博士論文

Perception and Acceptability of Robots in the First Time Interaction

(ロボットの認識と心理的受容性に関する研究:
初対面の場において)

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A thesis presented for the degree of
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THE UNIVERSITY OF TOKYO

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Dedicated to

My parents

论文の内容の要旨

Thesis Summary

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Robots no longer belong to the world of science fiction – they are reality, and sooner rather than later, they will have a real impact on the way we live our lives. If robots are to coexist with people, then it is highly important that we investigate how people perceive and how they accept robots in their personal space when they first encounter them. Despite the display of advanced human robot interaction in popular culture, people are not yet interacting directly with them. This thesis focuses on the perception people form when they interact for the very first time with a robot. It explores how the robot's appearance and behaviours influence people's view of anthropomorphic social robots.

Four series of studies were conducted to investigate the details of human perception, attitude, and acceptability of robots in human robot interaction. First, the influence of a robot's appearance on people's assessment was evaluated by using four different types of robots, and found that participants assessed distinct robot types significantly differently. The second and third series then focused on the perception of two selected robot types, a humanoid and an android robot. This series also measured the level of trust shown towards the android robot with an economic trust game. The fourth series explored the influence of cultural differences on the perception and trust of robots. The findings in this thesis highlight the necessity to quantitatively measure and understand the perception of robots and their acceptance in first time interactions. The results are discussed and can be used for future development in successfully integrating robots into our society.

Acknowledgements

First and foremost I offer my sincerest gratitude to my advisor Prof. Katsumi Watanabe for his continued support. Not only has his expertise, motivation, enthusiasm and understanding added considerably to my graduate experience, he also assisted me extensively in writing reports (i.e., grant proposals, scholarship applications, research papers and this thesis). I appreciate his vast knowledge and skills in the area of Cognitive Science which never ceases to impress and motivate me to improve my research. Without his support, the whole experience of my stay in Japan and this thesis would not have been possible. I could not have imagined having a better advisor and mentor for my Ph.D study.

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I must also acknowledge the financial support I received during my time in Japan, first with the award of the Mitsubishi Shoji Scholarship and then the support from the JSPS Research Fellowship. Those prestigious awards did not only take a huge financial pressure off of my family and me, but it also is an honour for me to see my research being appreciated and supported.

Beyond research, I always could count on my family and friends. Kristina, who has been my dearest friend and a strong support through rough moments, and even more importantly, there to share all the happy ones! Also to my friends who have been daring enough to read through this thesis, and all those I shared great times with here in Japan. Also my parents and my sister, even though I was not sure if they always understood what I was doing ("something with robots"), they always supported me in every way they could and encouraged me with their best wishes. They were even proudly sharing the television appearance of my research and the robots that I was working with to all our extended friends and family, as well as sharing my successes over all those years. Even if many of them are 10,000km away, I always had the feeling they are very close.

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Chapter 1

Introduction

Robots no longer belong to the world of science fiction – they are reality, and more sooner than later, they will be having a real impact on the way we live. The modern development of personal and service robots is extraordinarily advanced compared to the robot technology of just a decade ago. Social robots will be soon be present in our daily lives in close proximity to ordinary people (e.g. in homes, workplaces, museums, schools, hospitals, and shops). Such robots are able to walk, recognize people, talk, and even smile, and they can cover a variety of purposes such as research platforms, toys, educational tools, therapeutic aids, support, and entertainment. This recent progress in robotics has motivated research on robots designed to interact with people that will be able to participate in human societies. Although the research field is growing, it has not yet been well established, and it remains to be determined how people will accept and perceive robots that coexist in environments inhabited by humans. It is the goal of this work to explore the factors related to human perception of sophisticated robots when people interact with them for the very first time.

1.1 Challenges

The development of social robots is a young and fast-changing field. The production of sophisticated robots enables researchers, for the first time, to conduct examinations of Human Robot Interaction (HRI), allowing increasingly complex technological challenges to be overcome. Still, technological hurdles from the engineering side are numerous (e.g. navigation, manipulation, vision, speech, sensing, integration, physical planning, functionality, and safety), and these are key factors, in addition to the study of the many influences in forming a social experience with a robot, from the human factors side. The social aspect in the acceptance and perception of robots is critical if robots are to become a part of people's daily lives. Even if all technological challenges are overcome and the robot performs well in its intended function, a robot which is, for example, repulsive, not likeable, annoying, or perceived as unsafe will most likely be rejected. Research in this field examines the interaction from the human side by factors which are isolated for study purposes.

1.2 Motivation

The overall goal of HRI can be thought of as making the interaction between a robot and a person intuitive, efficient, and enjoyable, and to create a natural-appearing social interaction. Interactions between people and technology have long been considered comparable to human-human interactions [6], but influenced by many factors. To achieve the goal of a natural-appearing social interaction, this work collected data from a series of experiments and surveys to examine possible influences of robot design appearance on people's assessment, how the perception of a specific robot changes in short-term interactions when people physically interact with a robot for the first time, and how cultural background influences perception and perception change.

1.3 Literature Review

A relevant feature of the robots considered in this study is that they are designed to interact with people. Social acceptability is important for a coexistence with humans in the same environment. To achieve social acceptability it is crucial to identify the key determinants of people's acceptance. Recent research on robot acceptance has focused in large parts on user attitudes towards robots [7]. The

Negative Attitudes Towards Robot Scale (NARS, [8]), for example, has been used to show that Japanese participants have more negative attitudes towards robots than do Chinese or Dutch individuals [9]. Similarly, the Robot Anxiety Scale [10] evaluates only negative affect, and therefore, both scales are limited in that they focus only on a lack of people's positive perception of the robots. The evaluation of acceptance of social robots is particularly difficult as they are much more complex in their interaction capabilities than are other technologies. We therefore focus here on the importance of robot design appearance, which is reported to have a relevant impact on people's perception of robots.

1.3.1 Exposure to Robots

Despite recent progress of robotics and robots showing more and more capabilities, our perceptions and expectations towards robots are more shaped by what we see in the news, videos or movies than by real interaction with an actual physically present robot [11]. Even in the studies here conducted in technological advanced countries (Japan, Australia), real contact to a robot was the exception rather than the norm. It has been shown that the physical embodiment [12], means the actual presence of a robot, does play a crucial role in HRI and the perception of a robot. These studies address this issue by letting humans directly interact with a robot.

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1.4 Robot Appearance

Nowadays, robots come in a vast variety of designs [13]. The image term "robot" also can range from a very simplistic mechanical machine-like robot (e.g. industrial robot) to a caricatured robot, to an extremely sophisticated anthropomorphic robot (e.g. android robot), and it differs across individuals [13]. Recent breakthroughs in robotic technology have led to the development of robots at decreasing costs; between 1990 and 2001, the average cost of an industrial robot, for example, has decreased by 88.8% [14]. People form a quick impression about an entity – in this case, about a robot – even when only little information is available [15]. As robots enter everyday life and start to interact with ordinary people [16], it becomes increasingly important to consider that humans are extremely sensitive to the particular pattern of features of appearance, especially in first-time and short-term interactions, when there is a lack of more concrete data and few opportunities exist for evaluation aside from extracting certain cues from the exterior design. To ensure enjoyable and natural interaction with robots, it has been proposed that robots should be designed with an appearance that gives people intuitive clues to understand their behaviour [17] and also to appropriately match the robot's appearance to its capabilities to improve its perception and acceptability [18]. It has been stated that the appearance of a robot is expected to influence perception, acceptance, and attitude [7]. Possible factors include the human-likeness, structure, and form, or characteristics like animal-likeness or machine-likeness.

Robots were primarily designed to complete tasks that humans cannot complete or that robots can do better (e.g. work on assembly lines). Such robots are developed purely for functionality and are not intended to interact with people; therefore, their design appearance concerns are minimal. Social robots amongst people are a novel entity with no preconceptions from previous personal experiences, so people will conceptualize them like already-known entities (e.g. objects, animals, and people [19]). In order to interact with robots, they will primarily be anthropomorphized [20], and a growing number of studies suggest that people connect their expectations to the assumptions they make about a robot's appearance [19, 21–25]. To enhance HRI, it is necessary to investigate and understand people's attitudes, expectations, and perceptions of different design appearances of social robots.

1.5 Robot Perception

When it comes to the perception of a social robot, it is not only the question of the influence of the design appearance of the robot itself, but also how to measure and evaluate the human factor side of robot perception. The evaluation of specific factors influencing the perception of social robots could be used to develop constraints in the future which serve as a guideline for robot designers. Despite its importance, the user perception of robot function, intelligence, or capability is still described as an area in need of exploration [7]. A false perception of intelligence of a social robot, for example, could create a potential mismatch between the actual robot's capabilities and the expectations towards it, thereby producing a negative impact [26]. People also tend to anthropomorphize, which means they attribute human-like traits to non-human agents [27]. Thus, the perception of a robot's appearance depends on the extent to which people anthropomorphize a robot and ascribe human-like characteristics to it, even if the robot design is not based on a human model [7].

Furthermore, regarding user acceptance of technology, within four main classes of user factors determining technology acceptance, three are relevant for this work: personality traits (need for achievement, degree of defensiveness, locus of control, and risk-taking propensity), demographic variables (age, gender), and user-situational variables (training, experience, and user involvement) [28].

Personality traits have been shown to influence the preferences for robot appearance, such that introverted people tend to prefer robots with a more mechanical looking appearance [29]. It has also been found that higher scores on the personality trait of extraversion are associated with a higher tolerance of approach directions in a study presenting a robot approaching humans [30]. Moreover, personality seems to factor into how trustworthy people perceive a robotic interaction partner to be [5].

Demographic variables were also evaluated, as this is standard and good practice in scientific surveys, and other variables were compared against those. Social robots will need to interact with a wide range of users, including those of different ages, cultural backgrounds, and genders, and therefore, all those are variables to consider when evaluating the perception of a robot. For user-situational variables in the interaction with social robots, this work accounted for previous exposure and experience with virtual agents (i.e. virtual characters in software services or computer games) as well as robots in the media and real life.

1.6 Cross-Cultural Differences

Cross-cultural differences have long been studied, and such differences explain why what appears effective and proper in one culture can seem ineffective, funny, or, in the worst case, inappropriate or offensive in another. Researchers have tried to identify attributes, such as nationality, religion, race, and socioeconomic class, which influence how people think and behave [31]. When it comes to robots, we know that even in technologically advanced countries, exposure to physically present robots is still quite low, and therefore, no culture has had the opportunity to develop a concept for this new technology. However, there might be a strong influence of people's cultural background and their media display of robots. One of the most common stereotypes encountered by popular culture is the one of Japan as a nation of robot lovers and the entire Western world as being extremely critical of them, with the thought that robots might develop self-awareness and take over the world (which is a scenario from a fictional Hollywood movie). There are, of course, many differences between Japanese and Western cultures. For instance, in the distance people keep from each other (which also differs between many countries, even when on they are the same continent [32]). Further, the display of robots in Japanese popular culture (e.g. Manga comics) is unique in the sense that robots are helpers or heroes which are able to experience emotions. There are speculations that Japanese culture believes that that living beings, non-living objects, and gods are all ascribed as having a soul [33], whereas Western cultures distinguish between natural and artificial to a greater extent [34].

The theory that the perception of robots differs between cultures is therefore grounded in already-established cultural differences. For example, it has been shown that even recognition of facial expressions is culturally dependent [35], but there is also doubt that that the cultural gap is really as wide as the stereotypes claim [13,36].

Chapter 2

Robot Appearance

2.1 Motivation

People have always been sensitive to certain patterns of appearance, and social robots have the potential to tap into that human sensitivity. Recent technological breakthroughs enable the construction of robots which will sooner or later be in direct contact with humans and interact on a daily basis in their homes, workplace and public spaces like schools, hospitals, and museums. The design of a social robot's appearance is one factor which is suspected to play a crucial role in the acceptance and interaction with such a robot.

Social robot producers deliver robots with diverse design appearances that are able to perform different tasks. This variety means that a robot can literally have all kind of abilities and forms. Therefore, the term "robot" elicits a range of images in people, from a very simplistic mechanical machine-like robot to caricatured robots to extremely sophisticated anthropomorphic robots. When it comes to social robots, the human factor plays an important role. With the large variety of robot shapes, the perception and acceptance of a robot can differ according to the individual [13]. It is therefore important to determine what people expect from a certain robot appearance.

2.2 Related Work

Primarily designed robots like industrial ones were high in functionality and their roles was to do things humans can't do, like repeatedly perform the same actions with high precision and constant quality and minimal human robot interaction. Slowly, robots start to do tasks instead of (but still often with lower quality outcomes) a human being like vacuum cleaning [37] in which robots start to occupy the same space as people but the interaction with the robot is still minimal. Newer developments of social robot have a higher level of interaction with people, for example a robot bringing beer [38] or delivering snacks [39]. Those robots are designed to act in close proximity to humans and interact socially to a certain extend and therefore should have an appealing appearance, which is not necessary for a robot for industrial use with minimal interaction with people and designed purely for functionality. Even though research has started to consider robot appearance as a factor in interaction [18, 29], it is still not clear what a certain robot design appearance evokes in people.

To advance HRI, it is important to understand how a robot's design influences the perception, attitude, expectation and interaction. People conceptualize entities [19] like animals, objects or other people, but a robot is a novel entity. Studies have shown [40] that despite technological advances, people so far have not been interacting much with robots in real life, so social robots are new and have not been undergoing this conceptualization yet. Even if they may not have a preconception about their attributes yet, robots seem to be easily anthropomorphized by people [20], especially, but not necessarily, those with a humanoid appearance. Previous studies revealed that people have expectations from a robot even if they have not interacted with it yet [41]. It could therefore happen that people create a misleading idea about the robot's abilities simply based on its appearance. It is suspected that people also associate and assume certain abilities and tasks only based on a robot's design appearance. This has been shown by several studies examining the robot's (perceived) gender [21–23], voice [19], face [24], and goes even as far as the place of manufacture [25].

The appearance of a robot has long been suspected to have an influence on how it is perceived and what kind of expectations it shapes. To come to an initial understanding what kind of design and what particular feature of a robot could affect people's expectation, their perception and their attitude towards it, an experiment was designed to investigate people's view of different robot types. For that, four different robot types were identified and the associations, the associated tasks, perception, fears and expectations towards those robots were examined and compared.

2.3 Method

There is considerable variation in modern social robot appearance. Therefore, this study focussed only on robots which fulfil the criteria of being able to display social interaction (e.g. through sounds, speech, and reactions), to move, to occupy the same space as people, and do not have a machine-like appearance. In order to obtain data from realistic robots, fictional robots were excluded from the evaluation, and only images of existing robots were used. A total of 24 images were collected from websites and sorted into one of the four conditions according to their appearance: pet robot, service robot, humanoid robot, and android robot. Table 2.1 gives an overview of the robot types and their appearance criteria. Examples of the picture selection are shown in Figures 2.1 and 2.2.

2.3.1 Questionnaire

To get an initial idea about the attitude, expectations, associations and fear people have concerning those four different robot types, they were asked to fill in questionnaire. The problem with newly developed questionnaires can be that the experimenter introduces a bias with questions based on their personal postulations. To avoid this issue, the answer choices in the closed questions are based on prior developed and validated questionnaires [39, 42, 43] and also allowed an additional open answer. The participants were asked about the possible abilities of the robots, theirs fears, associations, and the possible role of such a robot on personal and societal level.

To get an initial idea about the attitude, expectations, associations, and fear

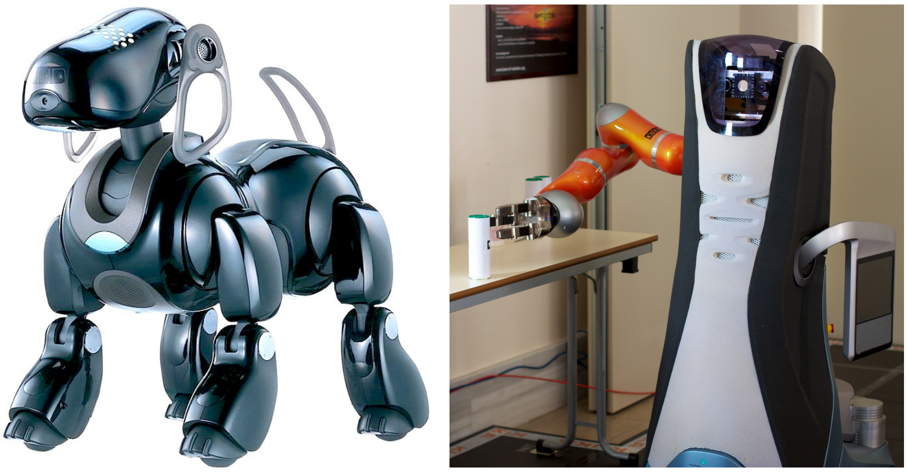


Figure 2.1: Examples for images used in the study. Here displayed pictures are (from left to right) the Sony Aibo (a dog shaped pet robot, ©2007 by fogl83 and made available under a Attribution-Noncommercial-ShareAlike 2.0 license) and the Fraunhofer IPA Care-O-bot®3 (service robot, ©2010 by Jiuguang Wang and made available under a Attribution-Noncommercial-ShareAlike 2.0 license).

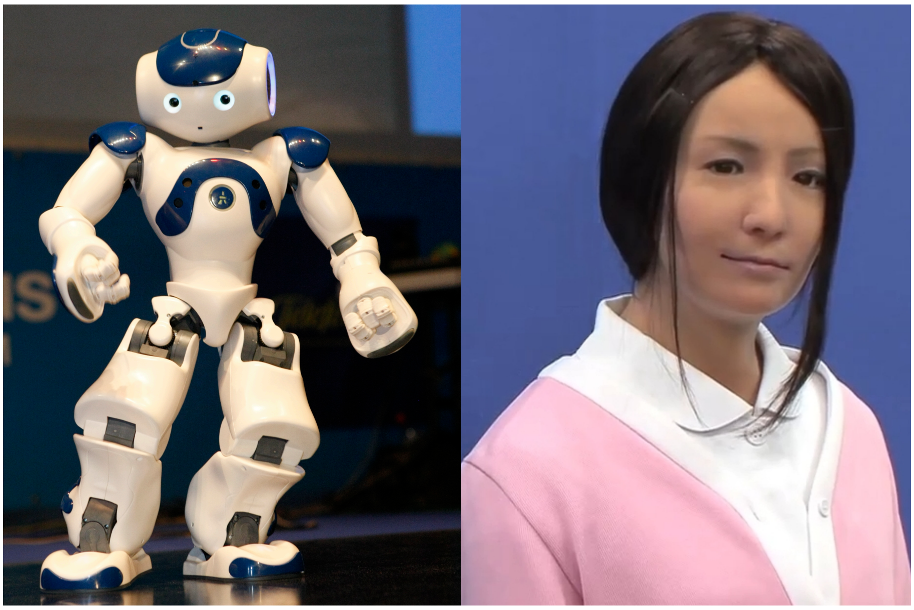


Figure 2.2: Examples for images used in the study. Here displayed pictures are (from left to right) the Aldebaran NAO robot (a 58cm/23in sized humanoid robot, ©2009 by Campus Party Valencia and made available under a Attribution-Noncommercial-ShareAlike 2.0 license) and the Geminoid F (female version of an android robot).

Table 2.1: Experiment conditions sorted after robot appearance, the number of example robots in each condition shown to the participants, and the criteria of each condition ©2013 IEEE [1].

Condition	Number	Criteria
Pet robots	n=5	Robots resembling pets or animals like a dog (e.g. Sony Aibo), a robotic cat and a robotic dinosaur.
Service robots	n=8	Robots clearly carrying out a service task (e.g. serving drinks)
Humanoid robots	n=7	Robots with gross human features like head, torso, arms and legs, but no details like skin, hair or eyelashes
Android robots	n=4	Robots aiming to look like a human copy (Doppelgaenger)

people have concerning those four different robot types, participants were asked to complete a questionnaire. The problem with newly developed questionnaires is that the experimenter can introduce bias with questions based on their personal postulations. To avoid this issue, the answer choices in the closed questions were based on previously developed and validated questionnaires [39, 42, 43] and allowed an additional open answer. Participants were asked about the possible abilities of the robots, their fears, associations, and the possible role of such a robot on a personal and societal level.

Further, participants' prior exposure to robots through media (e.g. pictures, video) as well as in real life was examined. As Japan is perceived as the country with with "robot-mania," [36] participants were asked how advanced they would assess Japan to be in robotics and which countries are, in their opinion, leading in robotics. The questionnaire set with all possible answers can be found in Appendix A.

Hypotheses

The goal of this study was to test the following hypotheses:

H1

Robots, regardless of their types, are perceived as a machine and not real replacement for humans or pets.

H2

The robot's appearance influences the associated tasks.

H3

The closer a robot looks to its biological model, the more it will be associated with its behaviour.

H4

The android robot will trigger more relations to fear than other robot types.

2.4 Results

2.4.1 Participants

To shed some light on the perception of robot types, four robot type groups were created according to the robots appearance and then a total of 101 participants (33 females and 68 males, mean age M=21.1, age ranged from 18 to 31, see Table 2.2) were randomly assigned to each condition. The interaction context was in Japanese and participants received monetary reimbursement for their participation.

Table 2.2: Participant demographics for the four conditions.

	Pet	**Service**	**Humanoid**	**Android**
Total	20	30	23	28
Female	9	9	5	10
Male	11	21	18	18
Mean Age	21.1	21.4	21.0	21.0

Even though the experiment was conducted in a technological advanced country (Japan) with young students, none of the participants had prior experiences in direct contact with robots, which supports the earlier statement of people in general having a low exposure to robots.

2.4.2 Data Analyse

The data was analyzed to test the research hypothesis and explore the effects of differences between the fours robot types. Differences were compared with a chi square test to determine whether there is a significant difference between the observed frequencies in the different experiment conditions. If not noted otherwise, Pearson's chi-squared test was used and when Fisher's exact test was used it is noted.

2.4.3 Associated Tasks

The tasks associated with a robot could depend on the robot type, so participants where asked what they would think this robot is able to do. As displayed in figure 2.3, compared to the other three robot conditions, the service robot was significantly more associated with *recognizing people* (Fisher's exact test, $p=0.02$ compared to pet robot, $p=0.09$ compared to the humanoid and $p=0.06$ compared to the android robot) and less with *reacting to noise* (Fisher's exact test, $p=0.04$ to the pet, $p=0.09$ to the humanoid and $p=0.03$ to the android robot). The service robot was highly associated with tasks like *visual input* and *recognize people* (Fisher's exact test, $p=0.02$ compared to pet robot). There were no significant differences found between robot for the association with *intelligent behaviour*, but even the humanoid robot, which was associated the most with *intelligent behaviour* is significantly higher associated with any reaction to sensory input (Fisher's exact test, $p<0.0001$ for *react to noise*, $p<0.0001$ for *react to visual input*, $p<0.001$ for *recognize people*).

The humanoid robot type was significantly more associated with *autonomous behaviour* (Fisher's exact test, $p=0.06$ compared to the android robot). Supporting hypothesis 3 stating that close resemblance to a biological model with also be associated with the behaviour of this biological model, it was found that human behaviour

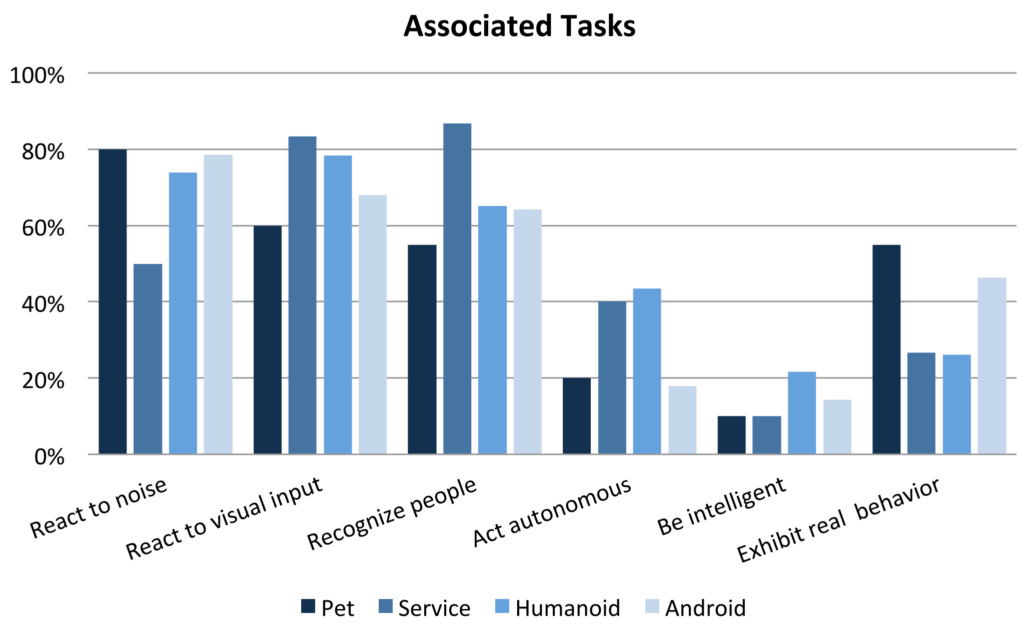


Figure 2.3: The tasks associated with a robotic pet, a service robot, a humanoid, and an android robot ©2013 IEEE [1].

is associated with the android robot and pet behaviour with the pet robot (Fisher's exact test, p=0.06 for the pet robot compared to served and humanoid type).

2.4.4 General Associations

Participants could choose from 42 responses as shown in appendix A what they associate with their particular robot condition. Significant differences in the data were found for *lack of activity*, which was associated more with the pet (Fisher's exact test, p=0.01 compared to service and p=0.05 compared to humanoid robot) and the android robot (Fisher's exact test, p=0.01 compared to service and p=0.07 compared to humanoid robot). *Freedom* was significantly more associated with the humanoid robot ((Fisher's exact test, compared to pet p=0.02, to service p=0.03 and to android p=0.03).

As participants had the choice of a total of 42 associations, the associations could be ranked for each robot type and independent of the type. It showed that certain associations were ranked very similar for each robot type like *research* (ranked 6th), *humanoid* (ranked 8th), *utility* (ranked 10th), *help for humans* (ranked 11th), and *medicine* (ranked 17th). What was clearly shown in the ranking of associations was that for all four robot types, the first three most common associations were *technology*, *machine* and *dangerous tasks* as displayed in Figure 2.4.

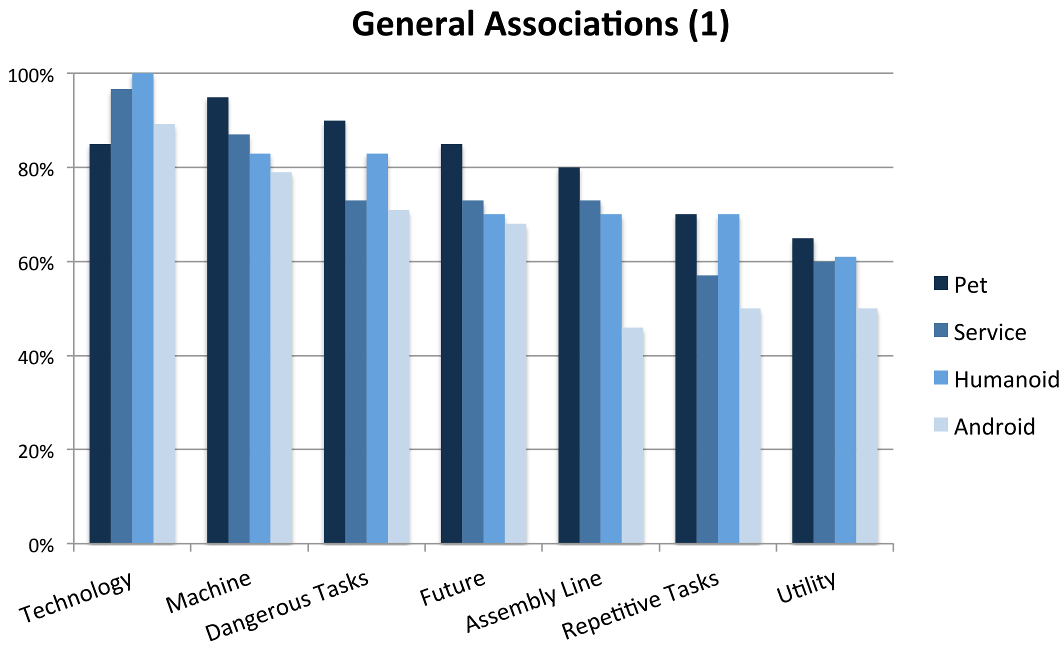


Figure 2.4: The associations with a robotic pet, a service robot, a humanoid, and an android robot ©KST-2013 [2].

The humanoid robot is slightly significantly higher associated with *technology* (Fisher's exact test, p=0.09). Figure 2.4 also shows that the android robot is significantly less associated with *assembly line* than the pet robot type (Fisher's exact test, p=0.03) and the service robot (Fisher's exact test, p=0.05)

Other frequent, positive or neutral associations with robots were for example *research*, *help for handicapped and elderly* as well as *future* whilst associations with more negative connotation were mentioned only in the second half of the overall rankings as shown in Figure 2.5 (e.g. *danger* (ranked 27th), *lack of activity*, *job loss* and *fear* (ranked 29th-31st).

Figure shows that *accurate work* is slightly significant higher associated with the pet robot than the android robot (Fisher's exact test, p=0.07). *Lack of activity* is significantly higher for the pet robot (Fisher's exact test, p=0.01 compared to the service and p=0.07 compared to the humanoid robot) and the android robot (Fisher's exact test, p=0.01 compared to the service and p=0.05 compared to the humanoid robot). When it comes to the association of *simplify* life for people, the

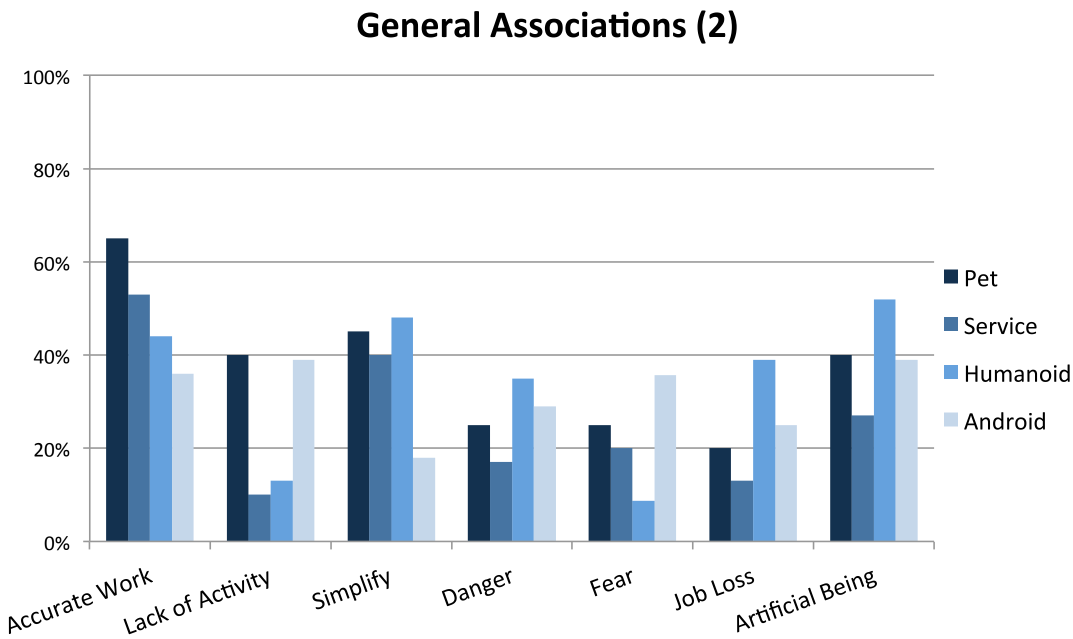


Figure 2.5: The associations with a robotic pet, a service robot, a humanoid, and an android robot ©KST-2013 [2].

humanoid (Fisher's exact test, p=0.03), the pet (Fisher's exact test, p=0.05) and the humanoid (Fisher's exact test, p=0.08) are associated higher than the android robot. *danger* did not show significant differences, but the android robot was significantly higher associated with *fear* (Fisher's exact test, p=0.04). *Job loss* was shown to be higher associated with the humanoid robot when compared to the service robot (Fisher's exact test, p=0.05), with the same difference for the association as *artificial being* (Fisher's exact test, p=0.08). The data also showed a slightly significant lower association for *entertainment* for the service robot (Fisher's exact test, compared to the android p=0.06, pet p=0.09 and humanoid robot p=0.09).

2.4.5 Role of the Robot

The role of the robot was asked on two levels – personal and societal. The personal level was described to participants as private elements appearing in the their daily life at work or in their homes. The societal level was described as non-private elements like economy, progress and industry. Participants were choosing for both levels from the same set of keywords. The data showed that the roles of the robots are perceived very different on personal and societal level. Personally, the role of a robot, independent of its type, is seen for *make life easier*, and *help for old and handicapped people* (see Figure 2.6). In contrast, for society their role was defined as *entertainment* (see Figure 2.7). On both levels, the role of the robot was clearly seen as the robot performing *dangerous tasks*.

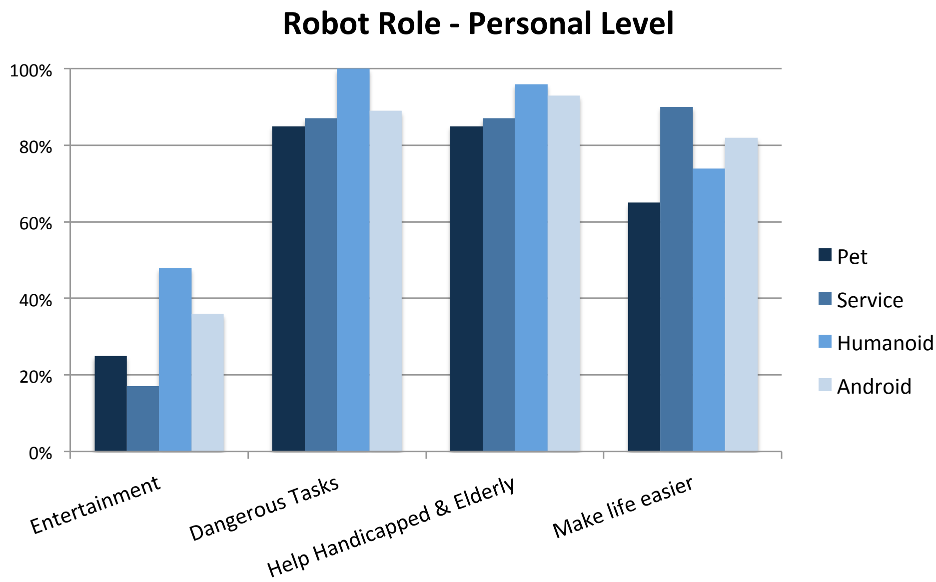


Figure 2.6: Participants' answers when asked for the role a robot should have in their personal life ©KST-2013 [2].

Figure 2.6, the role of the robot on personal level, shows a significant difference of the robot role in terms of *entertainment* between the service and the humanoid robot, seeing the humanoid clearly more in this role (Fisher's exact test, p=0.01). For the robot performing *dangerous tasks* the humanoid robot is seen slightly significant more in this role than the pet robot (Fisher's exact test, p=0.09). For the *help for old and handicapped people* there were no differences found but when it come to *make life easier* the service robot is seen more in that role than the pet type (Fisher's exact test, p=0.06).

In general, for all four conditions, participants saw more possible roles for a robot on societal level like for example *economy*, *progress*, *accuracy*, *efficiency*, and *entertainment* and *company*. On societal level, the android robot is seen significantly more in the role for *entertainment* than the pet robot Fisher's exact test, p=0.04). Other than that, there were no significant differences found for the robot role on

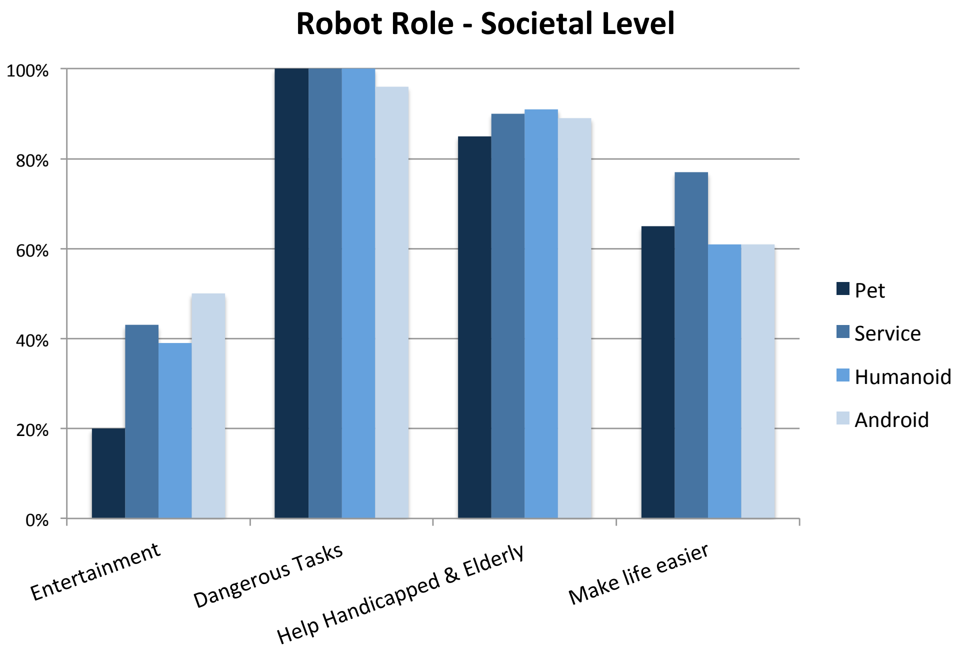


Figure 2.7: Participants' answers when asked for the role a robot should have for society ©KST-2013 [2].

societal level.

2.4.6 Touching the Robot

To evaluate if participants are more likely to touch a certain robot type, they were asked if they would touch this robot type and also, if they would allow the robot to touch them. The data showed, that independent of the robot type, participants were significantly more likely to be touched (passively) by a robot than to actively touch the robot ($\chi^2(1,N{=}101){=}5.44$, p=0.01, see Figure 2.8).

The humanoid robot is reported to likely be touched significantly more than the android robot (Fisher's exact test, p=0.02) whilst for the robot-initiated touch no differences between the four conditions were found.

2.4.7 Fears

In western popular culture, robots are often depicted as scary, out of control machines but the data here was obtained only from participants in Japan where robots are pictured differently in the media. Participants were asked the very general ques-

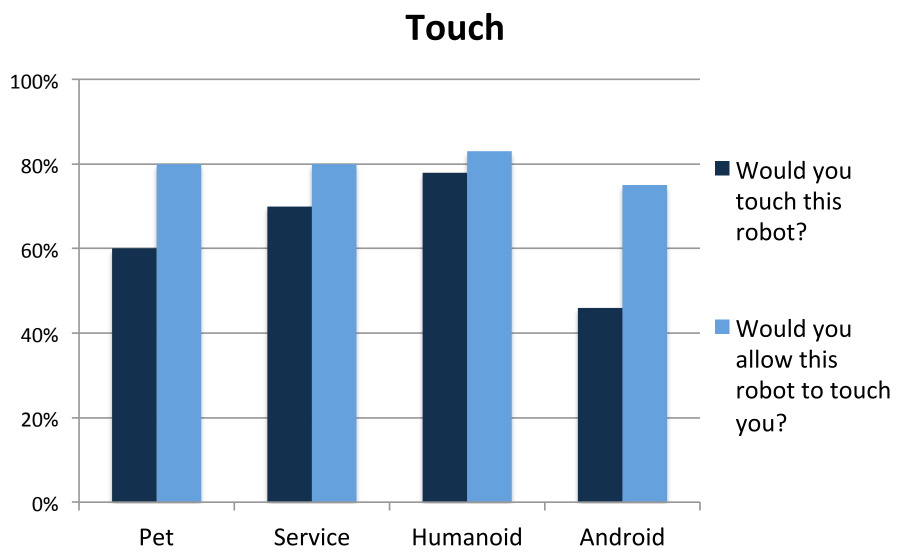


Figure 2.8: Participants' answers when asked if they would touch the robot and if they would allow the robot to touch them ©2013 IEEE [1].

tion in their condition group if they have any fears from the robot (see Figure 2.9), which was answered significantly higher with "yes" for the android robot than all other robot types (Fisher's exact test, $p<0.0001$ for the pet, $p=0.003$ for the service and $p=0.005$ for the humanoid robot). There were no significant differences between the other types of robots. The data from eight participants were missing due to not completed questionnaires.

To evaluate the details of those fears, we asked what certain kind of fears a robot evokes in the participants on a personal (Figure 2.10) and a societal level (Figure 2.11). Participants were given the same items to choose from no both levels. Again, as observed before for the role of the robot, the most differences where observed between personal and societal level and less within. The data showed that on personal and societal level, the most reported fear is the potential *misuse* of the robot, independent of the robot type. Participants expressed globally more fears on a societal than personal level. and then

On a personal level, *misuse*, *autonomy of the robot*, and *job loss* were feared. There were no significant differences found between the robot types.

The most fears on societal level were, next to *misuse*, were *loss of control*, *loss of job*, and *dependence*. Whilst on personal level, the android triggered more fears

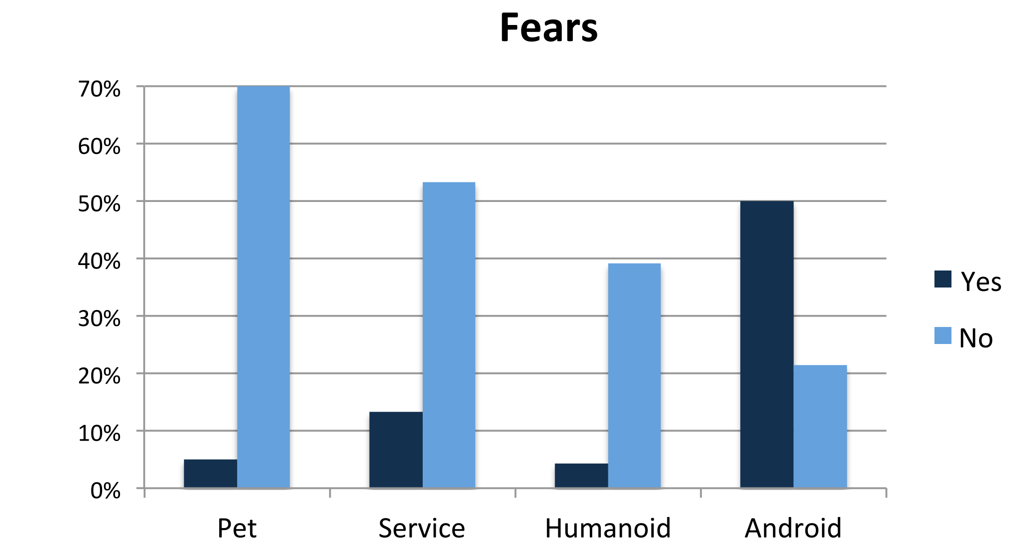


Figure 2.9: Participants' answers when asked if they have any fears from a particular robot type ©KST-2013 [2].

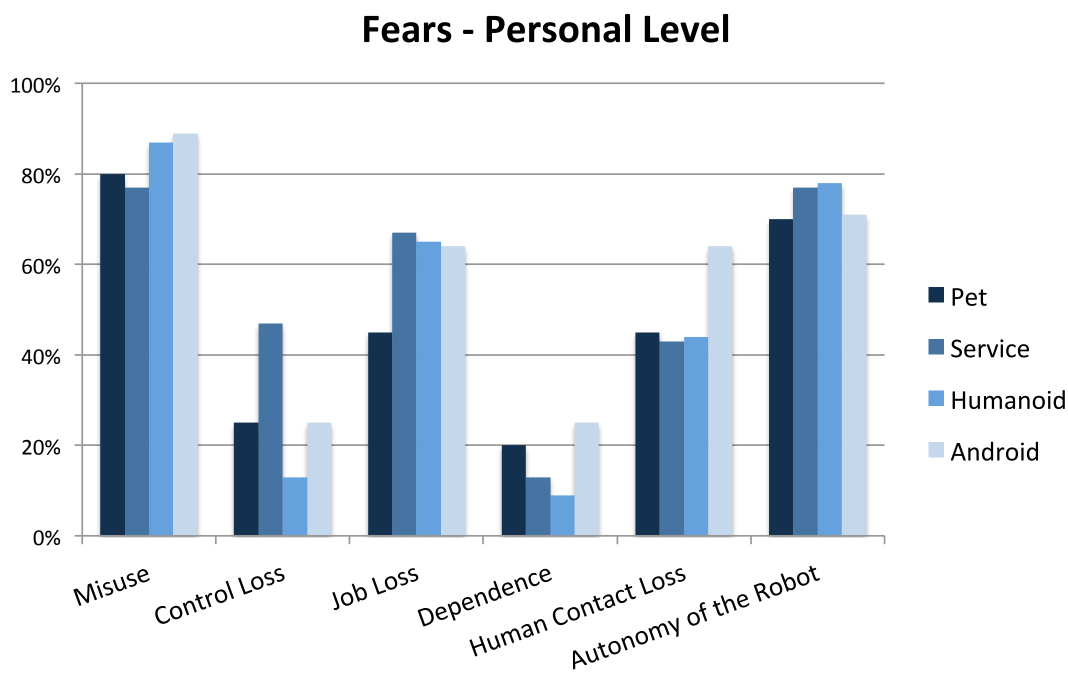


Figure 2.10: Participants' answers when asked if they have any fear from a robot in their personal life for the four robot types pet robot, service robot, humanoid, and android robot ©KST-2013 [2].

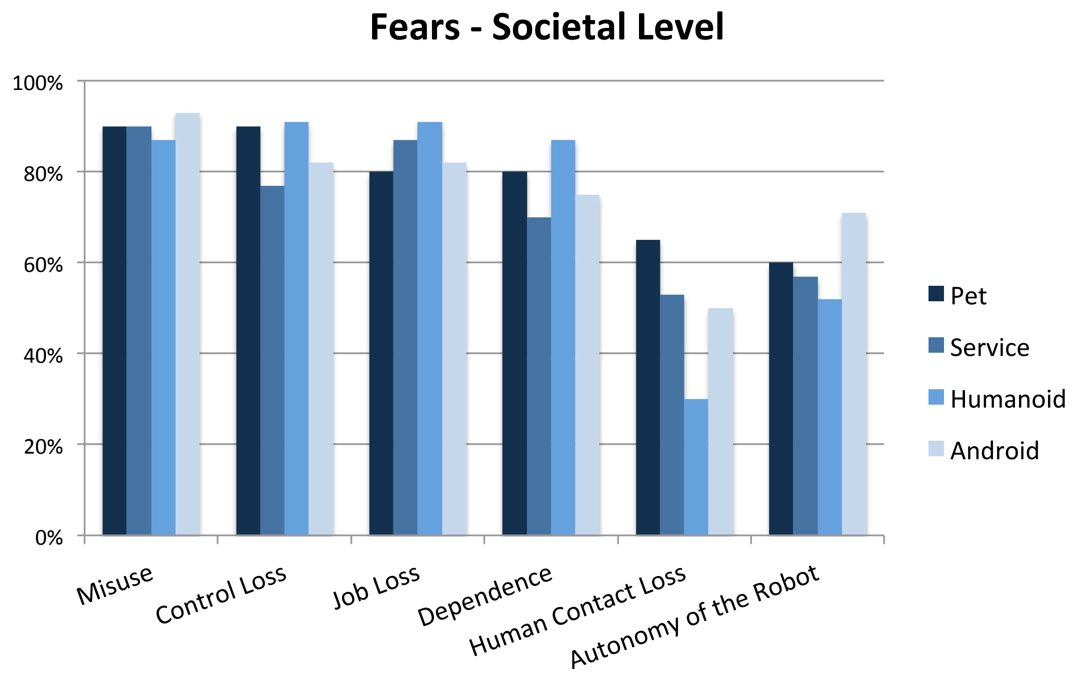


Figure 2.11: Participants' answers when asked if they have any fear from a robot for society for the four robot types pet robot, service robot, humanoid, and android robot ©KST-2013 [2].

from *loss of human*, on societal level, the pet robot was reported significantly higher than the humanoid robot (Fisher's exact test, p=0.03).

2.4.8 Exposure

Despite technological advances, the exposure to robots is still quite low. To examine details about the kind of exposure for each robot type, participants were asked if they had seen the robot in either a picture (e.g. comic, manga, newspaper, online), a video (e.g. TV, online) or in reality (e.g. exhibition). The data shows that the humanoid robot type has the most media exposure through images and videos (see Figure 2.12). All robot types have a low to nearly no exposure in real life. This shows, that people actually have never been in direct, physical contact with a robot.

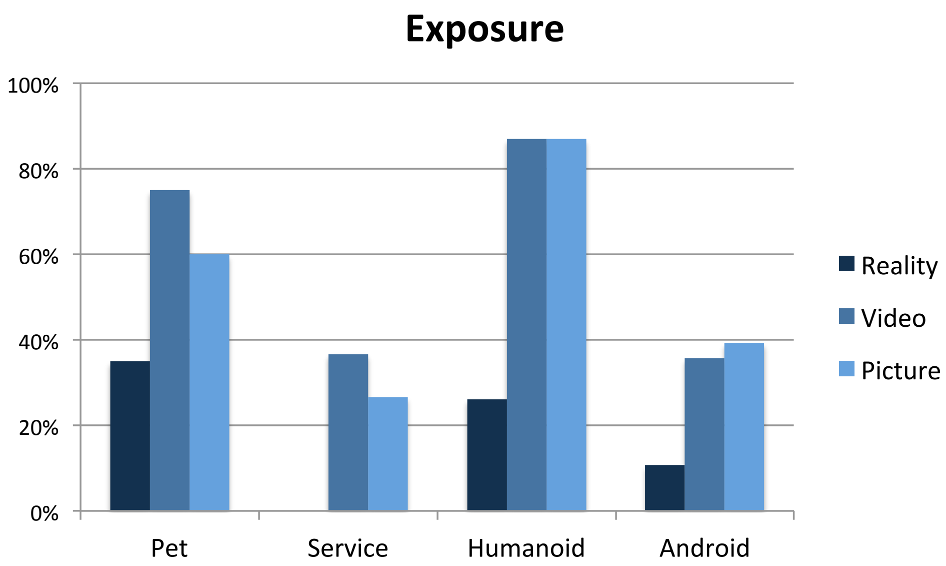


Figure 2.12: Prior exposure of the participants to the four the four robot types pet robot pet, service robot, humanoid and android robot ©2013 IEEE [1].

2.4.9 Most Advanced Countries

It was shown in the global data that participants saw America (48.9%) and Japan (40.6%) as the most advanced countries in robotic research. For other countries, which also could play a role, China, Russia, Germany, and Great Britain were perceived as leading.

2.5 Discussion

The data from this study clearly suggest that the design appearance of a robot has an influence on what people associate with the robot. For four different robot types, the associations, associated tasks, role of the robot, and possible fears for each robot were examined.

Hypothesis 1, which stated that robots would be perceived less as a human replacement and more as a machine, was not directly confirmed with the data, but there was indirect support and indications that people do perceive robots more as a machine than as a replacement. All robot types were highly associated with being technology and a machine. Further, at least for people's personal lives, the fear that robots might replace humans was comparatively low. The robots were highly connected to technological or supporting tasks (e.g. research, help for handicapped and elderly individuals). Furthermore, none of the robots were associated with intelligence, which is thought to be an indicator that they are perceived more as machines, programmed to do a certain set of predefined actions but lacking the capacity for intelligent reasoning. In terms of replacement in a work environment, the fear of job loss on a personal level was also reported to be quite low, although the number increased on a societal level, which could indicate that there might be some hidden concerns about robots in work environments. This could also result from the fact that participants here did not interact directly with physically present robots and were not able to experience the (still persistent) restrictions in the abilities of current robots.

Hypotheses 2 and 3, which stated that the robot's appearance and the connections of a robot modelled after a biological model would influence people's expectations of biological behaviour, was confirmed with the data in this study. People associated realistic human behaviour most with the most realistic robot, the android robot, and they associated realistic animal behaviour with the pet robot. Those robots were not associated with supporting of helping tasks, whilst the service and humanoid robots were seen as support for humans to improve life. It is thought that the service and humanoid robots, despite showing several human features, are not attempting to be a copy of a biological model and therefore are not expected to display realistic behaviour. Instead, they are expected to provide support for people.

Hypothesis 4, that the android robot would evoke more fear than would other robot types, was confirmed by the data in this study. The android robot triggered by far the most responses when people were asked if they generally feel any fear from each robot. It also was seen as highly likely to be subject to misuse on a societal level. In general, the android robot type evoked different responses when compared to the other robot types. The influence of this robot's appearance was different in terms of its associations with more typical machinery tasks or repetitive factory work. It seems that the highly realistic design appearance of this robot also shaped expectations that it would have human abilities, but at the same time that it is not equally qualified to perform machinery tasks, as opposed to the service or pet robots. From the present data, it seems that people could not derive a clear task, use, or application for the android robot, though they clearly do so for the service robot. Thus, people likely had concerns and doubts about this robot's necessity or usefulness. These results are very interesting in terms of the possible expectations, acceptance, and perception people have with such a realistic looking robot. Next, Chapter 4 describes an experiment with a physically present android robot to explain some of the present findings.

It was also found that the role of the robots and the fears associated with them differed on personal and societal level. It is suspected that, when imagining robots in close proximity and environments like at home, people perceive robots as entering their private space, which is usually reserved for close friends and family members. Therefore, a robot has a different impact than the general idea of a robot supporting a person they might not know.

The results for the humanoid robot showed that despite its association with fear (e.g. misuse, loss of control, loss of autonomy), it was simultaneously considered a very useful and highly developed tool. It is not clear from the data here if the numerous human features of this robot combined with its possible (anticipated) abilities threatened people with the idea of human replacement for certain tasks and a potential situation in which they lose control over the robot. In addition, the pictures depicted humanoid robots as mostly being smaller than adult humans, whilst some of the service robots were comparatively larger but did not trigger similar fears as did the humanoid robot. To shed light on these results, an experiment with an actual physically present humanoid robot was performed, and the results are reported in Chapter 3.

With the new technological developments in the area of robotics, increased media coverage of robots, and popular culture displays, it would seem that people are already regularly exposed to robots. This is not the case according to the data in this study, and this has been confirmed by other studies evaluating the degree of exposure to robots [40]. It is thought that greater exposure through videos of humanoid robots is due to recent marketing of evolving robot technologies like the

Honda Asimo or the Aldebaran NAO (see Figure 2.2). A service robot, despite its usefulness, might be less effective for marketing purposes and therefore still be subject to a very specialized audience, whilst the android robot, tapping into the recently rediscovered uncanny valley in Section 4.1.3, polarizes people and catches their attention. This is, of course, subject to change in upcoming years, and it will be interesting to see how people's perceptions and expectations of robots will change with increased exposure through both the media and, ultimately, real-life contact. Further, in terms of cultural differences, Japan has been said to have a special position, as their culture perceives robots differently, an assumption which is evaluated in detail in Chapter 5.

As robots will be around people in close proximity, participants were asked if they would touch a robot and if they would let the robot touch them. Despite only 63% reporting that they would touch a robot (46% in the android robot condition), the following chapter, Chapter 4, describes an experiment with an android robot in which all the participants touched the robot's hand when the robot asked them to do so. It seems that the actual presence of a robot in close proximity to people plays a critical role when it comes to touch. These results are described in detail in Section 4.4.

It was shown that the sheer appearance of a robot is an important factor that influences what people associate with a certain robot type. People generally have a very positive attitude towards robots [13, 44] and, according to the data here, they expect robots to function as supportive technology in the future. It was also shown that the appearance of robots could play a major role in shaping people's expectations.

The present questionnaire asked directly if the robots were thought to be intelligent, and the results showed that this was not the case. Nevertheless, robots seem to take a special place in people's life when they are more exposed to a physical present robot. It seems, that the perception of a robot can't only be described by one concept of perceived intelligence of the robot, but also has to take into account that people tend to anthropomorphize not only robots [20], but even machines [45] or inanimate objects [46]. Socially intelligent robots and robots expressing emotions has been suggested to enhance the complex process of interaction [47] but are just recently being studied [39,48–50] and seem to trigger reactions in humans which have only been observed to far being triggered by living beings [51]. The next Chapter 3 examines in detail the concepts of perception of robots.

The present questionnaire directly asked participants if they perceived robots to be intelligent, and the results showed that this was not the case. Nevertheless, robots seem to take a special place in people's lives when they are exposed to a physically present robot. It seems that the perception of a robot cannot only be described by perceived intelligence, but that it also must account for people's tendency to anthropomorphize not only robots [20], but also machines [45] and inanimate objects [46]. Socially intelligent robots and robots expressing emotions have been suggested to enhance the complex process of interaction [47]. However, these have only recently been studied [39, 48–50], though they seem to trigger reactions in humans which had only been observed as being triggered by living beings [51]. Next, Chapter 3 examines in detail the concepts related to perception of robots.

Chapter 3

Perception of a Humanoid Robot

3.1 Motivation

Over the last few decades, interaction and communication have changed through the development of new technologies (e.g. personal computers, internet, and smartphones). People tend to apply social rules to those technologies [52] and anthropomorphize them [20], even though their design, appearance, and shape are far from anthropomorphic. The new technology of social robots – robots designed to interact with people – will be a special case of interaction in the future, and it is important to know how people perceive such robots if developers want to create a positive interaction experience. Moving humanoid robots intelligent enough to socially interact with people are expected to play a major role in future HRI.

The development of robots has come to a point where social robots are developed cheaper and in a wider variety. Therefore, they are more available to the market and no longer belong to the world of science fiction. There are already some isolated cases of people interacting with social robots over an extended period of time (e.g. the seal robot "Paro"; see Figure 3.1, [53]). Social robots are expected to soon be interacting with people, sharing the same living and working space (e.g. in museums, hospitals, schools, shops, private living spaces, and shops). It is therefore crucial to examine how people perceive such robots in their close environment and use this perception as feedback to improve HRI.

Figure 3.1: Two children interacting with the seal robot "Paro" (©2007 by Shoko Muraguchi and made available under a Attribution-Noncommercial-ShareAlike 2.0 license).

3.1.1 History of Anthropomorphic Robots

This section is a brief summary about the history of robots. The focus is on humanoid shaped or anthropomorphic robots, and how long people (sometimes not knowingly) have been developing and exposed to robots.

What we describe nowadays as "robot" has a long history. People seem to have a particular interest in simulating nature and human beings, dating back as far as over 2000 years ago. For example around c.10 - c.70AD, Heron of Alexandria built, amongst other automata, moving statutes that pour wine.

The etymology of the term "robot" itself is quite recent and derived from the Czech word for compulsory work. It was first used in the 1920s Czech play "R.U.R: Rossum's Universal Robots" written by Karel Capek. The robots here were "artificial people", machines that could be mistaken to be a real human. This idea can be found over and over again in literature like for example "Der Sandmann", movies like "Blade Runner", or in modern robotics like the development of present-day android robots aiming to be an exact copy of a human [54].

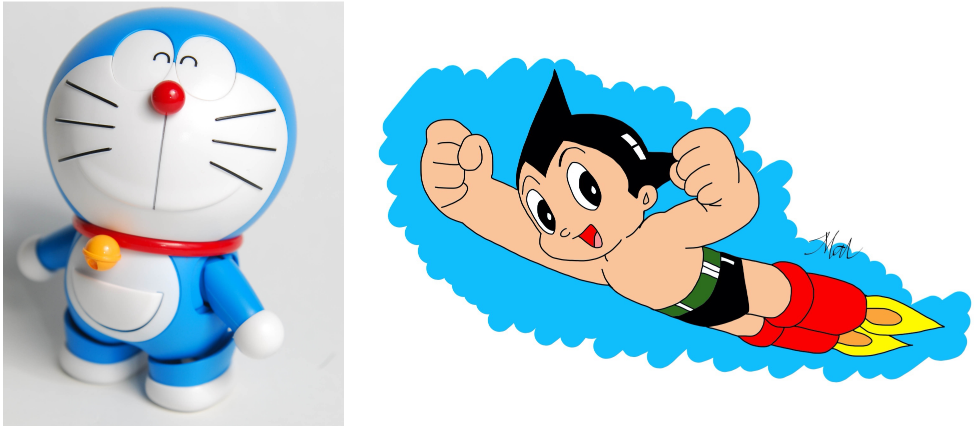
The Japanese take a significant spot in the history of robotics with the development of the Karakuri Ningyo (からくり人形), or mechanical puppets. The tea-serving doll Chahakobi Ningyo (茶運び人形) is said to have appeared in the mid-Edo period (1603-1868). The Karakuri Ningyo are very aesthetic humanoid dolls with excellent mechanics and its existence in a home provided entertainment for host and guest. The Karakuri Ningyo tradition is deeply integrated in Japanese culture and is thought to have a strong influence on how Japanese create and view robots. Therefore it is not only important to evaluate perception and acceptability of robots in general but also take into account possible cultural influences with regard to the different robot technology and display of robots in the media in Japan as it is done in Chapter 5.

In the 20th century, shortly after Isaac Asimov formulated the now famous laws of robotics in 1942 [55], industrial robots were on the rise. In 1997, about 700000 industrial robots were used worldwide, 60% of them working in Japanese factories and only 10% in the United States, the birthplace of industrial robots [56]. In the same year, two now world famous robots modeled after a biological model were announced from Japanese corporations: the Sony Aibo pet robot, shaped like a dog and the Honda Asimov, a bipedal walking robot in humanoid shape, the advent of the home robot era. The pet robot was marketed under the name AIBO (**A**rtificial **I**ntelligence Ro**bo**t, or "相棒" Japanese for "partner." Since then, many more robots modelled after a biological model have been released in Japan, e.g. the cat-shaped robot Tama and NeCoRo developed by Omron [57].

Ever since more and more robots have been developed worldwide and newer technologies enable the faster and cheaper development of robots and their availability for everyday people. This development increases constantly the probability of an interaction with a robot in people's daily life.

3.1.2 Exposure to Robots

As stated in the previous Chapter 2 people are actually not yet exposed or interact much to robots in real life. They are, however, present in popular culture like comics, movies and news reports. Manga comics in Japan like Doraemon (Figure 3.2a) and Astroboy (Figure 3.2b) display a robot as a supporter and loveable entity. Hollywood movies used to display robots in a terrifying appearance as out of control



(a) Doraemon (b) Astroboy

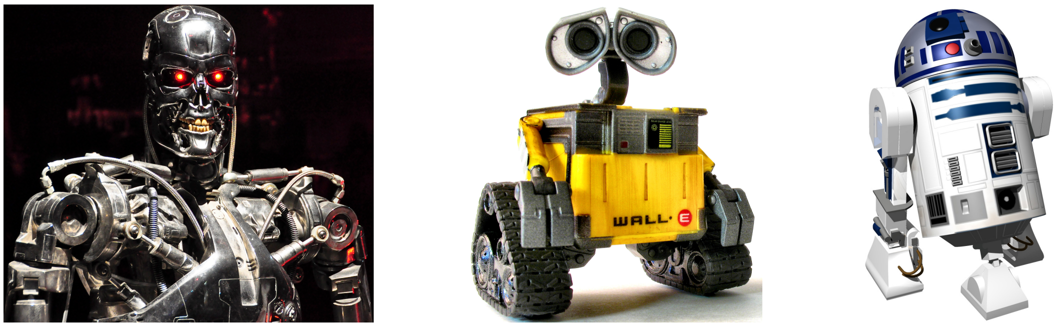
Figure 3.2: A popular display of the two famous robots: Doraemon (©2011 by Wacko Photographer and made available under a Attribution-Noncommercial-ShareAlike 2.0 license) and Astroboy (©2013 by Mal Booth and made available under a Attribution-Noncommercial-ShareAlike 2.0 license).

machines in movies like "The Terminator" (Figure 3.3a), but often not mentioned are the positively displayed robots like "R2D2" (Figure 3.3c) and "C-3PO" from the movie "Star Wars" , and also more recently the cute and supporting entities with emotions in films like "WALL-E" (Figure 3.3b) or "Robot & Frank." News reports all over the world show robot innovations like the humanoid robot Asimo developed by Honda, android robots like the Geminoid F (described in Chapter 4, and social pet robots like Paro (Figure 3.1).

Despite the media exposure which showed to be comparatively high in some studies [13, 40, 44], interactions with a physical present robot are not common (yet). In fact, it has been shown that sometimes, people participating in robot studies have never been in contact with a real robot at all. The following experiments with a humanoid robot and an android robot are therefore designed over several trials.

3.1.3 Human Perception of Robots

Human perception of robots has thus far only evolved indirectly through media exposure rather than direct interaction with physically present robots. Recent research has tried to evaluate the perception of robots with the aid of artificial virtual



(a) The Terminator (b) WALL-E (c) R2D2

Figure 3.3: The display of three robots in Hollywood movies: The Terminator (©2009 by SebKe and made available under a Attribution-Noncommercial-ShareAlike 2.0 license), WALL-E (©2008 by Don and made available under a Attribution-Noncommercial-ShareAlike 2.0 license), and R2D2 (©2009 by Mark Anderson and made available under a Attribution-Noncommercial-ShareAlike 2.0 license).

agents similar to virtual characters in software services or computer games, using simulated robots appearing on a screen or video recordings of robots. The results of these studies have only limited application to "real" HRI with a physically present robot, as the embodiment of the robot in the same interaction space is thought to have an effect on the interaction itself [12, 58–62]. These studies imply that a robot's physical presence or embodiment affects human perception of the robot as a social partner and that their responses differ from those to computer agents. Some research even suggests that sharing the same physical space with an android robot influences how the robot is perceived. It is thought that this is related to what the Japanese call "Son Zaikan" (存在感), the feeling of presence.

3.1.4 Sonzaikan and Concepts of Presence

Sonzai Kan is Japanese can be roughly translated as "presence" or better "feeling of a (human) presence." It is what we feel when we share the same space (i.e. the same room) with another person. This feeling is not triggered by modern technologic voice or video chat services people use to communicate with family or friends over distant locations. The effect of Sonzaikan could explain why, despite that social simulation with virtual agents in network services increases opportunities for social connections, people still feel somewhat socially isolated [63].

Even if studies don't refer to the Japanese term, they report an effect of social presence [60], which has been defined as "psychological state in which the virtuality of experience is unnoticed" [64], which in the case of HRI could be interpreted that people do not notice, to a certain extend, the artificial nature of the entity experienced. The challenges of this concept have also been described as:

> "The biggest challenge to developing telepresence is achieving that sense of 'being there'." (by Marvin Minsky, 1980)

and

> "What do people do at work? They go to meetings. How do we deal with meetings? What is it about sitting face to face that we need to capture?" (by Bill Gates, 1999)

Whilst researchers don't doubt the existence of such an effect of presence, they are still investigating the minimal design approach which would trigger a presence effect [65] and how humans actually recognize such presence in studies using an android robot [66]. Android robots are robots attempting to look like an exact copy of a human and are explained in detail in the next section.

It is therefore concluded that the presence in HRI is an important factor when designing experiments and, as described earlier, the embodiment of a robot is a factor to concern when designing HRI experiments. The following experiments are evaluating the perception of a humanoid and an android robot are therefore conducted with a physically present robot.

3.1.5 Perception Measurements

Psychologists research human cognition and perception extensively and have developed methods and tests toward further understanding relevant phenomena. This is a large research area with its own challenges, pitfalls, and difficulties. However, the recent research area of perception of robots has not yet been researched extensively. To evaluate the perception of robots, researchers need to discover and establish measurement methods for the data which such interactions could produce. The interdisciplinary field of HRI therefore uses methods previously established by psychologists and engineers, as well as concepts from Human Computer Interaction (HCI). As of now, the perception of a robot can be measured quantitatively in several ways.

Performance Criteria

Industrial robots' output can be measured with performance criteria, such as the number of processed pieces, production time, and quality. Those criteria are not necessarily a goal for social or entertainment robots, so the success and acceptance of such robots cannot be measured within the robots themselves, but rather, it must be evaluated on the human side.

Physiological Measurements

Popular physiological measurements are heart rate, heart rate variability, electroencephalogram, and galvanic skin response measurements. The collected data show participants' real-time arousal and can be taken during the interaction with the robot. Although the precision of physiological assessment is improving, it is still not highly accurate (around 70–80% [67]). Other limitations are that the origin of the arousal (e.g. anger, joy) cannot be distinguished in the data, the practical application is limited to short-term usability, and the participant can be easily biased due to the amount of sensors attached to the body. This also could lead to comfort issues for the participant. In terms of data analysis, the amount of obtained data might be overwhelming and inconclusive due to noise. Physiological measurements could provide some insights to supplement other measurements, but at present, they require too much effort in terms of equipment, software, and time consumption, and they are too prone to errors to provide constructive additional information. Therefore, they are not considered here.

Behavioural Observations

Behavioural observations offer a more reliable and objective method to measure the perception of a robot. Such methods have been previously established in behavioural psychology and cognitive science. Behavioural observations include reaction time, proxemics (distance to the robot), and interaction time. Behavioural measurements are used to gain additional information and to evaluate the perception of robots in this work.

Questionnaires

Questionnaires are often used to measure people's attitudes. Questionnaires have some shortcomings – for example, they only can be administered after the actual interaction with robots and also, participants could adapt their response to a more socially acceptable one (i.e. social desirability bias [68]).

Despite these shortcomings, questionnaires are frequently used in scientific research. It is thought that the advantages outweigh the shortcomings when they are utilized properly. The advantages of questionnaires are that they are very quick to conduct, able to collect a large amount of information, and cost-effective, especially when involving large sample sizes and large geographical areas. Once their validity and reliability are established, results will not be adversely affected if questionnaires are conducted properly. The results can be easily and quickly quantified, and standardized responses are more objective than are other forms of evaluation (e.g. video analyses by a researcher). Quantitative data can be used to measure changes within the data and can be compared to other studies using the same questionnaires.

For the following experiments, the same robot perception questionnaire (Godspeed Questionnaire) was used and, in case of the experiment with the humanoid robot, extended by few items. The two experiments were quite similar, though not identical, as they were adjusted to the robot's abilities and sizes. Still, the main findings of both studies can be used to compare different robot types and evaluate people's perceptions of them.

3.1.6 Perception Questionnaire

The Godspeed Questionnaire [69] is a measurement tool for Human Robot Interaction (HRI) which enables researchers to compare the results from different studies. It measures five key concepts in HRI using 5-point scales semantic differential scales: anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety. These questionnaire concepts report a Cronbach's Alpha of 0.878 for Anthropomorphism [70], 0.702 for Animacy [71], 0.865 for Likeability [70], and 0.75 for perceived intelligence [72]. The alpha values are all above 0.7 and therefore sufficiently high to conclude that these key concepts have internal consistency reliability. The validity for perceived safety is assumed due to the high Cronbach's Alpha of 0.91 before this concept was revised from a Likert scale into a semantic differential scale. Both scales yielded the same statistical outcome [69, 73]. Every of the five categories was evaluated and compared to other collected data. The full questionnaire in its English and Japanese version can be found in Appendix B.

Anthropomorphism

Anthropomorphism, or personification, is the attribution of a human form and human characteristics to anything other than a human being. Examples are the ascribing of motives or emotions to non-living entities or assigning human form to a deity.

Animacy

The recognition of animacy is to distinguish between animate and inanimate entities. For humans, this distinction is not present in toddlers [74] and it is not yet clearly understood, how humans make this distinction later on in life [71]. In HRI, animacy expresses how much people perceive the robot as a lifelike creature. Usually, perceiving an entity as alive allows humans to distinguish other humans from machines. Animacy does relate to the recognition of agency, biological movement, and, as emphasized in Piaget's framework [75], major factors of "being alive" are movement and intentional behaviour.

Likeability

The likeability in HRI describes the first positive impression people form of a robot. Previous research suggests that robots are treated as a social agent and therefore judged in a similar way [6].

Perceived Intelligence

The perceived intelligence in HRI measures how intelligent people judge the behaviour and the actions of a robot. This can be heavily influenced by the interface of the interaction (i.e touch pad, speech) or the robot's abilities (i.e. stationary, freely move in space). Is has been stated [69], that people's perception also depends on the robot's competence.

Perceived Safety

The perceived safety during the interaction with a robot describes the level of comfort and the level of (possible) danger people experience. As robot can come in many shapes, sizes and abilities and also are subject to popular cultures in different scenarios from the "out-of-control" robot (e.g. "The Terminator") to helpful support and loved by everyone (e.g. "Astroboy"), it is important to measure how safe people feel during an interaction.

3.2 Perception of the Humanoid Robot Robi

Humanoid social robots are developed to interact with people. To measure, evaluate and improve those interactions, it is crucial to consider how people perceive such a robot and compare this perception to other robot designs. As there are many factors to consider, like the physical design and the Chapter of the robot, this experiment uses a small humanoid entertainment robot to evaluate people's perception and obtain variables which can be used to be compared to other robots. The focus of this study is on perception. Particularly, it investigates how people perceive "Robi" (displayed in Figure 3.4) – a small- sized, friendly-looking humanoid robot.

3.2.1 Related Work on Humanoid Robots

The theory of the "uncanny valley", explained in more detail in Chapter 4 makes assumptions about the human-likeness of a robot in relation to people's affinity towards it [76]. It basically states for the case of humanoid robots that the more humanlike a robot looks, the greater its affinity is.

A moving humanoid robot would, according to this theory, be placed somewhere around 50% on the human-likeness scale and trigger a positive affinity towards it. The graph (Figure 4.3) does not indicate exact values, but the affinity of a robot like Robi would be higher than the one of an industrial robot and would not drop into the uncanny valley, meaning having a negative affinity due to it's design. Androids robots in contrast, as they are describes in Chapter 4, are thought to drop into the valley. The results how people perceive and trust such an android robot are described in the next section of this work.

It has been shown that people use visual clues to create impressions of others [77] and also, that those same visual clues are applied with robots [22, 78]. How people use this strategy indicates that the appearance of a robot is an important factor in the perception of a robot, as initial impressions of robots are based on visual clues and this has the potential power to influence the acceptance and the perception of a robot [13, 79, 80]. The appearance also can shape expectations [43] and even cause false beliefs about the robot's abilities [1].

Humanoid designed similar like Robi have been suggested to support intuitive interaction [81] and due to their anthropomorphic appearance, are researched in the area of anthropomorphism [20]. Also, human-like features in robots shape the perception of it as an anthropomorphic entity and the expectations of human-like behaviour [82]. People have been observed to anthropomorphize even inanimate objects [83], technologies and this effect has been found to be more prevalent for robots [20, 84–86].

It has been shown that the effect of a physically present (embodied) robot is different from a virtual agent or a video display of a robot [62, 87] and also, that sharing the same personal space with a robot has a strong effect on social presence [60], also described in Section 3.1.4 as Sonzai-Kan. To evaluate the perception of a small entertainment robot in a more natural way, people interacted in this study with the physical present robot.

In HRI, the person interaction with the robot had been defined as supervisor, operators, team mate, and bystander [88]. Current HRI experiments focus particular on one person, the operator interacting with one robot. This is the simplest form of an HRI experiment setting where the operator is the person who is directly in contact with the robot.

To expand the focus, this experiment introduces a second person who observes the interaction in the role of a bystander [89]. The settings of the experiment remain the same for both participants, they share the same physical space and both have a general understanding what the robot will be doing with the only difference that the bystander is not interacting directly with the robot.

Hypotheses

For this experiment series, following hypotheses (**H**ypotheses **H**umanoid) are stated:

HH1

> There are significant differences in the perception of the robot between the operator actively interacting with the robot and a bystander passively observing the interaction.

HH2

> The robot will be perceived as highly likeable and safe, but perceived low for animacy.

HH3

> The robot will be perceived to have low mental capacities.

HH4

> The perception of mental capacities will not change in the course of the experiment.

3.2.2 Method

The Humanoid Robot Robi

The focus of this experiment is the perception of the humanoid robot Robi (Figure 3.4). Robi – a small- sized, friendly-looking humanoid robot- - was chosen because it has an anthropomorphic body, biological motion and is able to understand specific vocal instructions and respond trough sound (i.e. speech and music) and movement. Robi is a small (34cm) entertainment robot which weights around 1kg and has 20 degrees of freedom.

Figure 3.4: The robot "Robi" designed by Tomotaka Takahasi. It was developed by the Japanese company RoboGarage and is currently sold in Japan by De Agostini. The robot used in this experiment was an English-speaking version currently being developed for international distribution ©by Tomotaka Takahashi.

Participants

A total of 42 participants (22 female, 19 male, 1 not specified) with a mean age of M = 23.33 years old (SD = 6.01) were recruited at the University of New South Wales, Australia. None of the participants reported to have had previous experience interacting with Robi. Only one participant stated to have ever heard of it before. An overview of the participants' basic demographics is included in Table 5.3.

Table 3.1: Participant demographics for the 2 x 2 condition. The terms "Sep" and "No-Sep" refer to the conditions with and without the separation wall respectively.

	Group A		**Group P**	
	No-Sep	**Sep**	**No-Sep**	**Sep**
Total	11	10	11	10
Female	8	4	4	6
Male	3	6	7	7
Non-specified	0	0	0	1
Mean Age	20.7	23.3	20.5	29.3
SD Age	3.28	2.58	2.91	8.92
Mean exposure to Virtual Agents	2.9	3.1	3.1	2.8
SD Virtual Agents	1.37	1.28	1.47	1.39

Experiment Condition

This experiment was set up as a 2 x 2 condition. Participants were randomly assigned to two groups for the first condition: (1) the active group, in which the role of "robot operator" was assigned to one participant for the first interaction trail with the robot (also referred to as group A) and (2) the passive group (also referred to as group P), in which the role of "bystander" was assigned to the other participant to passively observe the interaction between the robot and the operator (participant in group A). In the following second trial, participants then switched roles with the operator becoming the bystander and vice versa. Both participants shared the same physical space in this condition. The second condition, however, introduced a movable separation wall between the participants to prevent any form of interaction between them (Figure 3.5). Participants were randomly assigned to one of two experimental conditions, see Table 5.3.

Experiment Flow

The interaction experiment with the robot Robi was divided in three stages. Participants were first introduced to Robi and explained, that it is a Japanese robot being

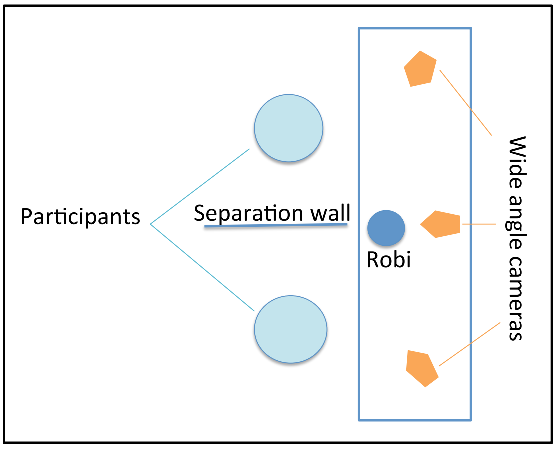


Figure 3.5: Experimental room setup during the interaction tasks with Robi.

tested on its English version for the first time. They were shown how Robi was switched on in a seated position. When switched on, the robot's eyes start to blink and he makes a small movement until seated stable in his basic sitting position. This part is phase_0 of the experiment flow (see Figure 3.6). The participants then filled out two questionnaires, one about their basic demographic data and the other one about their perception of the robot. During filling in the questionnaires, Robi was brought to a different room where the interaction trial where conducted. The room was installed with three small wide angle cameras to record the experiment (Figure 3.5).

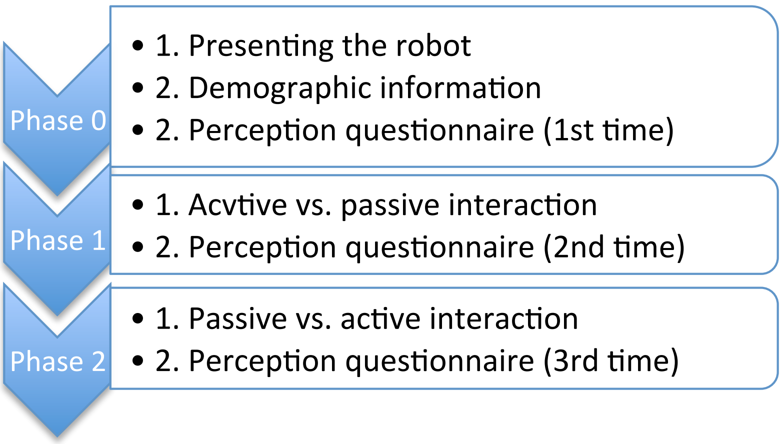


Figure 3.6: Outline of the experiment with Robi. The perception questionnaire was filled in three times.

In the following phase_1 and 2, the first and second interaction tasks took place, each followed by the same robot perception questionnaire used during phase_0. Both phases followed the same interaction protocol. The participant assigned as the operator was instructed to interact with the robot through speech, using a fixed protocol with seven pre-defined phrases that the robot is able to recognize and wait for its response. The phrases, the robot's reactions and movements are listed in Table 3.2. If Robi did not react, participants were instructed to repeat the phrase up to three times and then proceed to the next phrase if they still did not have a reaction from the robot. Subsequent to the interaction tasks, the perception questionnaire was filled in by both participants, the active operator and the passive bystander. They then repeated the task in the second interaction in phase_2 with switched roles.

Questionnaires

The experiment used the previously described robot perception questionnaire [69] (Godspeed Questionnaire) extended by additional items to determine if people ascribe mental capacities beyond the observable behaviour to the robot [90]. The goal was to examine of people think the robot can experience (feel, sense) things or possesses agency (acts, plans). In this case, participants were asked the 5-point scale questions list in Table 3.3

3.2.3 Experimental Results

The data was evaluated for significant differences and possible correlations between the 2 x 2 conditions. We examined the data with regard to possible differences in the perception of the robot and the robot's mental capabilities between the initial presentation of the robot (phase_0) and after interaction trials (phase_1 and 2). The data for the initial phase_0 was measured right after the presentation of the robot to the participants and phase_1 and 2 refer to the data measured right after the first respective second interaction with the robot (see also Figure 3.6).

Table 3.2: The seven pre-defined phrases participants uttered to the robot and the programmed answers and actions of Robi.

Participant Phrase	**Robi Answer**	**Position**	**Movement**
Nice to meet you	Nice to meet you	Seated	Turns head
Introduce yourself	I'm Robi. I am a robot. I was put together with lots of parts. I can chat and do many things.	Seated	Moves head
What can you do?	I can turn on the TV, keep you company, play games, dance, and many other things.	Seated	Moves head
Come here.	Oki doki	Seated	Stands up and makes 3 steps
Let's dance	Then, here we go. (After dancing: I'm tired)	Standing	Dances to music sound
You're so cute	Hehe, not at all.	Standing	"Blushes" (Lights around eyes turn red)
Bye Bye	Bye Bye	Standing	Waves with right arm

Table 3.3: Additional items asked to determine if the robot, from the participants' viewpoint, is able to experience or possesses agency.

Experience
Do you think this robot feels fear?
Do you think this robot feels pain?
Do you think this robot feels pleasure?
Agency
Do you think this robot plans?
Do you think this robot exercises self-control?
Do you think this robot memorizes?

Exposure to Virtual Agents and Robots

Based on a five-point scale rating, participants in this experiment indicated to currently have moderate exposure to virtual agents (i.e virtual characters in software services or computer games), as displayed in Table 5.3. Furthermore, it was concluded that 51.2% of the participants were exposed to robots only through videos, 26.8% have seen them in person and only 17.1% has operated or interacted with them before. The type of the robot was not more specified in this question.

Robot Perception Change

The perception of animacy (t(9)=-2.63, p=0.02) and likeability (t(9)=-1.94, p=0.08) increased slightly significant between the introductory phase_0 and the first interaction (phase_1) for the passive group when the separation wall was used (Figure 3.8 and 3.9). Also, Animacy increased slightly in phase_2 for the passive group without the separation wall (t(10)=1.89, p=0.08). The other key concepts evaluated (anthropomorphism, perceived intelligence and perceived safety, Figure 3.7, 3.10, and 3.11) did not show any significant changes.

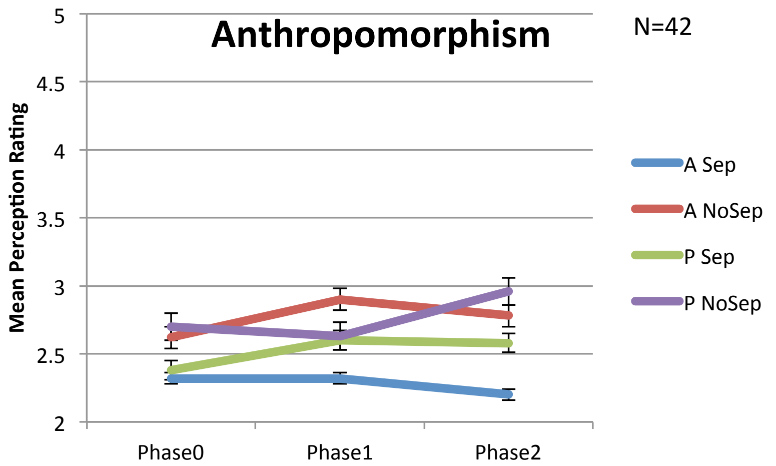


Figure 3.7: The perception of anthropomorphism over time of the robot Robi. In this and subsequent figures, the condition groups are the active (A) and passive (P) groups with and without separation wall (Sep and NoSep). The error bars show the Standard error and N indicates the number of participants.

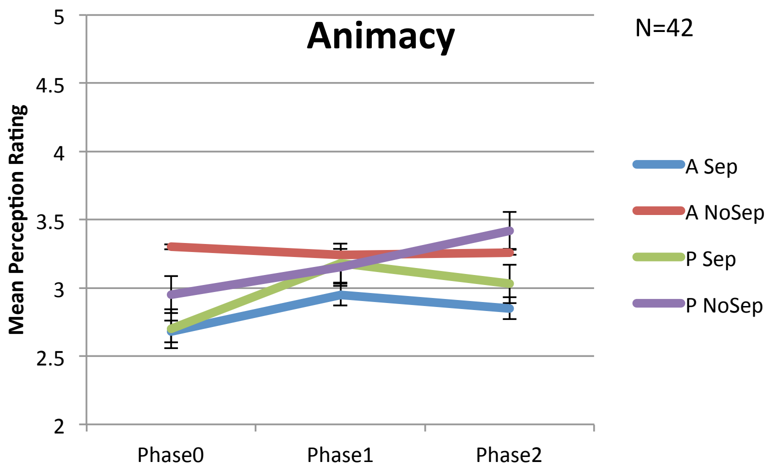


Figure 3.8: The perception of animacy over time of the robot Robi.

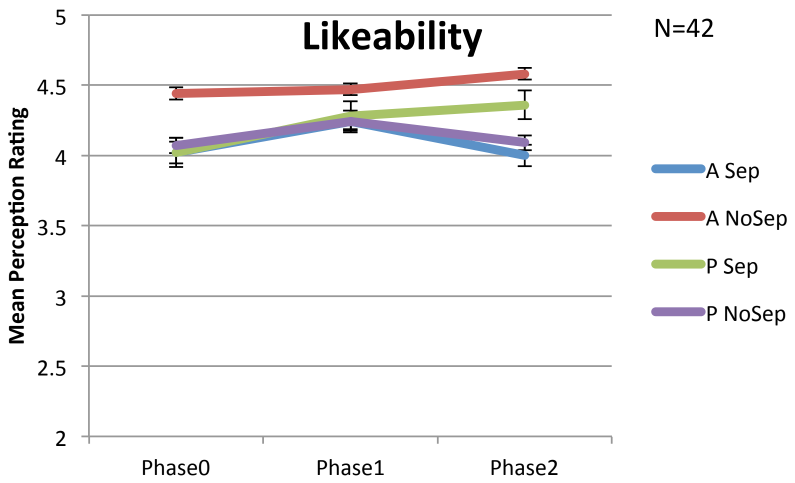


Figure 3.9: The perception of likeability over time of the robot Robi.

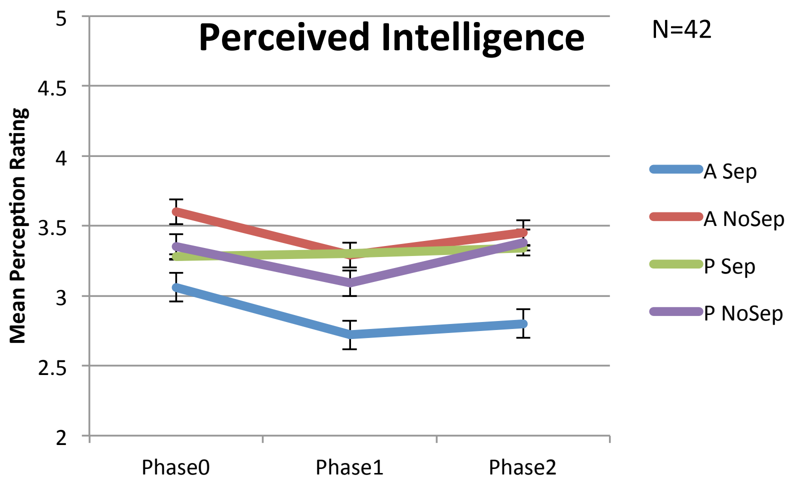


Figure 3.10: The perception of intelligence over time of the robot Robi.

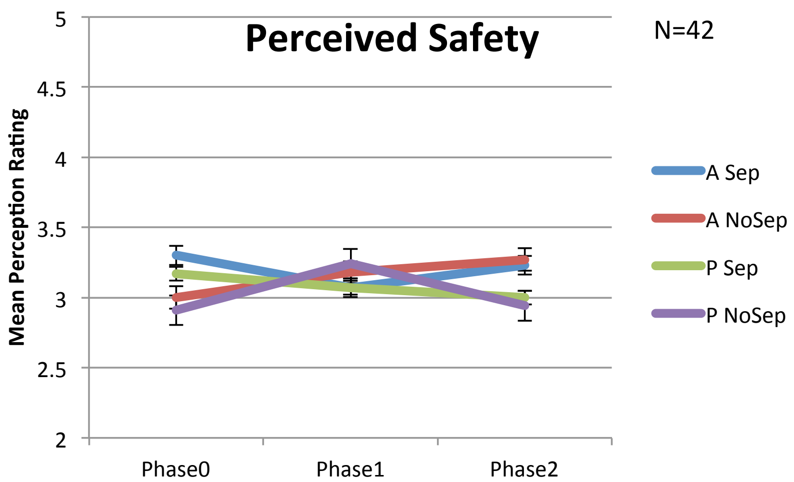


Figure 3.11: The perception of safety over time of the robot Robi.

A slightly significant difference F((3,38)=2.31,p=0.09) was observed for the perception of intelligence after phase_2, second interaction, where the active group using the separation wall perceived had a lower perception of intelligence when compared to the other experimental conditions (Figure 3.12).

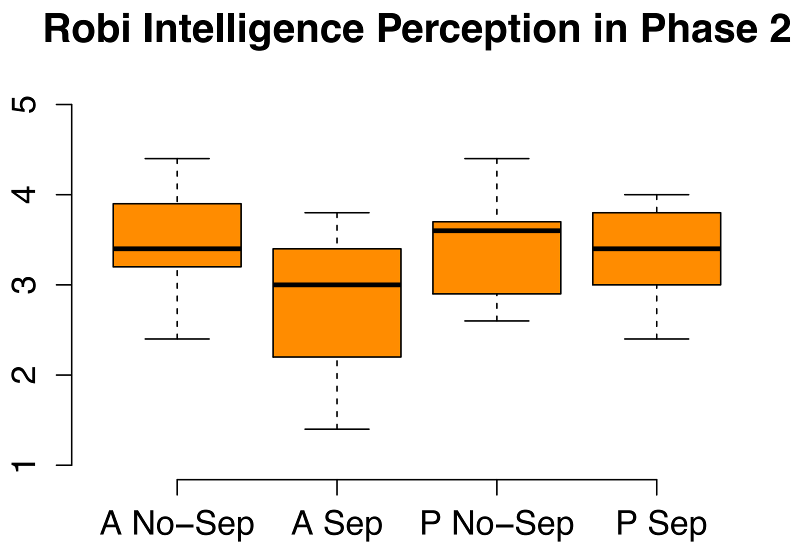


Figure 3.12: Perceived intelligence of the robot Robi after the second interaction (phase_2). The horizontal lines at the bottom define the sample minimum and the sample maximum at the top. The lines inside each box represent the sample medians. Each box represents quartiles, with the lower quartile defined by the lower and the upper quartile defined by the upper limit of the box.

Further evaluation of the global dataset revealed that the experimental conditions might not show significant data for the differences between single conditions, but significant changes when the full dataset independent of the 2 x 2 conditions is considered. The perception of animacy (t(41)=-1.9, p=0.06) increases slightly significant between phase_0 and 1, and perception of intelligence (t(41)=-1.86, p=0.06) decreases slightly, see Figure3.13.

Robot's Mental Capabilities Change

Globally, the perception of the robot Robi being able to experience was quite low Figure 3.14). There were no significant differences between the conditions and the data evaluation did not show any significant perception changes along the dimension

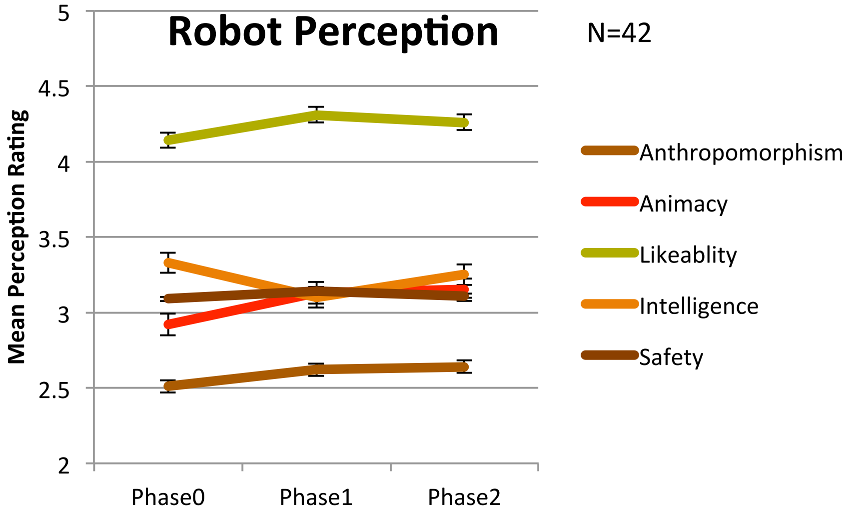


Figure 3.13: Perception changes of the robot Robi in the five key concepts by considering the full dataset without the 2 x 2 conditions.

of experience.

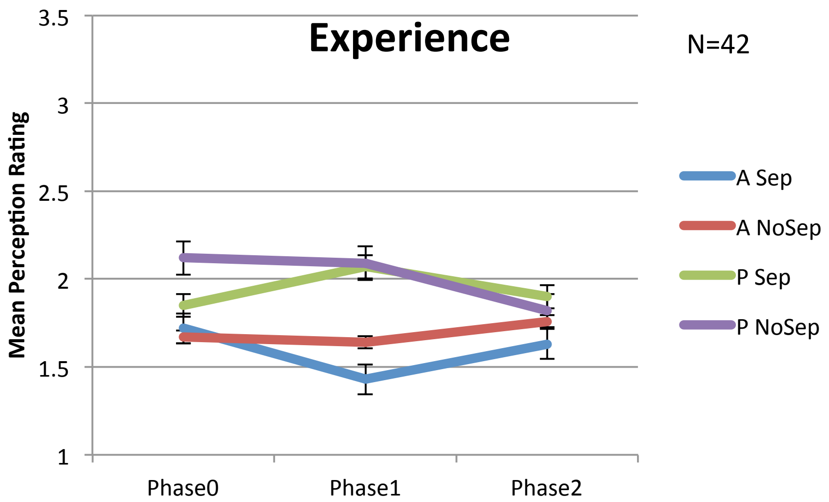


Figure 3.14: The perception of the robot's ability to experience over time.

In terms of agency, the participants' perception of the robot as having the capability of acting or planning, (Figure 3.15) agency was perceived significantly higher than the perception of experience (phase_2: $t(75.6)=-3.69$, $p<0.001$) even though this perception decreased within the active group with separation wall between phase_0 and 2 ($t(9)=2.98$, $p=0.01$), and the passive group without separation wall between phase_Figure 1 and 2 ($t(10)=3.01$, $p=0.01$).

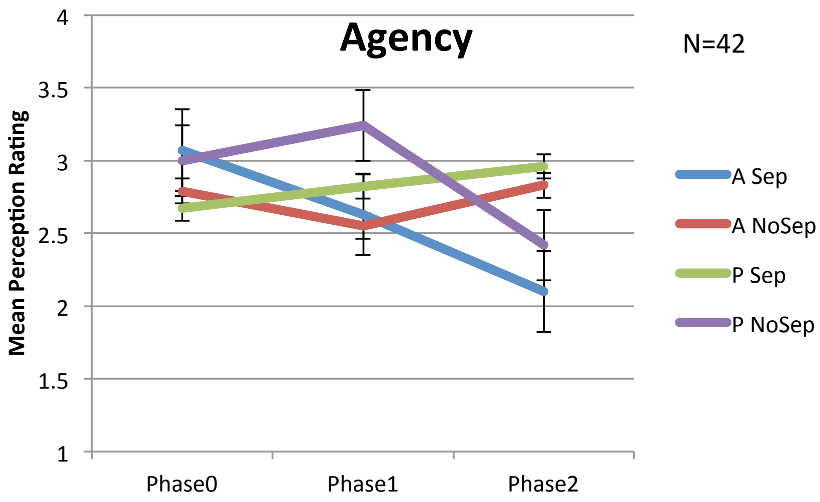


Figure 3.15: The perception of the robot's ability of agency over time.

Active and Passive Group

As mentioned above, with the ongoing evaluation of the dataset the suspicion was formed, that one of the conditions might not have had a significant effect on the perception of the robot Robi. When the condition of the separator wall was ignored in the dataset and the data analyzed for the differences between the active and the passive group, without considering the wall, it was found that there are no significant differences between active and passive groups for the perception of anthropomorphism, likeability and perceived intelligence. The perception of animacy in the passive group, however, is different from the active group. Whilst there are no differences in the active group, the perception of animacy increases significantly between the initial phase and phase_1 (t(20)=-2.29, p=0.03) as well as the initial phase compared to phase_2 (t(20)=-2.34, p=0.02) in the passive group, see Figure 3.16. Furthermore, the passive group shows a decrease for perceived safety (t(20)=2.09, p=0.04) between phases 1 and 2.

The capability of Robi to experience is perceived significantly higher (t(20)=2.09, p=0.04) in the passive group in phase_1 but there are no significant changes after the second interaction (Figure 3.17). Globally, there are no significant changes for the perception of Robi's capabilities of experience and agency.

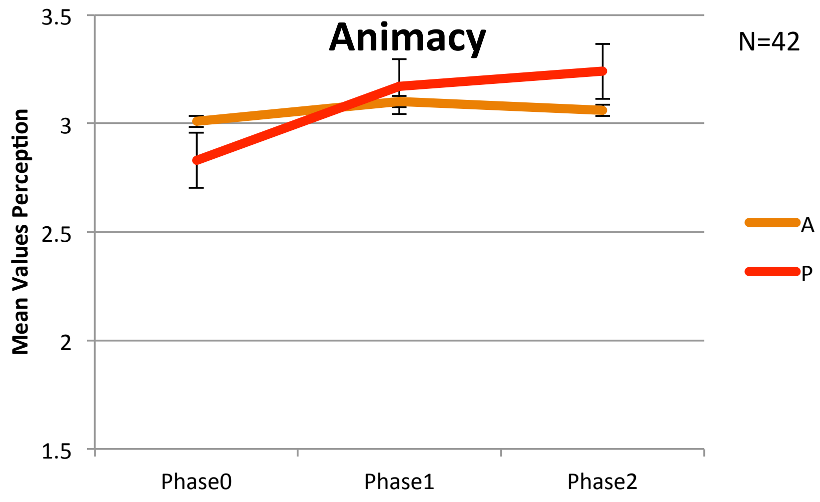


Figure 3.16: The perception of animacy over time of the robot Robi independent of the separator wall condition.

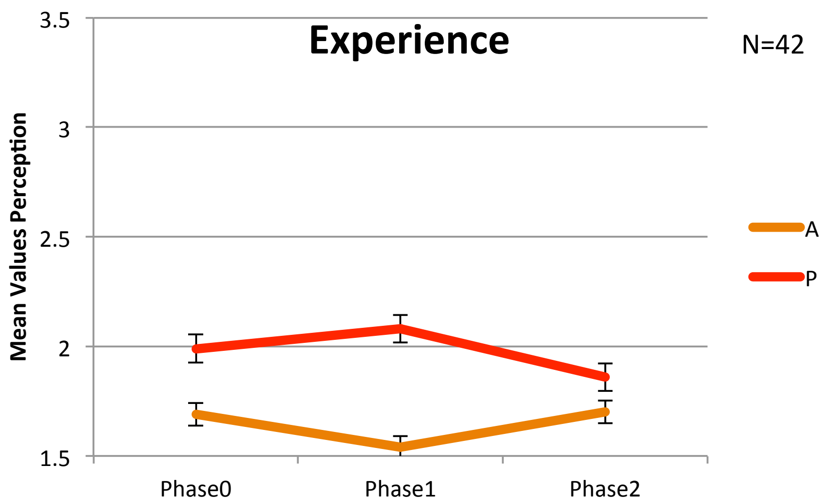


Figure 3.17: The perception over time of the robot Robi's mental capability to experience independent of the separator wall condition.

3.3 Discussion

The perception of the robot Robi changed significantly between its initial presentation to people and after the first interaction. The experimental data revealed that when people were passively observing the robot for the first time, their perception of animacy and likeability increased.

The global data evaluation – independent of the 2 x 2 conditions – demonstrated that the perception of animacy between phases_0 and 1 increased, and the perception of intelligence decreased. The condition with the separator wall between participants to prevent interaction, particularly to prevent visual clues about the reactions of other participants, did not lead to a decrease in perceptions of intelligence. The conditions of active and passive interaction showed a significant increase for animacy in the passive group. It is therefore concluded that the interaction mode – active or passive – influences the perception of animacy, whilst the separator condition might not have an influence on perception. It is thought that passive observation shapes an increasing perception of animacy while avoiding the (possible) negative emotions (e.g. frustration) generated in the operator (active interaction) when the robot did not respond to its commands. After changing roles, it is apparent that the expectations of the new operator (before passive bystander) shift to a more realistic expectation, and thus the perception of animacy does not change any further.

When analysing the global dataset independent of experimental conditions, it appears that people formed a perception of the robot after the first interaction, and then did not significantly change it after subsequent interactions. This is thought to be an indication that human perception of a robot is formed similarly regardless of active and passive interactive behaviours when people are in close proximity to the robot. The global decrease in perceived intelligence could be explained by specifics of the experimental setting. People were instructed to interact with the robot through a fixed speech protocol (i.e. not a free interaction). As participants had no previous knowledge of the robot, its abilities, or the experiment setting, the results show a shift from participants' initial expectations (a higher perceived intelligence) to their newly obtained knowledge after each interaction.

The analysis of the global dataset as well as in each separate condition also shows a very high likeability of the robot, with a tendency to increase over time. This robot seems to be highly appealing to people. It is thought that this high likeability is a result of many combining factors, such as the friendly appearance, design, small size, and non-threatening behaviour. According to participants' comments, the robot was often referred to as "very cute" throughout the course of the experiment. It is concluded, together with the results from the previous study, that a friendly appearance design shapes an expectation of a friendly robot and is related to an increased likeability perception. The free comments of participants could be used in future studies to determine the individual importance of the measured concepts.

The data evaluation showed no significant changes for the separator condition, so the data were analysed with regard to the active and passive conditions. The perception of animacy differed between those groups. In particular, it seems that passive observing in the first interaction enforced perception of the robot as lifelike, interactive, and responsive compared to the active interaction. Furthermore, passive observing could be linked to a higher perception of the robot as being able to experience. However, this effect was reduced when the passive observers then actively interacted with the robot in the second interaction. It can be said that the ability of this robot to experience – its ability to feel pain or pleasure – was generally quite low.

The robot Robi is designed for social interaction and could be treated as a kind of social actor with a mind. When it comes to mind perception along the dimension of experience (e.g. feeling, sensation) and the capability for agency (e.g. acting, planning), adult humans are seen as capable of both, whereas children and animals are more perceived as being mainly able to experience, and robots and concepts like gods are capable of mainly agency [91]. The study with the robot Robi supports this theory, as the data showed that people perceived the robot as being more capable of agency than of experience.

This study is subject to several limitations, as all participants were recruited from the same geographical area, and it is therefore possible that the same experiment would yield different results if conducted in a different country with a different cultural background. Indeed, there are interesting cultural differences in the perception of robots, which were outlined in detail in Chapter 5. Further, the experiment was conducted in a laboratory environment, and participants were aware of the laboratory surrounding (e.g. visible cameras, participant disclaimers), despite being blinded to the purpose of the experiment. This kind of experiment and the current technology allow only short-term interactions, and results may vary when people interact with robots in different environments (e.g. homes or exhibitions) or in long-term settings.

It seems that the perception of a physically present robot in close proximity to two people is more dependent on the design of the robot, its performance, and its abilities than on the actual interaction mode. The crucial factors are thought to be the physical presence and the close proximity of both persons to the robot. It is concluded that people seem to form an initial perception of the robot and its mental capabilities during initial contact and only adjust that perception within the first interaction, independent of whether that interaction is active or passive. They do not perform any major adjustments to their perception when the interaction roles are switched.

Next, Chapter 4 describes a similar experiment with the same measurement in terms of perception with an android robot. This investigation will seek to answer the research question of how people perceive a different robot type using the same measurements.

Chapter 4

Perception of an Android Robot

The study of the perception and acceptability of an android robot was adjusted to the abilities of the robot and previous research results. In the following, the results of an interaction experiment with an android robot are reported. The specific variables reported here are the perception of the android robot before and after the interaction, trust in the robot, interaction time measurements for the touch of the robot's hand, proxemics (physical distance) of people during the interaction to the robot, and the character of the interacting person. The measurements of each variable were analysed, compared, and correlated against each other. It was found that the character of the person interacting with the robot has an influence on the amount sent in an economic trust game used to evaluate trust, and there was a distance change observed over time, meaning that people came closer to the robot.

4.1 Motivation

An android robot is a unique robot type in the sense that it's design is an attempt to be an exact copy of a human being whilst other robots do not aim to have fully biological human movements or appearance. An android robot has a human body shape and in addition detailed features like realistic skin, eyelashes, eye blinking movements, breathing movements, hair etc.

For this experiment, the android robot Actroid-F (where F stands for the female version) was used. The robot is displayed in Figure 4.1 together with two female researchers and in Figure 4.2 together with it's male version. From those pictures, it becomes clear that when people look at the robot for a short period of time (under 2 seconds), they tend to fail to recognize Geminoid as a robot (70% of subjects failed to distinguish human and android [92]).

Figure 4.1: The android robot (in the middle) in between to two real female humans (©2013 by Peter Rae).

Figure 4.2: The android robots in the male version on the left and female version on the right (©by Yoshio Matsumoto).

It has been suggested that this robot type, when people realise that the entity they are facing is not a real human, gives them an eerie feeling, also described as the "Uncanny Valley", first described by Mori in 1970 [3]. This theory only recently gained new popularity with due to popular culture and new technological improvements in Hollywood productions with very realistic, but artificial characters and the rejection of those movies by a broad wide audience (e.g. the controversial movie Polar express and described by the CNN reviewer Paul Clinton with "[the] human characters in the film come across as downright ... well, creepy."). Also only recently, an authorized translation of the original paper was published [76]. In short, the theory states that as the appearance of robots comes closer to a human appearance (from i.e an industrial robot), the higher people's affinity, until the very point is reached when the robot is too similar to a human and people's response to it drops into an "uncanny" valley of revulsion. This study does not attempt to prove this theory but considers it as an important contribution in the field of human robot interaction and the "Uncanny Valley" is therefore described in detail in Section 4.1.3.

4.1.1 Research Challenges

The challenges of measuring perception have been previously described in Section 3.1.3. The same robot perception questionnaire is used in this experiment.

Another challenge in the area of human robot interaction the question how to quantitatively measure how much people trust a robot. Previous studies have suggested the use of an economic trust game [93] for the use in human robot interaction studies under laboratory conditions [94]. Economic trust games allow to measure interaction behaviour between people and robots and empirically quantify trust in human-robot relationships in a reliable and standardized way. An adapted form of the Trust Game [93] or otherwise called "investment game" was played between the participants and the robot. This game-theoretic approach to empirical measurement of trust in human robot interaction can be recreated and applied in future studies and allows possible comparison between different robots in terms of trust towards them. The Trust Game is described in detail in the section 4.1.2.

Previous studies have suggested, that the interaction between humans and robot also is influenced by their personality traits [95]. They state that individuals with a more extravert personality tend to prefer more humanoid robots whilst individuals with a more introvert personality prefer more mechanical looking robots. Another example for the many possibilities how the interaction is influenced by the physical appearance of a robot is the a study evaluating the appearance of robot faces and concluding, that people behaved as if they attribute complex human-like motivations to the presented robot faces [96], presented in a photo-based survey and therefore not triggered the previously mentioned effect of presence in Chapter 2.

In addition, the research about the normal distance people keep from each other during social interaction has been found to be the same distance 60% of participants chose in an interaction with a robots in a study about proxemics to robots [97]. Other studies about proxemics to robots revealed that the experience owning a pet or pets decreased the personal space between the participants [98].

For the experiment design here factors which could have a possible influence on robot perception and the acceptability of such a robot were integrated in the experiment for evaluation. The factors evaluated here were previously studied in different conditions and contexts. This experiment includes the possible influence of prior experiences with robots and prior relationships with non-human agents like pets [99], the subject's personality [97, 100, 101], proxemics to the robot and the possible influence of the robot's gaze during interaction which had been shown to have an effect on proxemics behaviour [98,99]. The crucial factor of physical presence of the robot as described in Section 3.1.4 is also included in the experiment.

To evaluate all those factors a complex human robot interaction experiment was designed with the goal to evaluate changes in people's perception before and after interacting with a physical present robot in relation to their personality, trust towards the robot and behavioural measurements taken during the experiment (e.g. proxemics, interaction times).

The goal of this experiment was to evaluate those factors under laboratory conditions and determine their relevance in an HRI experiment with this robot. The perception evaluation is the same as described in Section 3.1.6 and a previously validated scale of personality evaluation was used. In total, participants interacted three times with the robot around one minute each time. The robot engaged them in a small conversation (e.g. asking the participant's name) and then explained a simple task (move a colored box to the robot's left respective right the second time) in the first two interaction tasks. The third time, the participant was asked to touch the robot's hand.

4.1.2 The Trust Game

The original version of the Trust Game (investment game) was used to measure trust in economic decisions [93]. This study pairs a participant with the robot and it is explained to them, that both parties receive a certain amount of money. This study used an amount of 1000JPY (approximately 10USD). The first player, always by default the participant, is told that he can send money to the second player, the robot. The participant had to decide to send any amount between zero and the full amount to the robot. The participant also was informed that the amount he sends was tripled when the robot receives it. They are explained that the robot then will "send and amount back." The experimenter leaves the room to go to the experiment space to "consult" the robot. This part of the Trust Game is manipulated by the researcher and the participant receives an amount slightly higher or lower than he initially send, depending on the experiment condition he has randomly been assigned to.

It has previously been shown that social interactions can be influenced by several factors. As the interaction with a robot is treated here as such a social exchange, it is suggested that the participant's decision in this economic trust game might be influenced by the personality type as it has recently been shown in studies from the perspective of personality psychology [25, 102–105]. One study showed clearly, that the personality trait extraversion (directed towards the objective world) is related to a higher amount sent in the trust game [102].

The use of an economic trust game in HRI has been reported recently and been used to assess the cooperative intentions of novel interaction partners [69, 106]. In HRI research, an adapted game-theory methodology of an one-shot investment game has been used to compare the trustworthiness of more mechanical robots to more human robots with the result, that mechanical looking robots got entrusted with a significant higher wager [107].

4.1.3 The Uncanny Valley

The uncanny valley is a theory first stated by Masahiro Mori as Bukimi no Tani Gensho (不気味の谷現象) in 1970. At that time, he hypothesized that the more humanlike a robots looks, the more endearing it would be for people until a person's response would shift abruptly to a strong revulsion when the robot has nearly, but just not, a lifelike appearance. This hypotheses has not received a lot of attention until only more recently not only more humanlike android robots have been developed, but also popular culture has attempted (and failed so far) to create lifelike computer-graphics animations in Hollywood movies [108].

Figure 4.3 shows the valley, which was defined by Mori as the uncanny valley, which is reached on the way towards making robots appear like humans. The original graph shows the increase in affinity from a very functional designed industrial robot to a more roughly humanoid looking toy robot with a head, arms, legs and torso. Research has shown that (not only) children seem to feel attached to those types of robots [76]. Less known in popular culture but important regarding the nowadays technological progress is the second graph Mori developed with the distinction of moving and still robots shown in Figure 4.3.

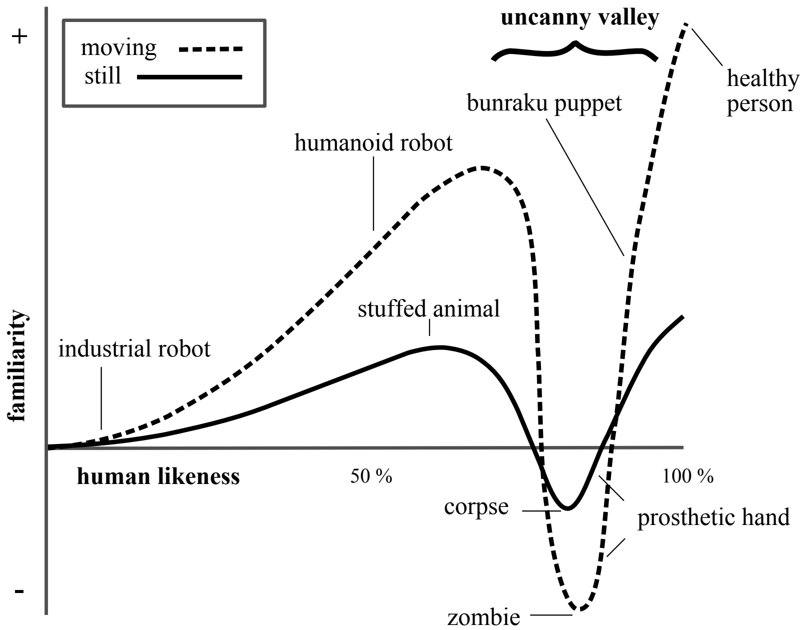


Figure 4.3: The uncanny valley according to Mori [3]. Bunraku is a form of traditional Japanese puppet theater from the 17th century.

Here, the entity at the very bottom of the graph is described as “zombie.” Still in the valley, is for example a very humanlike but not fully realistic prosthetic hand given and then both curves, moving and still, unify at the maximum of both scales affinity and human likeness as “healthy person” (implying that there is a chance that people might tend to reject unhealthy looking people).

The android robot used in this study is a moving robot with very high human likeness, which could be on the scale somewhere right in the drop of the uncanny valley. Newer fMRI studies have shown that android robots trigger an effect different from mechanical robot and also different from humans which could be explained by the mismatch in (biological) appearance and (mechanical) movement [109].

Hypotheses and Research Questions

It was hypothesized (**H**ypotheses **A**ndroid) that:

HA1

Subjects would reduce the amount of space between them and the robot over the three trials.

HA2

The subject’s performance in the trust game would be linked to their likeability towards the robot.

HA3

Participant’s previous experience with non-human agents (e.g. pets, virtual agents, etc.) would decrease their distance to the robot [98].

HA4

Individuals with extravert personality traits would make higher offers in the trust game.

Furthermore, the main research questions were how the perception of the robot changes before and after the interaction and how the proxemics and trust game data compares to similar experiments with humans.

4.2 Method

4.2.1 The Android Robot

The android robot used during this study was the female version of the Actroid androids, Actroid-F, a highly human-like android robot with the appearance of a young Japanese woman (Figure 4.4) developed in collaboration with Osaka University and Kokoro CompanyLtd. This robot is able to exhibit various human-like facial expressions (e.g. smile, surprise, anger) by moving its eyebrows, eyelids, eyeballs, and mouth; it also has body gestures as it can turn and lean its head and has the ability to bow [110]. The Actroid's face and hands are made of a soft silicon rubber copied from a biological model, its hands are designed to look and feel natural when touched.

The complete platform consists of the robot itself, an air compressor, an operational computer, a web camera, and a microphone. Twelve valves in the android's body control the airflow and enable it to move without making any noise. The web camera is used to capture the operator's (one of the researchers) facial movements while the robot immediately mimics those movements. The robot's voice is generated via a speech synthesiser and a text-to-speech interface that allows the operator to communicate with the participants. In the current experiment the robot was dressed in jeans, a white blouse, and a pink cardigan as shown in Figure 4.4.

Figure 4.4: A participant interacting with the android robot Actroid-F during the experiment.

4.2.2 Participants

For this experiment, 56 participants were recruited from local universities in Japan from which one participant was excluded from the data evaluation due to participant bias (demand characteristics). The remaining 55 subjects were between 18 and 66 years (M=22.65, SD= 7.47), with 37 female and 18 male participants. None of the participants has ever interacted with an android robot before. Questionnaires, the instructions of the robot and the general interaction context were in Japanese. The participants received monetary reimbursement for their participation and were naïve to the purpose of this experiment.

4.2.3 Experiment Conditions

The experiment is designed in a 2 x 2 condition to which participants were randomly assigned to: The robot either turned its head towards the colored boxed it was talking about or just kept looking straight at the participant (gaze vs. no gaze) and the manipulated payback in the trust game after the interaction with an either higher or lower payback than the amount sent by the participant (higher vs. lower payback). Participants were randomly assigned to each condition.

4.2.4 Experiment Flow

The experiment had three main stages: First the evaluation of basic demographic data, personality traits and initial robot perception, second the interaction tasks with the robot and last the trust game and the final evaluation of the robot perception. The experiment flow is displayed in Figure 4.5.

The first stage evaluated the participant's personality traits with a validated translation of the Eysenck Personality questionnaire [111] and the robot perception was evaluated with the Godspeed Questionnaire [69] (see also Section 3.1.6). As we did not observe any perception changes after the first interaction in the experiment with the robot Robi described in Section 3.2, the perception of the android robot was only administered before the interaction tasks (showing pictures of android robots) and after the interaction tasks with the robot. To evaluate if prior exposure to

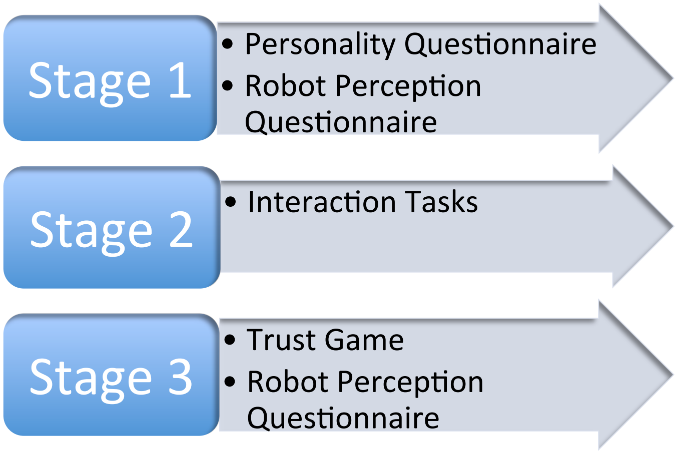


Figure 4.5: The three stages of the interaction experiment with the android robot Actroid-F.

virtual agents or to robots has an influence on perception, it was asked participants about their exposure on a 5-point scale. Also, as prior studies have shown that pet ownership might influence interaction [98], it was asked if they ever owned a pet.

The second part are three interaction tasks with the robot in which the robot greets participants, engages them in some small talk and then instructs them to move a pink box to their left in interaction task 1 and respective a green box to their right in interaction task 2 (see Figure 4.6). During task 3, the robot asks the participants if they would like to touch the hand. Every time a task was completed, the robot thanked them for their participation and asked them to wait outside the experiment room.

After the interaction tasks in the last stage, participants played an economic trust game with the robot as described in Section 4.1.2. This two-player trust game has been used in similar contexts to evaluate trust under laboratory conditions [93]. In the modified version here, the participant is always player 1 and endowed with a fixed amount of money and has to send any portion between zero and the total amount to the robot. Depending on the assigned payback condition, the participant receives an amount "from the robot" which is manipulated by the experimenter and either slightly higher or lower than the amount originally sent by the participant. In case the amount sent it zero, the participant receives nothing in return.

4.2.5 Experiment Setting

The experiment took place in a separated room as outlined in Figure 4.6. The participants interacted alone with the robot without a researcher present in the room.

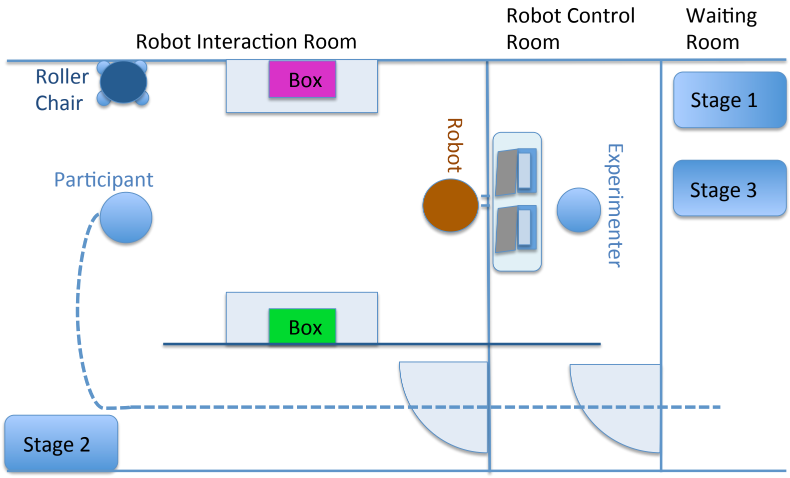


Figure 4.6: The bird's eye view of the experimental set-up for the interaction experiment with the Actroid-F robot. Stage 1 and 3 took place in the waiting room (right), the robot was controlled in the control/experimenter room (center), and the interaction itself with the robot in stage 2 took place in the interaction room (left).

4.2.6 Measurements

This experiment uses the previously introduced robot perception questionnaire (Godspeed Questionnaire [69], see Section 3.1.6). The personality of participants is evaluated with the Eysenck Personality questionnaire [112]. Personalities are categorized within the three factors of extraversion, neuroticism and psychoticism. As we intend to conduct the same experiment within a different culture and language, it was an important factor to use a personality evaluation with an existing and validated Japanese and English version. In particular, here the Japanese version of the short-form Eysenck Personality Questionnaire–Revised (EPQ-R) [111] was used.

In addition to the questionnaire series, the distance to the robot and touch times were measured. The proxemics data was measured from the robot's feet to the point the participant positioned their roller chair. At the beginning of each task, the chair was always positioned against the wall in a way, participants had to adjust its position in order to take a seat. The final position participants were seated was left completely open to them. Between the tasks, the experimenter adjusted the chair into its initial position at the wall (see Figure 4.6). The subjects were unaware of the purpose of chair adjustment and were not told that proxemics data was evaluated during interaction.

There were two different touch times measure. First, the time from the moment the robot finished to ask the participant if he or she would like to touch the hand until the first contact with the robot's hand. The second time was measure from the moment of first contact until the end of the touch interaction. If subjects hesitated or expressed doubt, the robot verbally reinforced them or simply asked them again to touch the hand now.

4.3 Experimental Results

The experiment data was analyzed with the software environment for statistical computing R. All outliers outside of 3 standard deviations of the mean (M $\pm$ 3SD) were removed from the dataset and the data was summarized over means and hypothesis tests employed.

4.3.1 Proxemics

The data evaluation of the distance to the robot over the three interaction showed a clear support for hypothesis HA1, stating that people come closer to the robot over time. The distance between each interaction task decreased significantly: Between task 1 and task 2 by 8.3 cm ($t(54)=4.87$, $p<0.001$, Bonferroni corrected) and between task 2 and 3 by 3.7cm ($t(54)=2.67$, $p<0.05$, Bonferroni corrected) as displayed in Table 4.1.

4.3.2 Perception Change

The perception of anthropomorphism, perceived intelligence and perceived safety of the robot changes significantly before and after the interaction tasks. In the area of

Table 4.1: Mean distances (in cm) to the robot in the three interaction trials ©Springer 2014 [5].

	Task 1	**Task 2**	**Task 3**
Mean (cm)	128.2	119.9	116.1
SD	35.7	33.2	3.2

animacy and likeability, there was no change observed. The results are displayed in Table 4.2. Whilst the perception of anthropomorphism (t(53)=4.22, p<0.001) and perceived intelligence (t(53)=7.55, p<0.001) decreased significantly, the perceived safety of the robot increased significantly (t(53)=-1.99, p=0.05). Data from one participant was missing due to an incomplete questionnaire.

Table 4.2: Mean values of the Godspeed robot perception questionnaire before and after the interaction trials ©Springer 2014 [5].

	Before		**After**	
	Mean	**SD**	**Mean**	**SD**
Anthropomorphism	3.10	0.92	2.45	0.91
Animacy	2.83	0.78	2.85	0.90
Likeability	2.85	0.66	2.85	0.53
Perceived Intelligence	3.49	0.65	2.85	0.55
Perceived Safety	2.67	0.62	2.85	0.63

4.3.3 Perception and Trust Game

The data found in this experiment did not support hypothesis HA2, stating that likeability of the robot and amount sent by participants in the trust game are positively correlated. Instead, it was found that the amount sent and the perception of intelligence of the robot were positively correlated (r(52)=0.28, p=0.03), meaning if the perception of intelligence before the interaction tasks was higher, participants also send a higher amount in the trust game.

4.3.4 Personality and Trust Game

The data of this experiment confirmed hypothesis HA4, stating that people with a higher extraversion score in the personality evaluation endow the robot with a higher amount in the trust game. It was found that extraversion and the amount sent were positively correlated ($r(52)=0.44$, $p<0.001$) whilst other character traits did not show any correlations with the trust game.

4.3.5 Perception and Exposure to Virtual Agents

The data showed that the exposure to virtual agents had an influence on the robot perception. A higher exposure to virtual agents correlated with a higher perception of anthropomorphism ($r(52)=0.33$, $p=0.01$) and animacy ($r(52)=0.30$, $p=0.02$) before the interaction trials. This was not observed after the interaction anymore, but at this time, the higher exposure to virtual agents showed a slightly higher correlation with perceived intelligence ($r(53)=0.23$, $p=0.08$) and safety ($r(53)=0.23$, $p=0.08$).

The global data showed a decrease for anthropomorphism and an increase for perceived safety independent of the exposure to virtual agents, but animacy showed no change in the global data and perceived intelligence showed a decrease. With a higher exposure to virtual agents, significant differences were found for the data for animacy ($F(1,52)=5.21$, $p=0.02$) and slightly significant differences for perceived intelligence ($F(1,53)=3.03$, $p=0.08$).

4.3.6 Perception and Reward Condition

The (manipulated) reward condition seemed to have a slightly significant effect on the perception of animacy. Participants in the higher reward condition rated animacy higher than participants in the lower reward condition ($F(1,53)=3.24$, $p=0.07$).

The perception animacy, likeability, perceived intelligence and perceived safety of the robot was significantly influenced by the reward condition when participants never owned a pet. Not owning a pet, the condition of a higher compared to a lower payback in the trust game increased significantly the perception of animacy

($F(1,51)=6.44$, $p=0.01$), likeability ($F(1,51)=5.63$, $p=0.02$), perceived intelligence ($F(1,51)=6.26$, $p=0.01$) and safety ($F(1,51)=6.69$, $p=0.01$).

4.3.7 Perception and Touch Times

In this experiment, two different touch times were measures. First, the time it took participants until they touched the robot after the request and second, the total touch time of the robot's hand.

The data showed that length and the perception of animacy before the interaction trials correlated positively, so participants perceived a higher animacy also touched longer in total ($F(1,49)=4.06$, $p=0.04$).

4.4 Touching an Android Robot

The modality of touch was mentioned in Chapter 2 and as well in the results section of the interaction experiment with the android robot, but because it includes several new research areas, detailed explanations and results are presented in this section. With robots slowly becoming more common in everyday life, it is also expected that people will intentionally and unintentionally communicate with robots via touch. To date, little research has been done on how people interact with robots via touch. To evaluate the data on touch collected in the android experiment described in Section 4.2.4, a previously developed touch dictionary of tactile behaviours was adapted, extended, and used to examine how people touched the hand of the android robot. The data were evaluated for touching behaviour, participants' personality traits, and their perception of the robot in terms of its anthropomorphism, animacy, likeability, perceived intelligence, and safety. This is the first study to report people's tactile behaviour with an android robot and to examine the correlation between people's personality traits and tactile gestures.

4.4.1 Motivation

Peoples use touch in everyday situations to share feeling and also to enhance other forms of communication [113]. The interpretation of the touch itself underlies many constraints like the social context of the interaction, the social beliefs of the people interacting, their cultural background and their emotions [114]. For example, depending on the social context, touching the buttocks of a stranger could be acceptable during a medical exam, but could communicate a completely different message and be interpreted as sexual harassment in an everyday social interaction [115].

Touch between people has been shown to influence people's behaviour and modulate their decision [116]. Furthermore, touch has the potential to change people's attitude towards each other [117]. This effect has been shown to extend to third-party observers [118]. I also has been shown that emotions like anger, fear, disgust, gratitude, and sympathy can be communicated through touch and humans have the ability to decode those emotions through touch alone [119, 120]. This also holds when people are watching others communicating via touch [121].

Touch seems to be a very common form of interaction between people and as robots have the potential to be treated as social agents and the between humans and robots reduces, there is an increasing need for robots to be capable of interacting fluently and intuitively with humans. However, the interpretation of touch modalities in HRI has so far received little attention relative to other sensory modalities. Interpretations of emotions in HRI have so far focussed more on body movements [122], physiological signals [123] and on facial expressions [124]. Recently emerging research about human touch in HRI interactions suggests that the robot's ability to sense and interpret the human touch correctly could be a significant factor in a pleasant interaction between the two [119, 125–128]. In an effort to match responses of a robot to touch, some robots were developed with a predefined mapping between responses and the corresponding touch, measured with tactile sensors built into the robot (i.e the robot seal "Paro" [129] or "Probo" [130]). More detailed data was examined how humans use touch to communicate emotions using a "Haptic Creature", a small furry robot with ears and a tail [131]. This study resulted in the compilation of a touch dictionary classifying tactile gestures of people expressing certain emotions to the "Haptic Creature", which also was partly used in this study to examine touch gestures towards the android robot. Another very recent study focussed on the development of a system to autonomously recognize human emotions and social messages conveyed via touch to an artificial arm covered with a robotic skin [119].

The focus in this part of the study was on the tactile interaction between participants and the android robot. In order to examine such touch behaviour, participants needed to touch the android robot (in the third interaction trial). It was known from previous non-recorded presentations of the robot in elderly homes, that people were curious about how the robot's hand feels but also would only touch the hand after some time and also only after the permission "from the robot." Therefore, a interaction trial in this experiment was created where the robot asks participants explicitly if they would try and touch its hand. This kind of interaction would most probably not occur between two people, but on one hand, despite its very humanlike appearance, the android robot is not human and people have realised this by this time, and also, we created an equal outline for all participants to measure into touch interaction times and the response times. This kind of experiment could be extended in the future in a more open interaction with for example waiting until participants request by themselves to touch the robot. The focus here, however, is how people touch the hand of a highly animate android robot and how this is correlated with their personality and their perception of the robot.

4.4.2 Method

The data of 51 participants was evaluated for this part of the study and the experiment flow was describes in Section 4.2.4. As this part of the experiment was integrated in the one outlined earlier in this work, the robot remained the same. The android's face and hands are made of a soft silicon rubber, its hands are designed to look and feel natural when touched. When squeezed, however, people can feel the lack of inner structure in its hand and fingers. The fingernails, however, look and feel quite human-like. In the experiment the robot was dressed in jeans, a white blouse, and a pink cardigan; the robot's left hand was laid flat on its left thigh and the right hand was turned approximately 90 degrees, with the little and ring fingers resting on the right thigh (Fig. 4.7).

During the third stage, the main interaction stage for the purpose of this study,

Figure 4.7: The hand position of the Actroid-F android robot during the experiment.

the android asked each participant to touch its hands by saying ”I am designed to look like and feel like a human. Would you like to try touching my hand?” If the participant asked further questions (e.g. “Now?” or “Is it ok?”) or hesitated too long, the robot responded by saying “Please come closer.” After the participant touched the android’s hand the robot would ask them “How does my hand feel?,” no further instructions were given. All of the touch interactions with the participants were video recorded for analysis.

4.4.3 Touch Dictionary

With regard to the complexity of human touch, we sought to adapt a previously existing dictionary of tactile gestures consisting of 30 items [131], developed from a review of human-human and human-animal touch, for the special case of people touching an android robot. Speaking of a touch or a touch gesture in the context of this HRI study with an android robot, it is referred to the placement of the participant’s hand on the robot’s hand with or without motion (see Fig. 4.8). The touch gestures in the previous dictionary were examined in order to identify any gestures which could not be performed with an android robot or which were not covered by the existing touch dictionary. After inappropriate or impractical gestures for the current experiment were removed, new gestures and and the specific body-parts (a robot’s hand) were incorporated. Gestures that included touching the human’s body or the face, for example, were not relevant to this experiment but more detailed information about the hands and fingers was essential, as they were designed very human-like.

Figure 4.8: Participant touching the hand of the Actroid-F during the third stage of the experiment.

Despite the human-like appearance of the fingers, they still do not feel exactly like a human hand and, combined with the knowledge that they touch a robot's hand, participants were observed to use their own fingers to squeeze and rapidly move the robot's fingers from side to side, a new gesture not previously considered and labeled here as "wiggle." Another addition to the touch dictionary was the distinction between a "handshake position," in which the participant grasped the robot's hand in a handshake position (two grasped hands: the participant's palm in contact with the robot's palm) but without performing a handshake-like movement, from the actual performance of a handshake (repeated up and down movement of grasped hands). Also added was a gestured labelled "lift" which refers to the raising of the robot's hand without the the grasping of the hands in a handshake position or the repeated handshake movement. The adapted touch dictionary is shown in Tables 4.3, 4.4, and in Figure 4.9

4.4.4 Measurement of Touch Behaviors

Using the touch dictionary from Tables 4.3 and 4.4, the video data of the tactile gestures of participants were classified by two independent raters blind to the purpose of the experiment with a 90% agreement. Two more characteristics, the time taken by participants before touching the robot's hand after the robot asked them to touch its hand and duration of the touch itself, were measured. The robot's hand

Table 4.3: Dictionary of touch gestures used in the present experiment.

Label	**Definition**
Stroke	Translational move with gentle pressure over robot's hand, one or several times
Lift	Lift or raise the robot's hand
Handshake	Performing a handshake
Squeeze	Press the robot's hands between two or more fingers
Touch without movement	Undefined form of contact that has no movement, like lying a hand on top of the robot's hand
Tap	Quick light touch with one or multiple fingers
Press	Exert a steady force (flattened fingers or hand). Longer duration than the tap and without stroking movement
Wiggle	Move fingers up and down or from side to side with small rapid movements

Figure 4.9: Examples of a tap with the left index finger on the top of the hand (left), a squeeze of the top of the hand and palm with the left index finger and thumb (middle), and a stroke of the top of the hand with several fingers (right).

Table 4.4: Dictionary of body areas used in the present experiment.

Robot hands	**Human hands**
Top hand and palm	Finger(s) and thumb
Fingers: index, middle, ring, and pinky	Fingers: index, middle, ring, and pinky
Thumb	Thumb
Top hand	Whole hand
Handshake position	Handshake position

is not equipped with any sensors or measurement instruments, therefore the force or intensity of the touch could not be evaluated.

All data obtained previously from the questionnaires and encoded video footage was evaluated using the R software for statistical computing (Version 2.15.3). Data was first analyzed using correlations and linear model analyses, if not indicated otherwise, and then the number of factors was reduced to enable the performance of individual statistical analyses. In all cases, p indicates the probability that a given effect was not due to chance.

4.4.5 Results of Touch Behaviors

It took participants on average 10.2 seconds to touch the robot's hand after asked to do so, and the average total touching time was 7.1 seconds. Globally, the most observed tactile gestures were "stroke" (32%), "squeeze" (26%), and "touch without movement" (15%), see Figure 4.10. Primarily, participants touched the top of the robot's hand (30%), a combination of the top of the hand and the palm (17%), and the index finger (13%). When compared against each other, the data shows that the top of the robot's hand was touched significantly more often than the robot's index finger (χ^2=6.26, p=0.01), and the right hand was touched significantly more (χ^2 =15.44, $p<0.001$) than the left hand. For the participants, they mainly used their right hand to touch the robot (93%) and also a combination of their index finger and thumb (37%). The full range of tactile gestures listed in Table 4.3 was observed, but in the following analysis, the particular focus is on the two most frequent gestures:

"stroke" and "squeeze."

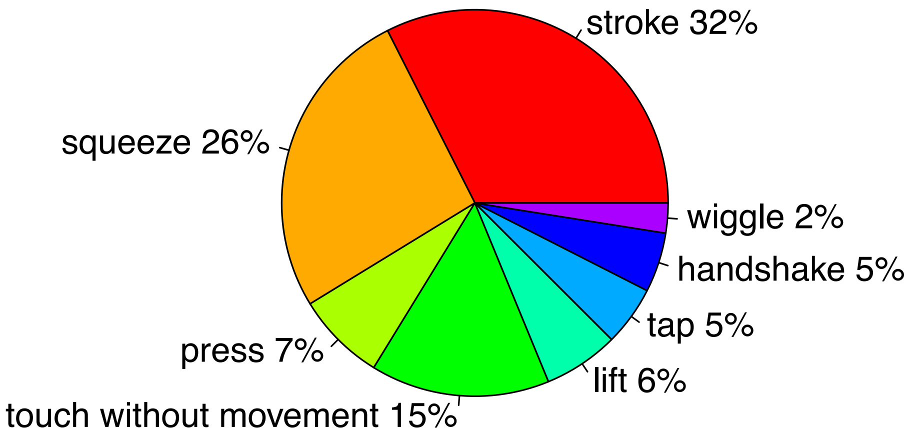


Figure 4.10: Distribution of different tactile behaviours.

4.4.6 Relationship between Tactile Behaviors and Personality Traits

The evaluation of personality traits and touch times showed, that extraversion was negatively correlated with the time until the robot was touched (R=-0.36, t(44)=-2.57, p=0.01), but positively correlated with neuroticism (R=0.32, t(42)=2.26, p=0.02). Furthermore, total touch duration was positively correlated with the perception of anthropomorphism after the interaction (R=0.29, t(44)=2.05, p=0.04) while it was observed that participants who stroked the robot also touched it for a longer amount of time (t(44)=2.44, p=0.01).

Evaluating personality traits and tactile gestures, the data also revealed that participants who squeezed the robot's hand showed a higher degree of extraversion (t(43.9)=2.37, p=0.02, Figure 4.11) while those who stroked the robot's hand exhibited a non-significant tendency towards higher neuroticism (t(39.2)=1.73, p=0.09, two values for neuroticism were missing due to questionnaires incorrectly filled, Figure 4.12).

Figure 4.11: Participants who squeezed the robot's hand showed a higher degree of extraversion. Horizontal lines at the bottom of the graph represent the sample minimum, lines at the top indicate the sample maximum, and lines inside each box represent the sample medians. Each box represents quartiles with the lower quartile defined by the lower limit of the box and the upper quartile defined by the upper limit.

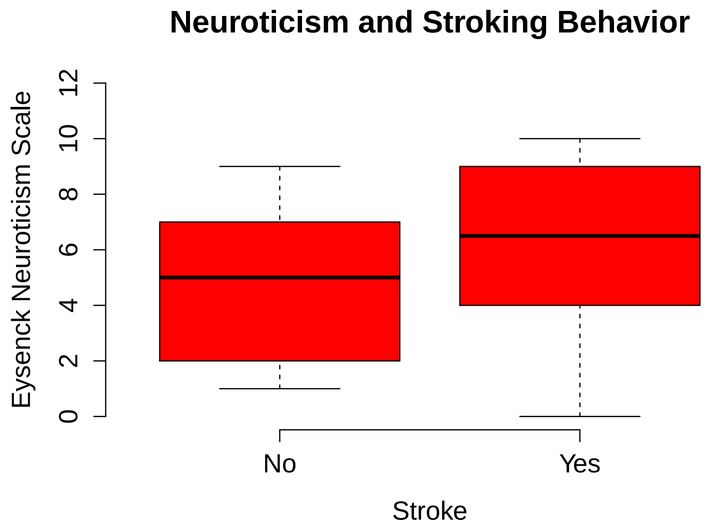


Figure 4.12: Participants who stroked the robot's hand tended towards a higher level of neuroticism.

4.4.7 Impression of the Robot's Hand

As last part of the interaction trials and after participants finished to touch the robot's hand, they were asked by the robot how the hands felt. It were describes participants using the terms rubbery (20%), real (16%), artificial (16%), soft (16%), good (14%), weird or strange (13%), and cold (13%). Since there was no particular structure given to the participants regarding this question, multiple answers could have been mentioned by a single participant. We could not find a particular correlation of any of those answers given with tactile behaviour.

4.5 Discussion

None of the participants had previous experience interacting with android robots nor had they seen or touched one before. Most of them were not even aware of the existence of a robot with such human-like appearance and behaviour. People's initial reaction to the robot ranged from apathetic to expressing enjoyment and excitement during the interaction. The experimenters had the impression that the majority of participants were curious about the robot and enjoyed the interaction. In this study, there were significant changes observed in perception before and after the interaction tasks. This shows how important the actual interaction with a physically present robot is for a realistic evaluation of people's perception of a robot, especially of such a realistic-looking one.

With the realistic appearance of the robot, people perceived the robot as highly anthropomorphic and intelligent before the interaction tasks and meeting the robot "in person." At the same time, the perceived safety was initially very low and people seemed to express uncomfortable feelings about the potential pleasantness and safety of the interaction with such a robot. It is possible that, from the picture of the robot shown to participants before the interaction, it was difficult to see that a robot and not a person was depicted. After the interaction, the perception changed to the exact opposite. The robot was perceived as less anthropomorphic and intelligent, but much safer. The actual interaction with the robot did not fulfil the expectations of human form and characteristics (anthropomorphism) and intelligence that people held prior to the interaction. The increased perceived safety of the robot shows that people felt more comfortable in the presence of the robot than they had initially expected. This could be closely related to the special appearance of the robot, as it attempted to look like a human Doppelgaenger, and the fact that popular culture depicts very humanlike robots as dangerous entities with superhuman capabilities, qualities of course not possessed by the real android robot in this experiment. It is thought that people realize during the interaction with the robot that it is not as anthropomorphic or intelligent as they initially perceived, and with the realization of its many technological shortcomings this robot compared to a real human, they also perceive it as unthreatening and safe for interaction.

One theoretical framework these results could be explained with is the Expectation Confirmation Theory (ECT, [132, 133]), a cognitive theory positing that satisfaction is influenced by expectations, perceived performance and disconfirmation of beliefs. The expectations in this study towards the robot are formed on its exterior appearance before the interaction and then the perceived performance is shaped during the actual interaction with the robot. The evaluations participants make of the robot are referred to as disconfirmation of beliefs. In this case, the original expectations for safety are outperformed and the original expectations in terms of anthropomorphism and intelligence are underperformed. Animacy and likeability of the robot seem to meet the expectaions. Generally speaking, a positive disconfirmation leads to an increased satisfaction with the robot and a negative disconfirmation to a decreased satisfaction. In the case of this study and this special type of robot, it is thought that the measured concepts should be weighted to determine the importance of each concept to people and, in the future, draw conclusions about the satisfaction of a certain robot. It is suggested for future studies to take into account comments participants make (freely) about the robot and to classify them in order to determine the importance of certain perception concepts of robots. It is suspected that prior expectation management and a natural interaction design with a resulting positive disconfirmation in all the measured concepts would lead to a higher satisfaction with the robot.

In terms of proxemics, this experiment showed that people had the overall tendency to come closer with each interaction task. It is concluded, that people get more familiar over time with the robot and show this in the decrease of personal space they put between them and the robot. An initial overwhelming effect of the robot's presence and its very lifelike appearance seems to be unlikely as there was a significant decrease in distance observed after the initial interaction. Previous literature states that people maintain a personal distance around themselves of around 1.2 meters which is generally not violated by others [134]. This study observed roughly the same distance to the android robot, which could indicate that the robot is perceived similar to a human in terms of personal space. It has also been shown, that people tend to maintain closer distance to people they feel closer with [134], but further distance to people they dislike or carry physical stigmata [135].

In terms of proxemics, this experiment showed that people had the overall tendency to come closer with each interaction task. It is concluded, then, that people get more familiar over time with the robot, which manifests in a decrease in personal space kept between them and the robot. An initial overwhelming effect of the robot's presence and its very lifelike appearance seems to be unlikely, as there was a significant decrease in distance observed after the initial interaction. Previous literature states that people maintain a personal distance around themselves of around 1.2 meters, which is generally not violated by others [134]. This study observed roughly the same distance to the android robot, which could indicate that the robot is perceived similar to a human in terms of personal space. It has also been shown that people tend to maintain closer distance to people they feel closer with [134], but further distance from people they dislike or those who carry physical stigmata [135].

The results of the trust game showed that people with higher extraversion also tend to entrust the android robot with a greater amount of money, as stated in hypothesis HA4. A previous study on the link between personality and trust game outcomes had similar results of a higher payback for more extraverted individuals [102]. The amount sent to the robot in the trust game was also similar to the amount sent to another human under laboratory conditions. The robot in this study is treated with a level of trust similar to that placed in a human agent in an economic trust game. As the trust game is a game theoretical approach to measure trust in novel partners, it seems that a certain kind of intelligence is required from the robot side to understand the game and therefore maximize the outcome on both sides. This could explain the positive correlation between perceived intelligence of the android robot and the amount sent in the trust game.

Globally, the reward condition correlated positively with the perception of animacy. It seems that the higher payback allowed participants to perceive the robot as being more similar to a human than to a machine. In particular, it was found that people who never owned a pet had a different perception of the robot depending on the reward condition. Namely, there was a positive correlation between perception of animacy, likeability, perceived intelligence, and safety. It seems that the lack of exposure to a non-human agent like a pet then solely relies on the monetary feedback, as opposed to the possible non-monetary rewards pet ownership imparts upon humans.

Prior exposure to virtual agents correlated with a higher perception of the robot as being lifelike and less like a machine (animacy), but this perception changed after the participants actually interacted with the robot. As the exposure to agents in virtual environments was high, it was assumed that people expected the robot to express similar animacy during and after the interaction. People found the robot to be less lifelike than the first impression of the picture would suggest. After the interaction tasks, exposure to virtual agents correlated positively with perception of intelligence, which could indicate that people who had experienced greater exposure to virtual agents underestimated the robot's intelligence at first (in contrast to the general trend that people's perception of the robot's intelligence decreases, i.e. an initial overestimation), and then adjusted their perception of the robot to that of a more competent one.

The third interaction trial with the robot aimed at evaluating the nature of touch during HRI. As none of the participants has ever seen an android robot before, the tactile gestures observed in this experiment are touch behaviours that arise when an individual first encounters and interacts with a highly human-like android robot. Through video analysis, a set of previously established touch gestures was found to be useful for this experiment, and the touch dictionary itself was further developed and used to classify tactile gestures originating from human participants towards an android robot.

The experimental setting created a condition in which all participants were asked at the same time in the experiment to touch the robot's hand. At least in normal interaction between people, this is an unusual request, and thus it was unsurprising that participants naturally hesitated and followed the request of the robot to touch in an average of 10 seconds before they touched the robot's hands for the first time. Higher levels of extraversion led participants to touch the robot faster, as is expected from more outgoing people. However, it was also found that higher levels of neuroticism correlated with participants hesitating longer before touching the robot's hand. It is thought that these patterns are attributable to the participants' perception of the robot as a human-like agent with an influence of the interaction person's personality.

Also correlated with the participants' personalities were the two most commonly used gestures: "stroke" and "squeeze." Squeezing was performed more often by extraverted participants, whilst stroking was more likely to be performed by participants higher in neuroticism. In other words, it might be possible to determine whether an individual is likely to be more extroverted or neurotic by observing how s/he touches the robot. Furthermore, the tactile gesture of squeezing the robot's hand was associated with a lower perception of anthropomorphism and animacy, whilst the opposite was found for the gesture of stroking, which was related to a higher perception of anthropomorphism and animacy. A possible explanation could be that more extraverted people tend to perceive the robot as being less human-like and less animated, and therefore, they are more forthcoming in approaching and squeezing the robot's hand, a gesture which might also be less likely to occur when people touch another person's hand. That is, they treat the robot more like an object. A higher level of neuroticism, which was correlated with a higher perception of the robot being more human-like and animated, could possibly explain why those participants hesitated to approach and touch the robot. More neurotic people used gestures which are thought to be more gentle (i.e. stroking) and treated the robot more like a human being or a live animal.

According to a previous study, the tactile gesture "squeeze" communicates mainly excitement, whilst "stroke" may be related to a variety of emotions [131]. The interpretation for the current experiment (touching a human-like robot's hand in communication), though, is that stroking might express greater concern and care (when compared to squeezing). This would be more acceptable in a social situation, which also would explain the higher attributions of human characteristics such as anthropomorphism and the perception of the robot's animacy (not alive, but very human-like). Furthermore, some participants expressed surprise or concern when the robot asked to be touched, and this is thought to be support for the interpretation here that people treated the robot more as a social agent than as an object. The touch itself was mainly explorative, but always gentle, as if it was possible to hurt or damage the robot. None of the gestures observed during the experiment were associated with negative emotions, as would be the case with hitting, trembling, or rigorous shaking.

It should be noted that this touch interaction study was conducted with a special type of robot (Actroid-F), so the results might only apply to tactile interactions between humans and this particular robot. Different results might surface with a different robot type. Further experiments with a human control study or an inanimate object are needed to generalise the findings here. Further, a more controlled setting could help to conduct explicit manipulations and analyse the relationship between the details of the tactile gestures used for the interpretation of touch, the perception of robots, and changes in perception as a result of touch in more detail, thus making it easier to infer causal relationships.

Even though this study has its limitations, it is predicted that, in the near- to long-term future, humans will use touch to communicate, to a certain extent, both emotions and social messages to robots. Accurate interpretations of the gestures used during communication, as well as a better understanding of the underlying processes for the use of such gestures, are central to successful HRI.

Chapter 5

Cross-Cultural Comparison of Robot Perception

Research in HRI faces significant challenges in terms of technological improvements towards the social acceptability of robots. Current technological advances in robotics will soon enable robots to live amongst people all over the world. The number of interactions with physically present robots will increase, and it is believed, that the social aspect in HRI is at least similar to social aspects in interaction between people [136].

When human perception and acceptability of robots are considered, generally the perception has been shaped by information through social media (e.g. movies, newspaper, and internet) and not through first-hand experiences with physically present robots. Despite all the advances thus far in HRI research, direct contact with a physically present robot remains the exception rather than the norm. We know that that the presence of an embodied robot plays a crucial role in the way people perceive it [137]. We also know that the stereotype of Japan as a kind of "robot kingdom" exists [36]. The objective of the studies here was to measure and compare human trust, perception, and attitudes towards a physically present android robot with the methods presented in Chapter 4 and to measure perception and attitudes towards a physically present humanoid robot as presented in Chapter 3 in two different countries – Japan and Australia.

5.1 Motivation

For years, researchers have studied how attributes such as nationality, religion, race, and socioeconomic class influence the way people think and behave. It has been known that cross-cultural differences exist [31]. For example, the country of origin of two people could have a strong influence on the distance kept between them during social interaction [138], and recent research has shown that it is possible that facial expression recognition is culturally dependent [139]. It is therefore thought that the origin and cultural background of people also affects perception of robots.

When it comes to robots and cross-cultural differences, it is commonly believed that robots are perceived differently by Eastern and Western cultures. American popular culture, for example, presents robots in movies such as "The Terminator" and "I, Robot" with negative connotations, displaying them as threatening technology, making various errors of assessment, and revolving around a "robots will take over the world" theme. The anxiety towards robots and people's fear towards technological creatures that could threaten humankind has been described as the Frankenstein Complex [140], a phenomenon which would make, in theory, the coexistence of humans and robots difficult.

In strong contrast to stereotypes displayed in Western popular culture, Eastern cultures such as Japan are thought to display robots as heroes or helpers (e.g. "Astroboy") living in harmonic coexistence with humans. The display of the manga comic character "Astroboy" in Japan can be compared to the American originated comic "Superman." Both science fiction characters have numerous superhuman powers and are national heroes in Japan and the West, respectively [56]. The main difference between these characters is that "Astroboy" is a beloved robot created by Tezuka Osamu, whilst "Superman" is an invincible man from outer space. The display of Superman as a robot would most likely not be accepted, whereas this concept is quite successful in Japan. It is thought that the Karakuri Ningyo tradition might have an influence on the Japanese perception of robots (see Section 3.1.1). It is not entirely known why Japanese culture seems so robot-friendly, but it has been speculated that the Japanese holistic life-view, that is, the notion that living beings, non-living objects, and gods are all ascribed as having a soul, might be basis for this attitude [33].

This stereotype is not necessarily true. Robotic heroes are also present in Western popular culture (e.g. in movies like "Star Wars", "Transformers", and "Wall-E"). Furthermore, previous studies have revealed that Japanese people are not "robot lovers", while Western cultures are not "robot haters" [13, 36].

Even though the gap in robot perception is not as wide as stereotypes might lead us to believe, recent studies have demonstrated that people's behaviour towards robots might yet vary between cultures. A study compared Chinese and American participants and reported that Chinese participants expressed a more negative attitude towards robot, and both are more likely to heed recommendations when robots behave in more culturally normative ways [32]. Similar to these results, it was found that Japanese individuals prefer a Japanese-speaking robot and feel a sense of discomfort when interacting with an Arabic robot, whilst the opposite feelings were reported among Egyptian participants [35]. Furthermore, Egyptian participants seem to be more accepting of a receptionist robot and perceive it as more anthropomorphic than do English-speaking participants [141]. A cultural comparison between Chinese, Korean, and German participants revealed cultural differences in participants' perception of likeability, engagement, trust, and satisfaction [80]. Cultural differences exist not only in adults, but also in children. For example, when children of different age groups interacted through a card game with the iCat robot, children from Pakistan were much more expressive than were Dutch children [142].

In contrast to cultural differences found for people interacting with robots, a questionnaire study about the seal robot "Paro" between participants from Japan and the UK reported no cultural differences, but that the physical interaction improved subjective evaluations in general [137]. Further, a comparison between Japanese, Chinese, and Dutch participants on attitudes towards robots did not find any differences [9]. Multiple similarities were discovered for Japanese and American participants in a study comparing explicit and implicit attitudes towards robots [36], directly contradicting the common belief that there are substantial cultural differences between Eastern and Western cultures in attitudes towards robots.

Even though the area of cross-cultural differences and similarities has been extensively studied, there is little research on the specific area of HRI and the perception of robots in different cultures. Previous research thus far suggests that cultural differences exist in certain areas of robot perception, but there are no further guidelines. The stereotype that Japanese individuals in general have a more positive attitude towards robots or perceive robots significantly more positive could not be proven. It is actually on of the hypothesis outlined below that the data in this study will refute the assumption that Japanese individuals are robot-lovers and reveal that they have similar concerns about robots as those held by Western cultures.

This study extends the experiment in Chapter 3 and 4 evaluating the perception of a humanoid robot and an android robot. A cross-cultural comparison with a total of 111 participants is presented for the android robot and a total of 42 participants participated in the cross-cultural study with the humanoid robot.

This study extends the previous experiments in Chapters 3 and 4 evaluating the perception of a humanoid robot and an android robot. A cross-cultural comparison with a total of 111 participants is presented for the android robot and a total of X participants participated in the cross-cultural study with the humanoid robot.

Hypotheses and Research Questions

It was hypothesized (**H**ypotheses **C**ulture) that:

HC1

Japanese participants do not perceive the android robot or the humanoid robot significantly more positive than Australian participants.

HC2

There are no significant differences in the distance participants keep to the android robot.

HC3

Australian participants will entrust the android robot more in the economic trust game.

HC4

Japanese participants will perceive the humanoid robot as more able to experience.

5.2 Method

5.2.1 Humanoid Robot

The experiments in Japan and Australia followed the same four-staged procedure using the humanoid robot Robi (Figure 3.4) as described in Chapter 3 . The measurements taken were a robot perception questionnaire (Godspeed Questionnaire), extended by the additional item of the robot's ability to experience and to plan.

5.2.2 Android Robot

The experiments in Japan and Australia followed the same four-staged procedure using a female version of an android robot, Actroid-F (Figure 4.2) as described in Chapter 4. The measurements taken were a robot perception questionnaire (Godspeed questionnaire), a personality questionnaire (Eyseneck Personality Questionnaire) as well as proxemics data and touch interaction times.

5.3 Experimental Results Humanoid Robot

To compare the data between Japan and Australia for the robot Robi, the exact same experiment was conducted as described in Chapter 3. As the condition with the separator did not show any significant differences in Australia, it was dropped for this experiment. To evaluate cultural differences and similarities in the perception of the humanoid robot, the data here were compared to the data collected in Australia.

5.3.1 Participants

A total of 42 participants were recruited at the University of New South Wales, Australia, as well as universities of Tokyo, Japan. Participants were recruited through advertisements including posters across both universities, email lists from researchers with no direct contact with students and through word of mouth. In Japan, 20 participants and in Australia, 22 participants took part in the experiment with a mean age of M=21.3 in Japan and M=20.6 years in Australia. The details are displayed in Table 5.1. Participants in Japan received monetary reimbursement for their participation, the participation in Australia was voluntary and not reimbursed.

Table 5.1: Participant demographics for Japan and Australia. Groups are divided as (A)ctive and (P)assive, according to their role.

	Japan		**Australia**	
	Active	**Passive**	**Active**	**Passive**
Total	10	10	11	11
Female	4	2	8	4
Male	6	7	3	7
Non-specified	0	1	0	0
Mean Age	20.9	21.8	20.7	20.5
SD Age	1.19	2.48	3.28	2.91
Mean exposure to Virtual Agents	2.7	2.6	2.9	3.18
SD Virtual Agents	1.56	1.42	1.37	1.47
Mean exposure to Robots	4.3	3.9	4.45	4.18
SD exposure to Robots	1.25	1.91	0.68	1.53

5.3.2 General Cross-Cultural Differences

The datasets from Japan and Australia were not too different and no significant differences were found apart from a higher pet-ownership in Australia (X(3, n=43)=15.3, p=0.001). The mean age of all four conditions does not differ and the low standard deviation values shows that there is not much dispersion from the average. This also is true for the exposure to virtual agents and the exposure to robots, even thought the mean values here are slightly higher for Australia. The degree of exposure to robots can be found in Table 5.2. This table shows that despite the higher mean value of exposure in Australia, people in Japan have a slightly, statistically not relevant, higher personal experience with operating a robot. None of the Australian and 30% of the Japanese participants stated that they have heard of the robot Robi before, but none has ever interacted with it before. As Robi is a robot so far only marketed in Japan, this data is not surprising. It was important in this experiment, that participants had no prior interaction with the robot.

Table 5.2: Detailed degree of exposure to robots in Japan and Australia in percent. The table shows how many participants were exposed to robots through video, have seen one in person and have operated or interacted with one before.

	Video	**In Person**	**Operated**
Japan	30%	25%	20%
Australia	50%	27.2%	13.6%

5.3.3 Changes in Human Perception of the Robot

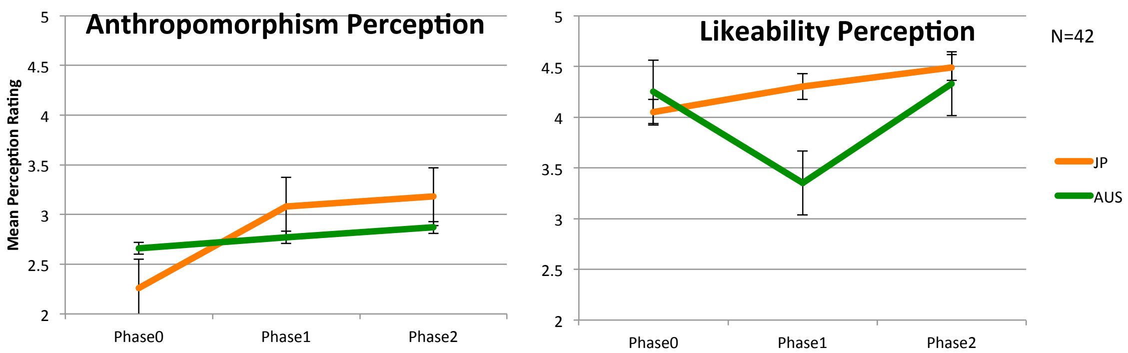


Figure 5.1: The perception of anthropomorphism and likeability of the robot Robi in Japan (JP) and Australia (AUS), independent of the experimental conditions.

The evaluation of both datasets over the interaction trials with Robi for Japan and Australia independent of the conditions showed no significant differences between Japan and Australia for the perception of anthropomorphism and likeability (Figure 5.1) in the three phases of the experiment. However, significant differences were found for animacy, perceived intelligence (Figure 5.2) and perceived safety (Figure 5.3) .

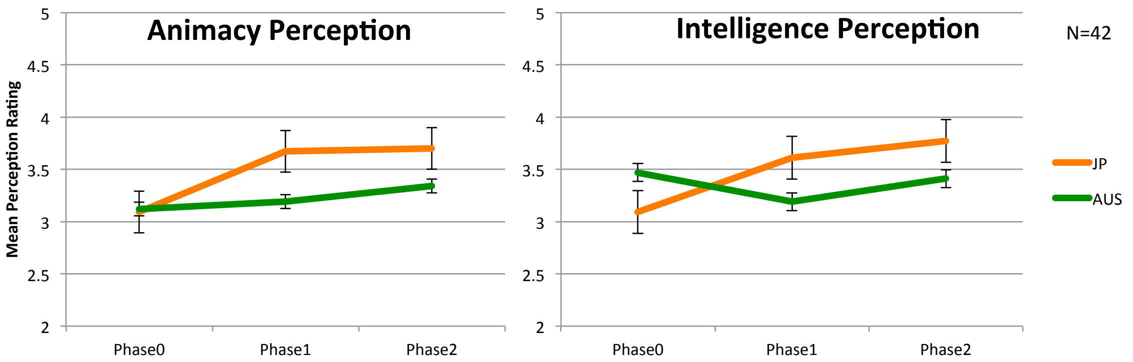


Figure 5.2: The perception of animacy and intelligence of the robot Robi in Japan (JP) and Australia (AUS) independent of the experimental conditions.

Animacy in phase1 after the first active respective passive interaction was significantly higher in Japan (t(39.7)=2.03, p=0.04, see Figure 5.2), intelligence in phase_0 (t(38.4)=-1.99, p=0.05) was significantly lower in Japan and phase1 (t(38.4)=1.8, p=0.07) was higher in Japan and safety in phase1 (t(39.0)=1.8, p=0.07) and phase2 (t(39.1)=2.6, p=0.01) was both higher in Japan (see Figure 5.2).

Figure 5.3: The perception of safety of the robot Robi in Japan (JP) and Australia (AUS) independent of the experimental conditions.

Anthropomorphism

The perception of anthropomorphism increased slightly in both cultures (see Figure 5.4), but the only statistically significant increase was observed for the passive group in Japan between the first time seeing the robot and then passively observing an interaction with the robot (t(9)=-2.24, p=0.05).

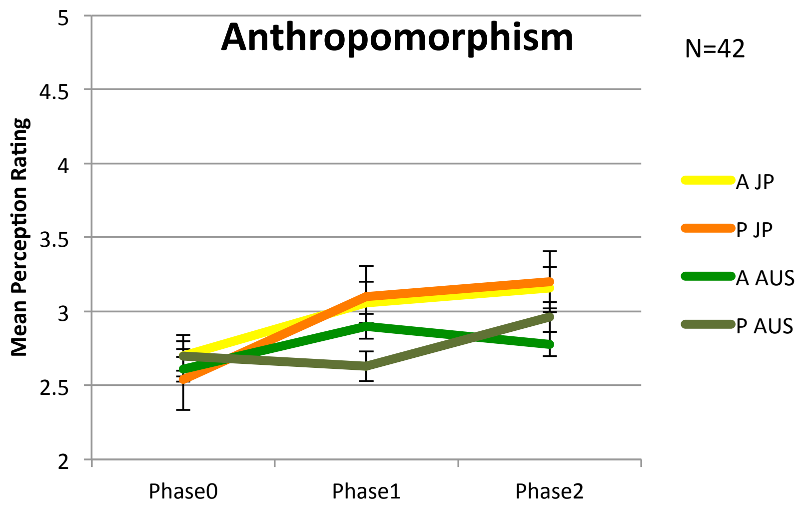


Figure 5.4: The perception change of anthropomorphism over the interaction trials with the robot Robi in Japan (JP) and Australia (AUS) for the active condition A and passive condition P.

Animcay

As mentioned in Section 5.3.3 the data for animacy was significantly higher in Japan when evaluated independent of the experiment conditions. It was found that in the passive condition in phase2, the perception of animacy was significantly higher in Japan ($t(17.2)=2.24$, $p=0.03$). The perception in the active group is higher in Japan, but not statistically significant (see Figure 5.5). Within the Japanese active condition, the perception increased over time ($t(9)=-3.05$, $p=0.01$ between phase_0 and 1, and $t(9)=-2.18$, $p=0.05$ between phase1 and 2). Similarly in the passive condition, there was a significant increase between phase_0 and 1 ($t(9)=-2.4$, $p=0.03$), but no increase after that (even though the difference to phase_0 is still significantly higher in phase2 $t(9)=-2.26$, $p=0.04$). The changes within the conditions in Australia showed no significant differences.

Likeability

For likeability, there were no significant differences found between the two cultures. It is notable, that the likeability of the robot is, as reported, quite high. This effect is also shown for cross-cultural data (see Figure 5.6). The global likeability increased

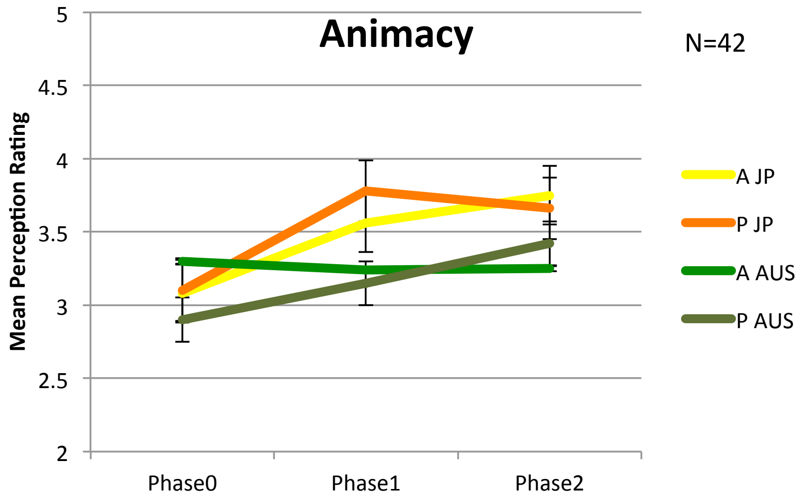


Figure 5.5: The perception change of animacy over the interaction trials with the robot Robi in Japan (JP) and Australia (AUS) for the active condition A and passive condition P.

between the initial phase_0 and phase_1 (t(9)=-2.15, p=0.05) as well as between the initial phase_0 and phase_2, so even though the increase was not observed after the first interaction, globally, the likeability is higher after the last interaction trial than right after the first time seeing the robot (t(9)=-2.12, p=0.003).

Perceived Intelligence

The perceived intelligence differs between Japan and Australia as it is lower first for both conditions in Japan in the initial phase_0 ,but then changes after the first interaction for both cultures into an opposite trend; higher in Japan and lower in Australia (see Figure 5.7). The difference between the passive condition in Australia and Japan is significant at phase1 (t(16.3)=2.12, p=0.04) and phase2 (t(18.8)=2.07, p=0.05) with it being significantly higher in Japan. The active condition also differs the same way but are not statistically significant.

Within the passive group in Japan, the perceived intelligence of the robot Robi increases significantly between phase_0 and 1 (t(9)=-3.21, p=0.01) as well as between phase1 and 2 (t(9)=-1.93, p=0.08).

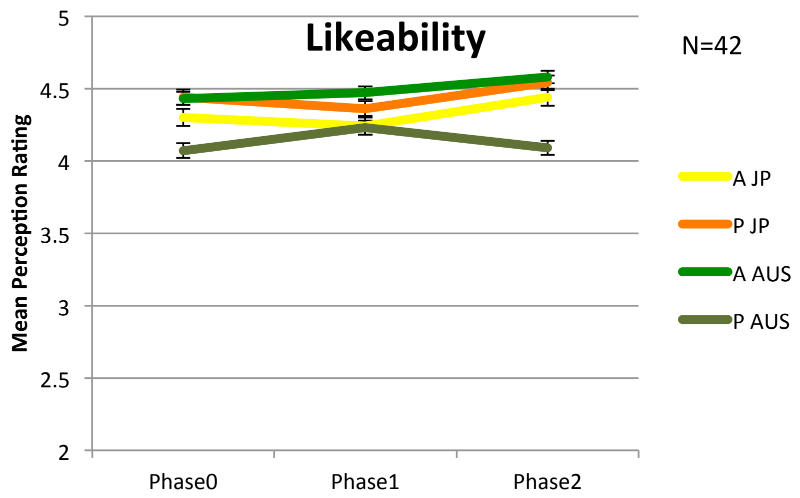


Figure 5.6: The perception change of likeability over the interaction trials with the robot Robi in Japan (JP) and Australia (AUS) for the active condition A and passive condition P.

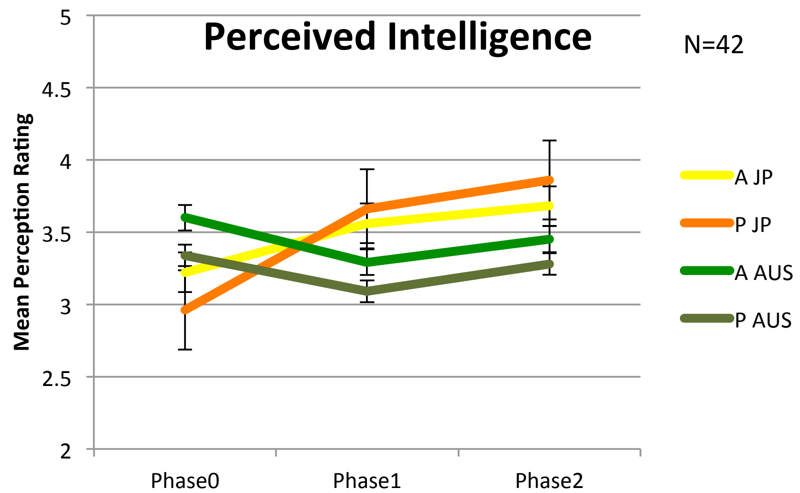


Figure 5.7: The perception change of intelligence over the interaction trials with the robot Robi in Japan (JP) and Australia (AUS) for the active condition A and passive condition P.

Perceived Safety

As described earlier in Section 5.3.3 the global perception of safety is higher in Japan than in Australia in phase1 and 2. When the data is analysed for the different conditions, it shows that the perception of safety is significantly higher in Japan for the passive condition phase1 (t(15.1)=2.01, p=0.06) and phase2 (t(18.6)=3.9, p<0.001, see Figure 5.8).

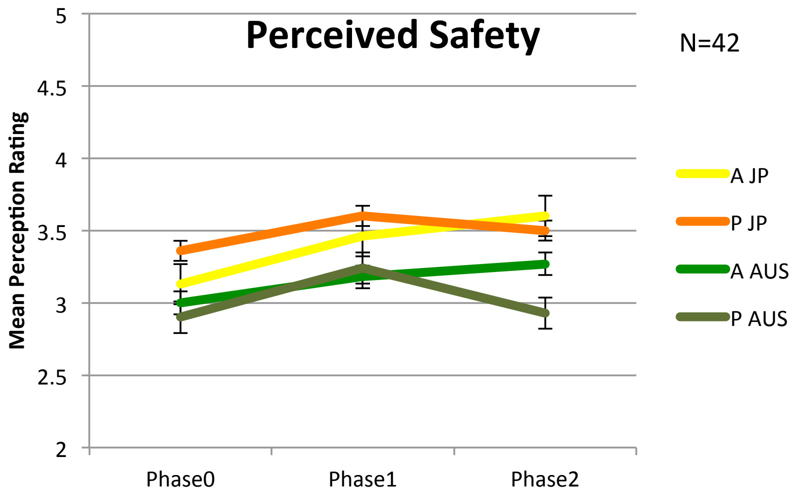


Figure 5.8: The perception change of safety over the interaction trials with the robot Robi in Japan (JP) and Australia (AUS) for the active condition A and passive condition P.

5.3.4 Robot's Mental Capabilities Change

Experience

The participants' perception of the robot's ability to experience differs significantly between Japan and Australia in phase1 (t(37.4)=2.07, p=0.04) and phase2 (t(37.0)=2.94, p=0.005) when the conditions are not taken into account. There is also a significant increase within the global Japanese data between phase_0 and phase2 (t(19)=-3.06, p=0.006). The graph (see Figure 5.9) shows that the passive condition in Japan not only increases significantly between phase_0 and 1 (t(9)=-2.14, p=0.06), but is also significantly higher than the active group in Japan (in phase1 t(15.2)=-2.01, p=0.06 and in phase2 t(11.3)=-1.93, p=0.07). For the passive condition, the perception in Japan not significantly different in phase_0, but higher in phase1 (t(18.9)=2.42, p=0.02) and phase2 (t(14.4)=3.7, p=0.002). The active conditions do not differ significantly.

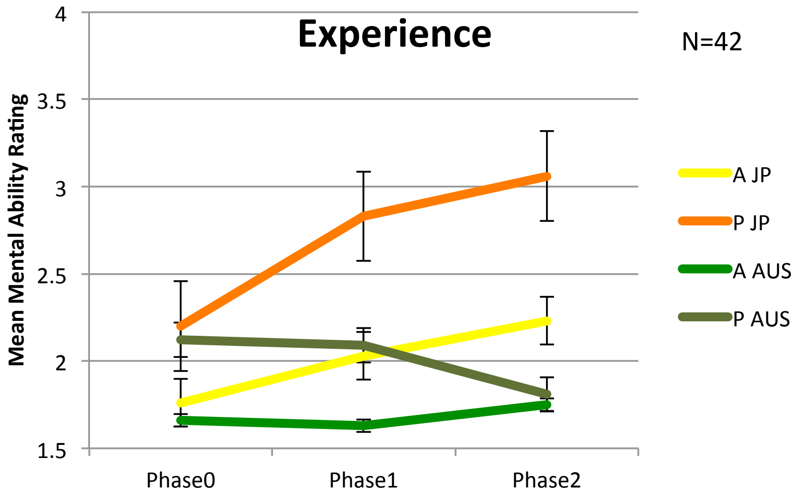


Figure 5.9: The perception change of experience over the interaction trials with the robot Robi in Japan (JP) and Australia (AUS) for the active condition A and passive condition P.

Agency

The perception of participants of the robot's ability of agency differs significantly between Japan and Australia in phase2 (t(39.9)=2.27, p=0.02) when the conditions are not taken into account. There is also a significant increase within the global Japanese data between phase_0 and phase2 (t(19)=-2.04, p=0.05). The perception of agency increases significantly for the Japanese passive group between phase_0 and phase1 (t(9)=-2.28, p=0.04) and decreases significantly for the Australian passive group between phase_0 and phase2 (t(10)=3.01, p=0.01). The passive condition in Japan is significantly higher in phase2 (t(16.9)=2.5, p=0.02), whilst the active condition is higher in Japan but the difference to Australia is not significant.

5.3.5 Prior Experience with the Robot

To evaluate the influence of prior exposure to the robot Robi, Pearson's product-moment correlations were performed on the Japanese dataset. In Australia, the

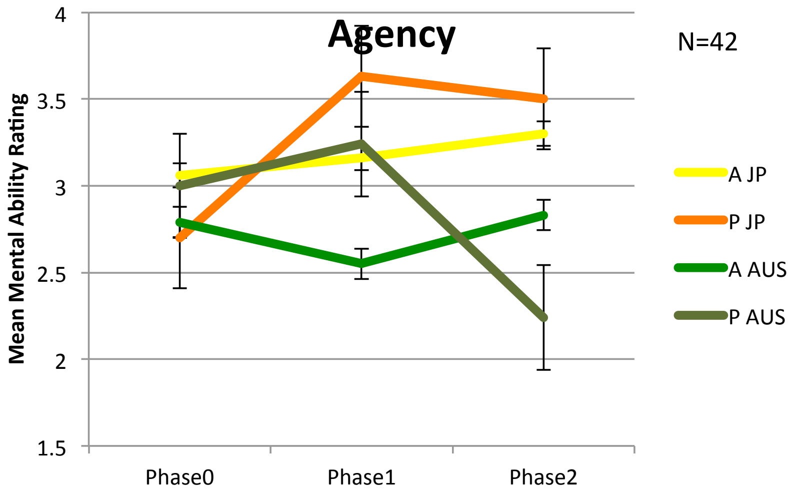


Figure 5.10: The perception change of agency over the interaction trials with the robot Robi in Japan (JP) and Australia (AUS) for the active condition A and passive condition P.

robot was completely unknown, in Japan, 30% have heard of the robot but never interacted with it. There was no correlation found for the first contact with with the robot. There also was no correlation found for the passive group at any time, but it seems that the perception of the active group of anthropomorphism in phase_0 (r(8)=-0.64, p=0.04) and phase1 (r(8)=-0.71, p=0.02), animacy in phase1 (r(8)=-0.69, p=0.02) and phase2 (r(8)=-0.70, p=0.02), likeability in phase1 (r(8)=-0.71, p=0.01) and phase2 (r(8)=-0.66, p=0.03), intelligence phase1 (r(8)=-0.66, p=0.03) and safety in phase1 (r(8)=-0.59, p=0.06) was correlated negatively with having heard of the robot prior to the experiment. This means all Japanese participants in the active condition who have heard of the robot before have a lower perception after the first interaction in anthropomorphism, animacy, likeability, perceived intelligence and safety.

5.4 Discussion: Cross-Cultural Results for the Humanoid Robot

The comparison of perception of the humanoid robot Robi between Japan and Australia revealed that Japanese participants perceive the robot after the first and second interaction task higher in anthropomorphism, animacy, perceived intelligence, perceived safety and agency. As it will be described in the following Section 5.5, safety seems generally to be perceived higher in Japan. This could be the result of the display of robots unpopular culture, but it also seems that the interaction with this robots decreases the safety concerns and they could potentially be overcome. The perception of the robot's mental capabilities to experience was also higher after the first interaction task for Japan and then similar after the second. Whilst not all those differences are statistically significant, it is thought that the data clearly shows a globally more positive perception and possibly higher acceptability for Japanese participants.

The data also shows that anthropomorphism, animacy, perceived intelligence, experience and agency increase significantly for the passive interaction group in Japan, but not in Australia. This is thought not only to be a cultural difference, but also shows that the difference between the interaction as active operator and passive bystander has an effect on the perception of the robot. It seems that interacting passively with the robot leads firstly to an increasingly higher perception in nearly all measured areas, and secondly, gives participants a clear expectation of the robot?s abilities. Subsequently, it lead to no major changes after they switched roles and then interacted actively as operator in the second interaction.

As there was the possibility that the higher exposure due to the marketing of the robot in Japan would influence the perception of the robot, the data was evaluated for possible correlations between having heard of the robot and influence on the perception. Having heard of the robot before the experiment does not seem to influences the initial perception of Robi. Also, as the data for the passive group showed significantly higher values, the separate conditions were evaluated. There was no correlation found for the passive group and the prior exposure to the robot Robi. Somewhat surprisingly was that the active group who has heard of the robot Robi, showed significantly lower values, mainly in the perception after the first interaction. One explanation could be, that prior exposure to the robot is related to a lower perception due to a gap between expectations towards the robot in the interaction and actual abilities. The passive group, even if having heard of the robot, then seem to have the chance to adjust their expectations of it‘s abilities before the active interaction, and is therefore not influenced anymore through prior exposure. It has to be noted though, that these prior exposures were not through the robot being physically present.

Independent of the culture, all the measured variables here show an upper trend between the initial presentation of the robot and the interactions. It is concluded, that the interactions with the physical present robot change how people perceive it, and in this case, the perception is affected positively.

5.5 Experimental Results Android Robot

5.5.1 Participants

A total of 111 participants were recruited at the University of New South Wales, Australia and universities of Tokyo, Japan through general advertisement using posters across both universities, email lists from researcher with no direct contact with students and through word of mouth. In Japan, 55 participants and in Australia, 56 participants took part in the experiment with a mean age of M=22.6 in Japan and M=28.8 years in Australia. The details are displayed in Table 5.3. None of the participants reported to have had previous experience interacting with android robots. Participants received monetary reimbursement (approximately AUD 5) for their participation.

5.5.2 General Cross-Cultural Differences

The Japanese participants came significantly closer to the robot in each subsequent task (Table 5.4; task 1 vs. task 2 $t(54) = 4.87$, $p = 0.001$; task 2 vs. task 3 $t(54) = 2.67$, $p = 0.05$; Bonferroni corrected, as reported previously in Chapter 4. This effect was not observed in the Australian participants. The results of the proxemics measurements are shown in Table 5.4.

For a general difference between both datasets, the Australian dataset showed a higher pet ownership (Chi square test; $p<0.001$), higher psychoticism ($t(107.92)$

Table 5.3: Participant demographics for Australia and Japan. The mean exposure to robots and virtual agents results from a 1-5 rating scale, parts extracted from ©Springer 2014 [4].

	Australia	**Japan**
Total	56	55
Female	35	37
Male	21	18
Mean Age	28.86	22.65
SD Age	13.19	7.47
Mean exposure to robots	4.00	3.72
SD exposure to robots	1.59	1.60
Mean exposure to Virtual Agents	2.54	2.43
SD exposure to Virtual Agents	1.41	1.19

Table 5.4: Mean distances (in cm) to the robot for Australia and Japan ©Springer 2014 [4].

	Task 1	**Task 2**	**Task 3**
Australia	123.8	121.5	122.7
Japan	128.2	119.9	116.1

= -2.96, p = 0.003) and higher extraversion (t(102.92) = 5.47, p<0.001) for the participants.

5.5.3 Changes in Human Perception of the Robot

Anthropomorphism

For both, the Japanese and the Australian dataset, lower anthropomorphism ratings were observed after the interaction: t(53) = 4.22, p<0.001 for Japan and t(55) = 2.50, p = 0.01 for Australia. In other words, in both cases the perception of anthropomorphism of the android reduced significantly after the interaction. Furthermore, a cultural difference was found for anthropomorphism which was rated significantly higher in Australia—when compared to Japan—after the interaction ($t(108.7) = 1.9$, $p = 0.05$), but not before (Fig. 5.11).

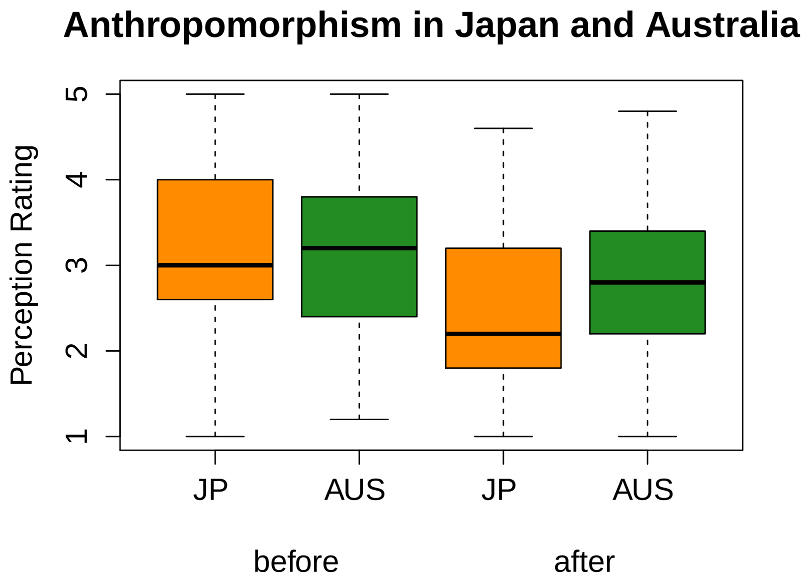


Figure 5.11: Anthropomorphism for Japan (yellow) and Australia (green). The plot shows a decrease in anthropompohism for both countries with a significant higher rating for Australia after the interaction ©Springer 2014 [4].

Animacy

The rating of anomaly did not significantly differ between Japan and Australia and there were no significant changes as a result of the interaction in either country.

Likeability

Australian participants liked the robot significantly more than Japanese participants before, as well as after the interaction task (Fig. 5.12). Before the interaction, Australians rated the robot more likeable ($t(107.91) = 3.48$, $p<0.001$). After the interaction, the likeability of the robot even increased significantly in Australia ($t(56) = -4.95$, $p<0.001$) and did not change significantly in Japan.

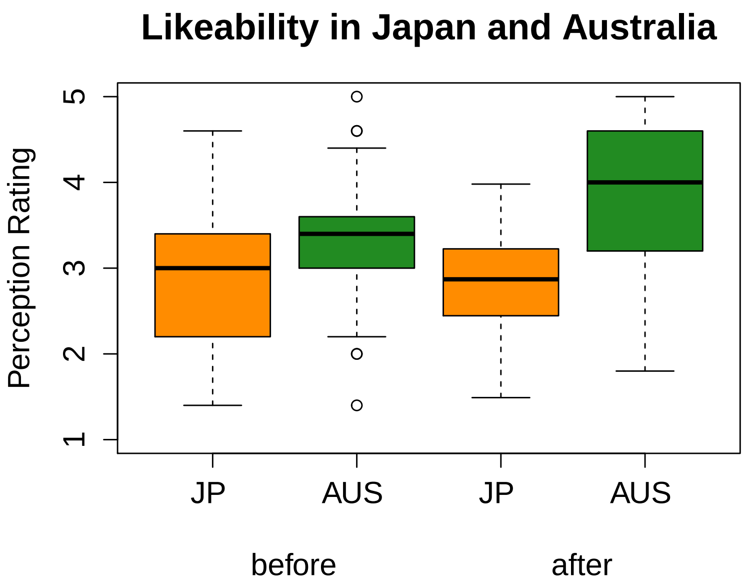


Figure 5.12: Likeability for Japan (yellow) and Australia (green). The plot shows an increase in likeability only for Australia ©Springer 2014 [4].

Perceived Intelligence

For the Japanese dataset, the perceived intelligence dropped significantly (t(53) = 7.55, p<0.001) after the interaction whilst there was no significant change for the Australian dataset observed. There was a significant difference between Australian and Japanese participants' perception after the interaction task (t(92.83) = 6.10, p<0.001), with Australian participants rating the perceived intelligence significantly higher.

Perceived Safety

After participants interacted with the robot, perceived safety increased for both datasets. In both countries, ratings for perceived safety increased after the interaction tasks: t(55)=-1.99, p=0.05 for Japan and t(55)=-3.97, p<0.001 for Australia. Even though the same trend was observed in both countries, the overall ratings were significantly lower in Australia before (t(104.46)=3.02, p=0.003) and after (t(98.89)=2.11, p=0.03) the interaction.

5.5.4 Economic Trust Game

Is has been shown in previous studies that extravert personality types tend to send higher amounts of money during an economic trust game [102]. In the current experiments, Australian participants entrusted the robot with a significant higher amounts than Japanese participants (t(109)=4.02, p<0.001). However, at the same time, the Australian dataset showed a higher rate of extraversion (t(102.74)=5.5458, p<0.0001). To further examine the effect of the higher amount of money sent in the Australian dataset, the correlation between extraversion and payback amount was examined for both datasets. The correlation revealed that extraversion affected the payback amount in the trust game only in Japan (positive correlated, R=0.43, t(44)=3.12, p=0.003, see Figure 5.14), but not in Australia (R=-0.09, see Figure 5.14).

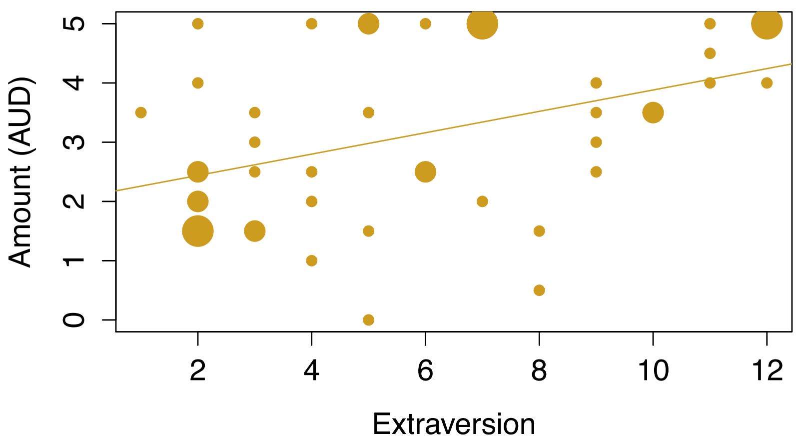


Figure 5.13: The amount paid (exchanged in AUD) as a function of extraversion score in the economic trust game for Japan. Disk sizes represent the number of participants. Japanese participants show an increase of the payback with increasing extraversion score ©Springer 2014 [4].

Furthermore, for Japan a correlation with no-pet ownership and robot perception when the payback was lower or higher was found. There were no such significant differences observed in Australia. Other character traits showed no further correlations with the amount send in the trust game in either country.

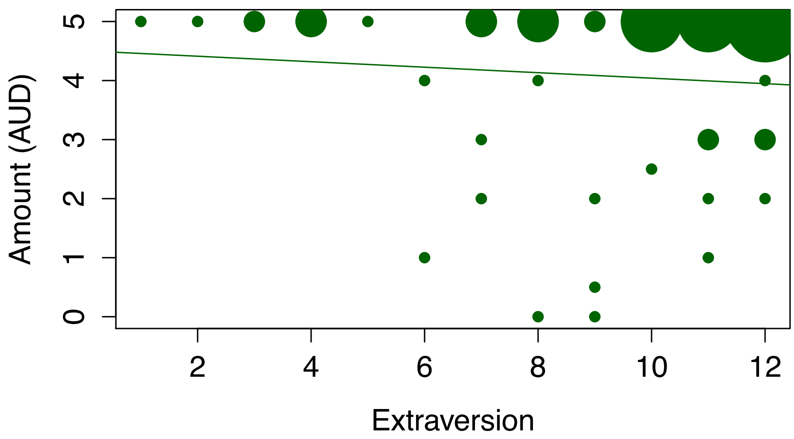


Figure 5.14: The amount paid (in AUD) as a function of extraversion score in the economic trust game for Australia. Disk sizes represent the number of participants. Australian participants show higher amounts paid but no correlation with extraversion score ©Springer 2014 [4].

5.6 Discussion: Cross-Cultural Results for the Android Robot

This experiment shows the results of a cross-cultural comparison between Japan and Australia on trust and robot perception using the android robot Actroid-F. Japanese participants rated the robot less favourably than did Australian participants for anthropomorphism, animacy, likeability, and perceived intelligence before interacting with it. This contradicts the stereotype that Western cultures reject robots and Japanese individuals are more accepting, confirming hypothesis HC1 that Japanese participants do not perceive the android robot significantly more positively as compared to Australian participants. The data for the android robot demonstrated that quite the contrary might be true for this robot type in terms of trust and perception.

The only stereotype that was confirmed was that of perceived safety. Australian participants rated the robot lower than did their Japanese counterparts, and therefore, they seemed to express more concerns about the dangers of such a robot. Although perceived safety increased in both cultures after interacting with the robot, the Australian participants were consistently lower in their rating of the perceived safety of the robot. It is thought that the global increase in perceived safety, which was observed in both countries here, is a response following the first interaction when they realize that the android robot is, despite its very humanlike appearance, still far away from humanlike abilities, and that, in its current technological condition, it is incapable of causing any damage. However, the cultural gap here shows that the concern in terms of robot safety was higher in Australian participants, which could be related to the common display of robots in popular Western culture.

Despite lower perceptions of safety, Australians perceived the robots as being more "trustworthy" during the economic trust game. Although less safe, the robot as entrusted more than it was among Japanese participants. To interpret these results, it must be considered that safety might not be the main factor of "trust" from a game theory perspective, where the "smart" thing to do is to send higher amounts of money in order to maximize profit on both sides. The robot is obviously trusted by Australian participants in that sense. The overall concept of trust towards a robot or a social agent, however, even when simplified in an economic game, seems to be much more complex.

During the experiment it was observed that, in the final open question condition in which the android robot asked people if they had any questions, Australian participants were generally more open to the experience and asked the robot several more questions, whereas the Japanese participants asked only one or two questions. Japanese participants often asked for the robot's age and then had no further questions, whilst Australian participants tried to challenge the robot with more tricky questions and even focused on the robot's "choices" (e.g. favourite colour), "dreams", and feelings (e.g. Are you able to dream? How does it feel to be a robot?). It is concluded that Western cultures might be more curious in the initial short-term interaction with an android robot, and also interested and open to interact with the robot. At the same time, however, they may also be more careful, explorative, and challenging of the robot's limitations.

Chapter 6

Conclusions

This thesis investigated the perception and acceptability of robots in short-term interactions when people interact with them for the first time. The primary motivation for this work was to investigate the perception of a robot as concept for robot acceptability. It is thought that the perception of a robot could act as a key factor as well as feedback for robot designers when it comes to improve the acceptability of a robot. It is concluded that robot perception is an important concept in future developments of theories of robot satisfaction and acceptability.

The domain of perception during the first encounter and the first interactions with a robot was selected as it is thought to be a crucial, as well as a challenging factor to improve interaction and acceptability of robots. One of the many challenges in this research is due to the fact that perception can be difficult to measure and interpret.

In order to successfully integrate robots into people's everyday lives and for those robots to behave in a socially appropriate manner, the evaluation of the design appearance and the perception that people form of a robot as well as the factors influencing this perception are important. First impressions on an encounter with this new technology could lay the foundation for the future of HRI. Knowing what a certain robot design evokes in people and how they perceive and therefore potentially accept such a robot can be used to create more enjoyable and intuitive HRI.

The first step towards understanding human-robot interaction in the domain of perception and acceptability in first time interactions, is to assess different factors like design appearance, the perception of such an appearance and the possible human factors that could influence their perception and acceptability.

6.0.1 Appearance

Although it was found that robots are generally associated with technology, the associations that people have with a certain robot differs with the robot's design appearance (e.g. the service robot was highly associated with recognising people compared to the pet robot type, but the opposite was the case when it comes to reactions to noise). The appearance also shapes expectations towards the robot's behaviour, e.g. a robot modeled after a biological model, like the pet robot, is expected to behave like its biological model. The pet robot type could not be closely connected to any particular fears, which is thought to be due to it's likeable and toy like appearance. The service robot type was shown to be associated as useful machine for support, which they hopefully will be in the near future. It was seen as a close link to their appearance that those robots, carrying out service tasks to support people, were highly associated with supporting tasks. The humanoid robot type was ambiguously associated at the same time with fears and as being a useful robot. It is thought that the lack of actual physical presence during the questioning of those relatively small, and designed to appear non-threatening to people, robots could be a reason for those results. Therefore, and additional experiment series was conducted with a physical present humanoid robot to explore those findings in more detail. The android robot type triggered the most fears in participants and to them, it does not appear to be linked with any specific task. It could therefore be, that in the eyes of the participants, this robot does not have a purpose for existing. This special design attempt, to make a robot look like an exact copy of a human, was considered significantly different from other robot types. Therefore, the android robot is also subject to closer investigation in an experiment series with a physical present android robot.

6.0.2 Perception of Humanoid

The perception of the humanoid robot Robi showed the largest changes between the initial presentation of the robot to people and after the first interaction with the robot. Even though people were presented with a physically present robot initially, their perception changes after the interaction. This perception then seemed to be relatively terminal, at least for the short-term interaction conducted in this experiment series, as the perception does not show major changes after the second interaction. It did not seem to matter if participants were interacting themselves with the robot as active operator or observing an interaction as passive bystander in close proximity to the operator. Participants expressed that they look forward to the interaction with the robot when it was presented to them and seemed to enjoy the interaction with it. This was also reflected in the data as the humanoid robot was overall perceived as highly likeable and that perception, if any, only increased with the interaction.

6.0.3 Perception of Android

The presence of the android robot can be quite overwhelming at first. Whilst it looks quite realistic on a photograph or from far away, it is identified as a robot after a short time in close proximity [92]. Therefore, people were given the chance to interact several times with the robot to reduce the initial effect. There were significant changes observed in the perception of the android robot before and after the interaction with it. Participants ascribed human-like traits to the robot and perceived it as quite intelligent before the interaction, but not very safe. After they met the robot "in person" and interacted several times with it, they knew more about it's abilities (or lack of it) and also were able to take a closer look and even touch it.This led to a perception change of the exact opposite; safer, but less anthropomorphic and intelligent. Even though the robot was opera ted by a human and able to answer all questions, there were noteable time delays that could have caused the drop in intelligence. For researchers, such intelligence in an autonomous robot would be outstanding. Yet for the participants in this experiment series the perception of intelligence decreased after the interaction. Being less intelligent than they expected and also having limited abilities in terms of movement, the robot seemed to be safer to people than its first highly anthropomorphic design appearance suggested. It seems that people expected certain human behaviours and abilities from the robot, which were not fulfilled, and therefore led to the change in perception.

As for the results of the economic trust game, people with higher extraversion scores in the personality evaluation also entrusted the robot with a higher amount in the trust game. This is similar to studies with humans [102]. Furthermore, the overall amount was comparable with the results seen in human studies. This is thought to show that the robot was treated to a certain extend as a social agent.

The field of tactile interaction between robots and people has so far not received a lot of attention. However, as both will be living in closer proximity at some stage, touch of a robot or vice versa (direct interaction) might be inevitable. It was shown that people with higher extraversion touched the robot faster and also seemed to perform a squeeze of the robot's hand. The type of touch could therefore, when properly detected by the robot through sensors, shed light on the perception of the robot and the current mental state of the person interacting with it. This could result in better interpretations and more situational adapted interactions.

6.0.4 Cultural Differences

The humanoid robot is perceived more positively in Japan for nearly every aspect measured in the questionnaire. Only likeability was perceived equally and especially very high in both countries, Japan and Australia. It was also shown that the passive interaction with the robot in Japan led to an increase of anthropomorphism, animacy, perceived intelligence, experience and agency. Therefore, not only cultural differences in the perception of this robot, but also the influence of the interaction mode were confirmed in this study. Furthermore, the passive interaction in Japan and the correlated more positive perception was not correlated with prior exposure to the robot that had so far only been marketed in Japan. In contrast, a prior exposure was related to a less positive perception of the robot for the active interaction. It seems that there was a gap in the active group between the expectations towards the robot and the actual abilities of it. This does not account for the passive group. This group might have had the chance to adapt their expectations during the observation of an interaction rather than actually interacting with the robot themselves.

Whilst the humanoid robot seemed to be perceived overall slightly more positively and more so by the Japanese participants, the android robot was, against most stereotypical expectations, perceived more positively in Australia. It was not only shown that the android was perceived with higher for anthropomorphism, animacy, likeability and perceived intelligence in Australia, it also was entrusted with more money. The only stereotype Australian participants fulfilled, was to express more concern for the safety issue of such a robot. This is thought to be related with the different display of robots in popular culture in the two countries. Overall, it is concluded that the perception and acceptability of a robot in a certain culture is dependent on the design appearance of the robot and the perception will be adjusted to its abilities when interacting with it.

6.0.5 Acceptability of Robots

The perception of a robot measured in these studies could be an indicator for the future acceptability of robots. Here, we measured human responses to different robot types and evaluated the expectations before an interaction and the change in perception after the interaction with a robot. It is thought that the assessment of the expectations a robot design evokes along with a possible modification of the expectations towards a robot matching its abilities could lead to an increased acceptability. So far, technology acceptance models have not been developed for robots which can be perceived as social entities. To develop a full model of robot acceptability, the current constraints have to be overcome. A more holistic theory of acceptability should evaluate short and long term perception and go beyond the here presented concepts of presence, perception, attitude, expectations and trust.

6.1 Lessons from Experimental Practices

When conducting the experiments, researchers observed the participants for all times. In this section, I would like to provide additional insights to the experiments. As suggested earlier, the comments participants make about the robots could indicate the importance of each concept measured during the experiment. For example, the experimenter noticed that the humanoid robot was very often referred to as "cute" during the very first presentation to the participants. It is also worth mentioning that the robot, when speaking Japanese, refers to himself as "僕 (boku)", a Japanese term for young males to address themselves – or to address a young male, which would imply that the robot is like a young boy. The classification of such comments could provide feedback and help robot developers to identify and improve the perception of their robot along the measured concepts and even be a first step towards a guideline for robot design.

For the android robot, it was noticed that participants in Australia seemed to try to challenge the robot much more than in Japan. For example, when a participant was asked to move the box during the interaction trial, he responded with "Why?" Such a response was not observed in Japanese participants. The question was answered by the operators that the android robot is unable to walk – which appeared to be a sufficient reason as the participant then moved the box. Quite outstanding and sometimes very stressful for the operators of the android robot, was the open question at the end of the interaction trials. Australian participants asked a wider variety of question, as well as many more questions, than Japanese participants. Whilst Japanese participants questioned mainly about the origin of the robot or its age, Australians asked if the android robots would dream, the robot's favourite colour, what would happen during a power outage, how it feels to be a robot, if "she" has visited Sydney and the beach, if she went into the ocean and even if she believes in God. The operators replied as: The favourite colour is either blue or green, the robot states to sleep when there is no power, the robot likes Sydney very much but has not been able to visit the beach yet due to "her" work at the university, etc.

6.2 Future Work

A possible effect of long-term interaction was observed in the colleagues and research assistants during the experiment in Japan. Here, some people demanded the robot to be covered or hidden behind a separator wall during the times no experiments were conducted as it was described as "creepy." In contrast, another research assistant started to take care of the robot's appearance and changing its hairstyle daily so that the robot "looks nice" in the mornings before the experiments started.

This work considered the interaction with a robot for only a certain period of time, namely the first encounter and some short interactions after that. It is expected that the perception and the acceptability of a robot change in long-term interactions with it. Also, perception and acceptability will slowly change over time with an increased exposure to a wider variety of robots. What exactly these changes will be are thought to depend on the abilities of the robot. Here, the perception of two distinct robots are evaluated, and it is concluded that their initial perception is closely linked with their appearance. It is then adjusted when people learn about the abilities of the robot. Studies with similar robots but with different appearances or abilities, could give a closer insight on the details of perception and acceptability. All studies were conducted in a laboratory environment with visible cameras and people being aware that their behaviour was being recorded and observed. Studies conducted in a more natural environment could provide deeper insights about the perception of a robot when interacting more naturally with it. All results apply to the geographical areas in which the studies have been conducted and the same study could potentially lead to different results when conducted with people from a different cultural background. There are still many factors to consider in the vast research of human-robot interaction, and to isolate those conditions for closer examination is a challenging and difficult task.

6.3 Conclusions

6.3.1 Summary of Contributions

This study is the first to report the changes in perception of the android robot Actroid-F, and the first to examine the perception of the robot Robi. Both robots are state of the art and so far, have not been used to evaluate human factors in terms of perception and cultural differences with a physically present robot. This thesis reports possible ways how people form a certain perception of a robot, and evaluates factors influencing this perception. It is also the first study evaluating the results of an economic trust game between humans and an android robot. Furthermore, the condition of a bystander in an interaction study with robots has rarely been considered and shown to have an effect on perception. As the investigation of cultural differences is not new, the outcome of a western culture being more open to a certain robot type, but less open to another one, shows new aspects for the perception of robots in different cultures.

6.3.2 Conclusion

This research gives an early outlook on the future interactions that people will have with social robots. Participants in the studies here enjoyed the interaction with the small humanoid robot and mainly also with the android robot even though this robot encountered some cases of repulsion. It has been shown how people perceive a robot when they see it for the very first time; physically present and in close proximity, and also how this perception then changes in only one short interaction with the robot. As people are not yet in close contact with robots, it is a significant step towards the understanding of acceptability and potential relationships that could be formed with robots. Robots will be physically present in people's lives. Therefore it will not only be the impression they make as technology that will influence people's perception, but perhaps even more importantly, it will be how people perceive them as a social agent. A robot might not be perfect in the sense of its performance output, but it could well be that such a robot is accepted by people socially.

Appendix A

Questionnaire Different Robot Types

A.1 Questionnaire Items

1. Which one of these tasks do you think this robot can do?

   - react to noise
   - react to visual input
   - recognize people
   - act autonomous
   - intelligent
   - real human behavior (real animal behavior)

2. Please tick in box of things you associate with this special robot type?

   - technology
   - help for handicapped and elderly
   - future
   - time saving
   - food processor

- medicine
- surgery
- simplify
- improve life
- give relief to humans
- assembly line
- machine
- repetitive tasks
- help for human
- dangerous tasks
- accurate work
- household tasks
- untiring
- humanoid
- utility
- job loss
- artificial being
- space exploration
- research
- toy for children
- gadget
- loss of human contact
- intelligent
- autonomous
- independent
- robots competition

- hope for humanity
- replacement of human
- entertainment
- freedom
- mobile
- danger
- boredom
- lack of activity
- alive
- perfect
- fear
- others:

3. Please tick in the boxes (see 4.) what role robots could play in your personal daily life (like your household, for entertainment and for company)

4. Please tick in the boxes what role robots could play in general in industry and society.

   - Could do dangerous tasks
   - technological advance
   - progress
   - industry productivity
   - economy
   - rapidity
   - efficiency
   - accuracy
   - help for household tasks
   - difficult and repetitive tasks

- global help
- free time
- make life easier
- daily help
- comfort and well-being
- help for old and handicapped people
- entertainment and company
- medicine
- security

5. What do you fear from the increasing number of robots for your own person (see 6.)?

6. What do you fear from the increasing number of robots for the society?

   - autonomy of the robot
   - loss of job
   - loss of control and dysfunction
   - dependence
   - loss of autonomy
   - laziness
   - replacement of humans
   - replacement of pets
   - loss of human contact
   - misuse

7. Have you ever seen this robot in reality?

   - Yes
   - No

8. Have you ever seen this robot in motion, for example on TV or online videos?
    - Yes
    - No
9. Have you ever seen a picture of this robot before?
    - Yes
    - No
10. What is the most advanced country for robotic research?
11. What are other very advanced countries in robotic research?

Appendix B

Godspeed Questionnaire

B.1 Godspeed I: Anthropomorphism

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください

Table B.1: Anthropomorphism

Fake	◯	◯	◯	◯	◯	Natural
偽物のような	◯	◯	◯	◯	◯	自然な
Machinelike	◯	◯	◯	◯	◯	Humanlike
機械的	◯	◯	◯	◯	◯	人間的
Unconscious	◯	◯	◯	◯	◯	Conscious
意識を持たない	◯	◯	◯	◯	◯	意識を持っている
Artificial	◯	◯	◯	◯	◯	Lifelike
人工的	◯	◯	◯	◯	◯	生物的
Moving rigidly	◯	◯	◯	◯	◯	Moving elegantly
ぎこちない動き	◯	◯	◯	◯	◯	洗練された動き

B.2 Godspeed II: Animacy

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください

Table B.2: Animacy

Dead	◯	◯	◯	◯	◯	Alive
死んでいる	◯	◯	◯	◯	◯	生きている
Stagnant	◯	◯	◯	◯	◯	Lively
活気のない	◯	◯	◯	◯	◯	生き生きとした
Mechanical	◯	◯	◯	◯	◯	Organic
機械的な	◯	◯	◯	◯	◯	有機的な
Artificial	◯	◯	◯	◯	◯	Lifelike
人工的な	◯	◯	◯	◯	◯	生物的な
Inert	◯	◯	◯	◯	◯	Interaktiv
不活発な	◯	◯	◯	◯	◯	対話的な
Apathetic	◯	◯	◯	◯	◯	Responsive
無関心な	◯	◯	◯	◯	◯	反応のある

B.3 Godspeed III: Likeability

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください

Table B.3: Likeability

Dislike	◯	◯	◯	◯	◯	Like
嫌い	◯	◯	◯	◯	◯	好き
Unfriendly	◯	◯	◯	◯	◯	Friendly
親しみにくい	◯	◯	◯	◯	◯	親しみやすい
Unkind	◯	◯	◯	◯	◯	Kind
不親切な	◯	◯	◯	◯	◯	親切な
Unpleasant	◯	◯	◯	◯	◯	Pleasant
不愉快な	◯	◯	◯	◯	◯	愉快な
Awful	◯	◯	◯	◯	◯	Nice
ひどい	◯	◯	◯	◯	◯	良い

B.4 Godspeed IV: Perceived Intelligence

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください

Table B.4: Perceived Intelligence

Incompetent	◯	◯	◯	◯	◯	Competent
無能な	◯	◯	◯	◯	◯	有能な
Ignorant	◯	◯	◯	◯	◯	Knowledgeable
無知な	◯	◯	◯	◯	◯	物知りな
Irresponsible	◯	◯	◯	◯	◯	Responsible
無責任な	◯	◯	◯	◯	◯	責任のある
Unintelligent	◯	◯	◯	◯	◯	Intelligent
知的でない	◯	◯	◯	◯	◯	知的な
Foolish	◯	◯	◯	◯	◯	Sensible
愚かな	◯	◯	◯	◯	◯	賢明な

B.5 Godspeed V: Perceived Safety

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください

Table B.5: Perceived Safety

Anxious	○	○	○	○	○	Relaxed
不安な	○	○	○	○	○	落ち着いた
Calm	○	○	○	○	○	Agitated
冷静な	○	○	○	○	○	動揺している
Quiescent	○	○	○	○	○	Surprised
平穏な	○	○	○	○	○	驚いた

A detailed discussion of the questionnaire has been published [69] and the Godspeed Questionnaire series is available in English, German, Spanish, Dutch, Japanese, and Chinese at:

`http://www.bartneck.de/2008/03/11/the-godspeed-questionnaire-series/#sthash.D1XlxonU.dpuf`

Appendix C

Interaction Protocol with the Android Robot

The abbreviation (R) stands for “robot” and (P) for “participant”. The interaction is divided into three trials. The English version is displayed first followed by the Japanese version.

C.1 Interaction Trial 1

C.1.1 English Version

R: ”Hello, nice to meet you. Please reposition the chair from the corner and take a seat.”

(waiting for participant’s reaction)

R: ”Hello, my name is Geminoid. I am a robot from Tsukuba. Nice to meet you.”

(waiting for participant’s reaction)

R: ”What is your name?”

(waiting for participant’s answer)

R: ”What is your participant number?”

(waiting for participant’s answer)

R: “Where are you from?” (waiting for participant’s answer)

R: “Let’s start with the first task. Are you ready?”

(waiting for participant’s answer)

R: “ Do you see the green box on your right?” [robot turns head to left, subjects right side]

(waiting for participant’s answer)

R: “Please go over there and move the box from Position 1 to Position 2”

(waiting for participant’s reaction)

R: “Thank you.” [if subject still stands: “Please sit down again”]

(waiting for participant’s reaction)

R: “Thank you, we are finished with the first task. Would you please put the chair back in the corner and wait outside”

R: “Thank you very much”

C.1.2 Japanese Version

R: こんにちは、初めまして。角のイスを取って、好きな所へ座ってください。

R: こんにちは、私の名前はGeminoidです。筑波から来たロボットです。初めまして。

R: あなたの名前は何ですか？

R: あなたの被験者番号は何ですか？

R: どこから来ましたか？

R: では、最初の課題を始めましょう。準備はいいですか？

R: あなたの右にある緑の箱が見えますか？

R: 緑の箱を１から２へ動かしてください。

R: ありがとう。（座ってください。

R: ありがとう、課題１は終了です。イスを角に戻して、外で待っていてもらえますか？

R: おつかれさまでした。

C.2 Interaction Trial 2

C.2.1 English Version

R: “Hello, welcome back. Please reposition the chair from the corner and take a seat.”

R: “Nice to see you again.”

(waiting for participant’s reaction)

R: ”What is your participant number?”

(waiting for participant’s answer)

R: “Was the last task ok?”

(waiting for participant’s answer)

R: “Ok, Let?s start with the second task. Are you ready?”

(waiting for participant’s answer)

R: “Do you see the pink box on your left?” [turns head to right, subjects left side]

(waiting for participant’s answer)

R: “Please go over there and move the box from Position 1 to Position 2”

(waiting for participant’s reaction)

R: “Thank you.” [if subject still stands: “Please sit down again”]

(waiting for participant’s reaction)

R: “Thank you, we are finished with the second task. Would you please put the chair back in the corner and wait outside”

R: “Thank you very much”

C.2.2 Japanese Version

R: お帰りなさい。角のイスを取って、好きな所へ座ってください。

R: また会えてうれしいです。

R: 被験者番号をもいちど教えてください。

R: 先ほどの課題は大丈夫でしたか？

R: では、次の課題を始めましょう。準備はいいですか？

R: あなたの左のピンクの箱が見えますか？

R: ピンクの箱を1から2へ動かしてください。

R: ありがとう。（座ってください。）

R: おつかれさまでした。

C.3 Interaction Trial 3

C.3.1 English Version

R: “Hello, welcome back. Please reposition the chair from the corner and take a seat.”

R: “Nice to see you again.”

(waiting for participant’s reaction)

R: “Ok, Let?s start with the third and last task. Are you ready?”

(waiting for participant’s answer)

R: “What is your participant number?”

(waiting for participant’s answer)

R: “I am designed to look like a person. Also, it is fine to touch my hand. Would you like to try and touch my hand?”

(waiting for participant’s answer)

[P: yes. R: “Please come closer and touch my hand”.]

[P: hesitates ... R: “Are you sure. I would be great if you would try it. ”] (waiting for participant’s reaction)

R: “Please come closer and touch my hand. ”

(waiting for participant’s reaction)

R: “Thank you.” (if subject still stands: “please sit down again.”)

R: “How does my hand feels like?”

(waiting for participant’s answer)

R: “Do you have any questions you would like to ask me?”

(waiting for participant’s questions and answers them)

R: “Thank you, we are finished with the second task. Would you please put the chair back in the corner and wait outside?”

R: “Thank you very much”

R: “Bye bye”

C.3.2 Japanese Version

R: お帰りなさい。角の椅子を取って、好きな所へ座ってください。

R: また会えてうれしいです。

R: 被験番号をもういちど教えてください。

R: ほどの課題は大丈夫でしたか？

R: では、次の課題を始めましょう。準備はいいですか？

R: 私は人間をイメージしてつくられたロボットです。私の手を触っても構いません。触ってみませんか？

[P: はい ... R: 近づいて、私の手を触ってみてください。

[P: いいえ ... R: 本当に良いのですか？触ってくれたら嬉しいです。]

R: 触った場合

R: 私の手はどんな感じですか？

R: 何か私に聞きたいことはありますか？

R: ありがとう、最後の課題も終了です。イスを角に戻して、外で待っていてもらえますか？

R: おつかれさまでした。

R: バイバイ

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