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Context-Specific Affective and Cognitive Responses to Humanoid Robots

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Context-Specific Affective and Cognitive Responses to Humanoid Robots

Abstract

The uncanny valley model explains the relationship between the resemblance that robots have to humans and attitudes towards these humanoid robots. This model is an influential theory in human-robot interaction and helps us understand individuals' attitudes towards humanoids. Despite its extraordinary worth, prior research has examined the model in general or context-free situations. Given that humanoids have begun to permeate social spheres and are used in actual business areas, it is important to investigate the uncanny valley in specific and actual situations. Additionally, there has been little work on the impact of affective responses presented in the uncanny valley to other appraisals of humanoids. To remedy these constraints, this study tries to explore context-specific affective and cognitive responses to humanoids in the framework of the uncanny valley. In particular, this study examines the effect of affective responses on trust, which is regarded as a critical cognitive factor influencing technology adoption, in two situations: hotel reception (low expertise) and tutoring (high expertise). By providing a richer understanding of human reactions to humanoids, this study expands on the uncanny valley theory and ultimately makes contributions to research on human-robot interactions.

Keywords: human-robot interaction, uncanny valley, trust, context.

Introduction

Although robots are widely used in manufacturing industries, they are available to the general public only in science-fiction movies. However, as robots are developed and used to provide services for consumers, people are becoming more familiar with them and are likely to have increasing interactions with robots in their casual life. Recently, humanoid robots, which resemble humans, have been employed in diverse applications in our daily life. Sprint Corporation announced that humanoid robots would be placed in its retail outlets in 2017, and Pizza Hut is beginning to deploy humanoid robots in its stores (Transparency Market Research, 2018). The usage of humanoid robots has expanded to various service contexts for laypersons, including retail, education, entertainment, and personal assistance. It is expected that the global humanoid market will have an average growth rate of 46% and reach over US \$4 billion by 2023 (Research and Markets, 2017).

The diffusion of robots in the social realm increases individuals' interactions with robots and requires a profound understanding of human-robot interactions. One noticeable phenomenon regarding human-robot interaction is that the more human-like the appearance or behaviors of robots are, the more favorably humans find them, while human-like robots that imperfectly resemble humans make people experience extremely negative feelings. The highest amount of positive emotion occurs when robots look identical to humans (see Figure 1). This phenomenon is called the “uncanny valley” (Mori, 1970) and is commonly explained by the evolutionary view that humans are inclined to turn from an atypical stimulus or partner because its unusualness can imply that it is “infected” or “threatening” (Burleigh et al., 2013). The uncanny valley hypothesis is also explained by the category conflict argument that robots, whose appearance or behavior is ambiguously set between typical robots and humans, cause cognitive dissonance or discomfort (Seyama & Nagayama, 2007).

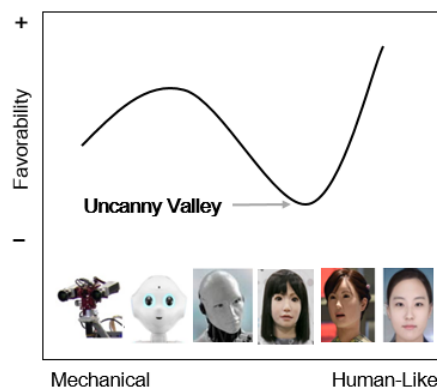


Figure 1. The uncanny valley

There has been extensive discussion about the uncanny valley, particularly about its existence, causes, and methodological approaches (Gray & Wegner, 2012; Ho & MacDorman, 2010). Since humanoid robots are not yet pervasive in social and business areas, prior studies have examined the uncanny valley in no context conditions rather than assuming a context-specific use of humanoid robots (e.g., Burleigh, Schoenherr, & Lacroix, 2013; Gray & Wegner, 2012; Ho & MacMorman, 2010). As robots for consumers are beginning to be used in diverse contexts of social and business spheres, it is necessary to examine the uncanny valley in specific use contexts. Users' responses to a robot have reportedly been significantly influenced by the types of interactions they engage in with the robot (Gaudiello et al., 2016). Accordingly, we expect that the uncanny valley effect may depend on contextual factors (e.g., task type or complexity). The first research question of this study examine *whether the context of interacting with humanoid robots affects the uncanny valley*. More specifically, this study investigates the uncanny valley in different expertise contexts. Advances in artificial intelligence (AI) technologies deploy humanoid robots in diverse contexts of use by providing them with diverse levels of expertise. We thus attempt to examine variation in the uncanny valley depending on different contexts and the level of expertise.

Another limitation of the uncanny valley hypothesis is that it examines only the emotional response to humanoid robots and excludes a cognitive response. Since users' interactions with humanoid robots are growing, they will become more complicated, and thus, a more comprehensive understanding of their reactions is required. Both affective and cognitive processes contribute to human decision-making and behavior (Lowenstein et al., 2001). Prior research has shown that individuals' cognitive assessment of humanoid robots is significantly related to their affective responses presented in the uncanny valley (Mathur & Reichling, 2016). In particular, trust in robots can be an eloquent cognitive factor in humans' interaction with robots (Gaudiello et al., 2016). Humanoid robots imitate human characteristics and behave in human-like ways. People may assume that their interactions with humanoid robots are comparable to interactions with humans; in other words, the individual (trustor) expects the robot (trustee) to perform a particular action in his or her own interest. Unfamiliar interactions with humanoids, however, can arouse suspicion regarding satisfactory interactions with robots. Trust in technologies has been typically regarded as a central factor

in their adoption (McKnight, 2005). Similarly, trust in humanoid robots plays a critical role in human-robot interaction and may be essential in the current, preliminary stage of service robots. In this study, considering that affective responses influence the formation of trust in the other party during interactions with others (Dunn & Schweitzer, 2005), we examined *how trust in humanoid robots reflects affective responses presented in the uncanny valley* (the second research question). Additionally, for our third research question, we investigated *whether the context of interacting with humanoid robots influences trust in robots*. Given that trust could reflect affective responses depending on the context, it is assumed that trust could be influenced by the context. Empirical research also suggests a significant impact of environmental factors on trust in robots (Hancock et al., 2011). Figure 2 shows our research model.

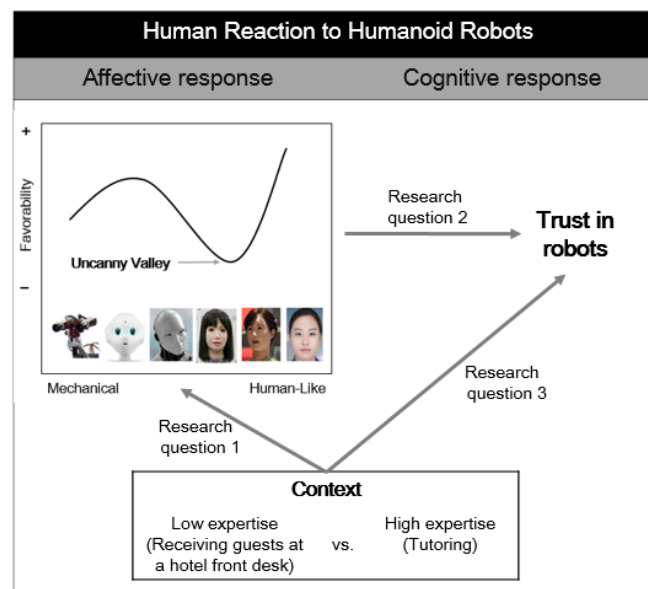


Figure 2. Research model

Trust in Humanoid Robots

Trust indicates an individual's willingness to accept vulnerability to another party's behavior (Rousseau et al., 1998). Trust facilitates interaction among individuals, and has been widely used to explain individuals' behavior in numerous computer-mediated environments, such as virtual work groups (Jarvenpaa & Leidner, 1998), business-to-business e-commerce (Nicolaou & McKnight, 2006), and business-to-customer e-commerce (Gefen et al., 2003).

While many studies employ *trust-in-people* to explain individuals' interaction practices mediated by the Internet, some studies assume that IT itself can be a trustee and examine

trust in technology. Given that trust formation depends on the counter party's characteristics (Rousseau et al., 1998), individuals may evaluate the trustworthiness of the IT based on its attributes in the context of interaction with the IT. For example, Wang and Benbasat (2005) reveal that trust is a critical factor in users' interaction with online recommendation agents, which is online software that provides online consumers with shopping recommendations based on their preferences. In their study, the recommendation agent software is regarded as a trustee. Similarly, people may assess humanoid robots' trustworthiness when interacting with them. People may even be more inclined to treat humanoid robots in the same way they treat humans than other types of IT since humanoid robots have the characteristics of humans in terms of appearance and engage in social interaction with other humans (Groom & Nass, 2007). Trust is regarded as an imperative indicator for assessing the quality of human-computer interaction (Lee & See, 2004). Its persuasive function in social interactions could affect individuals' acceptance of robots (Salem et al., 2015). Although there are many other factors and models that explain user adoption of robots (e.g., usefulness, enjoyment), trust can be a strong indicator of users' perception of robots as social agents (Gaudiello et al., 2016).

Hancock et al. (2011) conducted a meta-analysis to examine the factors that influence trust in robots by classifying them as user-related (e.g., prior experience), robot-related (e.g., robot attributes), and environmental factors (task type). They found that while robot-related and environmental factors had significant influence on trust in robots, user factors had little effect. Supposing that the uncanny valley mirrors robots' traits, trust could be closely related to the uncanny valley. Individuals' emotional states influence their decision-making (Vohs et al., 2008). When individuals make judgements, their feelings serve as critical references (Schwarz & Clore, 1988). The relationship between affect and decision-making is also applied in trust formation. Although rational models of trust posit that trust development depends on careful and deliberative processing, trust is considerably influenced by affect, which is derived from available cues (Lount, 2010). It is argued that individuals with positive emotions are more likely to trust another party (Dunn & Schweitzer, 2005). The significant impact of feeling on believing has been employed in IT contexts. Users' affective reaction to e-tailors is an imperative antecedent to trusting them (Gefen & Straub, 2004; Hwang & Kim, 2007). It has also been revealed that affective responses presented in the uncanny valley deeply influence individuals' assessment of humanoid robots' trustworthiness (Mathur & Reichling, 2016).

As found in Hancock et al. (2011), environmental components are other factors that determine trust in robots. Some studies have examined the contextual impact of trust in robots. Gaudiello et al. (2016) found that users have more trust in robots in the functional context than in the social context. Salem et al. (2015) posited that whether task outcomes conducted by robots are revocable affects users' acceptance of robots' recommendation. Given that robots have become increasingly used in various personal and social contexts, more investigation of robot trust in a wider range of contexts is required.

Methodology

To select the pictures of humanoids presented in an experimental questionnaire, we reviewed humanoid pictures that were used in previous relevant studies as well as photos on the Internet found using the “humanoid” keyword. In the initial phase, we collected ten humanoids' pictures. Through a pilot test asking about the human-resemblance of each picture, we finally chose five that presented a clear gradation of the uncanny valley for parsimonious analyses (Figure 3). Additionally, in the pilot test, we checked the expertise level of two task contexts: receiving guests at a hotel front desk vs. tutoring. We chose these two situations because they have been widely presented as possible or actual applications of humanoids. The results confirmed a significant difference in the expertise level of these two contexts ($t=2.910, p\text{-value} < 0.01$).

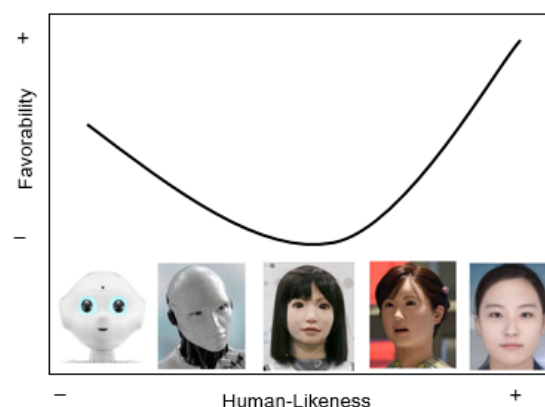


Figure 3. Humanoid pictures in an experimental questionnaire

We adopted measurement questions that have been used in prior studies on the uncanny valley (e.g., Gray & Wegner, 2012; Mathur & Reichling, 2016) and added questions regarding the degree of human-likeness of humanoids (“Do you agree that this robot in the

picture looks like a human?") and measuring favorability ("Do you feel uneasy or unfriendly when watching the robot in the picture?"). We also developed a question to measure overall trust in robots: "Do you agree that the robot in the picture is trustworthy as a hotel reception staff (or tutor)?" All items were measured using a 7-point Likert scale ranging from "strongly disagree" to "strongly agree."

We conducted a between-subject experimental survey in which participants provided their answers to questions about their affective responses (favorability) and cognitive responses (trust) for five different types of humanoid robot photos in one of two situations (receiving guests at a hotel front desk vs. tutoring). Data was collected from the panel members of an online research firm in South Korea. Web-based online surveys were conducted over a one-week period in March 2018. Data was separately gathered in these two contexts. After eliminating invalid responses, the final sample of 505 participants was included in the analysis (251 in the context of hotel reception, 254 in tutoring). Participants had a mean age of 39.3. In the first stage of the survey, participants assessed the human-likeness of five humanoid pictures. Next, they read a short scenario describing the context and provided their responses of favorability and trust for each of five humanoid pictures, which were randomly presented. Finally, participants answered demographic questions.

Results

The results of a paired-difference test confirmed a hierarchy of the human-likeness of five humanoid pictures, whose favorability showed U-curve indicating the uncanny valley, as did the results of the pilot test (Figure 4).

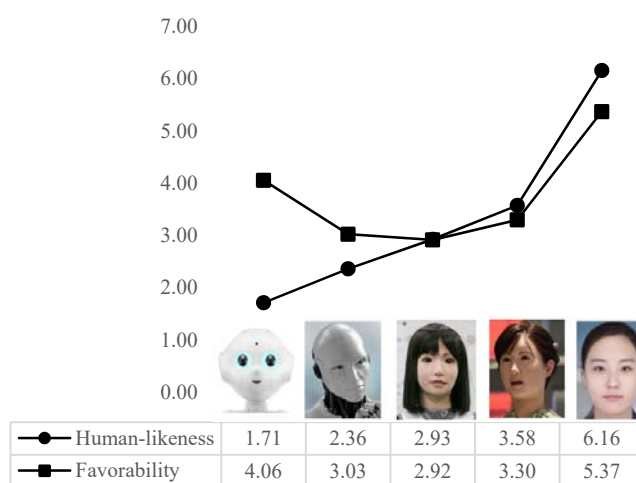


Figure 4. Human-likeness and favorability of five humanoid pictures

We conducted analysis of variance (ANOVA) to examine differences by context. The data achieved ANOVA's assumption of homogeneity of variance and the results showed significant contextual differences in favorability and trust for all stages except for favorability in the last stage (Table 1 and Figure 5). Both favorability and trust were more positively evaluated in the tutoring context than in the hotel reception context, but F-values (mean differences) revealed a variation in this result. The contextual effect on participants' appraisals was more powerful in favorability in stages 1, 2, and 3. We also conducted a regression analysis to examine the influence of favorability on trust and obtained an adjusted R^2 of 0.319 and a favorability coefficient of 0.556 ($t = 15.41$, $p\text{-value} = .00$). This result shows that favorability has a significant impact on trust.

Table 1. ANOVA results of favorability and trust by context

Favorability		Mean	Standard Deviation	Homogeneity Test		Difference of Means	
				Levene's Statistic	p-value	F	p-value
Stage 1	Hotel reception	3.87	1.28	.39	.55	14.97	.00
	Tutoring	4.36	1.33				
Stage 2	Hotel reception	2.80	1.05	.45	.50	9.99	.00
	Tutoring	3.11	1.14				
Stage 3	Hotel reception	2.75	1.04	.92	.34	5.15	.02
	Tutoring	2.97	1.13				
Stage 4	Hotel reception	3.20	1.10	2.59	.11	4.99	.03
	Tutoring	3.43	1.23				
Stage 5	Hotel reception	5.29	1.19	2.34	.13	.87	.35
	Tutoring	5.39	1.33				
Trust		Mean	Standard Deviation	Homogeneity Test		Difference of Means	
				Levene's Statistic	p-value	F	p-value
Stage 1	Hotel reception	4.14	1.15	.43	.51	4.03	.04
	Tutoring	4.35	1.10				
Stage 2	Hotel reception	4.00	1.21	.74	.39	8.62	.00
	Tutoring	4.33	1.27				
Stage 3	Hotel reception	3.68	1.13	.98	.32	4.14	.04
	Tutoring	3.89	1.20				
Stage 4	Hotel reception	3.93	1.11	.87	.35	4.70	.03
	Tutoring	4.12	1.18				
Stage 5	Hotel reception	4.89	1.22	.28	.60	4.71	.03
	Tutoring	5.11	1.09				

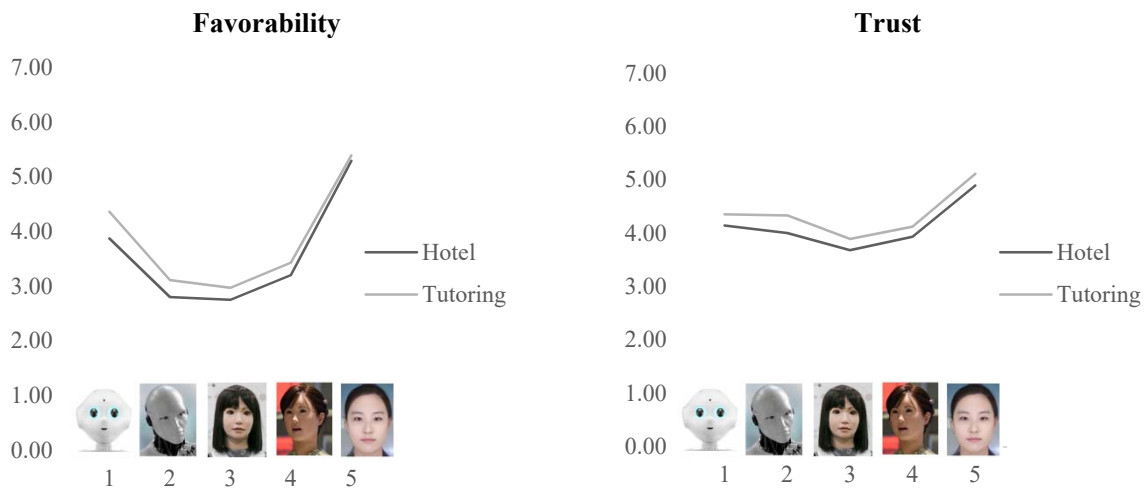


Figure 5. Comparison of favorability and trust by context

Discussion

From an uncanny valley perspective, this study examined how peoples' affective and cognitive responses to humanoid robots were different in two contexts, hotel reception and tutoring. Findings showed that the primitive evaluation or affective appraisal of humanoids (i.e., the uncanny valley) influenced the degree of trust in the humanoid. In other words, the uncanny valley phenomenon is applicable to human cognitive appraisals of humanoids.

These results also revealed that affective and cognitive responses were more positive for the high-expertise humanoid (tutoring) than for the low-expertise humanoid (hotel reception) in all stages of the uncanny valley except for the last stage, where the humanoid's face is the same as a human's face. This finding suggests that when people form an impression of a humanoid conducting a certain task for them, their assessment differs according to the task type. More specifically, people are less influenced by the humanoid's peripheral cues (e.g., appearances) in tasks requiring higher expertise. One plausible explanation for this is that when a humanoid's task is complicated or knowledge-intensive, people's dominant attention to its ability to successfully complete a task mitigates the influence of the humanoid's appearance on their reaction to it.

Our findings reveal a significant effect of favorability on trust, implying that the affective appraisals of humanoids have a role in the initial impression, which is the foundation for their further evaluation. Accordingly, this finding suggests that the uncanny valley is the principal reaction to humanoids, and its influence is not limited to affective responses, it is applicable

to cognitive responses to humanoids as well.

This study provides insight into human–robot interactions. By examining contextual understandings of the uncanny valley and examining both affective and cognitive responses, this study improves the theoretical foundation of the uncanny valley theory.

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