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# Too Human To Be a Machine?

## Social robots, anthropomorphic appearance, and concerns on the negative impact of this technology on humans and their identity.

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*Alla mia famiglia*

# Content

# Introduction

In this thesis I will talk about social robots, their appearance, and people's concerns about potential negative impacts that social robotics technology could have on humans and their identity.

The aim is to contribute to the understanding of why people fear social robots, and what the role of humanlike appearance is within this process. Social robots represent a new, fascinating technology. Research in social robotics not only develops new and better social robots but also tries to understand and prevent eventual problems that could arise when people and robots coexist. Moreover, the relations and reactions to social robots, especially those who highly resemble humans, is also an interesting topic from a social psychology point of view. Taking up professor Ishiguro's words, developing androids opens up the question of "what is human?" (Guizzo, 2010). The study of psychological processes related to machines that imitate real persons allows us to know more about ourselves as human beings.

In Chapter 1, I will define what a social robot is and then focus on their appearance. After discussing the motives that lead to the development of robots with an anthropomorphic appearance, I will focus on the Uncanny Valley. Based on a review of the literature, I identified two open issues: the difficulty of comparing the results of empirical studies due to the fact that different questionnaires are used from study to study and the relatively few studies that investigate the relation between anthropomorphic appearance and the social acceptance of social robots. These issues were empirically addressed in Chapters 2 and 3, respectively. In Chapter 2, I report a study of validation of the Psychological Scale of General Impressions of Humanoids (Kamide et al., 2012) in an Italian sample. In Chapter 3, I investigate, through a social psychological perspective, the relation between anthropomorphic appearance and the concern related to this kind of technology. Specifically, a *threat to distinctiveness hypothesis* was advanced and two studies are presented. Finally, in Chapter 4, I discuss the findings of the present research and their implications on social robotics research.

As the present thesis and its studies were developed under the supervision of prof. Paladino, in the next chapters the ideas and hypothesis will be introduced using the form “we”.

# CHAPTER 1

# Theoretical Introduction

## 1.1 Technology to interact with: Social Robots

Social robots are autonomous machines that aim to perform social tasks. Several definitions of "social robots" have been advanced. Kanda, Ishiguro and Ishida (2001) defined a social robot as "a robot that interacts with humans and participates in human society" (pp. 4166). Duffy (2003) portrayed these machines as "physical entities embodied in a complex, dynamic, and social environment sufficiently empowered to behave in a manner conducive to their own goals and those of their community" (pp. 177-178). Dautenhahn and Billard (1999) referred to social robots as "embodied agents that are part of a heterogeneous group: a society of robots or humans. They are able to recognize each other and engage in social interactions, they possess histories (perceive and interpret the world in terms of their own experience), and they explicitly communicate with and learn from each other" (pp. 366-367).

Generally speaking, the aim of social robots is to support human beings in social activities and/or to replace them in jobs where human social capabilities are needed but not available. For instance, Robovie was used in a shopping mall in Japan to provide indications to the costumers about shops and restaurants (Kanda, Shiomi, Miyashita, Ishiguro, & Hagita, 2009), whereas Reem was employed within a hospital in Rome to give information to the patients (Amoroso, 2014).

Social robots can also assist people with physical and mental difficulties. Paro, the seal baby robot, was used to improve the elders' quality of life within a geriatric center (Wada, Shibata, Musha, & Kimura, 2008), while the humanoid robots KASPAR and Nao were employed to improve the social skills of children affected by Autism Spectrum Disorder (Wainer, Dautenhahn, Robins, & Amirabdollahian, 2010; Shamsuddin, Yussof, Ismail, Hanapiah, Mohamed, Piah, & Zahari, 2012).

One of the social changes that social robots could respond to is aging populations. The report of the United Nations on World Population Ageing (United Nations, 2002) states that in 2050 there will be nearly 2 billion people 60 or over on our planet and they will represent more than one third of the entire European population. The development of new technologies able to interact with and assist humans could be one of the responses to limit the cost for the society.

Social robotics also has a potential economic impact on our society. The creation of interacting machines, which perform social tasks, enlarges the possible markets and applications of robotics (Breazeal, 2004) from the industrial sector to the domestic, medical/welfare and public sector (Ballve, 2014).

In this line, social robots represent a challenge for research and technology setting new goals and overcoming the boundaries of previous technological tools. The social goal of this kind of machines required the creation of a new multidisciplinary framework (i.e. the social robotics) where engineering, informatics and social, psychological and neuro sciences collaborate to such development. Social robots also deeply changed the conception of technology. Hence, social robots can be considered integrating elements of our society, something between a technological tool and a social agent.

One of the central questions in social robotics is how to design a social robot and which of its features (e.g., appearance, movements, voice, behaviors, etc.) could eventually improve the interaction with humans.

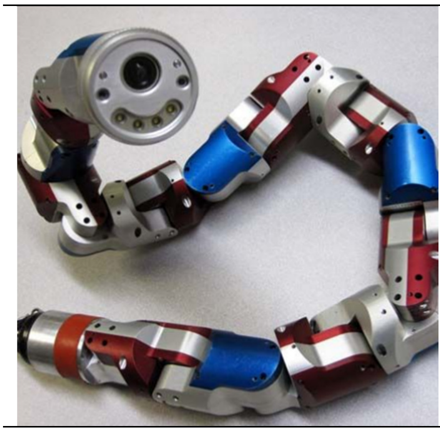
The present chapter focuses on robots' appearance. In the next paragraphs the importance of social robots' humanlike appearance will be discussed, analyzing both the functional and the psychological motives that lead to the development of such robots. Then, we will turn to the emotional reactions to human likeness in robots, describing the Uncanny Valley (UV) of Mori (1970) and the various accounts advanced for this effect. Finally, we will present the research questions that are investigated in the present thesis.

## 1.2 Meeting social robots I: The appearance

In the last years, several social robot prototypes have been developed in research labs around the world and recently some of these have entered the market (e.g., NAO, ASIMO, Reem and REEM-C, etc.). Each robot has been developed to implement some specific functions and abilities, and, more importantly for the sake of present thesis, with a different appearance. On the basis of the aesthetic form, Fong, Nourbakhsh and Dautenhahn (2003) differentiated four categories of social robots: anthropomorphic, zoomorphic, caricatured and functional. The first two categories include machines whose look is inspired by biology, specifically, the human body for anthropomorphic robots, and the animal body for zoomorphic robots (see Table 1). Caricatured robots refer to mechanical agents that present some exaggerated, distinctive or striking features as if they were characters of animations or cartoons. Functional robots include machines that are designed to implement a specific function, without any attempt to remind any living agents (humans or animals). The look of such a robot might thus remind one of an industrial robot (e.g., Careobot III of Fraunhofer Institute for Manufacturing Engineering and Automation IPA, etc.). In the present work, we investigated the effects of robots' human likenesses, and from now on in this thesis, we will uniquely focus on anthropomorphic robots. The goal of this is twofold: to give a brief overview of the different aesthetic forms that these robots have taken and to present and discuss different approaches to make sense of these robots differences in terms of human likeness. Finally we will introduce how this issue was approached in the empirical part of the thesis.

An anthropomorphic appearance in social robots is very common and highly recommended as it is thought to facilitate human-robot interaction (see next paragraph). However, a rapid look at the existing social robots suggests that the way human-likeness is achieved differs from one robot to the other. To map this variability, Duffy (2003) proposed the *anthropomorphism design space.* As shown

**Table 1.** Examples of zoomorphic robots

| Uncle Sam | Aibo | Paro the seal baby robot |
|---|---|---|
|  |  |  |

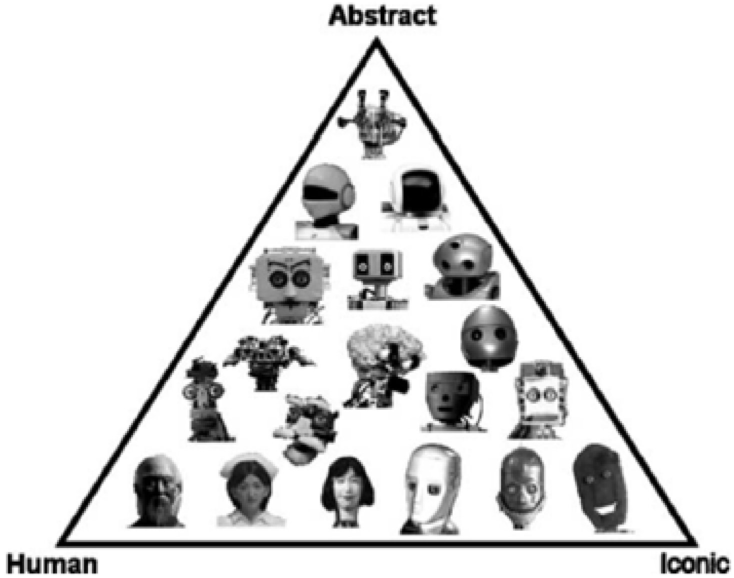
***Notes.*** In the pictures (from left to right) the modular snake Uncle Same, Aibo and Paro the seal baby robot. Uncle Same of Carnegie Mellon University was developed through taking inspiration from snake shapes, but it shows a very mechanical appearance. The aim of this modular robot is to access locations that humans or other machines cannot reach (for example in a disaster scenario). Aibo resemble a dog but is clearly recognizable as a robot. It was created by Sony as robot companion. PARO was designed by the Intelligent System Research Institute of Japan's AIST. It is covered by synthetic fur and it can show facial expressions to interact with humans. Its aim is to provide the benefits of animal therapy in environments such as hospitals where the presence of real animals is not allowed.
We can observe that similarities to real animals can change (also in relation to the function of the robot). Fong, Nourbakhsh and Dautenhahn (2003) highlighted that the avoidance of negative emotional reactions toward robots, as in the Uncanny Valley phenomenon (see paragraph 1.4 in this chapter), may be easier for zoomorphic than anthropomorphic robots, because the relationship between owner and pet is simpler than the human-human relationships.

in Figure 1, each corner of this triangular space represents a different approach to the human likeness of robot heads.

*"Human"* refers to robot heads that resemble human faces in detail, as those of android robots designed to resemble humans in details and with no evident exterior signs hinting to a mechanical agent. "*Iconic"* points to robot heads displaying some human features, such as eyes and mouths, that allow some expressiveness. Finally, "Abstract" refers to those robot heads with minimal, but still present, human-like aesthetics. The anthropomorphism design space does not provide a classification of robots' appearance in terms of degree of human likeness, but rather points to how human likeness is conveyed in robots' heads.

Other studies have approached robots' human likeness in terms of degree. Kamide, Mae, Kawabe, Shigemi and Arai (2012) differentiated anthropomorphic robots in three groups: androids and

**Figure 1.** Anthropomorphism design space for robot heads used by B.R. Duffy (2003)

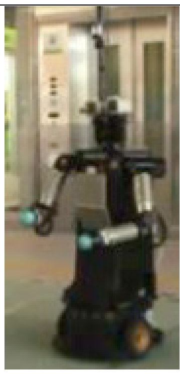
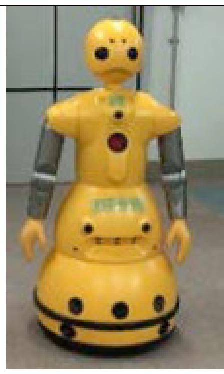
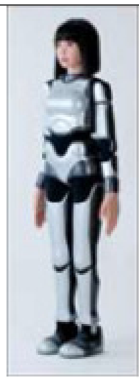
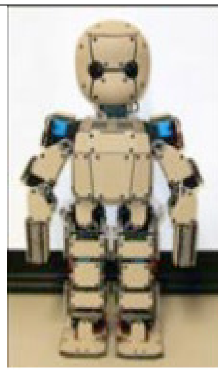
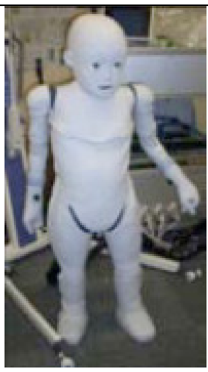
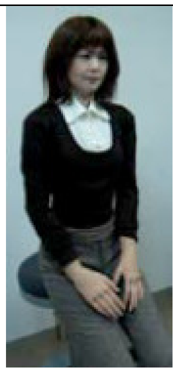
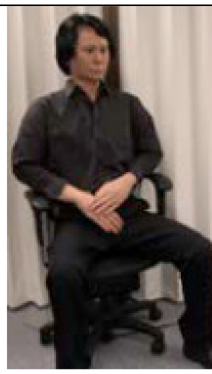
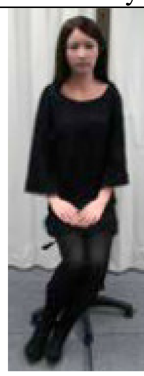



humanoids that were further distinct in biped-walking (i.e., ASIMO, HRP-2, HRP-4C and M3-Neony) and wheeled walking (i.e., Robovie, Wakamaru, and Enon). Androids include those robots whose look is designed as an almost perfect copy of the human body (i.e., CB2, Repliee Q2, Geminoid Hi and Geminoid F), whereas humanoids refer to those robots with an appearance that remind human body (e.g., a head over a body, etc.), but that they also present some obvious mechanical aspects that make these robots more robot-like. This a-priori differentiation was further validated in their research, which aimed to develop a psychological scale for the evaluation of social robots (the Psychological Scale for General Impressions of Humanoids, Kamide et al., 2012).

In this research, Kamide et al. (2012; Study 2) presented participants the videos of the eleven human-like robots shown in Table 2 and asked them to report their impressions by answering a 50-item scale. Among other aspects, they found that the three kinds of robots, androids, biped-walking and wheeled walking humanoids, were differently perceived on the "human likeness" dimension. Specifically, androids were rated as the robots that resembled humans to the greatest extent, followed by biped humanoids and finally by wheeled humanoids.

Also Rosenthal-von der Pütten and Kramer (2014) addressed robots' human likeness in terms of

**Table 2.** Robots used by Kamide et al. (2012) in their study to develop the Psychological Scale for General Impressions of Humanoids

| | | | | |
|---|---|---|---|---|
| Wheeled Humanoid |  Robovie |  Wakamaru |  Enon | |
| Biped Humanoid |  ASIMO |  HRP-2 |  HRP-4C |  M3-Neony |
| Android |  CB2 |  Repliee Q2 |  Geminoid HI |  Geminoid F |

degree, but relied on a bottom-up empirical approach. Instead of identifying a-priori categories of robots and their respective exemplars (as in Kamide et al., 2012), they differentiated robots on the basis of people's impressions. Specifically, they showed participants pictures of 40 robots and asked them to complete a survey (for each robot) that investigated, among other judgments, how human-like each robot was. Results showed that the four androids (i.e., Geminoid HI-1, Ibn Sina, Geminoid DK and HRP-4C) presented in the study were judged as the most humanlike robots.

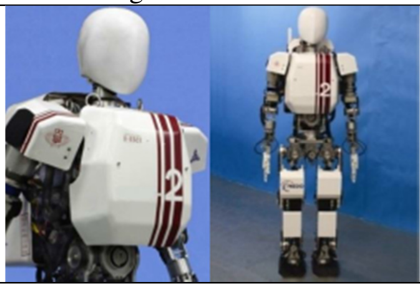
Some similarities and some differences can be noted among these works. All point to androids as the most human-like robots and differentiate them from other anthropomorphic robots with a mechanical aspect as humanoids. However, differences emerged when evaluating the human-likeness of humanoids. In Duffy, the focus is on the head of the robots, in Kamide et al., it is the lower part, whether the robot has wheels or legs that makes the differences (likely because videos were used in their study to show robots' motion). Finally, the categorization of some robots differed depending on the study and the approach. For instance, Kamide et al. included the HRP-4 among the biped-walking humanoids, whereas in Rosenthal-von der Pütten and Kramer (2014) this was judged as among the most human-like robots.

These differences among studies highlight the complexity of what could appear to be a very straightforward judgment. People seem to have no problem judging how human-like a robot's appearance is. However, it is hard to exactly establish whether some specific feature (e.g., eyes more than hands) contributes more than other features to this judgment. This difficulty emerges also in the lack of clear indications in the HRI research on *elements to increase robots' human-like appearance*.

We believe that the principle of Gestalt psychology introduced by Kurt Koffka for perception, "the whole is *something else* than the sum of the single parts" (Koffka, 2013, pp. 176), could shed light in this case. Likely also for robots' human-likeness appearance, the whole gestalt plays a more important role than the possession of single, specific human features. Consistently, androids that are designed as a copy of humans are always judged more anthropomorphic than humanoids that just present some human-like features.

The focus of the present research is to evaluate the effects of robot anthropomorphic appearance, specifically if too much similarity with humans could lead to a negative reaction toward robots. Taking advantage of the Koffka principle, in our studies we differentiated and compared three classes of robots whose gestalt strongly differed in terms of similarity to humans. The first group,

**Table 3.** Examples of mechanical, humanoid and android robots.

| Mechanical | Humanoid | Android |
|---|---|---|
| none or minimum humanlike features | human shapes but were clearly recognizable as robots | resembling human beings in details |
|  |  |  |
| TP-600-270<br>SuperDroid Robots | Wabian-2, Takanishi Lab<br>Waseda University | FACE of FabLab<br>University of Pisa |

called *mechanicals,* included robots with none or minimum humanlike features (e.g., the four legged explorer robot of Toshiba used at the Fukushima Daiichi nuclear implant[1]). Mechanical robots were clearly recognizable as machines as their bodies showed wheels, wires and no human shape. The second group, named *humanoids* (e.g., HRP-4 developed by AIST[2]), described those robots that showed human shapes but were clearly recognizable as robots. Humanoids were all biped robots with two arms and one head. Their wires and internal circuits were mostly not visible and protected by plastic or metallic covers. The third group included *androids* that resemble human beings in detail (e.g., the Geminoid DK[3] robots developed by Kokoro for the Aalborg University in Northern Denmark). Androids showed a very humanlike, detailed face with noses, eyebrows, eyes with pupil, iris and sclera, mouths with lips and teeth. Their internal circuits and wires were totally hidden by a silicone skin in the face and hands, and by human dress (e.g., jackets, shirts, sweaters, pants or skirts, and shoes) in the torso and legs.

[1] http://kmjeepics.blogspot.it/2012/11/toshiba-four-legged-fukushima-robot.html Retrieved November 25, 2013; http://cdn.phys.org/newman/gfx/news/2012/toshibashows.jpg Retrieved November 25, 2013;
[2] http://www.aist.go.jp/aist_e/latest_research/2010/20101108/20101108.html; AIST: National Institute of Advanced Industrial Science and Technology (of Japan). Retrieved November 25, 2013;
[3] http://androidegeminoid.blogspot.it/ Retrieved November 25, 2013;

This differentiation in mechanical, humanoid and android robots perhaps does not contribute in creating a clear classification of anthropomorphic features that differentiate humanlike robots; however, it does guarantee a clear operationalization of robot-human likeness (see Table 3).

## 1.3 Meeting social robots II: Why is humanlike appearance important?

Robot's appearance is not just an aesthetic choice. Appearance is the first element of perception and that could affect a (potential) human-robot interaction, influencing the user's behavior and expectations on the robot and its capabilities (Lohse, Hegel, Swadzba, Rohlfing, Wachsmuth, & Wrede, 2007; Goetz, Kiesler, & Powers, 2003). In social robotics, a humanlike appearance is recommended as it is thought to facilitate the human-robot interaction and, more generally, the introduction of robots in the society at large (Hanson, 2011). Such assumption involves both a more functional (is the interaction more smooth with anthropomorphic robots?) and a more psychological approach (is an anthropomorphic robot perceived as a more "human" partner in the interaction?) to the issue of human-robot interaction. These two perspectives are often confounded. Here they are going to be discussed separately.

### 1.3.1 Functional approach

From a functional standpoint, the development of robots with an anthropomorphic appearance can represent a series of advantages for the direct interaction with humans, and more generally, for the performance of the tasks that a social robot is designed to perform.

Human beings developed their homes, offices, cars and the whole society in general to be people-oriented. A human body (or something similar to it) is needed to drive our cars, to cook in our kitchens, to clean our houses and offices using the same tools we generally use. In this respect, an anthropomorphic robot can better fit in our human world, becoming a valid substitute of human beings without any additional economic costs to modify our environments.

An anthropomorphic appearance can also facilitate the interaction, making the behavioral exchange and the communication between humans and robots more smooth and intuitive. This idea is exemplified in a study of Imai, Ono and Ishiguro (2003) in which they showed the importance of the role of eye contact – generally involved in the process of joint attention in human communication exchanges – when interacting with the humanoid robot Robovie. The interaction between Robovie and each single participant (all Japanese) followed a precise script. After the participant entered the room, the robot passed in front of her/him and stopped in front of a poster. Here Robovie pointed to the poster with its arm and asked the participants to look at it. In the condition with eye-contact, Robovie performed first a visual contact with the participant and then moved its head toward the poster. In the condition without eye-contact, Robovie pointed at the poster and did not look toward the participant or toward the poster. All participants in the eye-contact condition observed looking at the poster, whereas only one in the no eye-contact condition paid attention to it. This demonstrates the fundamental role of eye contact (and joint attention) to facilitate the interaction with a humanoid robot.

Non-verbal communication cues in robots, such as pointing gestures, eye contact, smiling, etc., require that this mechanical agent possesses some human-like features (e.g. eyes, arms, etc.). As Imai, Ono and Ishiguro (2003) put it, “the design of a robot’s head and behavior is […] vital to achieving eye contact” (pp. 640). In this perspective, the development of an anthropomorphic robot appears to be a good choice, if not a pre-requisite, for a technology that is designed to interact and communicate with people. People do not need to drastically change their behaviors and interaction style to interact with robots and therefore it would be easier to communicate with this kind of technological device.

This said, it should be noted that in this functional perspective there is no need of a complete resemblance to human beings; robots do not need to lose their mechanical appearance.

### 1.3.2 Psychological approach

Researchers in human-robot interaction hypothesized that robots with human-like appearance might remind us of our human fellows, influencing our expectations on these robots that might even be seen at a psychological level (i.e. abilities, etc.) as more human-like (Duffy, 2003; Fink, 2012).

The tendency to attribute human psychological qualities to non-human agents such as robots is a process known in social sciences as *anthropomorphism* (Serpell, 2002; Epley, Akalis, Waytz & Cacioppo, 2008; Niemyjska & Drat-Ruszczak, 2013). According to the Three-Factor Theory of Anthropomorphism model (Epley, Waytz, & Cacioppo, 2007), there are three key determinants to this process: knowledge elicited by the agent, effectance motivation (i.e., need to interact with our own environment), and sociality motivation (i.e., need to establish social connection with others). In this model, the perceived similarity of the non-human agent to humans is a knowledge elicited by the agent that leads to anthropomorphism. Human-like appearance would enhance the accessibility of anthropomorphic knowledge, increasing the application of human qualities to non-human agents.

Some studies support this assumption. Note that, depending on the study, anthropomorphism (i.e. attribution of human qualities) was differently operationalized. For instance, Kiesler and Goetz (2002) found that sociability, intellect and personality were attributed to a larger extent to a humanoid robot compared to a toy robot resembling a truck. Focusing on empathy as a proxy of anthropomorphism, Riek, Rabinowitch, Chakrabarti, and Robinson (2009) compared reactions toward five different characters (presented in videos) that varied in their humanlike appearance, (i.e. the robotic vacuum cleaner Roomba, AUR the robot lamp with five degrees of freedom, Andrew the humanoid robot shown in the movie the “Bicentennial man,” Jean Marsh, the actress who interpreted the part of the android Alicia in the series “The Twilight Zone” and finally Anton as a human boy). They found that participants were more empathetic toward humanlike characters (i.e., Andrew, Alicia and Anton) in comparison with mechanical ones (i.e., AUR and Roomba).

Other researchers focused on the concept of mind attribution. Mind is what distinguishes humans from non-humans (Epley, & Waytz, 2009). In this line, Epley, Waytz and Cacioppo (2007) suggested that anthropomorphism can therefore be revealed observing the extent that the (human) mind is attributed to non-human entities. Gray and Wegner (2012) asked participants to attribute to a humanoid robot KASPAR (shown in a video) some typically mind agency related capacities (i.e., "This robot has the capacity to plan actions" and "This robot has the capacity to exercise self-control") and mind experience related capacities (i.e., "This robot has the capacity to feel pain" and "This robot has the capacity to feel fear"). Depending on the experimental condition, the humanoid robot KASPAR was filmed from behind, showing wires and electrical components (mechanical condition), or in front so as to make its expressive face clearly visible (lifelike – humanlike condition). Interestingly, although there was no difference in mind agency attribution, mind experience qualities were attributed at a greater extent to the robot in the humanlike condition compared to the mechanical condition. This pattern of results suggests that robots' human likeness increases the attribution of at least some mind capacities.

Kamide, Eyssel and Arai (2013) looked at mind attribution and, in addition, to attribution of humanness to robots following the Haslam (2006) approach. In this approach, there are two dimensions of humanness: *human uniqueness* (with traits that refer to civility, refinement, rationality and logic, moral sensibility and maturity), which distinguishes us from animals, and *human nature* (with traits on emotional responsiveness, interpersonal warmth, agency and individuality, cognitive openness and depth), which distinguishes us from machines. Human nature attribution is therefore particularly interesting in the context of anthropomorphism toward robots (Kim, & Kim, 2013; see also Zlotowski, Proudfoot, & Bartneck 2013). Kamide, Eyssel and Arai (2013) asked 1,200 Japanese to attribute mind (Gray, Gray & Wegner, 2007) and humanness (Haslam, 2006) to different social robots, as the wheeled humanoid robot Wakamaru, the biped humanoid robots HRP-2 and HRP-4C, the androids Geminoid F and Geminoid HI-4, a non-humanoid robot ASTERISK and two real persons (the models of Geminoid F and Geminoid HI-4). Results showed that the more a robot was physically similar to humans the more it was perceived to possess human traits and mind capabilities.

Krach, Hegel, Wrede, Sagerer, Binkofski and Kircher (2008) investigated the relation between human likeness and anthropomorphism in the brain. Their participants were asked to play the game of “prisoner dilemma” with a computer, a functional (or mechanical) robot, an anthropomorphic robot and a real human being. They found that the same cortical network generally activated when attributing mental states in human-human interactions, i.e., right posterior superior temporal sulcus (pSTS) at the temporo-parietal junction (TPJ) and the medial prefrontal cortex (mPFC) were activated during the interaction with the humanlike robots, but not with the functional robot or with the computer.

To conclude, there are functional and psychological approaches to robots’ anthropomorphic appearance. These two approaches are often confounded in social robotics in terms of their impact on the human-robot interaction. However, it should be noted that if an anthropomorphic appearance facilitates the human-robot interaction, at least at a behavioral level, it is not yet clear whether the attribution of human qualities (along which the human mind) has positive effects on the interaction.

For example, Gray and Wegner (2012) showed that when the expressive face (vs. the mechanical aspect) of the humanoid robot KASPAR was visible, participants tended to attribute mind experience qualities to the robot to a greater extent. However, they also reported a stronger feeling of eeriness toward it, suggesting a less smooth interaction with the robot. This study points to the importance of the emotional reactions to robots’ anthropomorphic appearance, turning us to the Uncanny Valley theory.

## 1.4 The Uncanny Valley theory

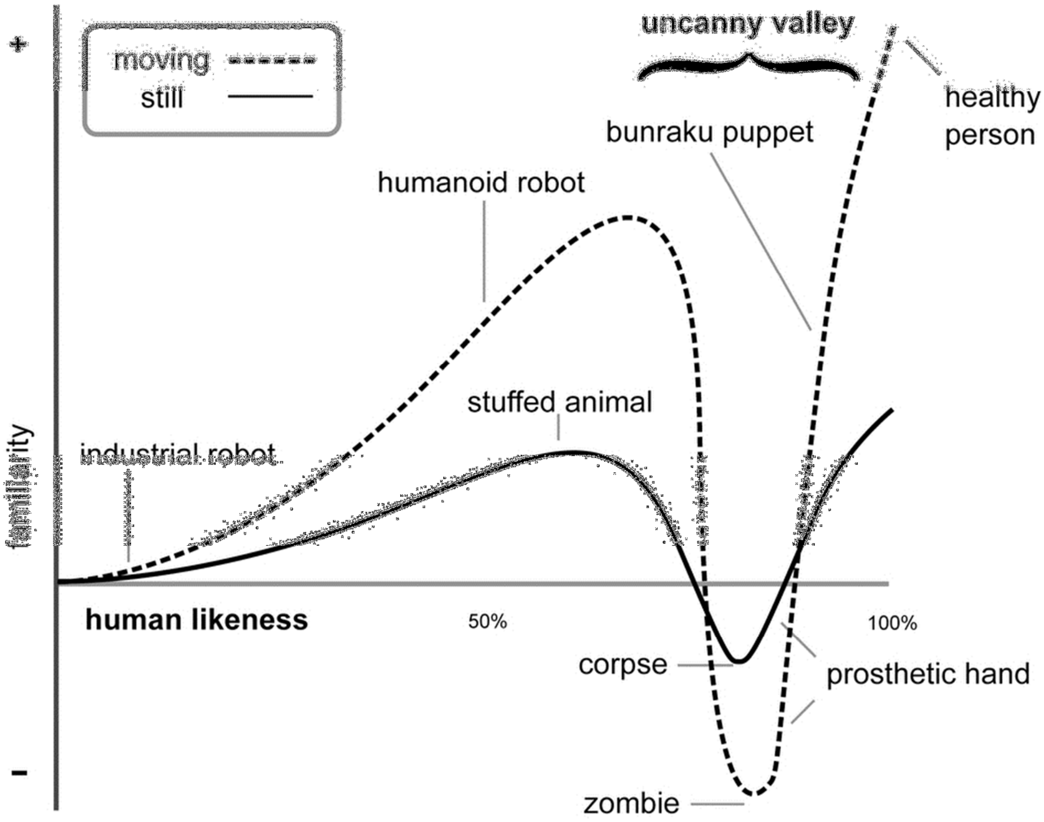
The Uncanny Valley (UV) of Mori (1970) describes the relation between robot's human likeness and emotional reactions during the human-robot interaction. This theory suggests that an enhance of robot's human likeness leads to an increase of familiarity toward it up to a certain limit after which, further increase in resembling humans provokes uneasiness and repulsion in people. The UV depicts a non-linear relation between human likeness and positive reaction of people toward robots (see Figure 2).

Following Mori's theory, we could expect that robots such as Honda's ASIMO or NAO of Alderan Robotics, which show humanlike shapes but are clearly recognizable as robots, stop at the first peak of the curve arousing an increase of familiarity. However, robots that strongly resemble human appearance, i.e., androids as Geminoid DK and Geminoid F, fall into the UV and lead people to experience eeriness. Furthermore, according to the UV theory, the motion of robots exacerbates the effects of their anthropomorphic appearance on people reactions. Following the previous example, we would expect that a humanoid robot in movement will be perceived as more familiar and affine, whereas an android will be perceived as creepier and the UV will be deeper (Mori, MacDorman & Kageki, 2012).

Several studies investigated the UV theory finding mixed support for it. Depending on the study, different manipulation of human likeness, experimental materials, and dependent variables were used. This makes it hard to compare the studies and to reach a conclusive answer on the existence of an uncanny effect for high humanlike robots.

Concerning the dependent variables, the problem partially lies on the ambiguity of the word *shinwa-kan* used to describe the UV in the original theorization. Depending on the study, *human likeness* and *familiarity* (Mori, 1970) or *affinity* (Mori, MacDorman & Kageki, 2012) was investigated in relation with the robotic appearance. Bartneck, Kanda, Ishiguro and Hagita (2009), in collaboration

**Figure 2.** Graphic of the Uncanny Valley described by Mori (1970).




with some Japanese linguists, analyzed the term *shinwa-kan* (originally translated with *familiarity*) and suggested that the more suitable English translation was *likeability*. Furthermore, Bartneck, Kanda, Ishiguro and Hagita (2009) stated that there is not a specific word in English to define this Japanese word, and maybe its real meaning is "lost in translation". Similarly, the negative opposite of familiarity/affinity (that represents the other end of the continuum), defined in Japanese with the word *bukimi,* was translated in English with *eerie* and *uncanny,* which mean "strange, mysterious and frightening." However, these terms do not define what kinds of emotions are involved within the UV.

Another problem with the UV theory is the too simplistic depiction of its different aspects. Bartneck, Kanda, Ishiguro and Hagita (2009) highlighted that the motion of a robot (as gesture) has social meaning that can influence the impressions toward the robot too. This aspect was not considered in UV theory. Ramey (2005) evidenced a problem in UV theory related to the same conceptualization of *human likeness*, pointing to the incorrect use of a continuum to describe elements that belong to different categories. He affirmed that UV "[…] links qualitatively different categories by quantitative metrics that call into question the originally differentiated categories (in this case – *human* and *robot*)" (pp. 8). If we use elements belonging to different categories as end points of a continuum, what is in the middle between them is not explicable and represents a *sorites paradox*. Finally, Brenton, Gillies, Ballin and Chatting (2005) suggested that UV, as it refers to an emotional reaction, could change over time. Particularly, they hypothesized that more experience with androids of robots would lead to less uncanny effect. Differently stated, the UV could be reduced thanks to a familiarization with highly humanlike robots.

Still, researchers suggested some factors that could reduce the UV effects.

Hanson, Olney, Pereira and Zielke (2005) conducted a survey morphing the photos of two characters (cartoonish girl and real girl) and asking participants to rate the acceptability of each image. As they did not report significant differences, they concluded that it is possible to overcome the UV if roboticists carefully design the aesthetics of the social robot. They called this hypothesis *Path of Engagement*. Conversely, Bartneck et al. (2007) suggested that UV cannot be overcome. In their study they showed participants pictures of humanoids, androids and real human beings, finding that participants judged the photos of humanoid and toy robots as the most likeable pictures, even more than photos of real persons. Researchers proposed the existence of an *Uncanny Cliff* in place of a valley, so that positive reactions toward humanlike agents always decrease when we overcome the first peak of the Mori's valley.

Another problematic aspect of the UV theory is the type of relation between robots' anthropomorphic appearance and the uncanny reaction. Following this theory, the relation between robots' human likeness and negative emotional reactions should be a non-linear cubic function (Mori, 1970). However, in studies that are somehow supportive of the theory, a linear pattern between robots' human likeness and negative reactions toward them emerged (Burleigh et al., 2013; Burleigh & Schoenherr, 2014; Kamide et al., 2012).

Finally, the UV could be a complex phenomenon, involving different psychological and emotional processes at the same time applications (Rosenthal-von der Pütten, 2014). As was noted by Rosenthal-von der Pütten, Krämer, Becker-Asano, Ogawa, Nishio and Ishiguro, “Uncanny Valley is tangent to diverse concepts like anthropomorphism, robot appearance or perception of agency” (2014, pp. 68). This turns us to the accounts of the uncanny valley effect. This is an interesting issue, as one way to establish whether a phenomenon occurs is to understand why it should occur. In the reminder of this paragraph, review the major explanations provided to the Uncanny valley. Inspired by the work of Rosenthal-von der Pütten (2014), we focused on 3 different explanations, (“evolutionary biological”, “expectancy violations and cognitive conflicts” and “social – motivational defense”). However, note that one explanation does not exclude the validity of the others, as the UV is a complex phenomenon that might be related to different psychological processes at the same time.

### 1.4.1 Evolutionary biological

Some researchers (MacDorman & Ishiguro, 2006; Ho, MacDorman & Pramono, 2008; Moosa, & Ud-Dean, 2010; Steckenfiger, & Ghazanfar, 2009) put the negative reactions toward very humanlike robots on par with an evolutionary perspective. According to this perspective, we as humans developed a series of mechanisms to increase our chances of survival. One of these is disgust. This emotional reaction signals our organism to potential sources of contagion, infection and pathogen agents (Rozin & Fallon, 1987).

MacDorman and Ishiguro (2006) advanced the idea that, given their high similarity to humans, androids could be unconsciously evaluated as potential vectors of disease. Norms generally applied to judge humans, their health and their productivity potential (e.g. youth, vitality, bilateral symmetry, skin quality, and the proportions of the face and body; MacDorman & Ishiguro, 2006, pp. 210) could be used to judge androids, but not humanoids, which are clearly recognizable as machines (and therefore not dangerous in this perspective). Lack of vitality in androids could elicit a sense of disgust in people that interact with them. Following this line of reasoning, MacDorman and Ishiguro (2006) advanced the idea that the eeriness of UV phenomenon might have the same purpose and therefore should be linked to disgust.

Ho, MacDorman and Pramono (2008) conducted a study to test this hypothesis. In their experiment, each participant watched one of 16 silent videos. The characters in these videos were 15 robots, which varied in their level of human likeness, and a real woman. After the clip, participants were asked to report their feeling of uncanniness (i.e. strangeness, eeriness, creepiness and human likeness) and other feelings toward the humanlike machines among which disgust. This last emotion was found to be a strong predictor of eerie reaction toward humanlike robots. The outcomes supported the idea advanced by MacDorman and Ishiguro (2006), but did not clarify if the uncanny reactions were specifically related to the mechanism of pathogen avoidance.

Moosa and Ud-Dean (2010) extended this approach, suggesting that the UV phenomenon might be related not only to pathogen avoidance, but to a more general danger avoidance predisposition. In their perspective, androids could signal toxicity and also natural disasters.

Finally, evidence that the UV phenomenon could also be rooted in human evolution are provided by Steckenfiger and Ghazanfar (2009), showing that the UV phenomenon is not limited to human beings. In their study, videos of real monkey's faces and unrealistic and realistic computer graphic monkey faces were presented to five macaque monkeys. To assess the preference toward the different stimuli, the researchers measured the time spent by the macaques in watching the different faces. Results showed that the monkeys looked at realistic synthetic monkey faces for a shorter time in comparison to the real and to the unrealistic monkey faces. Steckenfiger and Ghazanfar (2009) interpreted these outcomes as proof of the existence of the UV in macaques, suggesting that "it is not the increased realism that elicits the uncanny valley effect, but rather that the increased realism lowers the tolerance for abnormalities" (pp. 18364).

### 1.4.2 Expectancy violations and cognitive conflicts

Several scholars in social robotics suggested that negative emotional reactions toward humanlike robots might be linked to cognitive processing. The uncanny feeling would be the result of an "expectancy violation" and/or a "category conflict".

"Expectancy violation" includes those accounts that highlight the role of conflicts between the robot appearance and people expectations. MacDorman and Ishiguro (2006), for instance, suggested that androids might elicit the expectancy that they would be similar to humans in every aspect. Therefore, the observation of the robotic (and not human) motion of androids might violate observers' expectations and lead to negative emotions toward the robot. In this sense, Brenton, Gillies, Baliln and Chatting (2005) proposed the role of a perceptual paradox between anthropomorphic appearance and robotic motion as trigger element for the UV insurgence.

Violation of expectations might concern not only the very first impression of a certain robot, but also the general representation of machines. In one of their studies (described in paragraph 1.3.2 and 1.3.3), Gray and Wegner (2012) found that the robot KASPAR was perceived more uncanny when its expressive face, rather than its mechanical features, was visible. According to the researchers, an expressive face gives people the illusion that the robot is able to feel emotions, a capability not expected from the machines and that therefore violates persons' expectancies.

Some evidence on the role of expectancy violation in the UV emerged also in an fMRI study. Saygin, Chaminade, Ishiguro, Driver and Frith (2012) developed a study to observe the effect of the match vs. mismatch between humanlike appearance and motion on brain activity. They presented participants three video clips that showed the android Repliee Q2 in its original humanlike version, the android with its mechanical parts clearly visible, and a real person that is the human model of the android. The video showing the humanlike android represented the mismatch condition as the robot has a biological appearance but a non-biological motion; whereas the clip showing the mechanical-android or the human, represented the match conditions as the appearance and the motion were matched (non-biological appearance and non-biological motion for the mechanical android, whereas biological appearance and biological motion for the human). During the observation of the videos, participants' brain activity was registered in an fMRI. They found that suppression in the bilateral anterior intraparietal sulcus, a key node in the area of human action perception system (APS), was significantly stronger during the vision of the humanlike android in comparison with the observation of the real human and the mechanical-android. Saygin et al. (2012) proposed the Prediction Error Framework advancing the idea that stimuli mismatches can lead to the activation of an inaccurate neural model and that this framework might contribute in explaining the insurgence of the UV phenomenon.

Another study conducted by Mitchell, Szerszen, Lu, Schermerhorn and MacDorman (2011), focused on matching appearance and voice of robotic and human characters. They found that when a character displayed a mismatch between these two features (i.e., humanlike appearance & robotic voice, or robotic appearance & humanlike voice), people reacted more negatively toward it than toward a character with these features matched (i.e., humanlike appearance & humanlike voice, or robotic appearance & robotic voice).

Other researchers advanced the idea that the UV feeling would be the result of a "category conflict" that could eventually arise during the process of categorization. Different from "expectancy violation", this type of explanation links the UV reactions to simultaneous activation of different cognitive categories (i.e., human and machine).

This idea was initially introduced by Ramey (2005). He suggested that the negative reactions toward androids are related to the fact that these robots concurrently show features that belong to humans and features typically of robots, leading to a conflict in their categorization. Similarly, Bartneck, Kanda, Ishiguro, and Hagita (2007) proposed that androids activate the "human frame" (see the *framing theory* of Minsky, 1975) and that this "error" in categorization would elicit negative feelings toward these very humanlike robot.

In line with Ramey's account, Burleigh, Schoenherr and Lacroix (2013) recently proposed the Category Conflict Hypothesis (CCH) sustaining that "when human likeness is operationalized as a merger of human and non-human categories, stimuli which lie approximately mid-way between such categories will be perceived as ambiguous and thus elicit negative affect" (pp. 761). The scholars conducted a series of studies using computer graphic avatar faces and morphing them for feature atipicality and category membership (human vs. non-human). They asked participants to assess human likeness, eeriness and pleasantness of each target. Results confirmed the CCH, showing that the targets that were located between human and nonhuman categories elicited more negative emotions similar to those described in UV (e.g., eeriness).

Using a different experimental material, Yamada, Kawabe and Ihaya (2013) came to a similar conclusion. In their experiment, two images of real (Japanese people), stuffed (*Peanuts*' Charlie Brown toy) and cartoonish (Shinj Ikari of *Neon Genesis Evangelion*) humanlike characters were morphed. They found that participants reported more negative emotions toward the stimuli located on the boundaries of different categories (for similar results see also: Cheetham et al. 2011, 2013).

Despite these results, we have to highlight that these studies did not investigate the categorization process of real androids. So the role of category conflict in reactions to androids, as suggested by Ramey (2005), is still waiting for an empirical test.

#### 1.4.3 Social – motivational defense

Differently from the "evolutionary-biological" and "perceptual-cognitive conflicts" explanations, the social motivational determinants of UV do not seem connected to possible flaws of androids in resembling humans, but rather to the perfect imitation of real people and to the difficulty in distinguishing them from real humans. In these accounts to the UV, human likeness of robots is theorized as a potential threat to our human identity as it undermines the uniqueness of humans.

One of the first authors to raise the role of these processes in the UV is Ramey (2005). According to him, the uncanny feeling is both a cognitive (see previous paragraph) and an affective phenomenon. Related to this last aspect, Ramey suggested that the uncanny feeling evoked by humanlike robots is related to the challenge that these robots pose to the categorical distinction between humans and non-humans. For instance, once robots have a human look (e.g., androids), human uniqueness in appearance is undermined.

This approach has also been extended to other human characteristics and behaviors. For instance, Kaplan (2004) suggested that we are afraid of these new machines as they challenge (what we think to be) human uniqueness, forcing us to redefine ourselves and humanness in general. To illustrate the argument, he states that once robots can play chess, the game is no longer thought of as a typically human behavior. MacDorman, Vadusevan and Ho (2009) took this reasoning one step further when they asked what would happen to our sense of human specialness if perfect human replicas were created. MacDorman, Green, Ho and Koch (2009) stated that "what is potentially most disturbing about artificial human forms is not how they look but what they signify: a challenge to their maker's uniqueness" (pp. 5).

For Ramey (2005), Kaplan (2004) and MacDorman et al. (Vadusevan, & Ho, 2009; Green, Ho, & Koch, 2009), fears and concerns towards robots are thus related to how humans define and defend their identity as human beings. Literature in social psychology supports this hypothesis. According to the two dimensional model of humanness and dehumanization described by Haslam (2006), machines represent an important comparison outgroup for the human identity. In this perspective, we compare humans with machines to identify those characteristics that define human nature. If we are not able to differentiate a real person from a machine, how can we define what is human?

Thus, according to this approach, negative reaction toward androids could concern the possible damage these machines might bring to human beings' individually and as a group. In this regard, Kamide et al. (2012; see paragraph 1.2) found that participants were more worried of being replaced by robots and that human relations would be depleted by the introduction of such machines in society at large when they watched videos of androids than when they watched videos of wheeled and biped humanoid robots.

MacDorman and Ishiguro (2006) suggested that androids could elicit a subconscious fear of reduction, replacement and annihilation, and linked the UV with the existential fear of death. Taking advantage of a paradigm typically used in Terror Management Theory research, they asked participants to observe the picture of an android or of a real human being and to complete a questionnaire to assess the mortality salience (e.g., items on personal worldview, word completion puzzles, etc.). Results showed that the vision of an android (vs. a real human) elicited a stronger reminder of death.

It should be noted that although several authors advanced a social motivational explanation to the UV, there are few studies that empirically investigated the effects of robot humanlike appearance on fear that this robots could damage the humans and their identity. The present thesis aims to fill this gap (see Paragraph 1.6 Research questions).

### 1.5 Concluding remarks

In this chapter we focused on the role of social robots' appearance, in particular on human likeness. We discussed both functional and psychological motives that underline the development of robots with an anthropomorphic appearance. We also discussed whether and how robot human likeness could affect people's emotional reactions toward this technology. Specifically, we described the UV theory and the accounts advanced to this phenomenon. Here we will discuss the similarities and differences among these explanations in terms of the psychological process involved, the emotions elicited by highly humanlike robots, the consequences for the interaction and the level of analysis (for an overview see Table 3).

Concerning emotions, the three accounts to the UV underline different emotional reactions to highly humanlike robots. The "evolutionary – biological" approach links the negative reaction toward very humanlike robots with *disgust*. The "expectancies violation and cognitive conflicts" explanations add to *disgust* also the emotion of *fear* (intended as being *scared*). Finally, the "social – motivational defense" account points to *worry* and *anxiety* as the emotional barrier to androids and other highly anthropomorphic robots. These differences for what concerns emotions are strictly related with expected consequences for the human-robot interactions and the level of analysis/implication of the theory.

The "evolutionary – biological" and the "expectancies violation and cognitive conflicts" accounts speak to the human and robot interaction. Both approaches try to explain why potential users of social robots would feel uneasy in interacting with highly humanlike machines and therefore would avoid direct *contact* with them. Differently, "social – motivational defense" concerns more general *worries* and *anxiety* toward possible damages that humanlike robots could inflict on humans. In this regard, this approach offers an explanation also to societal resistance to the investments in the development and the introduction of very humanlike robots as well as the introduction of such machines in our everyday life.

**Table 3.** Overview of possible UV's explications and their characteristics

| Explications | Emotions | Psychological processes involved | Consequences | Level of explanation |
|---|---|---|---|---|
| Evolutionary biological | Disgust | Distal motivation: Pathogen avoidance | no contact with that specific humanlike robot | Micro |
| Expectancies violations and cognitive conflicts | Disgust and Fear (as Scared) | No motivation, cognitive conflicts | no contact with that specific humanlike robot | Micro |
| Social motivational defense | Fear (as Worry and Anxiety) | Motivation: Identity defense | contrast development of this technology | Macro |

Finally, in terms of psychological processes involved, the cognitive conflict accounts identify in our cognitive system problems toward anthropomorphic robots, whereas the other two involve some motivational processes.

**1.6 Research questions**

In the present thesis we focused on two important, though underrated, issues related to the research on anthropomorphic appearance in social robotics.

As mentioned earlier, one of the reasons why the research on the role of robots' anthropomorphic appearance in social robotics is inconclusive lies in the fact that different manipulation of appearance and dependent variables were used from study to study. This makes it impossible to compare the results of different studies and to obtain an overall coherent picture of anthropomorphic appearance's impact on human-robot interaction.

Thus, the first part of the present thesis (Chapter 2) aims to provide an empirical contribution to social robotics research validating the Psychological Scale for General Impressions of Humanoids (PSGIH) developed by Kamide et al. (2012). We focused on this scale because it was the first to be developed using a bottom-up approach, and more importantly, it investigates the possible concerns on the impact on humans and their identity due to the existence of robots. With our first study we wanted to observe if this scale and its items (that we used in the subsequent studies) were also reliable in a non-Japanese context.

The second part of the thesis (Chapter 3) focuses on the anthropomorphic appearance in social robotics as a source of worries for the potential negative impact on the human identity and humans as a group. Specifically, we investigated the psychological processes that underlie these reactions. Literature in social robotics generally focuses especially on the "evolutionary biological" and "expectancy violation and cognitive conflicts" approaches, whereas few studies were conducted in relation to the "social – motivational defense". In the present research we focused on this last perspective to examine the psychological processes that relate to the worries and anxiety generated by humanlike robots.

We proposed a *threat to distinctiveness hypothesis*. We advanced the idea that very humanlike robots, such as androids, are feared because they are perceived to blur the boundaries between humans and machines, and, for reasons we will explain later in the thesis, these boundaries are psychologically important for us as human beings. We conducted two studies to examine if the undermining of human distinctiveness and uniqueness underlies the perception of androids (vs. humanoids and mechanical robots) as possible damage to humans and their identity.

# CHAPTER 2 [4]

# Validation of "a Psychological Scale for General Impressions of Humanoids" in an Italian Sample

Social robots are designed to communicate and interact with people. Beliefs, attitudes, emotions are indeed an essential part of the evaluation of social robots. In this chapter we present a study that provides the a factorial validation of the Psychological Scale for General Impressions of Humanoids (PSGIH) on an Italian sample and therefore the first validation outside Japan. An Italian sample completed an Italian version of the scale. Responses were analyzed in an explorative factorial analysis of the principal components. Similarities and differences between the present work and the original study on PSGIH, as well as the implications for the research on social robotics of the present findings are discussed.

## 2.1 Introduction

Differently from industrial robots, social robots are meant to be agents able to efficaciously communicate and interact with people. Given this specificity, the evaluation of this kind of robots requires also a psychological analysis. Beliefs, feelings, attitudes, emotions, more generally opinions of people toward robots are indeed an essential part of the their evaluation.

In the last years a growing body of research has investigated the perception and the emotional and behavioral reactions towards different types of social robots (Nomura, Kanda, Suzuki, & Kato, 2008; Kanda, Ishiguro, Imai, & Ono, 2003). Both qualitative and quantitative approaches have been

[4] This work (Validation of the Psychological Scale for General Impressions of Humanoids in an Italian Sample) was presented and published in proceedings of the 13th International Conference on Intelligent Autonomous Systems, Workshop: Evaluating Social Robots, 18th July 2014, Padua, Italy (see Ferrari, & Paladino, 2014).

used and several questionnaires and scales, as well as other proxies of behavioral responses, have been put forward (Mutlu & Forlizzi, 2008; Bartneck, Kulić, Croft & Zoghbi, 2009; Broadbent, Lee, Stafford, Kuo & MacDonald, 2011). Often these measures have been designed for the specific purpose of the study (Krach, Hegel, Wrede, Sagerer, Binkofski & Kircher, 2008), raising the issue of comparability of research results. As we advanced in the previous chapter, a clear example in this respect is the research on the UV (Mori, 1970) in which this concept has been operationalized very differently from study to study using very diverse terms. This variety of operationalization (without any construct validation) leaves open the question of whether different results across studies are theoretically relevant, shows possible cultural differences in the sample of respondents, or simply reflects methodological choices and the use of different measurement instruments.

In our opinion, there are at least two main strategies to overcome the problem of comparability of research findings in the evaluation of social robots. One is to base research concerning social robots on theoretically and empirically well-established (and, obviously, relevant for the field of social robotics) psychological phenomena. This would offer to research evaluating robots the advantage of relying on a set of validated instruments/measures and of providing a theoretical background on which to compare results coming from different studies. The research of Eyssel and colleagues (Eyssel, Kuchenbrandt, & Bobinger, 2011; Eyssel, Kuchenbrandt, Hegel, & De Ruiter, 2012; Eyssel, & Reich, 2013) on robot anthropomorphism is a good example of this, that we would call, top-down approach. The other is a more a bottom-up approach typically used in social science to develop scales to measure socially relevant issues (i.e. prejudice). An excellent example in this respect in the field of social robotics is the Psychological Scale for General Impressions of Humanoids (PSGIH) of Kamide et al. (2012). Starting from interviews and going through questionnaires, Kamide and colleagues individuated a series of dimensions (and their relative scales) relevant in evaluating social robots.

Obviously the potential impact of this type of effort on the field of social robotics depends on whether the PSGIH is ready to be used also in other linguistic and cultural contexts.

**2.2 Factorial Validation of PSGIH**

The aim of this study was the factorial validation of Psychological Scale for General Impressions of Humanoids (PSGIH) in an Italian sample. At our knowledge this is the first attempt to validate this scale in a non-Japanese population. The PSGIH was recently developed in Japan by Kamide in a two steps procedures. In a first step, 900 Japanese participants (representative of the Japanese population) viewed the videos of 11 humanoid robots (wheeled and biped humanoids, and androids). Subsequently they were interviewed and asked about their emotions and thoughts toward the robot shown in the video. Five psychologists analyzed these interviews who individuated 10 different recurrent content dimensions. On the basis of this analysis, a questionnaire (with 50 items, 4-7 for each dimension) was created and administered to 2,700 Japanese who responded to it after they watched movies showing robots. A factorial validation was then performed from which nine factors - that explained the 61% of the variance – emerged. These factors were Humanness (physical similarity to human beings), Motion (appropriateness of robot's movements), Familiarity (perceived nearness with the robot), Utility (benefits obtained by using the robot), Performance (expectations on robot's functionalities), Repulsion (fear toward robot and its existence), Entitativity (attribution of will and consciousness to the robot), Voice (clearness of language spoken by the robot), and Sound (extent of noises when the robot was moving). The result of this impressive work is the Psychological Scale for General Impressions of Humanoids, a valuable instrument to measure individual's impressions on humanoid robots in Japan and potentially also in other countries.

In the present research, Italian participants were presented with photos of a (mechanical or a humanoid or an android) robot and then completed a shortened version of the scale (for details, see the procedure section). Although the PSGIH was developed to observe the impressions toward humanoids, in the present research we included also reactions towards mechanical robots as people interact and seem to establish relations also with non-humanoid robots that operate in their everyday environment (e.g. Sung, Guo, Grinter & Christensen, 2007). In addition, given that the impression of a robot is also influenced by information on the country in which it has been developed (Eyssel & Kuchenbrandt, 2012) and the scarce availability of videos showing a robot interacting in and with an Italian, in the present work we decide to show only photos and not videos of robots. This choice had two consequences. Movements, voice and sounds of the robot were not evaluated, and therefore our validation of the PSGIH focused just on those items concerning the impression and the emotional reactions towards social robots.

Responses were analyzed in an explorative analysis of the principal components (PCA). Factorial structure was discussed and compared to that of the original study of Kamide et al. (2012). With an exploratory purpose, the correlations between the factors and the differences between the types of robots were observed.

## 2.3 Method

### 2.3.1 Participants.

The responses to 182 questionnaires were usable. Participants ($N$ = 182, 91 women, 89 men, 2 not declared) were aged between 19 and 63 years ($M_{age}$ = 27.7, $SD$ = 6.36).

### 2.3.2 Pretest on Pictures of Robots.

In total, 18 photos were used to depict 3 mechanical, 3 humanoid, and 3 android robots, each with 2 photos (300 pixel width, 400 pixel height). The three mechanical robots were the four legged explorer robot of Toshiba used at the Fukushima Daiichi nuclear implant[5], the Modular Snake robot developed by the Robotics Institute at Carnagie Mellon University called Uncle Sam[6], and the Nomad Heavy Duty Wheeled Robot[7] of CrustCrawler Robotics. The three humanoid robots were the HRP-4 developed by AIST[8] and Kawasaky Heavy Industries, the expressive robot Kobian of Waseda University[9], and the advanced musculoskeletal humanoid robot Kojiro created at the JSK Laboratory at the University of Tokyo[10]. The 3 android robots were the Philip K Dick and Jules robots of Hanson Robotics[11], the Geminoid DK[12] robots developed by Kokoro for the Aalborg University in Northern Denmark. We showed only photos of androids with Caucasian appearance to avoid possible influences in perceiving robots as members of an outgroup (Kuchenbrandt, Eyssel, Bobinger & Neufeld, 2011).

The two photos of the mechanical robots depicted the robots from two different points of view. For all androids and humanoids, one photo depicted the face of the robot and the other the whole body or the upper part of the body (Jules and Geminoid DK). Most pictures were taken from websites of the laboratories that developed the robots (see footnotes for a complete list). Information on the lab and/or industry that designed the robots was removed from the photos.

We conducted a pilot study ($N$ = 24, 13 women, 10 men, 1 missing value; $M_{age}$ = 27.09, $SD$ = 2.31) to check that the androids, humanoids and mechanical robots we had chosen differed in terms of anthropomorphic appearance. Participants were presented with all 18 photos (two for each robot) and

[5] http://kmjeepics.blogspot.it/2012/11/toshiba-four-legged-fukushima-robot.html Retrieved November 25, 2013; http://cdn.phys.org/newman/gfx/news/2012/toshibashows.jpg Retrieved November 25, 2013;
[6] http://biorobotics.ri.cmu.edu/media/images/fullscreen/snake7.jpg Retrieved November 25, 2013; http://biorobotics.ri.cmu.edu/media/images/fullscreen/snake5.jpg Retrieved November 25, 2013;
[7] http://crustcrawler.com/products/Nomad/index.php Retrieved November 25, 2013;
[8] http://www.aist.go.jp/aist_e/latest_research/2010/20101108/20101108.html; AIST: National Institute of Advanced Industrial Science and Technology (of Japan). Retrieved November 25, 2013;
[9] http://www.takanishi.mech.waseda.ac.jp/top/research/kobian/KOBIAN-R/img/face_movie.jpg Retrieved November 25, 2013;
http://www.takanishi.mech.waseda.ac.jp/top/research/kobian/KOBIAN-R/img/2009_neutral.JPG Retrieved November 25, 2013;
[10] http://h2t-projects.webarchiv.kit.edu/asfour/Workshop-Humanoids2012/kojiro_small.jpg Retrieved November 25, 2013; http://spectrum.ieee.org/image/1534921 Retrieved November 25, 2013;
[11] http://www.hansonrobotics.com/robot/jules/ Retrieved November 25, 2013;
[12] http://androidegeminoid.blogspot.it/ Retrieved November 25, 2013;

they were asked "how much does this robot remind you of a human being's figure?" (responses were recorded on a 7-point scale ranging from 1 "not at all" to 7 "very much). Subsequently participants were asked to categorize the robots into one of three groups. They were asked to select Group 1 if, in their view, the robots had no or only minimal similarity to humans, Group 2 if the robot was somewhat similar to humans, and Group 3 if the robots showed high similarity to humans.

The results of the pilot study are reported in Table 5. We found that mechanical robots were assigned more frequently to the group of robots with minimal or no similarity to human beings (Group 1), humanoid robots to the group of robots that present only some similarity with humans (Group 2), and android robots to the group of robots presenting high similarity to humans (Group 3). To further explore these findings, we calculated a mean categorization score for the three groups of robots and submitted this to a one-way repeated measures ANOVA (robot: mechanical vs. humanoid vs. android). Least Significant Difference (LSD) was used as post-hoc comparison test. Mauchly's test revealed that the assumption of sphericity was violated, $\chi^2(2) = 17.711$, $p < .001$, and we therefore corrected the degrees of freedom (DoF) using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .64$). A significant main effect was found, $F(1.29, 29.62) = 299.95$, $p < .001$, showing that androids ($M = 6.51$, $SD = .57$)

**Table 5**. Results of a pilot study on anthropomorphic appearance of robots. Means refer to the first question asking about perceived anthropomorphic appearance of the robots used in the studies.

| **A) How much does this robot remind you of a human being's figure?** | | **B) Please indicate to which group each robot belongs.** | | |
|---|---|---|---|---|
| | ***M* (*SD*)** | **Group 1 Minimal or no similarity to humans** | **Group 2 Some Similarity to Humans** | **Group 3 Very similar to humans** |
| PkD | 6.79 (.51) | - | - | 100 % |
| Geminoid DK | 6.75 (.61) | - | - | 100 % |
| Jules | 6.00 (.98) | - | 8.3 % | 91.7 % |
| Kojiro | 3.92 (1.56) | 4.2 % | 95.8 % | - |
| HRP-4 | 3.74 (1.66) | 8.3 % | 91.7 % | - |
| Kobian | 3.67 (1.49) | 4.2 % | 95.8 % | - |
| Toshiba four legged | 1.21 (.42) | 95.8 % | 4.2 % | - |
| Nomad Heavy Robot | 1.04 (.20) | 100 % | - | - |
| Uncle Sam | 1.04 (.20) | 100 % | - | - |

***Notes.*** Means reported of the table reports the means of the answers to the first question of the pilot study. Part B reports the percentage with which each robot was associated to the three different groups.

were perceived as most similar to humans, followed by humanoids ($M$ = 3.76, $SD$ = 1.39), and then by mechanical robots ($M$ = 1.10, $SD$ = .18), all $ps$ < .001.

### 2.3.3 The "Psychological Scale of General Impressions of Humanoids"

We contacted by email professor Kamide, who kindly sent us an English version of PSGIH. The items were thus translated (and back translated) from English to Italian.

From the original scale we excluded 12 items that loaded on the factors referring to movements, voice and sounds of the robots, as we had pictures and not videos of the robots. We created a shortened version that included 28 items the investigated the following original factors: Humanness (8 items: "I could easily mistake the robot for a real person", "I do not get the impression that it is a robot at all when I look at it", "The robot looks like a human", "The robot looks like a robot", "I feel there are human qualities in the robot", "The robot is like a robot in every way", "I think the robot looks too much like a human", and "The robot has a very expressive face"), Familiarity (6 items: "The robot is cute", "I am afraid of the robot", "The robot makes me feel uncomfortable", "The robot is friendly", "The expression in the robot's eyes evokes a feeling of fear in me", and "The robot looks poorly designed"), Repulsion (4 items: "I think the robot will soon control humans", "The robot seems to lessen the value of human existence", "I get the feeling that the robot could damage relations between people", and "The robot could easily be used for evil"), Utility (3 items: "I do not understand why I would need the robot", "I do not know what to use the robot for", and "I do not feel any need for the robot") and Agency (2 items: "The robot looks as if it has a heart", and "The robot looks as if it has its own will").

Finally from Performance factor of PSGIH, 4 items ("I think the robot has superior functionality", "I am amazed at the progress of technology when I look at the robot", "The robot has a high level of understanding", "The robot looks quite expensive") were used as in the original version, whereas the item “The robot responds sensitively to outside stimuli” was adapted to the vision of robots’ pictures and modified in “I have the impression that the robot is able to respond sensitively to outside stimuli”.

As in the original scale, all the items were rated on a 7 point Likert scale with values ranging from 1 “strongly disagree”, to 4 “neither agree or disagree”, to 7 “strongly agree” . The order of the presentation of the items was randomized for each participant.

## 2.4 Results and Discussion

### 2.4.1 The Factors analysis of the PSGIH

A Principal Component Analysis (PCA) with Oblimin rotation ($\delta = 0$) was conducted on the participants responses to PSGHI. Keyser-Meyer Olkin measure of sampling adequacy indicated that our sample was adequate for the PCA analysis (KMO = .82), and Barlett test for social acceptability was also significant $\chi^2(378) = 2173.704$, $p < .001$.

A 7 factors solution that explained the 65.19% of the variance emerged from the analysis (Kaiser criterion, eigenvalues > 1.0) and from the scree plot.

In Table 6, items and their factor loadings are reported.

The first factor was called *Robot Human-like Appearance* and included the items that referred to robot’s look and its physical similarity to human beings. The second factor was named *Robot Warmth* and referred to cuteness, friendship, expressiveness and human qualities attributed to the robot. *Fear toward Robot* was the third factor extracted and its items investigated negative reactions, as fear and discomfort, elicited by the robot. The fourth factor called *Robot Performance* investigated the functionalities and capabilities of the robot. The fifth factor, *Robot Utility*, referred to the advantages in using the robot. *Robot mind perception*, the sixth factor, comprehended the items on perception of the robot as an agent with will and feelings. Finally *Damage to Humans and to Human Identity*, the

**Table 6.** Items and factor loadings

| Items | Robot Humanlike appearance | Robot warmth | Fear toward Robot | Robot Performanc e | Robot Utility | Robot Mind Perception | Damage to Humans and Human Identity |
|---|---|---|---|---|---|---|---|
| I could easily mistake the robot for a real person | **.776** | -.002 | -.067 | -.208 | .091 | -.113 | -.097 |
| I do not get the impression that it is a robot at all when I look at it | **.874** | -.149 | -.040 | .055 | .071 | -.008 | .091 |
| The robot looks like a human | **.691** | .197 | .125 | -.260 | .026 | -.026 | -.098 |
| The robot looks like a robot | **-.887** | .060 | -.007 | -.086 | -.001 | .035 | -.027 |
| The robot is like a robot in every way | **-.762** | -.062 | -.061 | -.219 | .115 | -.036 | .038 |
| I think the robot looks too much like a human | **.569** | .237 | .292 | -.309 | .074 | .157 | -.114 |
| The robot has a very expressive face | .509 | **.522** | .120 | -.135 | .026 | .000 | .055 |
| I feel there are human qualities in the robot | .069 | **.442** | .153 | -.121 | .076 | -.383 | .011 |
| The robot is cute | -.041 | **.719** | -.282 | .032 | -.102 | -.003 | -.198 |
| The robot is friendly | .047 | **.728** | -.039 | -.089 | -.026 | -.062 | .123 |
| I am afraid of the robot | .136 | -.327 | **.716** | -.028 | -.085 | -.113 | -.160 |
| The robot makes me feel uncomfortable | .097 | -.179 | **.800** | .034 | .047 | .031 | -.169 |
| The expression in the robot's eyes evokes a feeling of fear in me | .006 | .087 | **.839** | .046 | -.030 | .024 | -.034 |
| The robot looks poorly designed | -.195 | .110 | .361 | **.556** | .231 | -.120 | .227 |
| I am amazed at the progress of technology when I look at the robot | .068 | .019 | -.147 | **-.728** | -.009 | -.194 | -.035 |
| The robot looks quite expensive | -.131 | .139 | .162 | **-.638** | .023 | .035 | .073 |
| The robot responds sensitively to outside stimuli | -.146 | .187 | .176 | **-.362** | -.112 | -.321 | .120 |
| I do not understand why I would need the robot | .075 | .008 | -.010 | .135 | **.639** | .136 | -.298 |
| I do not know what to use the robot for | .023 | -.172 | -.142 | .002 | **.841** | -.251 | .138 |
| I do not feel any need for the robot | -.030 | .168 | .104 | -.013 | **.632** | .329 | -.114 |
| The robot looks as if it has a heart | .341 | .213 | .111 | .068 | .098 | **-.540** | .146 |
| The robot looks as if it has its own will | -.015 | .169 | .078 | .100 | .056 | **-.702** | -.340 |
| The robot has a high level of understanding | -.105 | .136 | .153 | -.204 | -.127 | **-.621** | -.127 |
| I think the robot has superior functionality | .045 | -.131 | -.120 | -.035 | -.026 | **-.683** | -.031 |
| I think the robot will soon control humans | .014 | .115 | .014 | .191 | -.097 | -.180 | **-.851** |
| The robot seems to lessen the value of human existence | .051 | -.027 | .228 | -.090 | .239 | .027 | **-.613** |
| I get the feeling that the robot could damage relations between people | .066 | -.064 | .225 | -.201 | .307 | .049 | **-.562** |
| The robot could easily be used for evil | -.023 | -.103 | .130 | -.299 | .078 | -.082 | **-.580** |
| Cronbach's α All robots | .89 | .68 | .84 | .57 | .67 | .69 | .76 |
| Cronbach's α Androids | .83 | .65 | .89 | .57 | .79 | .64 | .79 |
| Cronbach's α Humanoids | .67 | .56 | .82 | .53 | .57 | .73 | .73 |
| Cronbach's α Mechanicals | .63 | .59 | .71 | .56 | .61 | .67 | .76 |

**Table 7.** Inter-factor correlation matrix

| | | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 |
|---|---|---|---|---|---|---|---|---|
| **Factor 1** | **Robot Humanlike appearance** | 1 | .415** | .283** | .202** | -.159* | .319** | .345** |
| **Factor 2** | **Robot Warmth** | .415** | 1 | .017 | .431** | .111 | .510** | .108 |
| **Factor 3** | **Fear toward Robot** | .283** | .017 | 1 | -.013 | -.285** | .192** | .513** |
| **Factor 4** | **Robot Performance** | .202** | .431** | -.013 | 1 | .236** | .388** | .182* |
| **Factor 5** | **Robot Utility** | -.159* | .111 | -.285** | .236** | 1 | .118 | -.369** |
| **Factor 6** | **Robot Mind Perception** | .319** | .510** | .192** | .388** | .118 | 1 | .254** |
| **Factor 7** | **Damage to Humans and Human Identity** | .345** | .108 | .513** | .182* | -.369** | .254** | 1 |

**. Significant correlation at level 0.01 (2 tails)
*. Significant correlation at level 0.05 (2 tails)

seventh factor, included the items on participants' worries about the possible social consequences for human beings of the use of this type of robot.

The factors of *Fear toward Robot* and *Damage to Humans and to Human Identity* had negative valence, so higher values on this dimensions meant more negative reactions toward the robot.

We found lower reliability for *Performance* ($\alpha$ = .57), *Robot Warmth*, and *Robot Utility* (although overall acceptable, $\alpha$ = .68 and $\alpha$ = .67, respectively) in comparison with the other dimensions as *Robot Humanlike Appearance* ($\alpha$ = .89), *Fear toward Robot* ($\alpha$ = .84), *Robot Mind Perception* ($\alpha$=.69), and *Damage to Humans and to Human Identity* ($\alpha$ = .76).

**2.4.2 Similarities and differences between the present and the Kamide's results**

Comparing the results of our PCA with the original factor analysis of PSGIH we found, overall, more similarities than differences (Table 8).

As for the original analysis, the first factor included items investigating the physical resemblance of robots to humans. There was an almost complete overlap between the items included in the *Robot Humanlike Appearance* and in the Humanness factor in Kamide's study with the exception of "I feel there are human qualities in the robot" and "the robot has a very expressive face". These items indeed do not refer exclusively to physical appearance but also to other psychological qualities to the robot, and in our analysis loaded at a greater extent in the *Robot Warmth* factor.

We found a perfect overlap between items loading in factors *Robot Utility*, and *Damage to Humans and Human Identity*, and the factors named by Kamide Utility and Repulsion, respectively. We changed the name of this last factor because "repulsion" is a synonym of disgust (Oxford dictionaries online, 2014), which is a feeling related with the possibility of infection (Park, Faulkner & Schaller, 2003; Rozin, Haidt, & McCauley, 2008), while these items seemed to investigate the concerns and social consequences of using these robots for human beings and society.

There was also some overlap between items loaded in the *Robot Performance* and the Performance factor of Kamide scale, with some exceptions. The factor included also the item "the robot looks poorly designed" that in Kamide study was part of the Familiarity factor, whereas the items on high understanding and superior functionalities of the robot, originally part of the *Performance* factor loaded now in the *Robot Mind Perception* factor. This last factor included also the items referring to people perception of robot's cognitive skills and feelings and that loaded in the factor named Agency by Kamide. Given that according to social psychological approach to anthropomorphism agency and feelings are abilities that qualify perception of mind, we changed the name in *Robot Mind Perception* (Gray, Gray & Wegner, 2007).

**Table 8.** Similarities and differences in items loadings and factors between Kamide's original study and the present study

| **Original PSGIH factors** | **Items** | **Present study factors** |
|---|---|---|
| **Humanness** | I could easily mistake the robot for a real person | **Robot Human-like appearance** |
| | I do not get the impression that it is a robot at all when I look at it | |
| | The robot looks like a human | |
| | The robot looks like a robot | |
| | The robot is like a robot in every way | |
| | I think the robot looks too much like a human | |
| | The robot has a very expressive face | **Robot warmth** |
| | I feel there are human qualities in the robot | |
| **Familiarity** | The robot is cute | |
| | The robot is friendly | |
| | I am afraid of the robot | **Fear toward the robot** |
| | The robot makes me feel uncomfortable | |
| | The expression in the robot's eyes evokes a feeling of fear in me | |
| | The robot looks poorly designed | **Robot Performance** |
| **Performance** | I am amazed at the progress of technology when I look at the robot | |
| | The robot looks quite expensive | |
| | I have the impression that the robot is able to respond sensitively to outside stimuli | |
| | The robot has a high level of understanding | **Robot Mind** |
| | I think the robot has superior functionality | |
| **Agency** | The robot looks as if it has a heart | |
| | The robot looks as if it has its own will | |
| **Utility** | I do not understand why I would need the robot | **Robot Utility** |
| | I do not know what to use the robot for | |
| | I do not feel any need for the robot | |
| **Repulsion** | I think the robot will soon control humans | **Damage to Humans and Human Identity** |
| | The robot seems to lessen the value of human existence | |
| | I get the feeling that the robot could damage relations between people | |
| | The robot could easily be used for evil | |

The main differences between the original analysis and our PCA results were found for the factor previously called Familiarity. The items originally included in this dimension were divided mostly in two parts that referred to positive impression and negative feelings toward robots, and loaded on our second and third factor, *Robot Warmth* and *Fear toward the Robot*.

Although there are many similarities between the results of the present and the Kamide' study, some differences emerged as well. These could be attributed to cultural differences between the two contexts (Italy and Japan) and/or some methodological issues that are discussed here below.

First of all, the scale we administered was not translated from Japanese but from an English version that the author made available. Some elements of the original statements might have been lost in translation and these could be responsible for the fact that some items loaded on different factors in the Kamide and our study. Second, the material we used was not identical to that used in Kamide research in many respects. For instance, a different type and number of robots were used. In Kamide study the robots presented to participants were 11 some of which were androids and other (biped or wheeled) humanoids. In the present research the robots were 9, and only 3 were androids and 3 humanoids. In addition we used only photos, whereas in Kamide's study videos of robots were used. Finally, we used a shortened version of the PSGIH, no items on movements, sound and voice were included. Some or all these aspects could be responsible for the differences between the present and the original study.

However, although these differences between the studies, it should be noted that many similarities were found. The most important refers to the factorial structure. Despite that item loadings were not identical, similar dimensions (*Robot Human-like Appearance*, *Robot Performance*, *Robot Mind*, *Robot Utility*, and *Damage to Humans and Human Identity*) emerged in the present and in the Kamide research.

### 2.4.3 Inter-factor correlations

In Table 7 the correlation between the factors are shown. Given that the robots only differed in their appearance we focused on the correlations between the *Robot Humanlike Appearance* and the other factors.

We found a positive correlation with *Robot Mind Perception* ($r$ = .319, $p$ < .01), so that the increase of physical similarity of robots to humans is related with a greater attribution of psychological features, as it is generally suggested in social robotics (Duffy, 2003; Fink, 2012).

We observed a negative correlation between *Robot Humanlike Appearance* and *Robot Utility* ($r$ = -.159, $p$ < .05). Although this correlation was not so strong, it suggests that greater resemblance to human look was related with a lesser understanding of robot's tasks and its usefulness.

We found also some ambiguous results. On one side we observed a positive correlation of *Robot Humanlike Appearance* with *Robot Warmth* ($r$ = .415, $p$ < .01), so that greater similarity of robot to humans affects positively the impressions toward it. On the other side we found positive relation with both *Fear toward Robot* ($r$ = .283, $p$ < .01) and *Damage to Humans and to Human Identity* ($r$ = .345, $p$ < .01). The dimensions of *Fear toward Robots* investigated the negative reactions toward robots and concerns in particular the feeling of beings scared by them. In this respect, this finding is suggestive of possible "expectancy violations and cognitive conflicts" in observing the robots. Finally the correlation with *Damage to Humans and Human Identity* ($r$ =.345, $p$ < .01) suggested that physical appearance of the robot arises a feeling of threat and anxiety similar to those describe in the "social motivational defense" explications of the UV. This issue is going to be further examined in the next chapter. Here we will just discuss the relation between *Robot Humanlike Appearance* and *Fear toward Robots.*

To further understand this relation we calculated the means for the responses to the items loaded on the *Fear toward Robot* factor separately for the androids, humanoids and mechanical robot.

We found that Androids (*M* = 3.05, *SD* = 1.69) were judged as the most fearful kind of robots, followed by Humanoids (*M* = 2.66, *SD* = 1.67) and finally by Mechanicals (*M* = 1.96, *SD* = 1.20). This pattern of results is suggestive of a linear relation between the humanlike appearance of the robots and negative feelings toward the robot.

## 2.5 Conclusions

In the present study we conducted a first attempt to validate the factorial structure of the Psychological Scale for General Impression of Humanoids (PSGIH) in an Italian sample. The results suggest that the PSGIH is a valuable scale to reveal impressions and emotional reactions toward social robots and to be used in the evaluation of social robots.

We found several similarities between the dimensions of the original scale developed by Kamide and the factors of our work. Particularly important for this thesis are the outcomes that showed a strong correspondence between Humanness factor of Kamide et al. (2012) with *Robot Humanlike Appearance*, and a perfect correspondence of Repulsion with *Damage to Humans and Human Identity*. The match between them suggests that these factors are important aspects for the evaluation of robots both for Japanese and Italian people. Similarly a positive correlation between anthropomorphic appearance and perception of possible damage of robots to humans was found in both samples. This result shows that people, independently from their cultural context, link these two dimensions of robots. This issue will be further investigated in the next chapter in which we provided and tested a psychological explanation to this relation.

Moreover we found that, with the exception of *Robot Utility*, all the other factors were positively correlated with *Robot Humanlike Appearance*. This means that with the increasing of robot human likeness it become more difficult for people to understand the usefulness in developing this kind of technology. Interestingly *Robot Humanlike Appearance* was related positively also with *Robot* *warmth* that concerns positive feelings toward the robot. All these results suggest that the increasing of humanlike appearance of robots leads to a greater psychological involvement of people in relating to this kind of machines, but at the same time, it reduces the people's understanding of possible utility of the robot.

# CHAPTER 3 [13]

## Blurring Human-Machine Distinction

### Anthropomorphic Appearance in Social Robots as a Threat to Human Distinctiveness

In this chapter we present a research that aims to gain a better insight into the psychological barriers to the introduction of social robots in society at large. Based on social psychological research on intergroup distinctiveness, we suggested that concerns toward this technology are related to how we define and defend our human identity. A *threat to distinctiveness hypothesis* was advanced. We predicted that too much perceived similarity between social robots and humans triggers concerns about the negative impact of this technology on humans, as a group, and their identity more generally because similarity blurs category boundaries, undermining human uniqueness. Focusing on robots appearance (i.e., mechanicals vs. humanoids vs. androids), in two studies we tested the validity of this hypothesis. In Study 1, we differently reanalyzed the data collected for the validation of PSGIH developed by Kamide et al. (2012) and presented in the previous chapter. In Study 2 new data were collected to test our hypothesis on a new and independent sample and to gain a better insight on the process hypothesized.

## 3.1 Introduction

Technological changes bring innovation but also fears and concerns. From the mechanical innovations in the 19th century to the introduction of computers in the 1980s, enthusiasm toward a new technology coincides with suspicion and worries about its possible negative social impact. A similar combination of excitement and concern surrounds the introduction of social robots in today's world.

[13] This part of the thesis (Chapter 3) was submitted for publication to the International Journal of Social Robotics (see Ferrari, Paladino, & Jetten, 2015).

Social robots are designed to interact and communicate with people (Kanda, Ishiguro & Ishida, 2001; Lee, Kim & Kim, 2006) and they vary in terms of capacities and appearance — from virtual to humanlike. A recent 2012 Eurobarometer (European Commission, 2012) survey into public attitudes toward robots showed that not everyone is unconditionally positively disposed towards this relatively new technology. Whereas the majority (70%) of respondents reported positive attitudes towards robots, many respondents wished to restrict the domains of life where these robots would be used. For example, more than 60% of respondents indicated that it would be inappropriate to utilize these robots to assist in the care and monitoring of the elderly, children and disabled people.

A more fine-grained analysis suggests that the introduction of social robots leads to questions about human essence and what makes us unique as human beings (Kamide et al., 2012); MacDorman, & Ishiguro, 2006).

Why do people fear that the introduction of social robots will have such a negative impact on humans and their identity? Answering this question would enable us to understand the reasons for resistance to this technological innovation. This would be important because the widespread use of social robots in society at large is only possible when psychological barriers to the introduction of robots in our lives have been removed.

While fear responses can easily be discarded as irrational or caused by people's resistance to change, we argue that social robots pose a specific threat to people. Specifically, social robots, because they are designed to resemble human beings, might threaten the distinctiveness of the human category. According to this *threat to distinctiveness hypothesis,* too much perceived similarity between social robots and humans triggers concerns because similarity blurs the boundaries between humans and machines and this is perceived as damaging humans, as a group, and as altering the human identity. In two studies we put this hypothesis to the test by focusing on robots' anthropomorphic appearance (i.e., the extent to which the robot resembles a human body). In elaborating our predictions, we draw on social robotics' work examining the consequences of robots human-likeness and on social psychological research examining the effect of threat to distinctiveness on intergroup relations. Both lines of research will be reviewed in the next paragraphs.

### 3.2 Related work

The *threat to distinctiveness hypothesis* resembles to some UV theorizing in its reasoning why a robot's anthropomorphic appearance should be perceived as threatening. As we described previously (Chapter 1, paragraph 1.4.3), this hypothesis refers to a "social motivational defense" account to the UV. According to this standpoint, we fear of very humanlike robots, as androids, as they challenge the categorical distinction between human and non-humans (at least in their appearance). Undermining human uniqueness, it forces us to redefine our-selves and humanness in general (Ramey, 2005).

Similarly to *threat to distinctiveness hypothesis* that we advance in the present research, these authors argue that "too much similarity of robots to humans" gives rise to fears that this new technology will impact negatively on humans as a group.

Note however that despite the fact that there are now a number of studies that have tested UV theory predictions (e.g., MacDorman & Ishiguro, 2006; Rosenthal-von der Pütten, Krämer, Becker-Asano, Ogawa, Nishio & Ishiguro, 2014), to our knowledge, only MacDorman and Entezari (2015) have empirically examined processes related to human-robot distinctiveness. Focusing on the role of individual differences, in a recent correlational study involving a US sample, they found that the extent to which participants conceived of robots and humans as mutually exclusive categories predicted higher feeling of eeriness and lower warmth toward androids. Although the MacDorman and Entezari study underlines the importance of human-robot distinctiveness in the emotional reactions toward robots with a high anthropomorphic appearance, it is worth noting that this study does not provide a direct empirical test of the *threat of distinctiveness hypothesis* advanced in the present research because robot and human likeness was not manipulated. In addition, and more importantly, these researchers examined the participants' uncanny feelings toward androids (i.e., eerie vs. warm). It remains to be seen whether (as examined in the present research) the relationship between robot-human likeness and uncanny feelings map onto concerns about the potential damage to humans and to their identity when robots are introduced into society.

Answering this question is important to understand reasons of societal resistance toward the use and the development of this technology. To do so, we engage with a large body of social psychological work examining the effect of threat to distinctiveness on intergroup relations. Focusing on human groups, studies inspired by the Social Identity Theory (Tajfel & Turner, 1979) have repeatedly shown that people are motivated to see the social groups they belong to as distinct and different from other groups (Tajfel & Turner, 1979; Brewer, 1991). By understanding how their own group is different from other groups, group members better understand what makes their group unique (the so called "reflective distinctiveness hypothesis"; see Jetten, Spears & Manstead, 1996; Jetten, Spears & Manstead, 1997). Concerns arise then when there is too much similarity between their own group and another group. Too much intergroup similarity is threatening because it undermines the clarity of intergroup boundaries and challenges that what makes their own group distinctive. One way to cope with this threat is to restore intergroup distinctiveness by differentiating their own group positively from the outgroup (the so called "reactive distinctiveness hypothesis", see Jetten, Spears & Manstead, 1996; Jetten, Spears & Manstead, 1997).

We propose that similar processes are at play in relations between humans and robots. As social psychological research on folk conceptions of humanness has shown (Haslam, 2006; Vaes, Leyens, Paladino, & Pires Miranda, 2012), robots represent a relevant comparison group for humans. Therefore, people tend to spontaneously compare humans with machines to identify core human characteristics. Robots that are able to take on roles typically enacted by humans might thus represent a challenge to human-machine distinction and therefore their introduction in the society is met with greater resistance. Along these lines, in a recent survey investigating hopes and fears toward social robots, Enz, Diruf, Spielhagen, Zoll, and Vargas (2011) found that negative attitudes were expressed by respondents who read hypothetical scenarios in which robots were described to have rights equal to humans (i.e., citizenship) or took on roles such as school teacher (e.g., grading the tests of the pupils). It remains to be examined whether robots human-like appearance might also represent a challenge to human-machine distinctions.

The *threat to distinctiveness hypothesis* (and the *reactive distinctiveness hypothesis* in particular; see Jetten, Spears & Manstead, 1996; Jetten, Spears & Manstead, 1997) contributes to a better understanding of why people fear the impact of social robots on human identity and allows us to identify the type of robots that should be most threatening to humans. More specifically, concerns over intergroup distinctiveness would lead us to predict that robots with an high anthropomorphic appearance, that is those robots that, because of their physical appearance, can be confused with humans (i.e., androids), would be the most threatening.

Thus, in line with the distinctiveness threat hypotheses, we expect that for humans, the thought that androids would become part of our everyday life should be perceived as a threat to human identity because this should be perceived as undermining the distinction between humans and mechanical agents.

There is another reason why highly anthropomorphic robots as androids should be perceived as threatening than humanoids. Because of the human-like appearance of anthropomorphic robots and the inability to distinguish them from real humans, such robots could pass themselves off as humans. In other words, they would be able to interact in a human world without being detected and without being recognized for what they really are — and thus they would be imposters. We define imposters in line with a definition put forward by Hornsey and Jetten (2003). An imposter is an individual who publicly claims a group identity (i.e., being vegetarian, being gay, etc.), even if he/she fails to meet all or part of the criteria for group membership (e.g., not eating meat, having heterosexual relationships). An impostor is thus not a genuine group member, but one who tries to pass as if he/she were, hiding his/her true nature. Jetten, Summerville, Hornsey, and Mewse (2005) noted that imposters typically receive very harsh reactions once discovered, especially by members of the group in which they trespassed, as they are perceived as damaging the identity of the group they pretend to be part of (Warner, Hornsey & Jetten, 2007) and because they blur the boundaries between groups (Jetten, Summerville, Hornsey, & Mewse, 2005; Warner, Hornsey, & Jetten, 2007). For instance, Warner and colleagues (Warner, Hornsey, & Jetten, 2007) showed that a straight person claiming to be gay was judged by homosexual participants as blurring the boundaries between groups, boundaries that are important for group members as they contribute to self-definition. Even though robots with a highly anthropomorphic appearance may not autonomously decide to pass as a human being, their threat lies in the fact that they have the capability to dilute human identity: it increases the number of those that can appear or act as "humans" but at the same time it waters down the essence of what means to be human (Jetten, & Hornsey, 2010).

### 3.3 Overview of the research and hypotheses

Given the economic investment in the development of social robots and the likelihood that social robots will increasingly become part of everyday life, it is important to understand the reasons why people fear and resist this development. Several lines of work (reviewed above) suggest that too much similarity between robots and humans threatens the uniqueness of the human category. We predicted that androids (i.e., robots high in anthropomorphic appearance) in particular should be perceived to threaten intergroup distinctiveness (because they can pass themselves off as humans) are perceived to undermine intergroup boundaries and threaten human identity.

We conducted two studies to test these hypotheses. In both studies (using a between-subjects design in Study 1 and a within-subjects design in Study 2) we presented participants with pictures of three types of robots that differed in their anthropomorphic outlook, varying from no resemblance to humans (mechanical robots), to some body shape resemblance (biped humanoids) to a perfect copy of human appearance (androids). After exposure, we measured the damage that these robots are perceived to cause to humans as a group. We predicted that the perceived damage to humans and their identity would be the highest for androids and the lowest for mechanical robots, with damage perceptions for humanoids in between these two conditions (H1). In addition, in Study 1 we also examined attribution of human qualities and a mind, and predicted, in line with previous findings (Gray & Wegner, 2012), that mind attribution would be related to the anthropomorphic appearance of the robots, hence to be highest for the android, followed by the humanoid and lowest for mechanical robots. Importantly we expected that robot anthropomorphic appearance, as it elicits a threat to distinctiveness, would be responsible for the perceived potential damage of the robot to human essence and identity (H2).

In Study 2, we aimed to provide a more direct test of the *threat to distinctiveness hypothesis* asking participants to report to what extent androids, humanoids and mechanical robots were perceived as undermining the human-machine distinction (distinctiveness threat), and their perceived potential damage to humans and human identity. We expected that the perception of undermining human-machine distinctiveness would be highest for the androids and lowest for mechanical robots with treat perceptions for humanoids falling in between these two conditions (H3). Following the threat to distinctiveness account, we predicted that anthropomorphic appearance would elicit the perception that human distinctiveness is undermined (H4a), and this in turn would be responsible for the perception of potential damage to humans and human identity when robots enter into society (H4b).

## 3.4 Study 1

### 3.4.1 Method

***Participants***

Participants were the same of previous study on Validation of PSGIH in an Italian sample, (*N* = 182, 91 women, 89 men, 2 missing values) aged between 19 and 63 years ($M_{age}$ = 27.70, *SD* = 6.36), and 64% of them reported to have a university degree. For this study we used the same data set of the previous experiment. Participants, after PSGIH, were asked to complete items that investigated other dimensions (for a detailed description see below).

***Material: Photos of Robots***

We used the same 18 photos of previous study on validation of PSGIH in an Italian sample. These pictures depicted 3 mechanical (i.e., the four legged explorer robot of Toshiba, the Modular Snake Uncle Sam , and the Nomad Heavy Duty Wheeled Robot), 3 humanoid (HRP-4, Kobian and Kojiro), and 3 android robots (Philip K Dick, Jules and Geminoid DK), each with 2 photos (300 pixel width, 400 pixel height).

***Material: Human nature traits***

Forty traits were used to measure the attribution of Human Nature traits toward the robots. These traits were chosen on the basis of a pilot study in which participants (*N* = 48, 32 females, 16 males; $M_{age}$ = 24.83, *SD* = 3.8) were asked to rate 71 traits on the two dimensions of humanness identified by Haslam (2006). Specifically, Human Nature attributions was assessed ("Is this feature typical of the Human Nature, as it makes us human and therefore different from machines?") as well as Human Uniqueness ("To what extent each of the following characteristics is uniquely human, and therefore is not present in other animal species?"). We also assessed the valence of the trait ("Indicate for each trait to what extent it is, in your opinion, positive or negative"), and the appropriateness of the trait to describe a robot ("Would you use this feature to describe a robot, its functions and behavior?").

**Table 9.** Traits high and low in human nature.

| High Human Nature | Low Human Nature |
|---|---|
| Aggressive | Accurate in reasoning |
| Ambitious | Active |
| Childish | Analytic |
| Comfortable | Cold |
| Conscientious | Competent |
| Determined | Conservative |
| Easily distractive | Disinterested (no ulterior motives) |
| Friendly | Do the things automatically |
| Frivolous (fatuous) | Hard-hearted |
| Impatient | Ignorant |
| Impulsive | Unsophisticated (simple-minded) |
| Irresponsible (does not want to take responsibility) | Passive |
| Judicious | Rational |
| Not self-confident | Refined mentality |
| Pleasant from an interpersonal perspective | Reliable (of which you can be trusted) |
| Pleasant | Repetitive |
| Rude | Shallow |
| Sensible | Skillful |
| Sympathetic | Strict |
| Wary | Unable to collaborate |

From the 71 traits, we selected 20 traits high in human nature and 20 traits low in human nature (Table 9) that were equivalent in terms of valence, $t(47)=-.425$, $p>.05$, and that did not differ in terms of uniquely humanness, $t(25) = -.337$, $p > .05$. In addition, all selected items were judged to be appropriate to describe robots.

***Procedure***

Participants were contacted via-email and Facebook and invited to take part in an on-line study assessing people's opinions of robots. Participants were informed that data collection would be anonymous, that their responses would remain confidential and that they had the right to withdraw from the study at any stage without penalty. Once consent was obtained, participants were directed to a questionnaire showing pictures of one robot. Robot anthropomorphic appearance was manipulated between-subjects (androids vs. humanoids vs. mechanical robots). After viewing the pictures, participants completed a questionnaire including, among others, measures that are of interest to test the threat to distinctiveness hypothesis.

***Dependent Variables***

We relied on the work of Kamide et al. (2012), and used items of the PSGIH validated on an Italian sample (see chapter 2), when relevant, to measure the constructs under investigation. We relied on the validation of the PSGIH on an Italian sample (see Chapter 2). However, in the analysis some subscales were adjusted to better fit the goal of the present research (changes are presented and highlighted in the text).

***Anthropomorphic and Robotic Appearance***

An index of robot *Anthropomorphic Appearance* was created by averaging responses to the following three items: "I could easily mistake the robot for a real person", "The robot looks like a human", "I think the robot looks too much like a human" ($\alpha$ = .88). We created another index of Robotic Appearance averaging the responses to the items: "I do not get the impression that it is a robot at all when I look at it" (reverse scaled), "The robot looks like a robot", and "The robot is like a robot in every way" ($\alpha$ = .85). In the original PSGIH scale (Kamide et al., 2012; see also results of previous studies on validation of PSGIH) these items loaded on the same factor (labeled "Humanness"). Given that our hypotheses concern robot Anthropomorphic Appearance and not *Robotic Appearance* (see also the result session), we kept these set of items separate[14].

***Damage to Humans and to Human Identity***

Four items were used to assess perceived damage that the entering of the robot would cause on humans and their identity: "The robot seems to lessen the value of human existence", "I get the feeling that the robot could damage relations between people", "The robot could easily be used for evil (to fool, to harm, etc.)" and "I think the robot will soon control humans". Responses to these items were

[14] This factor included also 1 item assessing the human qualities attributed to the robot. This item will not be further considered as it is not relevant to assess the validity of the current hypotheses.

averaged to create an index of *Damage to Humans and to Human Identity* (α = .78). In the original PSGIH scale, these items concerning the potential social damage of robots loaded in the so-called "Repulsion - anxiety toward the existence of robots" factor.

Responses to measures tapping Anthropomorphic appearance, Robotic appearance and Damage to Humans and to their Identity were recorded on a 7-point Likert scale with values ranging from 1 = "strongly disagree", to 4 = "neither agree or disagree", to 7 = "strongly agree".

***Mind and Human Nature traits attribution***

Participants were asked to what extent the robots seemed like to have the following *Mind Experience* and *Mind Agency* capacities: fear, pain, pleasure, joy (for mind experience) and planning, emotion recognition, self-control, morality (for mind agency). An example item is: "it seems like this robot can feel pain". These capacities were chosen on the basis of a factor analysis by Gray, Gray and Wegner (2007) confirming these items well capture (i.e., highly loaded in the factor) the two types of minds. An index of mind experience attribution (average of the items' responses; α = .95), and another for mind agency (average of the items' responses; α = .71) were created. Responses were registered on a 7-point Likert scale ranging from 1 "not at all" to 7 "completely.

Participants were asked to what extent each of the twenty traits high and the twenty traits low in human nature were descriptive of the robot ("To what extent does this feature describe the robot in the picture?"). The order of presentation of the traits was randomized for each participant. Participants recorded their answers on a 7-point Likert scale (1 "not at all" to 7 "very much"). The responses to the 20 *High Human Nature* (α = .89) and the 20 *Low Human Nature* traits (α = .85) were averaged to create an index of high human nature and an index of low human nature robot attribution.

At the end of the questionnaires we asked participants to indicate their age, sex, education, and the device they use to respond to the questionnaire. Finally, participants were presented with a debrief and an email address in case they would like further information.

### 3.4.2 Results

Preliminary analysis including sex of the participants showed that this variable influenced the results for the following dependent variables: ratings of anthropomorphic appearance, damage to humans and to human identity, mind agency and high human nature traits attribution. These variables were analyzed in a Robot (mechanical vs. humanoid vs. android) X Participant sex between subjects ANOVA. For the rest of the variables, data were submitted to a one-way between subjects ANOVAs (Robots: mechanical vs. humanoid vs. android). In all cases, Least Significant Difference (LSD) were used as the post-hoc comparison test following up significant effects. The results for all dependent variables are presented in Table 10.

***Anthropomorphic and Robotic Appearance***

An ANOVA revealed an effect of Type of Robot on *Anthropomorphic Appearance*, $F(2,174) = 201.87$, $p < .001$, indicating that our manipulation was successful. Androids were judged as most similar to human beings ($M = 4.91$, $SD = 1.34$), followed by humanoids ($M = 2.15$, $SD = 1.1$) and then by mechanical robots ($M = 1.22$, $SD = .62$), all comparisons, $ps < .001$. Interestingly, the Type of Robot X Participant sex interaction was significant, $F(2, 174) = 3.09$, $p = .05$, showing that the tendency to judge androids and humanoids appearance differed between female and male participants. Androids tended to be rated as more human-like by female ($M = 5.16$, $SD = 1.22$) than male participants ($M = 4.68$, $SD = 1.43$), $F(1, 174) = 3.11$, $p=.08$, whereas humanoids were judged as slightly more human-like in appearance by male ($M = 2.38$, $SD = 1.13$) than female participants ($M = 1.92$, $SD = 1.01$), $F(1, 174) = 2.83$, $p = .10$. It is worth noting that both effects were only marginally significant, and more importantly, that the interaction did not alter the success of our manipulation. Indeed, when examining effects separately for male and female participants, we found the Type of Robot main effect both for female, $F(2, 88) = 126.16$, $p < .001$, and male participants, $F(2, 86) = 81.58$, $p < .001$. Both male and female participants judged androids as most human-like, followed by humanoids, and then mechanical robots (all mean comparisons *ps* < .02).

The three types of robots also differed in *Robotic Appearance*, *F*(2, 177) = 86.63, *p* < .001. Interestingly, Humanoids (*M* = 6.23, *SD* = .91) were judged as the robots with most typical appearance, followed by the mechanicals (*M* = 5.07, *SD* = 1.73) and finally by androids (*M* = 2.99, *SD* = 1.33), all *ps* < .001.

Taken together, these results show that androids were perceived as most resembling humans and least resembling robots. Interestingly, humanoids were judged to have the most robotic appearance of all three robot types suggesting this kind of robots best represents the mental schema of "robot" in participants' mind.

***Damage to Humans and to Human Identity***

Consistently with H1, there were differences between conditions in perceived damage to humans and to their identity, as indicated by the type of robot main effect, *F* (2, 174) = 9.00, *p* < .001. Specifically, androids were judged as potentially more damaging (*M* = 3.23, *SD* = 1.51) than humanoids (*M* = 2.62, *SD* = 1.32) and as more damaging than mechanical robots (*M* = 2.19, *SD* = 1.28), all *ps* < .02. Humanoids were perceived as marginally significantly more damaging than mechanical robots, *p* = .08. The main effect for participant sex was also significant, *F* (1, 174) = 5.68, *p* < .02, highlighting that females were more concerned about robots (*M* = 2.91, *SD* = 1.54) than males (*M* = 2.44, *SD* = 1.27).

***Mind attribution***

We also found that mind attribution was influenced by Type of Robot, *F* (2, 177) = 10.45, *p* < .001. *Mind experience* was attributed most to androids (*M* = 2.39, *SD* = 1.58), followed by humanoids (*M* = 1.80, *SD* = 1.22), and by mechanical robots (*M* = 1.35, *SD* = .84), all comparisons were significant, *ps* = .05.

For *mind agency* attribution, a main effect of Type of Robot, *F* (2, 174) = 4.47, p < .02 emerged. Mechanical robots (*M* = 2.50, *SD* = 1.16) were attributed less mind agency than androids (*M* = 3.17, *SD* = 1.37), *p* < .005, and (albeit only marginally significantly so) less mind agency than humanoids (*M* = 2.89, *SD* = 1.24, *p* = .09). Androids and humanoids were not significantly different from each other, *p* > .22. However, this main effect was qualified by an interaction between robots and participants sex, *F* (2, 174) = 3.43, *p* < .04. Separate one-way ANOVAs for male and female participants showed that the tendency highlighted by the main effect was present only for male participants, *F* (2, 86) = 7.23, *p* < .002. Mind agency was judged to characterize androids (*M* = 3.35, *SD* = 1.45) and humanoids (*M* = 3.16, *SD* = 1.21, not significantly different from each other p > .54), more so than mechanical robots (*M* = 2.21, *SD* = 1), all comparison with mechanical robots, *ps* < .005. In contrast, for female participants, there were no differences between conditions, *F* (2, 88) = .64, *p* > .52.

***Human nature traits attribution***

Analysis of *Human Nature traits attribution* revealed a main effect of Type of Robot, *F* (2, 174) = 9.09, *p* < .001. Androids (*M* = 2.86, *SD* = .90) were evaluated to possess these traits to a greater extent in comparison to mechanical robots (*M* = 2.15, *SD* = .87), *p* < .01, and only marginally significant more so than humanoids (*M* = 2.57, *SD* = .97), *p* = .08. Humanoids were judged to possess High Human Nature traits to a greater extent than mechanical robots, *p* < .02. There was also a marginal significant effect of participant sex, *F* (1, 174) = 3.59, *p* = .06, showing the tendency for females (*M* = 2.40, *SD* = .92) to attribute less high human nature traits to robots compared to males (*M* = 2.66, *SD* = .98).

An ANOVA revealed no main effect of Robots on *Low Human Nature traits*, *F* (2, 177) = 2.20, *p* > .11.

***Testing the role of anthropomorphic appearance on perceived damage to humans and their identity: Mediation analysis***

The results suggested a linear pattern between the increase of robots' anthropomorphic appearance and the perceived damage to humans and their identity. To further assess this relation we conducted additional analyses ($N$ = 181) to verify whether ratings of anthropomorphic appearance mediated the effect of robots on perceived damage to humans and their identity. All the analyses were conducted with INDIRECT, a macro for SPSS provided by Preacher and Hayes (2008; see also Hayes website, n.d).

We first regressed the potential mediator, anthropomorphic appearance, and then the dependent variable, damage to humans and their identity, on our independent variable, type of robot (coded as continuous variable, Mechanic = 0, Humanoid = 1, and Android = 2; for similar approach see Hahn-Holbrook, Holt-Lunstad, Holbrook, Coyne, & Lawson, 2011; Legault, Gutsell, & Inzlicht, 2011; Waytz, Heafner, & Epley, 2014). In line with the previous analysis, these regressions showed a significant effect both on anthropomorphic appearance ($b$ = 1.84, $SE$ = .11, $t$(179) = 17.56, $p$ < .001), and damage to humans and their identity ($b$ = .51, $SE$ = .12, $t$(179) = 4.12, $p$ = .001). Subsequently, we regressed damage to humans and their identity simultaneously on anthropomorphic appearance and type of robot, and found that anthropomorphic appearance was positively associated with the dependent variable ($b$ = .39, $SE$ = .08, $t$(179) = 4.63, $p$ < .001).

We tested the overall significance of mediation using the bootstrap method recommended by Fritz and MacKinnon (2007). For this analysis, the 95% confidence interval of the indirect effect was obtained with 5000 bootstrap resamples. We constructed bias-corrected confidence intervals around the product coefficient of the indirect (mediated) effect using the SPSS macro Preacher and Hayes (2008) created. The product coefficient is based on the size of the relationship between the independent variable and the mediator and the relationship between the mediator and the dependent variable. The indirect effect was .71, with a confidence interval ranging from .32 to 1.2. Because the confidence interval does not include zero, the indirect effect was significant. Finally, the analyses indicated that the direct effect of robots on perceived damage to humans and their identity did not reach significance ($b$ = .20, $SE$ = .19, $t(179) = 1.04$, $p > .3$), when controlling for ratings of anthropomorphic appearance, a pattern of results suggestive of full mediation.

Exploratory, we also investigated whether the attribution of mind experience or the attribution of traits high in human nature mediated the effect of type of robots on perceived damage to humans and their identity. Consistent with the ANOVA, "mind experience" and high human nature traits, were significantly affected by type of robot, all $ps > .001$. However, when simultaneous regressing perceived damage to humans and their identity on type of robot and mind experience, this latter variable was not significant ($p > .19$) suggesting that mind experience was not responsible for the effect of damage on type of robot. Likewise, there was no evidence that attribution of traits high in human nature mediated this relationship ($p > .19$)

### 3.4.3 Discussion

Consistent with H1 we found that androids - whose appearance is modeled on that of a human body - raised the highest concerns for the potential damage to humans and human identity, followed by humanoids and then mechanical robots. Importantly, and consistent with H2, mediation analyses demonstrated that it was robot anthropomorphic appearance, and not the attribution of mind and human nature traits that was responsible for the perceived damage that the robot could cause to humans and their identity. All in all, these findings are consistent with the idea that worries and concerns about the impact on humans and on human identity of highly human-like social robots are related to the fact that these robots look so similar to humans that they can be mistaken to be one of us.

### 3.5 Study 2

The aim of Study 2 was twofold. We aimed to replicate Study 1 findings and also sought to test the threat of distinctiveness hypothesis more directly. To do this, in addition to perceived anthropomorphic appearance and perceived damage to humans and human identity, participants were also asked to rate to what extent they perceived that androids, humanoids and mechanical robots were undermining the categories distinction between machines and humans. Following our threat to distinctiveness hypothesis, we expected a similar pattern of results on the perception of damage to humans and their identity (H1) as on a blurring of human-machine distinction measure (H3): androids should be perceived as most threatening and blurring boundaries, followed by humanoids and then mechanical robots. We also examined whether anthropomorphic appearance elicits the threat to human distinctiveness, operationalized as the perception that the human-machine distinction is undermined (H4a), and whether distinctiveness threat is responsible for the perceived potential damage of the robot to human essence and identity (H4b). These hypotheses were tested in a within-subjects design.

#### 3.5.1 Method

***Participants***

Fifty-one participants (49 females and 2 males) aged between 19 and 23 years ($M_{age}$ = 20.2, *SD* = .67) completed the questionnaire. Participants were all students of the Department of Psychology and Cognitive Science of University of Trento, and they received credits for their participation.

***Material***

Two pictures each (97 pixel for width x 130 pixel for height) for 4 Mechanic, 4 Humanoid and 4 Android robots (a total of 24 images) were used. The pictures were the same as used in Study 1, with a few exceptions. In the mechanical robot group, the photos of snake robot Uncle Sam were substituted with those of WowWee's Rovio[15]. In addition, we added the pictures of the tracked robot "TP-600-270"[16] developed by SuperDroid Robots. For humanoids, instead of HRP-4, we used photos of Wabian-2 of Waseda University[17], and those of Tichno R of V-Stone[18]. Finally for the android group, in addition to the photos used in Study 1, we added two images of FACE android developed by FabLab of University of Pisa (Mazzei, Billeci, Armato, Lazzeri, Cisternino, Pioggia, Igliozzi, Muratori, Ahluwalia, & De Rossi, 2010; Mazzei, Lazzeri, Billeci, Igliozzi, Mancini, Ahluwalia, Muratori, & De Rossi, 2011). Similar to Study 1, for mechanical robots, each photo depicted the robot from two different points of view, whereas for humanoid and android robots, one photo depicted the face of the robot and the other the whole body or the upper part of the body (Jules, Geminoid DK, and FACE). The majority of pictures were selected from websites of the laboratories that developed the robots (see footnotes for a complete list), with the exception of the photos of FACE android that were made available by the FACE Lab. As in Study 1, information on the labs and/or industries that developed the robots was removed from the photos.

***Procedure***

Participants, in groups of maximum 10 people, completed the online questionnaire in one of the university labs. After reading and signing the informed consent, they were invited by the experimenter to start the study. The study was presented as an investigation of opinions toward different kinds of

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[15] http://blog.tmcnet.com/blog/tom-keating/gadgets/rovio-wi-fi-voip-robotic-webcam.asp. Retrieved November 25, 2013;
[16] http://www.superdroidrobots.com/shop/item.aspx/new-prebuilt-hd2-s-robot-with-5-axis-arm-and-cofdm-ocu-sold/1279/ Retrieved November 25, 2013;
http://www.superdroidrobots.com/product_info/UGV%20System%20Design.pdf Retrieved November 25, 2013;
[17] http://www.takanishi.mech.waseda.ac.jp/top/research/wabian/img/wabi_front2008.jpg Retrieved November 25, 2013;
http://www.takanishi.mech.waseda.ac.jp/top/research/wabian/img/WABIAN-2R_2008.jpg Retrieved November 25, 2013;
[18] http://www.sansokan.jp/robot/showroom/11.html Retrieved November 25, 2013;
http://www.zimbio.com/pictures/p1UElotXSWW/Robot+Venture+Companies+Hold+Joint+Press+Conference/KF3TfpVxLcD/Vstone+Tichno Retrieved November 25, 2013;

robots. At the beginning participants were asked to indicate their age, sex, education and occupation and then they were asked to complete the Humanity Esteem Scale (Luke, & Maio, 2009)[19].

Then, pictures of all robots were presented on a single page, and participants were informed that all the robots depicted were real robots developed by different laboratories. Next, participants were asked to complete, among others, the scales on physical anthropomorphism, threat to human machines boundaries and damage to humans and their identity (and other items that will not be considered here) for androids, then for humanoids and finally for mechanical robots (the order of robots presentations and questions was randomized across participants). All items were presented next to the photos of the robots so that the pictures were always visible.

***Dependent variables***

If not further specified, responses were recorded on a 7-point Likert scale, (1 = "strongly disagree", 2 = "moderately disagree", 3 = "slightly disagree", 4 = "neither agree or disagree", 5 = "slightly agree", 6 = "moderately agree", 7 = "strongly agree").

***Anthropomorphic Appearance***

The same items of Study 1 were used. As previously, an index (average of the responses) for androids ($\alpha = .74$), humanoid ($\alpha = .60$) and mechanical (the Cronbach's alpha was not calculated for the lack of variability in the responses) robot was calculated for each participant.

***Undermine human-machines distinctiveness***

The following three items were used to assess this construct: "This type of robot gives me the impression that the differences between machines and humans have become increasingly flimsy", "Looking at this kind of robot I wonder/ask myself what are the differences between robots and

[19] Exploratory analysis indicated that Humanity Esteem did not moderate any of the findings. For the sake of brevity, these results are therefore not presented here.

humans", and "This type of robot blurs the boundaries between human beings and machines"[20]. These were adapted from the study of Warner et al., (2007). A mean score was calculated for the *undermine human-machine distinctiveness* measure— for androids (α = .83) for humanoids (α = .62) and for mechanical robots (α = .36).

***Damage to humans and their identity***

We used the same four items used in Study 1. The mean *Damage to humans and their identity* score was calculated for each participant — separately for mechanical robots (α = .59), humanoids (α = .72), and androids (α = .70).

**3.5.2 Results**

If not further specified, the data were analyzed in one-way repeated measures ANOVAs (Robots: mechanical vs. humanoid vs. android) and Least Significant Difference (LSD) was used as the post-hoc comparison test. The results for the dependent variables are described below and shown in Table 11.

***Anthropomorphic Appearance***

Mauchly's test revealed that the assumption of sphericity was marginally violated, $\chi^2(2) = 5.69$, $p = .058$, therefore DoF were corrected using Huynh-Feldt estimates of sphericity (ε = .93). As in Study 1, the main effect was significant, $F(1.87, 93.28) = 584.62$, $p < .001$, showing that androids were rated

**Table 11.** Means and Standard Deviation for the dependent variables and the different kinds of robots of Study 2

| Type of Robot | Anthropomorphic Appearance | Undermine Human-Machine Distinctiveness | Damage to Humans and Their Identity |
|---|---|---|---|
| | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) |
| Mechanical | 1.07 (.29) | 1.73 (.82) | 2.78 (1.09) |
| Humanoid | 2.03 (1) | 2.72 (1.26) | 3.08 (1.27) |
| Android | 5.97 (1) | 4.47 (1.61) | 4.16 (1.28) |

*Notes.* Values in each column are significantly different from each other at p < .015.

[20] Initially there was a fourth item ("This type of robot highlights that there are clear differences between humans and machines") that we excluded to increase the reliability of our "undermine human-machine distinctiveness" scale.

as physically most similar to human beings ($M$ = 5.97, $SD$ = 1), followed by humanoids ($M$ = 2.03, $SD$ = 1) and then by mechanical robots ($M$ = 1.07, $SD$ = .29), all $ps$ < .001.

***Undermine human-machine distinctiveness***

Mauchly's test revealed that sphericity was partially violated, $\chi^2(2) = 5.9$, $p = .052$, therefore, we corrected DoF using Huynh-Feldt estimates of sphericity ($\varepsilon$ = .93). There was a significant effect, $F(1.86, 92.95) = 90.4$, $p < .001$, showing that androids were perceived as the robots that blurred the distinctiveness between human and machines to the greatest extent ($M$ = 4.47, $SD$ = 1.61), followed by humanoids ($M$ = 2.72, $SD$ = 1.26) and then by mechanical robots ($M$ = 1.73, $SD$ = .82), all $ps$ < .001.

***Damage to Humans and their Identity***

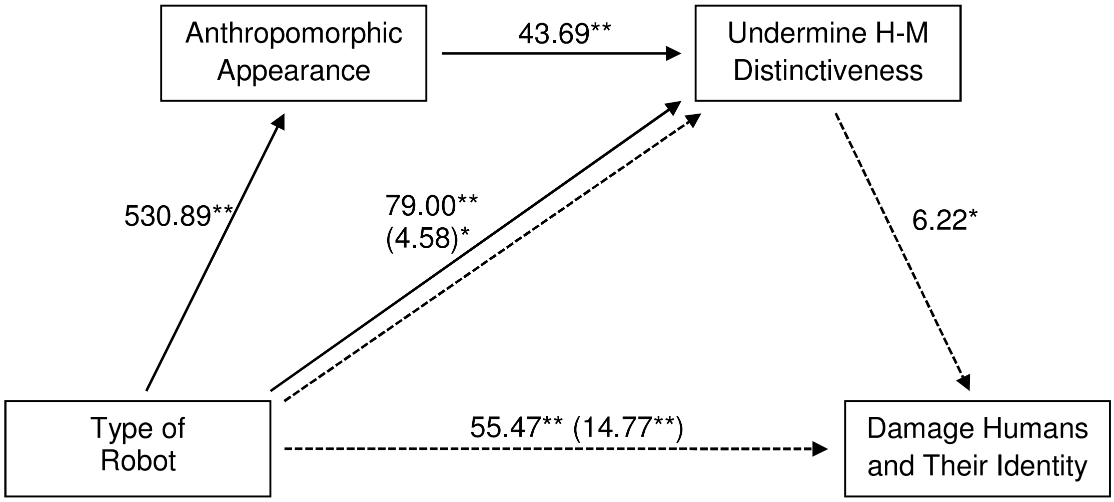
Mauchly's test was not significant, $\chi^2(2) = .944$, $p$ >.24, and sphericity not violated. Type of Robot revealed a significant effect, $F(2, 100) = 65.72$, $p < .001$. As in Study 1, Androids ($M$ = 4.16, $SD$ = 1.28) were perceived as the robots that were most likely to negatively affect humans, followed by humanoids ($M$ = 3.08, $SD$ = 1.27) and by mechanical robots ($M$ = 2.78, $SD$ = 1.09), all $ps$ < .015.

***Anthropomorphic Appearance, Undermine human-machine Distinctiveness, Damage to Humans and their Identity: Mediation analyses***

The results suggest a linear pattern for the increase of robots' Anthropomorphic Appearance, Undermine human-machine Distinctiveness and perceived Damage to Humans and their Identity. Further analysis were conducted to test the role of Anthropomorphic Appearance of the type of robots on Undermine human-machine Distinctiveness (H4a) and then the possible mediation of Undermine human-machine Distinctiveness on the relation between type of robots and Damage to Humans and their Identity (H4b). To this end, we conducted two separate analyses following the approach of *causal steps* (Hyman, 1955; Judd, & Kenny, 1981; Baron, & Kenny, 1986). Through this approach we observed if the effect of kind of robot (factor) on the dependent variable (first Undermine human-machine Distinctiveness and then Damage to Humans and their Identity), was reduced when the mediator (first Anthropomorphic Appearance and then Undermine human-machine Distinctiveness) was included into the analysis/equation. A significant effect of mediator is suggestive of mediation. We analyzed the data using the Linear Mixed Model (LMMs) procedure in SPSS. If not further specified we selected for repeated measures a first order autoregressive (AR1) covariance structure, which assumes that residual errors within each subject are correlated but independent across subjects. Intercept and identity of participants were entered in the model as random effect.

We tested first the mediation of Anthropomorphic Appearance on Undermine human-machine Distinctiveness. When entered as a repeated measure fixed effect, in line with the previous analysis (ANOVAs), we found that Type of Robot significantly affected Undermine human-machine Distinctiveness (dependent variable), $F(2, 73.78) = 79.004$, $p < .001$, and Anthropomorphic Appearance (proposed mediator), $F(2, 68.38) = 530.893$, $p < .001$. In a further LMMs analysis, Anthropomorphic Appearance (covariate) was entered as repeated measure fixed effect and we found that it significantly affected Undermine human-machine Distinctiveness, $F(1, 68.34) = 244.604$, $p < .001$. Finally we entered simultaneously Type of Robot (Independent Variable) and Anthropomorphic Appearance (covariate) as fixed effects. We found that both the effect for Anthropomorphic Appearance, $F(1, 146.13) = 43.692$, $p < .001$, and for Type of Robot, $F(2, 89.98) = 4.581$, $p < .05$, were significant. However, it is worth noting that the influence of Type of Robot was strongly reduced when we included Anthropomorphic Appearance in the equation confirming its role as mediator of the effect of Type of Robot on Undermine human-machine. This pattern of data suggests that robots human-likeness directly increases the perception of robot as a source of danger to humans and their identity: the more the robot's appearance resembles that of a real person, the more the boundaries between humans and machines are perceived to be blurred.

**Figure 3**. Representation of mediation effects between Type of Robot factor, Anthropomorphic Appearance, Undermine Distinctiveness and Damage to humans and their identity.




***Notes.*** The continuous arrows indicate the first mediation analysis between Type of Robots, Anthropomorphic Appearance (Mediator 1), and Undermine Human-Machine Distinctiveness. The dotted arrows describe the second mediation analysis between Type of Robot, Undermine Human-Machine Distinctiveness (Mediator 2), and Damage Humans and Their Identity. We reported the *F* values of LMMs analysis for each relation and indicated in parentheses the *F* values of Type of Robot factor controlling for the mediators. * = $p < .05$; ** = $p < .001$.

We then tested whether Undermine human-machine Distinctiveness mediates the effect on Damage to Humans and their Identity. In line with the previous analysis (ANOVAs), we found that Type of Robot entered as a fixed effect significantly affected Damage to Humans and their Identity, $F(2, 63.89) = 55.465$, $p < .001$. Next, we entered Undermine human-machine Distinctiveness (covariate) as a fixed factor, and we found a significant effect on Damage to Humans and their Identity, $F(1, 88.97) = 73.13$, $p < .001$. A further LMMs analysis was conducted entering simultaneously Type of Robot (Independent Variable) and Undermine human-machine Distinctiveness (covariate) as fixed factors and Damage to Humans and their Identity as the dependent variable. The results showed that both the effect for Undermine human-machine Distinctiveness, $F(1, 124.693) = 6.221$, $p < .015$, and Type of Robot, $F(2, 74.028) = 14.769$, $p < .001$, were significant. However, when we included Undermine human-machine Distinctiveness in the equation, the influence of Type of Robot was reduced. Even though the effect of Type of Robot was still significant, the results are suggestive of mediation by Undermine human-machine Distinctiveness: highly anthropomorphic robots, such as androids, are perceived as damaging humans and their identity because they blur the boundaries between machines and human beings, undermining the sense of *being human* (see Figure 3).

### 3.5.3 Discussion

Consistent with H1 and the findings of Study 1, in Study 2, a clear linear effect emerged on all measures, showing that androids were rated as most anthropomorphic, most of a threat to the distinction between humans and machines and most damaging to humans, as a group, and to their identity (followed by humanoids and mechanical robots). Note that even though androids also elicited highest concerns for the potential damage to humans and their identity in Study 1, that linear relationship was not consistently observed on all measures. One reason for this difference may be that a within-subjects design was used in Study 2 whereby each participant saw and judged every type of robots. This methodological design has the advantage over a between-subjects design in that it better controls for individual differences, and maximizes comparisons between robots. Both aspects could have contributed to the finding that the differences among these three types of robots are more clear-cut in Study 2 compared to Study 1.

In addition, in this study we gained a clearer insight in the underlying processes. The mediational analyses showed that the rating of robot anthropomorphic appearance was responsible for the differences in the perception of undermined human-machines distinctiveness (confirming H4a). In turn, judgments of undermined distinctiveness accounted for the differences in the perceived robots damage to humans and their identity (confirming H4b). All in all, these findings are consistent with a *threat to distinctiveness hypothesis*: participants fear highly anthropomorphic robots, robots that look too similar to humans, as they blur the distinction between humans and mechanical agents.

### 3.6 Conclusion

In the present research we aimed to gain a better insight in the question why people fear the introduction of social robots in daily life. Based on works of Ramey (2005), Kaplan (2004), MacDorman and colleagues (MacDorman, Vasudevan, & Ho, 2009; MacDorman, & Entezari, 2015), and intergroup distinctiveness research (Jetten, Spears, & Manstead, 1996; Jetten, Spears, & Manstead, 1997), we suggested that concerns toward the negative impact of the entering of this technology in our life is related to how we define and defend our human identity. Specifically, we advanced the *threat to distinctiveness hypothesis* suggesting that too much similarity between robots and humans arise concerns as they blur the distinction between humans and mechanical agents and thereby threaten intergroup distinctiveness. In two studies we tested and found support for this hypothesis observing participants reactions to three types of robots that varied from low (i.e., mechanical robots) to medium (i.e., humanoids) to high anthropomorphic appearance (i.e., androids). In Study 1 we found that the increase of physical similarity of robots to real persons mediated the perception of possible damage that this kind of machines can lead to humans and their identity. In Study 2 we focused more on the perception of threat to distinctiveness related to anthropomorphic appearance of the robots. We found two different mediations that supported our hypothesis and help in explaining the fear toward humanlike robots. Specifically, results showed that the undermining of distinction between humans and robots is directly influenced by the anthropomorphic appearance of robots, and that this blurring of boundaries affected the perception of possible damage to humans and their identity.

In the present research we showed that robots that look “too human” and can therefore be mistaken to be one of us give rise to concerns that their introduction into society would negatively impact on humans as a group.

To avoid such resistance, roboticists should invest in the development of robots whose appearance does not challenge the psychological distinction between humans and mechanical agents.

# CHAPTER 4

# General Discussion, Limitations and Future Research

## 4.1 General Discussion

Social robots are machines developed to interact with humans and are expected to play a social role in the near future (Kanda, Ishiguro, & Ishida, 2001). Governments and international institutions are investing in the development of this new technology. However, surveys and questionnaires that investigated public attitudes toward social robots, highlight a concern toward the impact of this type of technology on our everyday life and its possible misuse (Romm, 2015; Eurobarometer, 2012; Kamide, 2012). The present thesis aims to gain some insights concerning the psychological barriers toward the introduction of social robots in the society at large, focusing on the role of social robots' anthropomorphic appearance.

In Chapter 1 we approached this issue by discussing the relevant literature. Specifically, we discussed the reasons that underlie the development of social robots with humanlike appearance and then turned our attention to the UV theory (Mori, 1970). The Uncanny Valley theory holds that human likeness increases *familiarity* and *affinity* toward robots until a certain (undetermined) limit. If the anthropomorphic appearance of the machines exceeds this boundary, and robots resemble too much human beings, it will lead to feelings of eeriness and uncanniness toward the robot. In our analysis, we focused on the theoretical accounts, and relative research, regarding the UV phenomenon. This analysis of the literature led us to identify two related and uninvestigated issues: (a) the difficulty of comparing the results empirical studies due to the use of different questionnaires from study to study, and (b) the relative few researches that examined the relation between anthropomorphic appearance and the social acceptance of social robots. These issues were taken on in the empirical part of the thesis.

Specifically, in Chapter 2 we presented a validation study of the Psychological Scale for General Impressions of Humanoids (Kamide et al, 2012) in an Italian sample. Results showed that the PSGIH is a valuable scale to measure impressions and emotional reactions toward social robots that can be used in the evaluation of social robots. We observed several similarities between the factors found in our study and those highlighted in the original work of Kamide et al. (2012). In particular there were strong correspondences for the items relative to the factor “anthropomorphic appearance” and “anxiety related to the existence of robots” in both studies. The match between them suggests that these factors are important aspects for the evaluation of robots for both Japanese and Italians. Interestingly, *Robot Humanlike Appearance* was positively related to all the dimensions we examined (*Robot Warmth*, *Fear toward Robot*, *Robot Performance*, *Robot Mind Perception*, *Damage to Humans and Human Identity*) except *Robot Utility*. Thus, the more a robot resembles a human being, the more people seem involved at emotional and psychological level. However, the increase of anthropomorphic appearance reduces perception of robots’ utility, so that people do not understand why humanlike robots should be used.

In Chapter 3, we focused on the relation between anthropomorphic appearance and the perception of social robots as damaging for humans and their identity. Specifically, we advanced the *threat to distinctiveness hypothesis*, which proposes that worry and anxiety toward social robots are related to the perception that they undermine to human-machine distinctions. Two studies were conducted and their results supported our hypothesis. We found that the more a robot’s appearance resembles that of a human being, the more it was perceived blurring the boundaries between humans and machines. Consequently, the undermining of human’s distinctiveness led participants to perceive very humanlike robots, as androids, as a potential damage to humans and their identity.

Both lines of studies underline the importance of robots anthropomorphic appearance for the social acceptance of this new technology. Here below, we discuss the implications of the present research for social robotics.

One way to improve robots acceptance is to increase robot familiarity. With this goal in mind, roboticists have developed humanlike robots as they are supposed to elicit responses and behaviors typically shown towards human partners (Duffy, 2003; Fink, 2012). Our research (see Chapter 3) suggests that this goal should however not conflict with "the need for distinctiveness" that typically characterizes intergroup comparisons. Indeed, and as we show here, such concerns extend to humans-robots relations. Robots are more likely to be accepted when differences and distinctiveness from human beings is somehow preserved. In this regard, it should be noted that according to the threat to distinctiveness hypothesis the factor that triggers concerns is not robot-human similarity *per se,* but "too much" similarity which blurs the boundaries between humans and mechanical agents. In the present research, only highly anthropomorphic android robots reached this point. Differently from humanoids and industrial robots, androids (who are built to be perfect copies of human bodies with no visible mechanical elements) were on average judged as "looking too much like a human" and "as easily mistaken for one of us" (see the scores of the anthropomorphic appearance ratings in both studies). At the same time, these robots elicited a feeling of fears (see Chapter 2) and their introduction in society was also judged on average as having a negative impact on humans as a group (see Chapter 3). In this regard, the present research provides empirical support to one of the guidelines proposed by the project "RoboLaw". Funded by the EU, the goal of this research project was to promote a technically feasible, and ethically and legally sound basis for future robotics developments (http://www.robolaw.eu). According to the researchers, one way to reach this goal is to avoid that a robot, including its appearance, could deceive people.

The present findings also have interesting implications for the uncanny valley theory and more generally for theoretical work on the effects of robot-human likeness. According to Ramey (2005), emotional reactions to highly anthropomorphic robots such as androids have to be considered in the context of the fact that these creatures challenge the categorical distinction between humans and machines. Consistent with this, MacDorman and Entenzari (2015) showed that the extent to which humans and robots were considered to be highly distinctive categories (measured as an individual difference) predicted uncanny feelings towards androids. In the present research we extend this finding by showing that distinctiveness is also key to understand resistance and concerns toward the introduction of these robots in society. Indeed, we found that androids (compared to humanoids and mechanical) were most likely to be seen to undermine human-robot distinctiveness (see Chapter 3).

The findings of our research also provide empirical support to Ramey's theorizing (2005) that androids represent a problem for the way we, as humans, define and defend our identity when presented with highly humanlike robots. Consistent with this, we showed that concerns toward androids are similar to those typically registered when responding to impostors: the fear that these individuals could alter the group's identity (Hornsey, & Jetten, 2003; Jetten, et al., 2005; Warner, et al., 2007). Furthermore, drawing a link between responses toward social robots and responses to other type of threats, our research underlines the importance to engage with social psychological theorizing on intergroup relations when designing and evaluating the impact of social robots (see also for other examples of studies in social robotics relying on intergroup relations theorizing Mitchell, Ho, Patel, & MacDorman, 2011; MacDorman, Coram, Ho, & Patel, 2010).

Our findings also help to understand societal resistance toward the introduction of social robots in society, providing a better insight in the question *why* people do or do not fear the use of social robots. Previous studies have shown that social beliefs concerning a technology play an important role. These beliefs can have a direct and an indirect influence (through social influence on what important others think) on its acceptance. For instance, willingness to use assistive social agents technology (e.g., RoboCare robot) among elderly adults depends also on the beliefs on the consequences of the use of that technology. If these are positive (i.e., the robot would make life interesting) and are shared by important others, it has been found that the intention of elderly people to use the robot significantly increases (Heerink, Kröse, Evers, & Wielinga, 2010). In this line of reasoning, our research suggest that robots that do not challenge the human-machine distinctiveness are more likely to be voluntary used and advised to use to others. This turns us to the question of how to design robots that evoke familiar responses and, at the same time, do not challenge human's need for distinctiveness. This will be discussed next.

### 4.2 Limitations and future research

As every research, the present one also has some limitations. The most obvious is that we used photos and not videos or direct interactions with robots. Thus, for the validation study of the PSGIH (Chapter 2) this represents a limitation; we did not conduct a complete validation of the scale, as items related with the robot movement were not included. For the other studies that investigated the relation between human likeness and anxiety toward robot (Chapter 3), this choice likely influenced the possible perception of the robot. Haring, Matsumoto and Watanabe (2013), for instance, found that the android Geminoid-F was rated as less intelligent, lifelike but safer when participants directly interacted with it compared to than when they just watched the photos of the robot. Based on this, it is possible that the use of photos in our studies increased participants' worries and anxiety toward androids. Likely, they might have attributed androids also very humanlike motion and behaviors (according to their appearance), increasing the perception that androids are very similar and could be confounded with real people.

Although a limitation, the use of robot photo as experimental material is common also in other studies investigating the role of robot appearance (e.g., Rosenthal-von der Pütten, & Krämer, 2014) as it allows for optimal control (e.g., no interference with a robot's movement ability that might differ from robot to robot inside the same category). That said, future studies on the societal resistance to the development of robots should also consider more complex and richer materials and contexts. Compared with just viewing a static image, we suggest that interacting with a robot can lead to a different and richer (sensorial and emotional) experience, especially for androids. Becker, Asano, Ogawa, Nishio, and Ishiguro, (2010), for instance, observed that only a minority of people interacting with a Geminoid HI-1 reported some negative feelings. More studies are therefore needed to evaluate whether, but also how, and which direct interactions attenuate (or exacerbate) the perceived fear of damage to humans and their identity.

Another limitation concerns the fact that the participants of our studies were all Italians. This raises the question whether the present findings would generalize to other national samples and cultural contexts. For example, some researchers (MacDorman, Vasudevan, & Ho, 2009) have suggested that, compared to Westerners, Japanese people might be more positive towards robots in general and androids in particular because East Asian culture is more tolerant toward objects that cross category boundaries. Having said that, previous empirical work provides no evidence for cultural differences in these attitudes between the West and East. Specifically, as we observed above, the study of Kamide et al. (2012) showed that also in a Japanese sample androids, compared to humanoids, were judged as more human-like and potentially endangering humans and human identity. In addition, survey studies showed that Japanese and European respondents (Haring, Mougenot, Ono, & Watanabe, 2014) did not differ substantially in their attitudes toward robots and in the belief that robots should not look like humans (for a US and Japanese comparison see also Bartneck, 2008). Nevertheless, we recommend that future studies should further explore potential cultural differences. It may also be of interest to examine how the human-machine divide is affected by other contextual effects relating to, for example, educational background or religious beliefs (see MacDorman and Entzari, 2015).

Future research should also focus on gaining a better understanding of the type of threat that robots, and especially androids, pose. In our study we relied on the Kamide et al. scale (2012) to assess the perceived damage to humans and their identity, as this scale has good psychometric properties and was created following rigorous piloting. This said, we acknowledge that this scale includes items assessing different fears than those relating specifically to threat to human identity (e.g., fear that humans could lose control, fear of being physically harmed, concerns about losing identity value and specificity, etc.). Even though we found in our studies that these different fears were highly correlated and that the pattern of results is similar for each of the items, future studies are needed to examine whether different types of robots pose different types of threat (e.g., androids might threaten human identity, whereas mechanical and humanoids robots are more threatening because people might fear being replaced by a robot in the workplace). It may also be worthwhile to examine whether androids represent not only a threat to humans and human identity but also a threat to the natural world more generally.

Finally, we want to discuss some ideas - that could be pursued in future research - on ways to prevent this threat to human distinctiveness to arise. Studies in social psychology would suggest that increasing the differences between humans and robots would preserve the human need for distinctiveness even when facing robots high in anthropomorphic appearance. For instance, adding a distinctive marker on androids (e.g., a tattoo or a specific dress) would create a visible difference and facilitate the identification and the distinction of these robots from humans. Note however that this would not alter the fact that androids are mechanical agents with a biological appearance. According to recent studies (Burleigh, Schoenherr, & Lacroix, 2013) stimuli that merge human and non-human features elicit a state of discomfort and fear as they activate competing interpretations. Following this line of reasoning, adding a marker may not be sufficient to preserve human distinctiveness, as the threatening element of androids would be the mix between human and mechanical features.

Future studies should also investigate whether other robot features, beyond those relating to that of appearance, can contribute to overcoming the resistance towards this technology. For example, Sorbello, Chella, Giardina, Mishio, and Ishiguro (2014), suggested that the robot's ability to show empathy towards humans would improve its acceptance. Results of their study are fascinating and at odds with those of Gray and Wegner (2012) showing that the ability of experiencing and understanding emotions increased rather than decreased robot Kaspar's (http://www.herts.ac.uk/kaspar) creepiness. One way to reconcile these contrasting findings is that people generally expect a match between the robot's appearance and behavior (see also Saygin et al., 2012). Although the present research was not designed to address this issue, it provides some indirect evidence in support of this reasoning. We found indeed that, compared to humanoids and mechanical robots, androids were judged as looking most like humans but also as behaving somehow more humanly, given that they were rated to possess to a greater extent qualities typical of human mind and nature (Chapter 2 and 3). Interestingly, the higher attribution of human mind and human traits did not account for the higher threat to distinctiveness and perceived damage to humans and their identity elicited by robots with an anthropomorphic appearance. This finding leaves open the possibility that humanlike behavior in androids would not increase the negative feelings towards these robots. Exploratory, we calculated correlations between worries of damage to humans and their identity and mind experience attribution separately for androids and humanoids and we found that the more a humanoid robot was perceived as having a mind experience (e.g. the abilities of feeling emotions), the more negative was the reactions toward this type of robot. Differently this relation between mind experience and negative reaction toward robots was not significant for androids robots. Thus, the ability to feel emotions and other human abilities can be perceived as a negative aspect if the robot is clearly machinelike (see Gray, &

Wegner, 2012), but it seems something more appropriate if the robot resemble a real person in details as androids. However, further studies are needed to further explore this possibility in details.

### 4.3 Conclusion

The present research contributes to the ongoing debate on the advantages and disadvantages of anthropomorphic appearance in social robots. We showed that robots that look “too human” and can therefore be mistaken to be one of us give rise to concerns that their entering in the society would negatively impact on humans as group. To avoid people resistance, roboticists should develop robots whose appearance does not challenge the psychological distinction between humans and mechanical agents. The present thesis also highlights the importance of social psychological theories to better understanding the processes that underlie people’s reactions toward social robots.

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