beck, A., Cañamero, L. and Bard, K. A. (2010). Towards an Affect Space for robots to display emotional body language. In *Proceedings - IEEE International Workshop on Robot and Human Interactive Communication*, pp. 464–469. doi: 10.1109/ROMAN.2010.5598649.
Beira, R., Lopes, M., Praça, M., Santos-Victor, J., Bernardino, A., Metta, G., ... & Saltarén, R. (2006, May). Design of the robot-cub (icub) head. In Proceedings 2006 IEEE International Conference on Robotics and Automation, 2006. ICRA 2006. (pp. 94-100). IEEE.
Blow, M., Dautenhahn, K., Appleby, A., Nehaniv, C. L., & Lee, D. C. (2006, September). Perception of robot smiles and dimensions for human-robot interaction design. In ROMAN 2006-The 15th IEEE International Symposium on Robot and Human Interactive Communication (pp. 469-474). IEEE.
Bonarini, A., Garzotto, F., Gelsomini, M., Romero, M., Clasadonte, F., & Yilmaz, A. N. Ç. (2016, August). A huggable, mobile robot for developmental disorder interventions in a multi-modal interaction space. In 2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN) (pp. 823-830). IEEE. doi: 10.1109/ROMAN.2016.7745214.
Breazeal, C. (2002). Designing sociable robots. *Computers & Mathematics with Applications*. London, England: Mit Press. doi: 10.1016/S0898-1221(03)80129-3.
Breazeal, C. (2003). Emotion and sociable humanoid robots. *International Journal of Human Computer Studies*, 59(1–2), pp. 119–155. doi: 10.1016/S1071-5819(03)00018-1.
Breazeal, C. and Aryananda, L. (2002). Recognition of affective communicative intent in robot-directed speech. *Autonomous Robots*, 12(1), pp. 83–104. doi: 10.1023/A:1013215010749.
Breazeal, C. and Brooks, R. (2005). Robot emotion: A functional perspective. In Fellous, J. M. and Arbib, M. A. (eds) *Who needs emotions*. New York: Oxford University Press. Available at: http://excedrin.media.mit.edu/wp-content/uploads/sites/14/2013/07/Breazeal-Brooks-03.pdf (Accessed: 27 January 2015).
Bruce, A., Nourbakhsh, I. and Simmons, R. (2002). The role of expressiveness and attention in human-robot interaction. In *Proceedings 2002 IEEE International Conference on Robotics and Automation*, 4, pp. 4138–4142. doi: 10.1109/ROBOT.2002.1014396.
Burkhardt, F., Paeschke, A., Rolfes, M., Sendlmeier, W. F., & Weiss, B. (2005). A database of German emotional speech. In Ninth European Conference on Speech Communication and Technology.
Campa, R. (2016). The Rise of Social Robots : A Review of the Recent Literature. *Journal of Evolution and Technology*, 26(1), pp. 106–113.
Cañamero, L. D. and Fredslund, J. (2000). How Does It Feel? Emotional Interaction with a Humanoid LEGO Robot. In *AAAI 2000 Fall Symposium - Socially Intelligent Agents: The Human in the Loop*, Technical, pp. 23–28.

Chen, T. L., King, C. H., Thomaz, A. L., & Kemp, C. C. (2011, March). Touched by a robot: An investigation of subjective responses to robot-initiated touch. In 2011 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 457-464). IEEE. doi: 10.1145/1957656.1957818.

Cohen, I., Looije, R. and Neerincx, M. A. (2011). Child's recognition of emotions in robot's face and body. In *Proceedings of the 6th international conference on Human-robot interaction - HRI '11*, p. 123. doi: 10.1145/1957656.1957692.

Cupchik, G. C. (1999, November). Emotion and industrial design: Reconciling meanings and feelings. In Proceedings of the 1st International Conference on Design and Emotion (pp. 75-82).

Dael, N., Mortillaro, M. and Scherer, K. R. (2012). Emotion expression in body action and posture. *Emotion*, 12(5), pp. 1085–1101. doi: 10.1037/a0025737.

Darwin, C. (1872). *The expression of the emotions in man and animals*. London: John Murray.

Dautenhahn, K. (2004). Robots we like to live with?! - a developmental perspective on a personalized, life-long robot companion. In *RO-MAN 2004. 13th IEEE International Workshop on Robot and Human Interactive Communication (IEEE Catalog No.04TH8759)*, pp. 17–22. doi: 10.1109/ROMAN.2004.1374720.

Dautenhahn, K., Walters, M., Woods, S., Koay, K. L., Nehaniv, C. L., Sisbot, A., ... & Siméon, T. (2006, March). How may I serve you?: a robot companion approaching a seated person in a helping context. In Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction (pp. 172-179). ACM. doi: 10.1145/1121241.1121272.

Demasio, A. R. (1994). *Descartes' error: Emotion, reason, and the human brain*.

Demirbilek, O. and Sener, B. (2003) 'Product design , semantics and emotional response', *Ergonomics*, 46, pp. 1346–1360.

Desmet, P. M. A. (2002). *Designing Emotions*. Delft: Delft University of Technology

Desmet, P. M., Porcelijn, R., & Van Dijk, M. B. (2007). Emotional Design; Application of a research-based design approach. *Knowledge, Technology & Policy*, 20(3), pp. 141–155.

Dignan, L. (2014, June 5). Softbank, Aldebaran launch Pepper, an emotional robot. zdnet.com. CBS Interactive. Retrieved from https://www.zdnet.com/article/softbank-aldebaran-launch-pepper-an-emotional-robot/

DiSalvo, C. F., Gemperle, F., Forlizzi, J., & Kiesler, S. (2002, June). All robots are not created equal: the design and perception of humanoid robot heads. In Proceedings of the 4th conference on Designing interactive systems: processes, practices, methods, and techniques (pp. 321-326). ACM. doi: 10.1145/778712.778756.

DiSalvo, C. F., Gemperle, F., Forlizzi, J., & Kiesler, S. (2002, June). All robots are not created equal: the design and perception of humanoid robot heads. In Proceedings of the 4th conference on Designing interactive systems: processes, practices, methods, and techniques (pp. 321-326). ACM.

DiSalvo, C. F., Hanington, B., & Forlizzi, J. (2004). An accessible framework of emotional experiences for new product conception. In Design and emotion (pp. 287-256).

Douglas-Cowie, E., Cowie, R. and Schröder, M. (2000). A New Emotion Database: Considerations, Sources and Scope, *In ISCA tutorial and research workshop (ITRW) on speech and emotion.* pp. 39–44.

Ekman, P. (2003a). *Emotions revealed*, *Recognizing Faces and Feelings to Improve*. New York: Times Books.

Ekman, P. (2003b). The face revealed. London: Weidenfeld & Nicolson.

Ekman P., & Friesen W. (1978). Facial Action Coding System: A Technique for the Measurement of Facial Movement. Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., Friesen, W. V. and Ellsworth, P. (1972). *Emotion in the human face: Guidelines for Research and an Integration of Findings*. Pergamon Press Inc. doi: 10.1016/0005-7916(73)90048-7.

Endo, N., Momoki, S., Zecca, M., Itoh, K., & Takanishi, A. (2008). Design and evaluation of the new head for the whole-body emotion expression hu-manoid robot KOBIAN. *Gerontechnology*, 7(2). doi: 10.4017/gt.2008.07.02.036.00.

Engberg, I. S., Hansen, A. V., Andersen, O., & Dalsgaard, P. (1997). Design, recording and verification of a Danish emotional speech database. In Fifth European Conference on Speech Communication and Technology. pp. 1695–1698.

Feil-Seifer, D. and Mataric, M. (2012). Distance-Based Computational Models for Facilitating Robot Interaction with Children. *Journal of Human-Robot Interaction*, 1(1), pp. 55–77. doi: 10.5898/JHRI.1.1.Feil-Seifer.

Feil-Seifer, D. and Mataric, M. J. (2005). Defining Socially Assistive Robotics. In *Proceedings of the 2005 IEEE 9th International Conference on Rehabilitation Robotics*, pp. 465–468.

Ferreira, M. I. A. and Sequeira, J. S. (2017). Designing a Robotic Interface for Children: The Monarch Project. In *In Advances in Cooperative Robotics*, pp. 652–659.

Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2002). *A Survey of Socially Interactive Robots: Concepts, Design and Applications*, Technical Report CMU-RI-TR-02-29. doi: 10.1016/S0921-8890(02)00372-X.

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

de Gelder, B., de Borst, A. W. and Watson, R. (2015). The perception of emotion in body expressions. *Wiley Interdisciplinary Reviews: Cognitive Science*, 6(2), pp. 149–158. doi: 10.1002/wcs.1335.

Giambattista, A., Teixeira, L., Ayanoğlu, H., Saraiva, M., & Duarte, E. (2016, July). Expression of emotions by a service robot: a pilot study. In International Conference of Design, User Experience, and Usability (pp. 328-336). Springer, Cham. doi: 10.1007/978-3-319-40406-6_31.

Gillespie D.L., Leffler A. (1983). Theories of non-verbal behavior: a critical review of proxemics research. Soc Theory 1:120–154

Gorp, T. Van and Adams, E. (2012). *Design for emotion*. Massachusetts: Morgan Kaufmann.

Hall, E. T. (1966). *The Hidden Dimension*, *Journal of Chemical Information and Modeling*. New York, NY: Doubleday. doi: 10.1017/CBO9781107415324.004.

Hameed, I. A., Tan, Z. H., Thomsen, N. B., & Duan, X. (2016). User acceptance of social robots. In Proceedings of the Ninth International Conference on Advances in Computer-Human Interactions (ACHI 2016), Venice, Italy (pp. 274-279).

Hancock, P. A., Pepe, A. A., & Murphy, L. L. (2005). Hedonomics: The Power of Positive and Pleasurable Ergonomics. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 13(1), pp. 8–14. doi: 10.1177/106480460501300104.

Häring, M., Bee, N. and André, E. (2011). Creation and Evaluation of Emotion Expression with Body Movement , Sound and Eye Color for Humanoid Robots. In *Ro-Man, 2011 IEEE*. IEEE, pp. 204–209.

Hashimoto, T., Hitramatsu, S., Tsuji, T., & Kobayashi, H. (2006, October). Development of the face robot SAYA for rich facial expressions. In 2006 SICE-ICASE International Joint Conference (pp. 5423-5428).

IEEE. doi: 10.1109/SICE.2006.315537.

Helander, M. G. (2002, September). Hedonomics-affective human factors design. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 46, No. 12, pp. 978-982). Sage CA: Los Angeles, CA: SAGE Publications.

Helander, M. G. and Khalid, H. M. (2012). Affective and Pleasurable Design. In Salvendy, G. (ed.) *Handbook of Human Factors and Ergonomics*. 4th Editio. John Wiley & Sons Inc, pp. 569–596.

Hu, J. S., Wang, J. J. and Ho, D. M. (2014). Design of sensing system and anticipative behavior for human following of mobile robots. In *IEEE Transactions on Industrial Electronics*, 61(4), pp. 1916–1927. doi: 10.1109/TIE.2013.2262758.

Hüttenrauch, H., Eklundh, K. S., Green, A., & Topp, E. A. (2006, October). Investigating spatial relationships in human-robot interaction. In 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (pp. 5052-5059). IEEE.

James, W., (1884). What is an Emotion? Mind 9, 188–205. doi:10.1093/mind/LI.202.200

Jordan, P. W. (2003). How to make brilliant stuff that people love... And make big money out of it. John Wiley & Sons.

Kanda, T. and Ishiguro, H. (2013). *Human-Robot Interaction in Social Robotics*. CRC Press. doi: 10.1201/b13004.

Kanoh, M., Iwata, S., Kato, S., & Itoh, H. (2005). Emotive facial expressions of sensitivity communication robot “Ifbot”. Kansei Engineering International, 5(3), 35-42. doi: 10.5057/kei.5.3_35.

Kato, Y., Kanda, T. and Ishiguro, H. (2015). May I help you? In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction - HRI ’15*, (March), pp. 35–42. doi: 10.1145/2696454.2696463.

Kato, S., Oshiro, H., Itoh, H., Kimura, K. (2004). Development of a communication robot Ifbot, in: Proceedings of the IEEE International Conference on Robotics and Automation. IEEE, New Orleans, pp 697-702. doi:10.1109/ROBOT.2004.1307230

Kessens, J. M., Neerincx, M. A., Looije, R., Kroes, M., & Bloothooft, G. (2009, September). Facial and vocal emotion expression of a personal computer assistant to engage, educate and motivate children. In 2009 3rd International Conference on Affective Computing and Intelligent Interaction and Workshops (pp. 1-7). IEEE.

Khalid, H. M. and Halander, M. G. (2006). Customer Emotional Needs in Product Design. *Concurrent Engineering*, 14(3), pp. 197–206. doi: 10.1177/1063293X06068387.

Khan, Z. (1998). Attitudes towards intelligent service robots, *NADA KTH, Stockholm*, 17.

Kim, Y. and Mutlu, B. (2014). How social distance shapes human–robot interaction. In *International Journal of Human-Computer Studies*. Elsevier, 72(12), pp. 783–795. doi: 10.1016/j.ijhcs.2014.05.005.

Kittmann, R., Fröhlich, T., Schäfer, J., Reiser, U., Weißhardt, F., & Haug, A. (2015). Let me introduce myself: I am Care-O-bot 4, a gentleman robot. Mensch und computer 2015–proceedings.

Klein, J., Moon, Y., Picard, R.W. (2002). This computer responds to user frustration: Theory, design, and results. Interact. Comput. 14, 119–140. doi:10.1016/S0953-5438(01)00053-4

Koay, K. L., Syrdal, D. S., Walters, M. L., & Dautenhahn, K. (2007, August). Living with robots: Investigating the habituation effect in participants' preferences during a longitudinal human-robot interaction study. In RO-MAN 2007-The 16th IEEE International Symposium on Robot and Human

Interactive Communication (pp. 564-569). IEEE.

Kraus, M. W. (2017). Voice-Only Communication Enhances Empathic Accuracy. *American Psychologist*, 72(7), pp. 644–654.

Kühnlenz, K., Sosnowski, S. and Buss, M. (2010). The Impact of Animal-like Features on Emotion Expression of Robot Head EDDIE. *Advanced Robotics*, 24(8–9), pp. 1239–1255.

Kwon, D. S., Kwak, Y. K., Park, J. C., Chung, M. J., Jee, E. S., Park, K. S., ... & Hyun, K. H. (2007, August). Emotion interaction system for a service robot. In RO-MAN 2007-The 16th IEEE International Symposium on Robot and Human Interactive Communication (pp. 351-356). IEEE. doi: 10.1109/ROMAN.2007.4415108.

Lasota, P. A., Fong, T. and Shah, J. A. (2017). A Survey of Methods for Safe Human-Robot Interaction. *Foundations and Trends in Robotics*, 5(3), pp. 261–349. doi: 10.1561/2300000052.

Lee, H. S., Park, J. W. and Chung, M. J. (2007). A Linear Affect-Expression Space Model and Control Points for Mascot-Type Facial Robots. In *IEEE Transactions on Robotics*, 23(5), pp. 863–873. doi: 10.1109/TRO.2007.907477.

Leite, I., Martinho, C. and 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.

Loza, D., Marcos Pablos, S., Zalama Casanova, E., Gómez García-Bermejo, J., & González, J. L. (2013). Application of the FACS in the Design and Construction of a Mechatronic Head with Realistic Appearance. *Journal of Physical Agents*, 7(1), pp. 31–38.

McGlynn, S. A., Kemple, S., Mitzner, T. L., King, C. H. A., & Rogers, W. A. (2017). Understanding the potential of PARO for healthy older adults. International journal of human-computer studies, 100, 33-47. doi: 10.1016/j.ijhcs.2016.12.004.

Mohammad, Y., Okada, S. and Nishida, T. (2010). Autonomous Development of Gaze Control for Natural Human-Robot Interaction. In *International IUI 2010 Workshop on Eye Gaze in Intelligent Human Machine Interaction*, pp. 63–70. doi: 10.1145/2002333.2002344.

Mokdad, M. and Abdel-Moniem, T. (2017). New Paradigms in Ergonomics: The Positive Ergonomics. In Korhan, O. (ed.) *Occupational Health*, pp. 3–24. doi: 10.5772/63281.

Montepare, J., Koff, E., Zaitchik, D., & Albert, M. (1999). The use of body movements and gestures as cues to emotions in younger and older adults. Journal of Nonverbal Behavior, 23(2), 133-152. doi: 10.1023/A:1021435526134.

Mori, M. (1970). The Uncanny Valley. *Energy*, 7(4), pp. 33–35.

Mukai, T., Hirano, S., Nakashima, H., Kato, Y., Sakaida, Y., Guo, S., & Hosoe, S. (2010, October). Development of a nursing-care assistant robot RIBA that can lift a human in its arms. In 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems (pp. 5996-6001). IEEE. doi: 10.1109/IROS.2010.5651735.

Mumm, J. & Mutlu, B. (2011). Human-robot proxemics : Physical and psychological distancing in human-robot interaction Human-Robot Proxemics : Physical and Psychological Distancing in Human-Robot Interaction. In *Proceedings of the 6th international conference on Human-robot interaction*, pp. 331–338. doi: 10.1145/1957656.1957786.

Mutlu, B. (2009). *Designing Gaze Behavior for Humanlike Robots*. Unpublished doctoral dissertation, Pittsburgh, PA, USA.

Nakata, T., Sato, T. and Mori, T. (1998). Expression of emotion and intention by robot body movement.

In *5th Conference on Intelligent Autonomous Systems*, pp. 352–359.

Nomura, T., Kanda, T., Suzuki, T., & Kato, K. (2004, September). Psychology in human-robot communication: An attempt through investigation of negative attitudes and anxiety toward robots. In RO-MAN 2004. 13th IEEE International Workshop on Robot and Human Interactive Communication (IEEE Catalog No. 04TH8759) (pp. 35-40). IEEE. doi: 10.1109/ROMAN.2004.1374726.

Nomura, T., Kanda, T., Suzuki, T., & Kato, K. (2006). Exploratory investigation into influence of negative attitudes toward robots on human-robot interaction. In Lazinica, A. (ed.) *Mobile Robots Towards New Applications*. I-Tech Education and Publishing, pp. 215–232. doi: 10.1007/s00146-005-0012-7.

Nomura, T., Yamada, S., Kanda, T., Suzuki, T., & Kato, K. (2009, March). Influences of concerns toward emotional interaction into social acceptability of robots. In In 2009 4th ACM/IEEE International Conference on Human-Robot Interaction, pp. 231–232. doi: 10.1145/1514095.1514151.

Nomura, T. (2017). Cultural Differences in Social Acceptance of Robots. In *Robot and Human Interactive Communication (RO-MAN), 2017*. IEEE, pp. 534–538.

Norman, D. A. (2004). *Emotional design: Why we love (or hate) everyday things*. Basic Civitas Books.

Oh, K. and Kim, M. (2010). Social attributes of robotic products: Observations of child-robot interactions in a school environment. *International Journal of Design*, 4(1), pp. 45–55. doi: G300-cX1077991.vn0p106.

Picard, R.W. (1997). *Affective Computing*. The MIT Press, Cambridge.

Picard, R.W. (2000). Towards Computers that recognize and respond to user emotion. *IBM Syst. J.* 39, 705-719.

Picard, R.W., Klein, J., (2002). Computers that Recognise and Respond to User Emotion: Theoretical and Practical Implications. Interact. Comput. 14, 141–169.

Plutchik R. (1980). Emotion: A psychoevolutionary synthesis. Harkes & Row, New York.

Plutchik, R. (1984). Emotions: a general psychevolutionary theory, in: Scherer, K., Elkman, P. (Eds.), Approaches to Emotion. Lawrence Erlbaum Associates, Hillsdale, pp. 197–219.

Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34. doi: 10.1007/s12369-012-0173-8.

Ray, C., Mondada, F. and Siegwart, R. (2008). What do people expect from robots? In *IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS*, pp. 3816–3821. doi: 10.1109/IROS.2008.4650714.

Riek, L. D., Rabinowitch, T. C., Chakrabarti, B., & Robinson, P. (2009, March). How anthropomorphism affects empathy toward robots. In Proceedings of the 4th ACM/IEEE international conference on Human robot interaction (pp. 245-246). ACM. doi: 10.1145/1514095.1514158.

Riek, L. D. and Robinson, P. (2011). Using robots to help people habituate to visible disabilities. In *IEEE International Conference on Rehabilitation Robotics*. doi: 10.1109/ICORR.2011.5975453.

Russell, J. (1997). Reading emotions from and into faces: resurrecting a dimensional–contextual perspective. In: Russell, J., Fernandez-Dols, J. (Eds.), The Psychology of Facial Expression. Cambridge University Press, Cambridge, pp. 295–320.

Russell, J. A., Bachorowski, J.-A. and Fernández-Dols, J.-M. (2003). Facial and Vocal Expressions of Emotion. *Annual Review of Psychology*, 54(1), pp. 329–349. doi:

10.1146/annurev.psych.54.101601.145102.
Saldien, J., Goris, K., Vanderborght, B., Vanderfaeillie, J., & Lefeber, D. (2010). Expressing emotions with the social robot probo. International Journal of Social Robotics, 2(4), 377-389. doi: 10.1007/s12369-010-0067-6.
Salichs, M. A., Barber, R., Khamis, A. M., Malfaz, M., Gorostiza, J. F., Pacheco, R., ... & Garcia, D. (2006, June). Maggie: A robotic platform for human-robot social interaction. In 2006 IEEE Conference on Robotics, Automation and Mechatronics (pp. 1-7). IEEE. doi: 10.1109/RAMECH.2006.252754.
Sanders, T. L., MacArthur, K., Volante, W., Hancock, G., MacGillivray, T., Shugars, W., & Hancock, P. A. (2017, September). Trust and prior experience in human-robot interaction. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 61, No. 1, pp. 1809-1813). Sage CA: Los Angeles, CA: SAGE Publications. doi: 10.1177/1541931213601934.
Satake, S., Kanda, T., Glas, D. F., Imai, M., Ishiguro, H., & Hagita, N. (2009, March). How to approach humans?: strategies for social robots to initiate interaction. In Proceedings of the 4th ACM/IEEE international conference on Human robot interaction (pp. 109-116). ACM.
Sauter, D. A. and Scott, S. K. (2007). More than one kind of happiness: Can we recognize vocal expressions of different positive states? *Motivation and Emotion*, 31(3), pp. 192–199. doi: 10.1007/s11031-007-9065-x.
Schachter, W., Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. Psychol. Rev. 69, 379-399.
Schaefer, K. E., Sanders, T. L., Yordon, R. E., Billings, D. R., & Hancock, P. A. (2012, September). Classification of robot form: factors predicting perceived trustworthiness. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 56(1), pp. 1548–1552. doi: 10.1177/1071181312561308.
Scheeff, M., Pinto, J., Rahardja, K., Snibbe, S., & Tow, R. (2002). Experiences with Sparky, a social robot. In Socially intelligent agents (pp. 173-180). Springer, Boston, MA.
Schröder, M. (2000). Experimental Study of Affect Bursts, *Speech Communication*, 4(1–2), pp. 99–116.
Simon-Thomas, E. R., Keltner, D. J., Sauter, D., Sinicropi-Yao, L., & Abramson, A. (2009). The voice conveys specific emotions: evidence from vocal burst displays. Emotion, 9(6), 838. doi: 10.1037/a0017810.
Sosnowski, S., Bittermann, A., Kuhnlenz, K., & Buss, M. (2006, October). Design and evaluation of emotion-display EDDIE. In 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (pp. 3113-3118). IEEE. doi: 10.1109/IROS.2006.282330.
Sünderhauf, N., Brock, O., Scheirer, W., Hadsell, R., Fox, D., Leitner, J., ... & Corke, P. (2018). The limits and potentials of deep learning for robotics. The International Journal of Robotics Research, 37(4-5), 405-420..
Syrdal, D. S., Dautenhahn, K., Koay, K. L., & Walters, M. L. (2009). The negative attitudes towards robots scale and reactions to robot behaviour in a live human-robot interaction study. In *23rd Convention of the Society for the Study of Artificiel Intelligence and Simulation of Behaviour, AISB*, pp. 109–115.
Tanevska, A., Rea, F., Sandini, G., & Sciutti, A. (2017, October). Towards an Affective Cognitive Architecture for Human-Robot Interaction for the iCub Robot. In 1st Workshop on “Behavior, Emotion and Representation: Building Blocks of Interaction”.
Tielman, M., Neerincx, M., Meyer, J. J., & Looije, R. (2014, March). Adaptive emotional expression in

robot-child interaction. In Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction (pp. 407-414). ACM.

Tiger, L. (2000). *The pursuit of pleasure*. New Brunswick.

Triberti, S., Chirico, A., La Rocca, G., & Riva, G. (2017). Developing emotional design: Emotions as cognitive processes and their role in the design of interactive technologies. Frontiers in psychology, 8, 1773. doi: 10.3389/fpsyg.2017.01773.

Tsui, K. M., Desai, M., Yanco, H. A., Cramer, H., & Kemper, N. (2010, September). Using the negative attitude toward robots scale with telepresence robots. In Proceedings of the 10th performance metrics for intelligent systems workshop (pp. 243-250). ACM.

Valli, A. (2008). The design of natural interaction. Multimed. Tools Appl. 38, 295–305. doi:10.1007/s11042-007-0190-z

van Oosterhout, T., & Visser, A. (2008). A visual method for robot proxemics measurements. In Proceedings of metrics for human-robot interaction: a workshop at the third ACM/IEEE international conference on human-robot interaction (HRI08) (pp. 61-68).

Wagner, A. R. (2015). Lies and Deception: Robots that use Falsehood as a Social Strategy. In J. Markowitz (Ed.). Robots that talk and listen: Technology and social impact (pp. 203-225). Berlin: de Gruyter.

Wallbott, H. G. (1998). Bodily expression of emotion. *European journal of social psychology*, 28(6), 879-896.

Walter, A. (2011). *Designing for emotion*. New York: Jeffrey Zeldman. Available at: http://www.mann-ivanov-ferber.ru/assets/files/bookparts/emotional_web_design/ewd_read.pdf (Accessed: 13 January 2015).

Walters, M. L., Dautenhahn, K., Te Boekhorst, R., Koay, K. L., Kaouri, C., Woods, S., ... & Werry, I. (2005, August). The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment. In ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005. (pp. 347-352). IEEE. doi: 10.1109/ROMAN.2005.1513803.

Wang, L., Rau, P. L. P., Evers, V., Robinson, B. K., & Hinds, P. (2010, March). When in Rome: the role of culture & context in adherence to robot recommendations. In Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction (pp. 359-366). IEEE Press. doi: 10.1145/1734454.1734578.

Weiss, W. (1992). Measurement of the Sensory Qualities in Tactile Interaction, Nursing Research, vol. 41, pp. 82-85.

Wensveen, S. & Overbeeke, K. (2003). Fun with your alarm clock: Designing for engaging experiences through emotionally rich interaction. In M.A.Blythe, K. Overbeeke, A. F. Monk, & P. C. Wright (Eds.), Funology: From usability to enjoyment (pp. 275-282). London: Kluwer Academic Publishers.

Woods, S., Dautenhahn, K. and Schulz, J. (2006). Exploring the design space of robots: Children's perspectives. *Interacting with Computers*, 18(6), pp. 1390–1418. doi: 10.1016/j.intcom.2006.05.001.

Woods, S., Dautenhahn, K. and Schulz, J. (2004). The design space of robots: investigating children's views. In *RO-MAN 2004. 13th IEEE International Workshop on Robot and Human Interactive Communication (IEEE Catalog No.04TH8759)*, pp. 47–52. doi: 10.1109/ROMAN.2004.1374728.

Woodworth, R. S. (1938). Experimental psychology. New York: Holt, Rinehart & Winston.

Yamaji, Y., Miyake, T., Yoshiike, Y., De Silva, P. R. S., & Okada, M. (2011). Stb: Child-dependent sociable trash box. International Journal of Social Robotics, 3(4), 359-370. doi: 10.1007/s12369-011-0114-y.

Yamazaki, A., Yamazaki, K., Kuno, Y., Burdelski, M., Kawashima, M., & Kuzuoka, H. (2008, April). Precision timing in human-robot interaction: coordination of head movement and utterance. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 131-140). ACM. doi: 10.1145/1357054.1357077.

Miwa, H., Itoh, K., Matsumoto, M., Zecca, M., Takanobu, H., Rocella, S., ... & Takanishi, A. (2004, September). Effective emotional expressions with expression humanoid robot we-4rii: integration of humanoid robot hand rch-1. In 2004 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)(IEEE Cat. No. 04CH37566) (Vol. 3, pp. 2203-2208). IEEE. doi: 10.1109/IROS.2004.1389736.

Zecca, M., Mizoguchi, Y., Endo, K., Iida, F., Kawabata, Y., Endo, N., ... & Takanishi, A. (2009, September). Whole body emotion expressions for KOBIAN humanoid robot—preliminary experiments with different Emotional patterns. In RO-MAN 2009-The 18th IEEE International Symposium on Robot and Human Interactive Communication (pp. 381-386). IEEE.doi: 10.1109/ROMAN.2009.5326184.

Zecca, M., Macrì, G., Mizoguchi, Y., Monaco, V., Endo, N., Itoh, K., Dario, P., Takanishi, A. (2010). Evaluation of the KOBIAN and HABIAN emotion expression humanoid robots with european elderly people, in: ROMANSY 18 Robot Design, Dynamics and Control. Springer, Vienna, pp. 449-456.

Zieber, N., Kangas, A., Hock, A., & Bhatt, R. S. (2014). Infants' perception of emotion from body movements. Child Development, 85(2), 675-684. doi: 10.1111/cdev.12134.