Exploring Children's Attitudes towards Static and Moving Humanoid Robots

Fang-Wu Tung[1] and Tsen-Yao Chang[2]

[1] Department of Industrial and Commercial Design, National Taiwan University of Science and Technology, 43,Sec. 4, Keelung Rd., Taipei, 106, Taiwan
[2] Department of Creative Design, National Yunlin University of Science and Technology, Yunlin County, 64002, Taiwan
fwtung@mail.ntust.edu.tw, changty8908@gmail.com

Abstract. This study investigates the uncanny valley for robots designed specifically for child users, and examines their attitudes toward humanoid robots with different anthropomorphic appearances and behaviors. An uncanny valley was identified in this study, indicating that the children were less attracted to images they considered highly human-like, although they were distinguishable from humans. The results of this study support Mori's uncanny valley hypothesis regarding children's perceptions of static robots. A significant finding is that moving robots can moderate an uncanny valley plot, which contradicts Mori's uncanny valley theory that the movement of a robot amplifies a generated emotional response. The moving robots exhibited various behaviors, such as facial expressions, speech, gazing, and gestures, which can generally enhance children's perceptions of robots. These behaviors were derived from human-human interactions, and can be considered social cues. The results of this study show that social cues can be applied to child-robot interactions. Children perceive robots are more socially and physically attractive when they exhibit sufficient social cues. Specifically, the display of social cues by robots that are less anthropomorphic can significantly enhance children's social perceptions of them. This has crucial implications for the behavior a child anticipates from a machine-like robot compared to a human-like robot. According to the study results, robots designed for children do not require excessively human-like designs. Middle- to low-level anthropomorphic designs combined with appropriate social cues can enhance children preferences and acceptance of robots. This also enables businesses to develop educational, care, or entertainment robots for children at a reasonable cost.

Keywords: humanoid robot, child-robot interaction, behavior, social cue.

1 Introduction

The paradigm of robotics is moving from a specific industrial technology to the consumer, home, and service markets. Service robots can be applied to people's living and working spaces as assistants, companions, or perform other social roles in the future [1]. Because robots are designed and built for purposes such as service, education, therapy, or entertainment, human-robot interactions become increasingly

M. Kurosu (Ed.): Human-Computer Interaction, Part III, HCII 2013, LNCS 8006, pp. 237–245, 2013.

socially situated and multi-faceted. Social and emotional levels of interaction influence a person's acceptance of a robot's role [2,3]. Furthermore, considering a robot's functionality, previous studies have examined the social aspects of human-robot interaction to evaluate how people respond to the appearance and behavior of robots in various contexts [4,5,6]. To understand people's views toward robot companions in households, an investigation by Dautenhahn et al. [7] showed that the majority of people were in favor of a robot companion and saw the potential role of a robot as being an assistant, machine, or servant. People desired human-like communication with potential robot companions. Attributing human-like characteristics to robots with a human appearance is a design consideration because this could facilitate human-robot interaction [8]. Robots designed with anthropomorphic characteristics are the embodiment of a human-computer interface, and forms the basis for potential social relationships. This argument is supported by research by Goetz et al. [9] which indicates that people anticipate human-like robots would be best suited for interactive tasks, whereas mechanical-looking robots would be best suited for routine jobs. Scopelliti et al. [10] focused on people's attitudes toward domestic robots across three generations. Their findings showed that younger people scored higher on positive feelings (e.g., amusing, dynamic, pleasant, or relaxing) toward a domestic robot compared to adults and older adults people. Younger people who were born in the digital era did not express any anxiety toward the idea of a domestic robot. They reported a preference for robots with human-like attributes so they can interact with it in leisure situations, rather than perceiving it as a useful device. Considering children as potential users, the use of human-like features such as behavior and appearance can engage children to interact with robots. The large number of current humanoid robotics projects exemplifies this tendency.

As discussed, various humanoid robots are designed specifically for children, for educational, entertainment, and therapeutic purposes. Attributing human-like characteristics to a robot can facilitate children's understandings of its functionalities, and establishes meaningful human-robot interactions. Such notions lead to an assumption that increasing the realism of a robot has practical benefits. Although many researchers have pursued a highly human-like form of social robots, a potential danger is that highly human-like robots might fall into Mori's [11] uncanny valley. Uncanny valley theory hypothesizes a positive correlation between the human-like appearance and motion of robots with people's positive emotional reactions towards them. However, as likeness increases, there is a breaking point beyond which familiarity drops and robots become "eerie". When the emotional reaction is plotted against the robots' level of anthropomorphism, a negative valley becomes visible, and is commonly referred to as the uncanny valley. Furthermore, Mori argued that a robot's movement amplifies the emotional response in comparison to static robots.

The uncanny valley hypothesis has received empirical support from several studies. These studies have focused on examining Mori's hypothesis with adult participants, using static robot pictures as stimuli. However, whether the movement of a robot amplifies the emotional response compared to that of static robots has seldom been investigated. Robots are not developed to remain motionless, rather to be responsive to and interactive with people. Therefore, understanding people's perceptions of robots exhibiting human-like behavior provides insights that may be useful when designing a robot's appearance and behavior to facilitate better human-robot interaction. Given that children are potential users of learning or entertainment robots, numerous humanoid robots have been created to serve as social companions or learning partners for children. This study investigates the uncanny valley for robots designed specifically for children, and examines their attitudes toward humanoid robots with various anthropomorphic appearances and behaviors. Obtaining insight about their perception toward robots that exhibit various degrees of anthropomorphic appearance and behavior could provide designers with valuable a reference

2 Method

2.1 Participants

For this study, we recruited a large sample group of 578 (N) children. We assigned 267 children to the static condition group, comprising 87 fourth graders (42 girls and 45 boys), 86 sixth graders (42 girls and 44 boys), and 94 eighth graders (45 girls and 49 boys). The remaining 311 children were assigned to the moving condition group, comprising 108 fourth graders (49 girls and 59 boys), 86 sixth graders (53 girls and 65 boys), and 94 eighth graders (43girls and 42 boys).

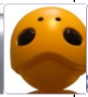
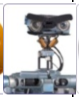
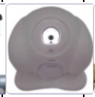
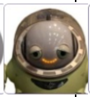
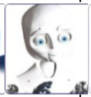
2.2 Experimental Stimuli

To conduct the investigation, we accessed numerous robot resources developed by companies, institutes, research labs, and artists, and acquired 54 robots ranging from "barely human" to "fully human". The 54 robot images obtained primarily from the Internet were edited by re-scaling and removing variables such as background color, marks, and other objects to ensure that the images were presented in a standardized format. Three professional designers subsequently examined the 54 images to remove redundant or inappropriate images regarding the anthropomorphism scale, and identified 34 images for inclusion in the study.

Twenty-nine children aged between 10 and 11 years were recruited to sort the 34 images by means of hierarchical clustering individual assessment. Upon commencement of a trial, the experimenters shuffled the cards in the set to ensure random presentation. To facilitate children's participation in this study, they were requested to sort the cards into the following three categories of realism: 1) low; 2) middle; and 3) high. Each subset was then divided into three groups based on identical criteria. Thus, each participant sorted the 34 robot images into nine groups ranging from low to high human likeness. Based on ranking data, we selected nine robots as experimental stimuli to show how children rate robots on an anthropomorphic scale, from "little resemblance to humans" to "highly human-like", (Table 1).

The robot pictures shown in Table 1 are the stimuli used in the static condition, whereas the robot videos are the stimuli employed for the moving condition. The length of the edited video clip is approximately 50 s, and the content fully demonstrated the behaviors of each robot, including locomotion, gesture, facial expression, and speech. Among the robots, R5 and R7 were capable of speech, whereas the remaining videos were accompanied by identical background music. Table 1 shows the behaviors of each stimulus presents in the video.

Table 1. The experimetal stimuli

Image / Behavior	R1	R2	R3	R4	R5	R6	R7	R8	R9
									
Speech					v		v		
Gesture	v	v	v			v	v	v	v
Facial expression					v		v		
Locomotion	v	v	v	v		v			v

2.3 Measurement Tools

The dependent variables for social attraction and physical attraction were modified from a version of McCroskey and McCain's [12] social and physical attraction scale, as well as from relevant studies that adopted the same scale to measure users' attitudes toward computers, robots, or media [13,14]. Social and physical attraction are two key dimensions of interpersonal attraction that have been found to facilitate interpersonal communication that leads to the formation of friendships. This study investigates whether various levels of anthropomorphic appearance and behavior influence children's social and physical attraction toward robots.

The social attraction scale comprises the following of five items: 1) I think this robot is friendly; 2) I like this robot; 3) I think this robot could be a friend of mine; 4) I would like to have a friendly chat with this robot; and 5) This robot would be pleasant to be with. The physical attraction scale comprises the following three items: 1) I think this robot is good looking; 2) I find this robot very physically attractive; and 3) I like the way this robot looks. We measured the two sets were measured using a set of paper-and-pencil questionnaires that employed a 7-point Likert scale ranging from 1 (very strongly disagree) to 7 (very strongly agree). The wording used in the questionnaires was designed after discussions with teachers and children to prevent any misunderstanding.

2.4 Procedure

Static condition group: the experiment was conducted using the discussed paper-and-pencil method. Each robot image was presented as a high-quality color printed image accompanying the aforementioned questionnaires. Participants were requested to evaluate the images of nine robots by completing questionnaires. The order of the stimuli was randomized for each child. The experiment was conducted at select schools. Participants completed the questionnaire survey in their classrooms or in a quiet place such as a school library.

Moving condition group: the experiment for the moving condition group was conducted using computers in a computer class room. The robot videos were played in random sequences. Each session contained 30 participants, and each participant was provided earphones, and experimental personnel were present to assist the participants while watching the nine robot videos and completing in the questionnaire. The total duration of the experiment was approximately 40 min.

3 Results

We calculated the internal consistency (Cronbach's α) to assess the reliability of these scales. Cronbach's α results for the social and physical attraction items were all more than 0.7. According to Nunnally [15], Cronbach's α values of 0.7 are adequate for internal consistency and reliability. Therefore, the measures used in this study show adequate reliability.

3.1 Social Attraction

Table 2 shows the mean social attraction scores rated by participants in the static and moving condition groups. Robot R6 received the highest score for social attraction in the static condition group, whereas Robot R5 received the highest score for the moving condition group. The social attraction that children felt toward the stimuli is plotted in Fig. 1. Their attitude toward static robots supports Mori's prediction, and an uncanny valley emerged when children evaluated Robots R7 and R8. These robots were highly human-like in appearance, although they could be distinguished as non-human. However, this uncanny valley in the moving condition group was less apparent, which does not support the hypothesis that moving robots could amplify people's emotional responses compared to static robots. Generally, participants felt higher social attraction toward moving robots than those that were static.

Table 2. Mean Social attraction scores rated by Static and Moving condition groups

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Static condition	3.31	3.30	3.40	4.30	4.49	5.57	3.76	2.62	4.45
Moving condition	4.89	4.72	4.74	4.81	5.71	5.26	4.85	4.12	5.03

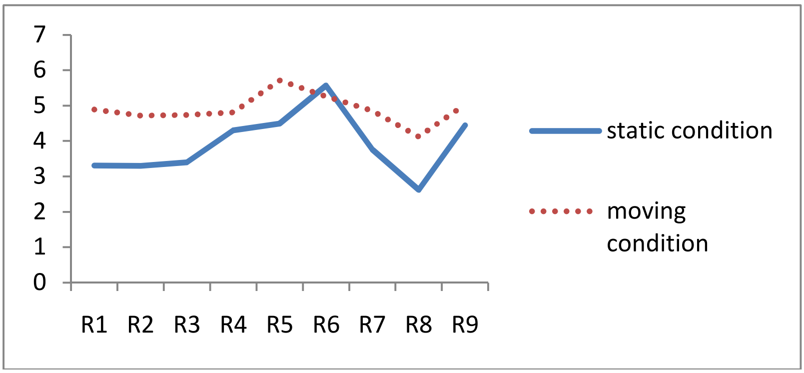


Fig. 1. Each robot's social attractiveness in the static and moving conditions

3.2 Physical Attraction

Table 3 shows the mean physical attraction scores rated by participants in the two conditions, and Fig. 2 shows the physical attraction children felt toward the static and moving robots. Similar findings were observed. Children reported that the moving robots were more attractive in appearance than those that were static. The curve is much flatter for the moving condition group than the static group.

Table 3. Mean Social attraction scores rated by Static and Moving condition groups

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Static condition	3.03	2.85	2.96	3.75	3.76	5.09	3.07	2.37	4.4
Moving condition	4.52	4.39	4.28	4.49	5.01	4.91	4.04	4.02	4.9

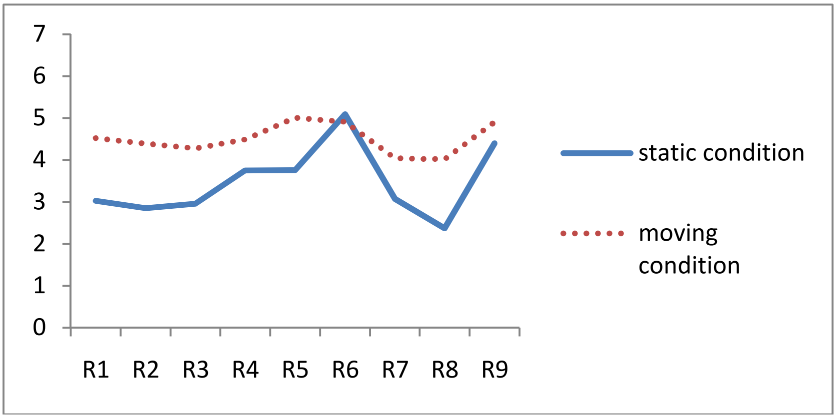


Fig. 2. Each robot's physical attractiveness in the static and moving conditions

4 Discussion

4.1 The Peak before the Uncanny Valley

The results from the static condition group show that the degrees of realism of robots have a significant influence on children's attitudes towards robots. Figures 1and 2 show a continuously positive change of realism versus children's evaluation of social and physical attraction until a point of realism beyond which children's evaluation decreases abruptly. As the appearance becomes less distinguishable from a human, children's responses become positive once again. Thus, an uncanny valley was observed in this study, indicating children were less attracted to images considered highly human-like, yet distinguishable from humans, which evoked a feeling of discomfort in the observer.

In the static condition group, Robot R6 received the highest evaluation from children for social and physical attractiveness. Robot R5 received the highest evaluation from the moving condition group. Robots R6 and R5 were at the peak before the uncanny valley. This finding is identical to that obtained by Bartneck et. al [16], which shows that toy robots and humanoids preferred over humans.

An objective of this study is to identify the threshold of "humanness" that is appropriate for robots designed for children. The implication of the observation is that designers of robots intended for children might consider combining human and machine features to put effort toward the first peak of the plot, rather than attempting to perfectly replicate human-like appearance. The finding that children preferred Robots R5 and R6 among all stimuli supports Woods's [17] finding that children prefer robots with cartoon-like appearances. People, including children, are sensitive to the particular pattern of features that form a face. Using mere representations of cartoon-like faces can avoid the uncanny valley phenomenon and cover a large aesthetic range [18].

4.2 Movement Can Moderate the Uncanny Valley

A significant finding of this study is that moving robots can moderate the uncanny-valley plot. This contradicts Mori's uncanny valley theory which states that movement of a robot amplifies the emotional response more than a static robot. A comparison of children's attitudes toward static and moving robots shows a relatively flat curve for moving robots (Figures 1-2). Moving robots exhibiting behaviors such as facial expressions, speech, gaze, locomotion, and gestures can generally enhance children's perceptions of robots. The behaviors other than locomotion derived from human-human interaction can be considered social cues. Social cues (e.g., voice, presence of a face, and facial expressions) have been adopted into user interface design to enhance human-computer interaction. Studies related to computers as social actors (CASA) have empirically proven that people tend to treat a computer as a social entity when the computer adequately exhibits social cues to elicit social responses from people [19, 20]. CASA principles argue that computers which exhibit social cues can convey a sense of sociability and intimacy, thereby inducing social responses from people. This consequently improves user attitudes toward computers and fosters a more favorable relationship between users and computers. *Social Agency Theory* [21] also argues that a greater frequency of social cues in an interaction improves the quality of that interaction. The results of this study show that social agency theory can also be applied to child-robot interactions. Children perceive robots more socially and physically attractive when they exhibit more social cues.

Comparing the results of the static and moving condition groups, children gave higher evaluations to Robot R5 than Robot R6, which received the highest scores from the static condition group. In the videos provided in this study, Robot R5 could speak and show simple facial expressions with its eyelids and lips, whereas Robot R6 could only walk with whole-body motions. The fact that Robot R6 did not exhibit more social cues rather than locomotion could be the reason why it was the only robot to receive lower scores from the moving condition group than from the static condition group. According to Piaget [22], self-moving is a crucial criterion used by children to judge the "aliveness" of an object. Results for Robot R2 receive from both groups show that locomotion could enhance children's attitudes toward robots, especially for those with low-degrees of human-like appearance. The more human-like robots appear, children might anticipate the robots to exhibit more human-like behaviors. In this sense, Robot R6, a humanoid robot, might be expected to have more social action capabilities rather than locomotion. This can also be observed in results for Robot R9, which has the appearance of an attractive young humanoid robot with influent whole-body motions. Robot R9 did not speak or show social cues such as facial expressions and gestures in the video provided. Thus, the moving Robot R9 did not significantly enhance children's social attraction toward it. This has significant implications for the accompanying behavior a person expects from a machine-like robot compared to a human-like robot. For instance, people might expect a human-like robot to have language capabilities, although they might not expect a machine-like robot to have any language communication abilities at all. Results from the moving condition group indicate that the human-like degree may not play an essential role in influencing children's emotional responses to robots. Appropriate action behaviors can enhance children's perception of humanoid robots, especially for robots with low- and mid-degree human-like appearances. This study recommends that designers consider applying social cues to robots to improve their social and physical attraction, in which child-friendly robot designs can be achieved at a reasonable cost.

5 Conclusion

In the innovation of robot service functions, developing educational or entertainment-oriented robots for children is a focal point for robot development. In this study, we investigated children's attitudes toward humanoid robots. Ultimately, by adopting this research as key reference, we hope to provide designers with design criteria for developing robots for children. According to the obtained results, robots designed for children do not require excessively human-like features. Mid- to low-level anthropomorphic designs combined with appropriate social cues can enhance children's preferences and acceptance of robots. The findings in this study also enable businesses to develop cost-effective educational, care, or entertainment robots for children.

Acknowledgments. This material is based upon work supported by the National Science Council of the Republic of China under grant NSC98-2221-E-239-012-MY2 and NSC100-2410-H-011-035-MY2.

References

1. Prats, M., Sanz, P.J., del Pobil, A.P., Martínez, E., Marín, R.: Towards multipurpose autonomous manipulation with the UJI service robot. Robotica 25, 245–256 (2007)
2. Bartneck, C., Forlizzi, J.: A design-centred framework for social human–robot interaction. In: Proceedings of the 13th IEEE International Workshop on Robot and Human Interactive Communication, pp. 591–594. IEEE Press, Kurashiki (2004)
3. Kiesler, S., Hinds, P.: Introduction to This Special Issue on Human-Robot Interaction. Human- Computer Interaction 19, 1–8 (2004)

4. Thrun, S., Beetz, M., Bennewitz, M., Burgard, W., Cremers, A.B., Dellaert, F.: Probablistic algorithms and the interactive museum tour-guide robot minerva. Journal of Robotics Research 19, 972–1000 (2000)
5. Falcone, E., Gockley, R., Porter, E., Nourbakhsh, I.: The personal rover project: the comprehensive design of a domestic personal robot. Robotics and Autonomous Systems 42, 245–258 (2003)
6. Kahn Jr., P.H., Friedman, B., Perez-Granados, D.R., Freier, N.G.: Robotic pets in the lives of preschool children. In: Poster presented at the 70th Anniversary of the Society for Research in Child Development-2003 Biennial Meeting, Tampa, FL, USA (2003)
7. Dutenhahn, K., Woods, S., Kaouri, C., Walters, M., Koay, K.L., Werry, I.: What is a robot companion–friend, assistant, or butler? In: IEEE/Robotics Society of Japan International Conference on Intelligent Robots and Systems (2005)
8. Friedman, B., Kahn Jr., P.H., Hagman, J.: Hardware companions? - What online AIBO discussion forums reveal about the human-robotic relationship. In: Cockton, G., Korhonen, P. (eds.) Proceedings of CHI 2003 Conference on Human Factors in Computing Systems, pp. 273–280. ACM Press, NY (2003)
9. Goetz, J., Kiesler, S., Powers, A.: Matching robot appearance and behavior to tasks to improve human-robot cooperation. In: Proceedings of the Twelfth IEEE International Workshop on Robot and Human Interactive Communication, Lisbon, Portugal (2003)
10. Scopelliti, M., Giuliani, M.V., D'Amico, A.M., Fornara, F.: If i had a robot at home Peoples'representation of domestic robots. In: Keates, S., Clarkson, J., Langdon, P., Robinson, P. (eds.) Designing a More Inclusive World, pp. 257–266. Springer, Cambridge (2004)
11. Mori, M.: The uncanny valley. Energy 7(4), 33–35 (1970)
12. McCroskey, J.C., McCain, T.A.: The measurement of interpersonal attraction. Speech Monographs 41, 261–266 (1974)
13. Moon, Y.: Similarity effects in human-computer interaction: Effects of user personality, computer personality, and user control on attraction and attributions of responsibility, Unpublished doctorial dissertation, Stanford University, Stanford (1996)
14. Lee, K.M., Peng, W., Yan, C., Jin, S.: Can Robots Manifest Personality? An Empirical Test of Personality Recognition, Social Responses, and Social Presence in Human-Robot Interaction. Journal of Communication 56, 754–772 (2006)
15. Nunnally, J.C.: Psychometric Theory. McGraw Hill, New York (1967)
16. Bartneck, C., Kanda, T., Ishiguro, H., Hagita, N.: Is the Uncanny Valley an Uncanny Cliff? In: Proceedings of the 16th IEEE International Symposium on Robot and Human Interactive Communication, pp. 368–373. IEEE Press, NJ (2007)
17. Woods, S.: Exploring the Design Space of Robots: Children's Perspectives. Interacting with Computers 18, 1390–1418 (2006)
18. Blow, M., Dautenhaun, K., Appleby, A., Nehaniv, C.L., Lee, D.: The art of designing robot faces: Dimensions for human-robot interaction. In: Proceedings of HRI 2006, pp. 331–332. ACM Press, New York (2006)
19. Nass, C., Steuer, J.: Anthropomorphism, Agency, and Ethopoeia: Computers as Social Actors. Human Communication Research 19(4), 504–527 (1993)
20. Reeves, B., Nass, C.: Media equation: how people treat computer, television, and new media like real people and places. Cambridge University Press, New York (1996)
21. Mayer, R.E., Sobko, K., Mautone, P.D.: Social cues in multimedia learning: role of speaker's voice. J. Educ. Psychol. 95, 419–425 (2003)
22. Piaget, J.: The child's conception of the world. Littlefield Adams, Savage (1929)