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Direct comparison of psychological evaluation between virtual and real humanoids: Personal space and subjective impressions ☆

Hiroko Kamide [a,*], Yasushi Mae [a], Tomohito Takubo [b], Kenichi Ohara [c], Tatsuo Arai [a]

[a] Graduate School of Engineering Science, Osaka University, 1-3, Machikaneyamacho, Toyonaka, Osaka 560-8531, Japan
[b] Graduate School of Engineering, Osaka City University, 3-3-138, Sugimoto, Sumiyoshi-ku, Osaka 558-8585, Japan
[c] Faculty of Science and Technology Organization, Meijo University, 1-501, Shiogamaguchi, Tempaku-ku, Nagoya 468-0073, Japan

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ABSTRACT

The aim of this study was to compare psychological evaluations of a robot constructed using a virtual reality (VR) system (VR robot) with a real robot. The same design was used for both the VR and real robot in order to make a direct comparison. For the psychological evaluation, we measured behavioral reactions (the amount of personal space the participants desired between themselves and the robot) and subjective impressions (from a psychological scale). The psychological scale included six dimensions that are typically used to evaluate a humanoid: utility, clumsiness of motion, possibility of communication, controllability, vulnerability, and objective hardness. Sixty-one participants observed both the VR and real robots walking toward them and reported their level of desired personal space. Next, the participants evaluated their psychological impressions of the robots. The results indicated no significant difference in the level of desired personal space between the situations with the real and VR robots. However, regarding the psychological dimensions, participants reported higher scores for utility and the possibility of communication, and lower scores for controllability for the real robot as compared with the VR robot. The usability of a VR robot is discussed.

1. Introduction

If robots are going to coexist with humans, then a better robot design is required. Previous work has found that both the robot′s appearance (Kanda et al., 2008) and behavioral reactions (Kanda et al., 2004; Muto et al., 2009) govern whether humans favorably evaluate them. Reeves and Nass (1996) have pointed out that the ways in which humans tend to interact with media mirrors the way in which they communicate with each other. In other words, interacting with media may be an example of social behavior. As a result, there has been an increase in the development of human-like robots and software agents. Some research has indicated that nonverbal gestures made by the robot′s head or arms increases the effectiveness of the robot′s interaction with humans (Nakano et al., 2003). Moreover, there has been much advancement in terms of making robots′ movements more similar to that of humans. For example, human-like nodding and eye contact (Liu et al., 2012), pointing (Tojo et al., 2000), and walking (Ujiie et al., 2006) have been realized. In this manner, humanoids are gathering more attentions as robots which will coexist with humans. However, each research in this area has been limited by the use of few real robots, partly because it costs very high to use various robots at once to compare with each other.

In the current study, we investigated a robot constructed by means of a virtual reality system (VR robot). Although there is a substantial cost associated with constructing a system that displays 3D virtual reality images, it is more cost effective than is designing multiple real robots in the long term. VR is beneficial for programming manipulator tasks (Yanagihara et al., 1996) and is useful as a task visualization aide when planning robotic systems and predicting robotic actions (Bejczy, 1996). Moreover, a virtual system is flexible because it is possible to create enriched learning environments (e.g., operational situations, robot configurations, learning aids, and mission scenarios) by simply changing the program, without incurring any additional expenses (Fletcher and Harris, 1996). In addition, use of VR robots increases physical security because a VR robot cannot ever attack a human.

Given the increase in the usage of VR robots, research into whether there are significant differences in humans′ reactions to VR and real robots is warranted. This is particularly important when one considers a future in which humans will be expected to harmoniously coexist in society with robots. For instance, VR robots can be used in research studies to determine with which robot designs humans prefer to interact, or to compare the utility of various designs. However, in order for VR robots to be a useful research tool, the basic differences and similarities between real and VR robots needs to be investigated. In the current study,

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* Corresponding author. Tel.: +81 6 6850 6686; fax: +81 6 6850 6368.
E-mail address: kamide@arai-lab.sys.es.osaka-u.ac.jp (H. Kamide).

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we directly compared real and VR robots in terms of humans′ psychological impressions and the amount of personal space humans desire between themselves and the robot as subjective and behavioral evaluations, respectively. We focused on humanoid robots which are expected to be integrated into humans′ lives in the near future.

2. Psychological evaluation of VR and real robots

2.1. Psychological evaluations of robots

Humans′ psychological reactions towards robots offer an important perspective on the investigation of differences between VR and real robots. Several studies have been conducted to determine how humans psychologically recognize robots in terms of the way robots act (Endo et al., 2008) and look (DiSalvo et al., 2002). This research has resulted in the development of robot facial expressions that include a gaze mechanism to facilitate smooth turn-taking in conversations with humans (Mutlu et al., 2012). In addition, it has been shown that the robot′s expression can alter a human′s response to it; for example, a smiling face creates a good impression of the robot (Becker-Asano et al., 2011; Breazeal, 2003). Humans′ favorable impressions of robots are also influenced by nonverbal behaviors, such as the timing of utterances (Muto et al., 2009) and human-like nods and eye movements (Liu et al., 2012). In addition, some studies have focused on more dynamic systems of robot′s behaviors, such as natural walking when multiple pedestrians are passing (Hayashi et al., 2011; Shiomi et al., 2012).

Thus, the focus of research based on the realization of the coexistence of robots and humans is to find ways to increase humans′ favorable impression of robots. The Research Committee on Human Friendly Robot (1998) indicated that robots should have enough physical familiarity to humans such as size and weight so that the robots can cooperate with humans safely. Especially, the robot should enable it to keep an objective distance from users in order to avoid collisions. That is, both people′s subjective impressions and objective safety are important perspectives to realize the coexistence between humans and robots.

2.2. Personal space

A significant factor influencing communication between humans is the amount of psychological space around each person (i.e., “proxemics” or personal space). Hall (1966) has suggested that during a communication episode between humans, the distance between each person and each person′s comfort level are dependent on spatial posture and the relationship with the other person. Four types of interpersonal-distance zones have been characterized: an intimate zone (i.e., a distance of 0–45 cm); a personal–casual zone (i.e., a distance of 45–120 cm); a socio-consultive zone (i.e., a distance of 120–360 cm); and a public zone (a distance of 360–750 cm). Typically, communication in the intimate zone is between romantic partners, very close friends, or family members, and that in the personal–casual zone is between close friends or relatives. By contrast, communication in the socio-consultive zone is typically between people who are encountered in the course of daily life, such as that between customers in restaurants or retail shops, colleagues, and teachers and students. Finally, communication in the public zone is more formal, such as that in public speaking or performing a live show on stage. Thus, the maximum distance of the public zone depends on the setting in which it occurs. This classification of personal space highlights that the distance between communication partners is a significant factor for the initiation of a communication episode and for maintaining the comfort level of those involved.

Recent research in the robotics field has focused on the personal space desired by humans when they interact with robots. Pacchierotti et al. (2005) showed that when a human and a robot pass each other, the average forward speed of robot, the distance at which the robot starts the maneuver of passage, and the distance that the robot keeps from the person at the passage point are the important parameter for the strategy. Koay et al. (2007) have focused on the distance, direction, and gestures to be used when a service robot gives an object to a person. In addition, Oskoei et al. (2010) have suggested development of a system that enables robots to maintain an appropriate distance from humans. When a robot follows behind a person, people prefer the way that the robot simply drives in the direction of the person′s current position than the robot follows the path that the person took as closely as possible (Gockley et al., 2007). Walters et al. (2005) measured humans′ desired level of personal space when interacting with a robot that was mechanistic in appearance and moved using wheels, and found that 60% of the humans maintained a distance in the socio-consultive or personal–casual zones, but 40% maintained a closer distance. Gockley and Matari´c (2006) focused on the personality of extraversion and found that more extroverted people prefer the robot to stay closer.

In the current study, we directly measured the amount of personal space ordinary people desired when faced with the real humanoid robot and the VR version.

2.3. Psychological impressions based on the Humanoid-Oriented scale

In addition to measuring the participants′ behavioral reactions (i.e., personal space), we investigated humans′ subjective impressions of both the real and VR robots. Previous studies have measured psychological impressions, such as humans′ fear of robots, by using questionnaires (Goetz et al., 2003; Nomura and Kanda, 2003; Nomura et al., 2004, 2005). Some of these studies have focused on the psychological impressions of both the real and VR robots (Negi et al., 2008; Ohara et al., 2009), but they used psychological scales originally developed to evaluate impressions of other humans′ personality, and, as a result, the wording used in the scales is directed toward humans and not robots. Thus, interpreting scores from these scales with reference to robots becomes complicated, and the scores may not accurately reflect psychological impressions towards robots.

To improve the psychological measurement scales used in work with robots, Kamide et al. (2010) collected natural impressions of robots from ordinary people who are not engineers or professionals of robotics in the form of free-response descriptions, and used those descriptions to develop the Humanoid-Oriented Scale. This work has revealed six basic dimensions that people use to perceive robots: utility; clumsiness of motion; possibility of communication; controllability; vulnerability; and objective hardness. The psychological scale PERNOD (PERception of humaNOiD robots) is based on these six dimensions and can be used to evaluate humanoid robots. The PERNOD has a clearer factor structure and higher reliability and validity as a psychological scale for evaluation of robots than the scale for human impressions, but it was developed using only one humanoid. Therefore, the universality of the scale has not yet been validated. Even so, the six dimensions used in PERNOD are more usable for research on robots than are those of scales developed for impressions of humans. Moreover, the scale items were written as abstractly as possible in order to make it possible to use the scale with a variety of robots.