Are physically embodied social agents better than disembodied social agents?: The effects of physical embodiment, tactile interaction, and people's loneliness in human–robot interaction

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Abstract

Two experiments were conducted to investigate the effects of physical embodiment in human–agent interaction. Experiment 1 ($N = 32$) shows positive effects of physical embodiment on the feeling of an agent's social presence, the evaluation of the agent, the assessment of public evaluation of the agent, and the evaluation of the interaction with the agent. A path analysis reveals that the feeling of the agent's social presence mediates the participants' evaluation of the social agent. Experiment 2 ($N = 32$) shows that physical embodiment with restricted tactile interaction causes null or even negative effects in human–agent interaction. In addition, Experiment 2 indicates that lonely people feel higher social presence of social agents, and provide more positive social responses to social agents than non-lonely people. The importance of physical embodiment and tactile communication in human–agent interaction and the diverse role of social robots, especially for the lonely population, are discussed.
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1. Introduction

Social robots are a new type of robot whose major purpose is to interact with humans in socially meaningful ways (Breazeal, 2002; Fong et al., 2003; Lee et al., 2004). In other words, social robots are designed to evoke meaningful social interaction with their users. For example, David, in the movie "A.I." directed by Steven Spielberg, is a social robot whose main purpose is to share emotional bonding (especially the feeling of love) with human beings. In reality we have not seen such a sophisticated social robot as David. Nevertheless, the movie successfully informs the public of the possibility that social robots could be as successful social actors as human beings.

Given the above definition, social robots, unlike utility robots, do not necessarily need to have physical embodiment to accomplish their purpose. Physical embodiment is a mandatory requirement for other types of robots, because they are built to accomplish labor-intensive *physical* work, ranging from household chores (e.g., cleaning, mowing, cooking) to industrial manufacturing (e.g., product assembly and delivery) and military operations (e.g., tele-surveillance, bombing and destroying). For social robots, however, physical embodiment may not be mandatory, because their major purpose—social interaction—is not directly related to physical activities per se; social interaction can be accomplished in both *embodied* and *disembodied* ways.

Therefore, one of the most fundamental questions about social robots is whether or not there is added value of

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physical embodiment for successful social interaction between humans and social agents. This is a critical question to industry practitioners, due to the high costs for manufacturing physically embodied robots, not to mention the technical difficulties. This is theoretically important also, because it tackles one of the core issues in human–agent interaction—the role of physical embodiment in social interaction between humans and agents (see Dautenhahn, 1997). Despite the practical and theoretical importance of physical embodiment in human–agent interaction, there are very limited empirical studies on this issue. In the current study, we directly address this issue with two experiments.

2. Literature review

2.1. Physical embodiment

Embodiment is a loaded term and has various meanings in philosophy, phenomenology, psychology, engineering, and everyday life. The explication of this concept is beyond the scope of the current paper. Instead, we are focusing on the widely accepted meaning of embodiment in the fields of Artificial Intelligence (AI) and Robotics—physical instantiation, or more simply, bodily presence (see Ziemke, 2001 for detailed discussion about five different notions of embodiment). Embodied agents or systems need to have embedded sensors and motors—sensorimotor embodiment—so that they can physically connect with their environment (Brooks, 2002). A physically embodied robot, thus, should have both an actual physical shape and embedded sensors and motors.

Given the above definition, what will be the effects of an agent's physical embodiment—more specifically bodily presence—in human–agent interaction? One possible positive effect of an agent's physical embodiment is that physical embodiment may result in better affordance, which may lead to less frustration for people. Affordance refers to fundamental properties of a device that determines its way of use (Norman, 1988). For example, a door bar provides a strong clue for pushing to open the door. Similarly, a physically embodied agent with its hands raised toward its users may provide a clue for a proper social interaction (e.g., hand-shaking, high-five). In fact, it is well known among the robotics community that the form and structure of a robot can easily establish some sort of social expectations from its users (Fong et al., 2003). Therefore, a physically embodied agent may facilitate better social interaction with its users by providing more affordance for proper social interaction than a disembodied agent may.

Bartneck (2002) conducted an empirical study to examine the effects of embodiment of an emotional robot, eMuu. Although he did not find the effect of embodiment on people's enjoyment of the interaction due to the lack of actual physical interaction during the experiment, he found a significant social facilitation effect in his study. Specifi-

cally, participants who engaged in a special form of social interaction—negotiation—spent significantly more effort and received higher scores when they interacted with an actual eMuu—a physically embodied agent—than when they interacted with a screen character version of eMuu—a disembodied agent. The result clearly indicates that physical embodiment facilitates social interaction. We believe that the social facilitation effect comes from increased social presence (see the next section for a detailed discussion on the concept of social presence in human–agent interaction) that might be made possible by physical embodiment. Based on the above discussion, we set the following hypotheses:

H1-1. People will evaluate a physically embodied agent—a social robot—more positively than a disembodied agent—a screen character version of the social robot.

H1-2. People will be more socially attracted to a physically embodied agent—a social robot—than a disembodied agent—a screen character version of the social robot.

H1-3. People will evaluate their interaction with a physically embodied agent—a social robot—more positively than their interaction with a disembodied agent—a screen character version of the social robot.

One's own personal evaluation of an agent and one's assessment of other people's evaluation of the agent might differ due to the third-person effects (see Perloff, 1993). Thus, we set a separate hypothesis on participants' assessments of other people's evaluation of the agent:

H1-4. People will assess that other people will evaluate a physically embodied agent—a social robot—more positively than a disembodied agent—a screen character version of the social robot.

2.2. Social presence

Researchers have realized that the feeling of presence—the perceptual illusion of non-mediation (Lombard et al., 2000)—lies at the heart of almost all mediated experiences, from reading a novel to interacting with computers (Lee, 2004a). According to Lee (2004a), there are three types of presence—physical, social, and self presence. Physical presence is the feeling that virtual objects are real. Physical presence occurs when technology users do not notice either the para-authentic nature of mediated objects (or environments) or the artificial nature of simulated objects (or environments). For example, when users of a virtual reality system try to avoid virtual rocks moving toward them, they are experiencing a strong sense of physical presence of the rocks. That is, they respond to the virtual rocks as if those were real ones, when they feel a strong sense of physical presence. Social presence, in short, is a mental simulation of other intelligences (Biocca, 1997). Successful simulation of other intelligences occurs when technology users do not notice either the artificiality or para-authenticity of