The Influence of Robot Appearance and Interactive Ability in HRI: A Cross-Cultural Study

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Abstract. It has been shown that human perception of robots changes after the first interaction. It is not clear, however, to which extent the robot's appearance and interactive abilities influences such changes in perception. In this paper, participants' perception of two robots with different appearance and interactive modalities are compared before and after a short interaction with the robots. Data from Japanese and Australian participants is evaluated and compared. Experimental results show significant differences in perception depending on the robot type and the time of interaction. As a result of cultural background, perception changes were observed only for Japanese participants on isolated key concepts.

Keywords: Culture · Human-robot interaction · Robot perception

1 Introduction

Humans form impressions of each other in as little as 100 ms [16]. It is believed that quick impressions of robots are formed in a similar way, depending solely on the robot's appearance [4,8,9]. The Expectation Confirmation Theory, furthermore, states that people form initial expectations towards technology (including robots) based on appearance alone [12], which is then (dis)confirmed after observing its performance. Although based on this theory it is believed that a mismatch between people's expectations of a robot based on its appearance and the real experience based on the robot's performance plays a significant role in how people perceive and interact with a robot [5], it is unclear to what extent each of these factors influence short and long-term interaction.

Social psychology, on the other hand, has shown that cultural differences exist in the way people perceive technology [15]. Although cultural differences have

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been shown to affect certain areas of human perception of robots [5,6], this is only one of many factors that contribute towards robot perception. Previous research also suggests that culture [5,6] has a significant effect in human perception of robots during passive HRI; that is, a situation where a person "does not explicitly interact with a robot but needs some model of robot behaviour to understand the consequences of the robot's actions" [13]. A robot that follows strategies of human behaviour when giving advice to other humans, for example, is perceived as effective when this interaction is observed but not necessarily when the person is interacting directly with the robot [14].

In this study two robots of different appearance and abilities were used to identify possible changes in human perception of robots between expectation and (dis)confirmation of beliefs. That is, before (expectation) and after (confirmation) a short interaction with the robots. Results from this study provide new information about the factors that influence human expectations from robots, based on their appearance, and how these perception changes due to the robot's behaviour and interactive abilities.

Following the work from Strait et al. [14], this study also extends to a scenario in which a passive person, a bystander [17], is present observing the interaction. Previous work that explores cross-cultural differences in human perception [6] is also extended to evaluate if the differences previously found occur regardless of the robot type. To our knowledge, no previous study has explored cross-cultural aspects of human perception of robots which differ in appearance and interactive abilities. Experimental results, performed with Japanese and Australian participants, suggest that the appearance followed by interactive modality have more influence on human perception than cultural background or interactive modality (i.e. bystander and interactant).

2 Methodology

This study evaluates human perception of two different robots before and after interaction. Japanese and Australian participants interacted with the robots in two different modes: active (interactant) and passive (bystander). For both conditions, participants were instructed to observe the reaction of the robot to the active participants' input. It is hypothesized that: (1) the perceptions of both robots will change after the interaction, and (2) the robot abilities and behaviour are the main factor influencing robot perception.

2.1 Robots

Two commercial robots were used: (1) the humanoid robot Robi^{TM} and (2) the non-biomimetic[1] robot My Keepon^{TM}, see Fig. 1. Both are small-sized robots with the ability to move and respond to speech (Robi) or touch (My Keepon).

[1] Although My Keepon has some elements of anthropomorphism (eyes and nose), in this document it is referred as non-biomimetic due to its non-biomimetic form and behaviour.

The interaction with Robi took place through seven pre-defined phrases (English in Australia and Japanese in Japan) and the robot's response using speech and movements. My Keepon, who was previously used to study the underlying mechanisms of social communication [10], responded to touch using non-verbal sound and movement (e.g. turns right when touched on the right side).

Fig. 1. Robots used in the present study: Robi by De Agostini (left), and My Keepon by Wow!Stuff (right).

2.2 Experimental Procedure

Pairs of participants were randomly assigned to either Robi or Keepon[2], with one participant assigned the role of interactant (active), while the second was the bystander (passively observing). The experiment was divided in two stages. First, the robot assigned to the pair of participants was shown to them sitting on top of a table, after which they were asked to answer a demographic survey and two perception questionnaires to measure their initial thoughts about the robot (before condition). Then, participants were instructed to interact with the robot through either speech (Robi) until completion of the last item of the pre-defined phrases, or touch (Keepon) with a time limit of two minutes. Participants were then asked to fill in the two perception questionnaires for a second time (after condition). The experiments were all performed in private rooms. All questionnaires were answered in a private room adjacent to the location of the robot, and the robots were not present during the questionnaires. The same procedure was followed in Japan and Australia, see Fig. 2.

2.3 Questionnaires

In addition to the demographics survey participants were asked to fill in two questionnaires: The Godspeed robot perception questionnaire [1] which measures human perception of robots using five concepts: anthropomorphism, animacy, likeability, intelligence, and safety; and a questionnaire that evaluates if participants ascribed to the robot any mental capabilities beyond the observable behaviour [3] using two concepts: the robot's perceived ability for experience (i.e. feel, sense) and agency (i.e. plan, memorize). In both questionnaires the participants reported using a 5-point scale for all items.

[2] In this document the names 'My Keepon' and 'Keepon' will be used interchangeably.

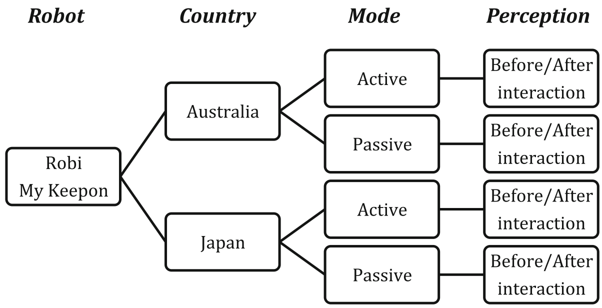

Fig. 2. Experimental conditions using two robots, two countries and two interaction modes as between condition, and participants' perception before and after the interaction as within condition.

2.4 Participants

A total of 126 participants were recruited at the University of New South Wales, Australia and the University of Tokyo, Japan; see Table 1. Participants were naïve to the objectives of the experiment, and have never interacted with either one of the robots.

Table 1. Participants demographics.

	Japan		Australia	
	My Keepon	Robi	My Keepon	Robi
Female/Male/Not specified	8/16/0	6/13/1	18/20/0	23/20/1
Age M (SD)	21.7 (2.15)	21.3 (1.95)	22.6 (5.07)	24.6 (8.5)

3 Results

The main focus of the study was to determine the effects and differences that may exist in human perception of robots depending on robot type, interactive modality, and participant's cultural background. For each one of the seven key perception concepts (Sect. 2.3), if not otherwise indicated, a repeated-measures ANOVA was performed with the key concept as dependent variable, and the interaction times before and after as independent variable. Only results with significant differences are presented in this section.

3.1 Mental Capability: Experience

Participants' attribution the robots' capability to experience (e.g. feel pain, pleasure) showed a significant effect for robot type ($F(1,122) = 3.84$, $p < 0.05$), ascribing lower ability to experience to Robi than to Keepon, see Table 2. A significant effect based on country was also found ($F(1,22) = 10.22$, $p < 0.001$), showing that Japanese participants ascribed a higher mental capability to both robots than Australian participants, see Table 2. The capability of experience increased significantly ($F(1,123) = 5.16$, $p < 0.02$) after the interaction ($M = 2.18$, $SD = 0.98$) with the robots (before: $M = 2.01$, $SD = 0.89$).

Table 2. Robots' capability to experience, according to participants. Mean (M) and standard deviation (SD) divided by country and robot type.

	Japan	Australia	Robi	Keepon
M (SD)	2.41 (1.02)	1.92 (0.85)	1.95 (0.83)	2.24 (1.02)

Results from a two-factor ANOVA showed a significant correlation between country and interaction time ($F(1,122) = 12.85$, $p < 0.001$), Fig. 3. Post-hoc t-tests showed that for Japanese participants the capability of experience increased significantly after the interaction ($t(43) = -3.27$, $p < 0.001$), rating both robots higher after the interaction ($t(79.8)=4.27$, $p < 0.001$).

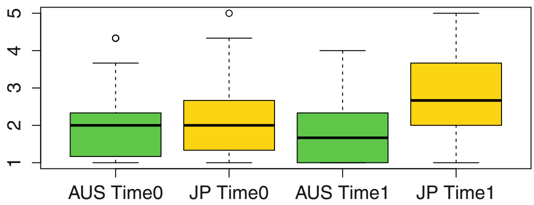

Fig. 3. Robots' capability to experience, according to participants, before (Time 0) and After (Time 1) the interaction with a significant increase for Japanese participants after the interaction.

3.2 Mental Capability: Agency

Participants' attribution of the mental capability of agency (e.g. plan, memorize) showed a significant effect for robot type ($F(1,122) = 7.55$, $p < 0.01$); see Table 3, ascribing Robi higher agency. Although the correlation between country and interaction time was significant ($F(1,122) = 4.56$, $p = 0.03$), this was not confirmed in the post-hoc test. A separate t-test for the difference between countries, however, showed that agency was rated higher in Japan ($t(81.1) = 2.08$, $p = 0.03$).

Table 3. Robots' capability for agency according to participants. Mean (M) and standard deviation (SD) divided by country and interaction time.

	Japan		Australia		Robi	Keepon
	Before	After	Before	After		
M (SD)	2.73 (1.08)	3.03 (1.10)	2.73 (0.75)	2.61 (0.99)	2.94 (0.98)	2.55 (0.91)

3.3 Perception: Anthropomorphism

Participants' perception of anthropomorphism showed a significant effect for robot type ($F(1,122) = 7.55$, $p < .01$), rating Robi as more anthropomorphic. The correlation between country and interaction time was also significant ($F(1,122) = 8.51$, $p <= 0.01$) showing that the perception of anthropomorphism increased significantly in Japanese participants after the interaction ($t(43) = -1.9$, $p = 0.05$). Detailed values are presented in Table 4.

Table 4. Robots' perceived anthropomorphism according to participants. Mean (M) and standard deviation (SD) divided by country and interaction time.

	Japan		Australia		Robi	Keepon
	Before	After	Before	After		
M (SD)	2.42 (0.67)	2.74 (0.89)	2.42 (0.69)	2.43 (0.89)	2.66 (0.82)	2.31 (0.74)

3.4 Perception: Animacy

Participants' perception of animacy showed a significant effect for robot type ($F(1,122) = 3.85$, $p = 0.05$), giving Robi a higher score ($M = 2.66$, $SD = 0.82$) over Keepon ($M = 2.31$, $SD = 0.74$). For the interaction time, furthermore, a significant increase in animacy was observed after ($M = 2.74$, $SD = 0.89$) the interaction ($F(1,123) = 9.79$, $p = 0.002$), with $M = 2.45$ and $SD = 0.67$ before the interaction.

3.5 Perception: Likeability

Participants' perception of likeability showed a significant effect for robot type ($F(1,122) = 15.75$, $p <= 0.001$) with Robi being more likeable ($M = 4.21$, $SD = 0.73$) than Keepon ($M = 3.73$, $SD = 0.85$). The correlation between robot and interaction time also showed a significant effect ($F(1,122) = 12.3$, $p <= 0.001$); for Robi likeability increased ($t(61) = -31.98$, $p = 0.05$) whilst for Keepon it decreased ($t(61) = 2.94$, $p < 0.01$), resulting in significantly higher values for Robi after the interaction ($t(114.6) = -4.71$, $p < 0.001$), Fig. 4. The mean and standard deviation values for these results are presented in Table 5.

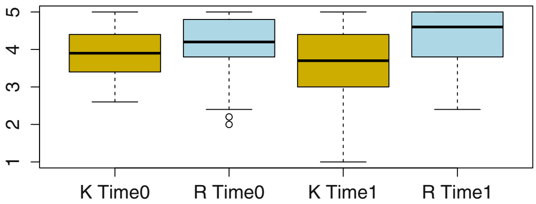

Fig. 4. Perception of likeability divided by robot: (R)oby and (K)eepon; and interaction time: before (Time 0) and after (Time 1). A significant decrease for Keepon and a significant increase for Robi can be observed.

Table 5. Robots' perceived likeability according to participants. Mean (M) and standard deviation (SD) divided by robot type and interaction time.

	Robi		Keepon	
	Before	After	Before	After
M (SD)	4.11 (0.71)	4.31 (0.75)	3.88 (0.68)	3.57 (0.97)

These results show that likeability and anthropomorphism are positively correlated before ($r(122) = 0.45$, $p < 0.001$) and after the interaction ($r = (122) = 0.50$, $p < 0.001$), with Robi perceived as more likeable than Keepon which is considered as support for the uncanny valley theory [11].

3.6 Perception: Intelligence

Participants' perception of intelligence showed a significant effect for robot type ($F(1,122) = 43.49$, $p< 0.001$), rating Robi higher ($M = 3.26$, $SD = 0.70$) than Keepon ($M = 2.60$, $SD = 0.64$). Additionally, a significant correlation between robot type, country, and interaction time was observed ($F(1,120) = 11.87$, $p < 0.001$). For Japanese participants the perception of intelligence increased significantly after the interaction with Robi ($t(19) = -2.94$, $p < 0.01$), who was also perceived significantly more intelligent after the interaction by Japanese participants ($t(36.8) = -2.37$, $p <= 0.05$). Robi was also perceived more intelligent than Keepon before the interaction by both Australians ($t(72.7) = -4.91$, $p < 0.001$) and Japanese ($t(41.3) = -2.45$, $p = 0.01$) participants. The same held after the interaction, where Robi was perceived as more intelligent both in Australia ($t(77.3) = -3.79$, $p < 0.001$) and Japan ($t(36.4) = -4.45$, $p < 0.001$). The data also show that agency and intelligence are positively correlated ($r(256) = 0.49$, $p < 0.001$). More details are in Table 6.

3.7 Perception: Safety

Participants' perception of safety only showed a marginal correlation between robot type and country ($F(1,120) = 3.4$, $p = 0.06$). A separate t-test shows that Keepon was perceived slightly safer in Japan after the interaction ($t(72.8) = -2.53$, $p = 0.01$).

Table 6. Robots' perceived intelligence according to participants. Mean (M) and standard deviation (SD) divided by country and interaction time.

	Japan		Australia	
	Before	After	Before	After
Robi: M (SD)	3.09 (0.70)	3.61 (0.79)	3.33 (0.53)	3.10 (0.77)
Keepon: M (SD)	2.59 (0.69)	2.63 (0.64)	2.68 (0.63)	2.51 (0.64)

4 Discussion

This paper presents a series of experiments aimed to investigate the differences that may exist in how people perceive robots of different appearance and interactive modality before and after a short-term interaction. Two commercial robots were used in these experiments; the humanoid robot Robi, who has the ability to respond to speech; and the non-biomimetic robot My Keepon, who responds to touch. Both modes of interaction, speech [14] and touch [7], have been found to influence how participants perceive a robot and the potential to contribute towards the success (or failure) of the interaction. All participants were recruited from two different universities (in Japan and Australia) and do not represent the full population of either of these countries; these participants, however, provide socio-economically similar samples from these countries that are valid for a cross-cultural comparison. Note that culture in this work simply refers to the country where the experiment was performed.

Experimental results suggest that participants' initial perception of a robot depend on the robot's appearance, with higher ratings provided to Robi (the humanoid robot) in five out of the seven key concepts measured: agency, anthropomorphism, animacy, likeablity, and perceived intelligence. These results, together with a positive correlation between agency and intelligence, suggest that a humanoid design (when compared to the non-biomimetic design) leads to a higher assumption of intelligence, and therefore agency, in a robot. Additionally, and supporting the theory of the uncanny valley [11], this experiments demonstrate that higher ratings of likeability were indeed correlated to a robot with a higher score in anthropomorphism.

From appearance to behaviour, the results presented in this paper show that observing a robot in motion also leads to an increased perception in animacy. This results support previous research in the perception of animacy that shows that perceived motion induces brain activity in a similar way than the perception of animacy [2].

In terms of perceived safety, this concept did not differ between the robots. This effect is attributed to the small size, non-threatening appearance, and generally limited movement of both robots.

The capability of experience stands out when the two robots are compared. My Keepon, the non-biomimetic robot, was rated higher in its ability to experience (e.g. feel pain, pleasure, etc.) than the Robi, the humanoid robot. The authors suspect that the ability to experience is influenced by the interaction modality—speech or touch—where My Keepon was able to "feel" the touch of participants, ascribing a higher ability to experience in other areas. This interesting result suggests that tactile interaction with robots can have a significant influence in how people relate with robots. Future research should isolate this effect to confirm the influence of touch in all key concepts of robot perception. Note that during this experiments participants were not allowed to touch Robi.

In terms of culture, this study confirms previous findings that suggest that cultural background is not a major key factor in robot perception [6], but yet could potentially influence how people change their perception when interacting with a physically present robot. This was reflected here through an increase in Japanese participants for perceived experience, anthropomorphism and intelligence for Robi, and safety for Keepon. Although previous results showed a significant effect to cultural differences in a passive interaction [6], in the current experiments the conditions of 'active' and 'passive' did not show any significant differences; the authors believe that future experiments with a reduced number of experimental conditions could give more insight on these differences.

Future research should also derive a more comprehensive experiment that describes relevant information regarding cultural and socioeconomic background, instead of only the country where the experiments where performed. Additionally, the current study did not control for the variables of appearance and interaction modality independently. Future work should consider these factors to explore the relative weight of each factor on robot perception. Although the authors are aware of the lack of numerical balance between the two populations tested, the statistical analysis does not suggest that any significant effects may occur with a more balanced population.

5 Conclusion

This study concludes that appearance, as well as the interaction modality of a robot play a crucial role in the perception of robots before and after short-term interactions. Although speech is the most common mode of interaction, and is an intuitive way to interact with robots, the results from this experiments suggest that tactile interaction is important to the way people perceive and interact with robots.

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