UC Merced
Proceedings of the Annual Meeting of the Cognitive Science Society

Title
Social Facilitation Effects of Virtual Humans

Permalink
https://escholarship.org/uc/item/8kh6f73k

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 29(29)

ISSN
1069-7977

Authors
Park, Sung
Catrambone, Richard

Publication Date
2007

Peer reviewed

Social Facilitation Effects of Virtual Humans

Sung Park (gtg116s@mail.gatech.edu)
School of Psychology, Georgia Institute of Technology, 654 Cherry Street
Atlanta, GA 30332 USA

Richard Catrambone (rc7@prism.gatech.edu)
School of Psychology, Georgia Institute of Technology, 654 Cherry Street
Atlanta, GA 30332 USA

Abstract

When people do an easy task, and another person is nearby, they tend to do that task better than when they are alone. Conversely, when people do a hard task, and another person is nearby, they tend to do that task less well than when they are alone. This phenomenon is referred to as "social facilitation". The present study investigated whether people show social facilitation in the presence of a virtual human. Participants were given different tasks to do that varied in difficulty. The tasks involved anagrams, mazes, and modular arithmetic. They did the tasks either alone, in the company of another person, or in the company of a virtual human on a computer screen. The virtual human produced the social facilitation effect: for easy tasks, performance in the virtual human condition was better than in the alone condition, and for difficult tasks, performance in the virtual human condition was worse than in the alone condition. These results suggest guidelines for the use of virtual humans in computer interfaces.

Keywords: Embodied conversational agent; virtual agent; animated character; avatar; anthropomorphism.

Introduction

Interest in virtual humans or embodied conversational agents (ECAs) is growing in the realm of human computer interaction. Our informal count of articles and papers appearing in peer-reviewed journals and conference proceedings that focus on the interaction between virtual humans and humans shows a steady increase from 2000 to 2006 (from 9 in 2000 to 54 in 2006). Recent improvements in computation have facilitated the use of virtual humans in various applications such as entertainment (Jeong, Hashimoto, & Makoto, 2004), clinical practice (Glantz, Rizzo, & Graap, 2003), and military (Hill et al., 2003). Anthropomorphizing an interface means adding human-like characteristics such as speech, gestures, and facial expressions. These components are remarkable in conveying information and communicating emotion. The human face, especially, is powerful in transmitting a great deal of information efficiently (Collier, 1985). For example, a virtual human with a confused face might be better (e.g., faster) at letting a user know that the virtual human does not understand the user's command than simply displaying "I don't understand" on the screen.

Nass, Steuer, and Tauber (1994) argue that individuals' interactions with computers are fundamentally social. Their evidence suggests that users can be induced to elicit social behaviors (e.g., direct requests for evaluations elicit more positive responses, other-praise is perceived as more valid than self-praise) even though users assume machines do not possess emotions, feelings, or "selves". Nass' work, and the work of other researchers (e.g., Lester et al., 1997; Nass et al., 1994; Reeves & Nass, 1996), suggests that there is a striking similarity between how humans interact with one another and how a human and a virtual human interact. An implication of this research is that designers of virtual humans should consider research on human social interaction when making decisions about virtual humans' behavior, appearance, speech, and other factors.

One social phenomenon of interest is whether virtual humans can elicit a social facilitation effect. Social facilitation is demonstrated when the mere presence of another person facilitates or inhibits task performance. Various researchers have offered theories to account for this effect (e.g., Cottrell, 1972; Zajonc, 1965; for a most up-to-date review, see Aiello & Douthitt, 2001). Social facilitation is generally referred to as performance enhancement on a simple or well learned task, and performance impairment on a complex or novel task. We behave differently, and presumably process information differently, when there is someone else near than when we are alone.

The aim of the present study is to investigate whether social facilitation can be observed with virtual humans. Such facilitation has implications for whether virtual humans should be "present" while a person is studying instructional material or attempting to do various tasks. Should the virtual human's face always present on the screen? Should it be invoked to appear only when necessary? An ever-present virtual human might make users feel uneasy by providing a sense of evaluation and hence impair task performance. Conversely, the presence of a virtual human might encourage the learner or help the learner focus when a task is easy, thereby enhancing performance.

Research on Social Facilitation of Virtual Humans

Social facilitation theory is one of the oldest theories in psychology. A large body of research has been conducted over more than 100 years, however, the development of social facilitation theory has been fragmented. While there are some prominent explanations, no single theory has

emerged that can unequivocally account for this phenomenon.

Only a handful of studies have investigated the social facilitation effect in the context of virtual humans. Walker, Sproull, and Subramani (1994) investigated participants' responses to a synthesized talking face displayed on a computer screen in the context of a questionnaire study. Compared to participants who answered questions presented via a text display on a screen, participants who answered the same questions spoken by a talking face spent more time, made fewer mistakes, and wrote more comments. Walker et al. claimed that this enhancement in task performance was due to social facilitation. However, one major aspect of the social facilitation effect is that performance is facilitated only if the task is simple or well learned. The researchers never explicitly stated or demonstrated whether the questionnaire task in their study was a simple task. Secondly, spending more time with the talking face does not necessarily mean enhancement in task performance. This might simply mean that it took longer to listen to a question than to read it and the study did not address this issue.

Rickenberg and Reeves (2000) investigated the effects of different virtual character presentations on user anxiety, task performance, and subjective evaluations in the context of web sites. Users felt more anxious when virtual characters monitored their web site work and this effect was strongest for users with an external control orientation. The presence of a monitoring character decreased task performance.

Zanbaka, Ulinski, Goolkasian, and Hodges (2004) attempted to investigate social facilitation due to virtual humans. Participants first learned a task and were then randomly assigned to perform the same task or a novel task either alone, in the presence of a real human, or in the presence of a virtual human. In general, Zanbaka et al. were unable to replicate the social facilitation effect. There was no significant improvement for easy tasks in the presence of the virtual human. The research reported some significant decrement on task performance for the complex task, which is in accordance with the social facilitation effect. However, this was observed for only some female participants within some blocks of the performance. Gender was not a planned factor in this experiment and thus not evenly distributed across conditions.

One reason that Zanbaka et al.'s (2004) research failed to replicate the social facilitation effect was, as noted in their paper, due to a ceiling effect. Participants were able to learn the correct pattern in the learning stage, which left little room for improvement later on. This is also a common problem in social facilitation research in social psychology (Bond & Titus, 1983).

Given the debate in social psychology on the causes of the social facilitation effect, and given the difficulties with the dependent measures used in prior studies investigating social facilitation with virtual humans, the present study was designed to examine whether the social facilitation effect will occur with a virtual human for tasks that are demonstrably different in difficulty.

As mentioned earlier, there is no single unified theory that can parsimoniously account for the social facilitation effect. In addition, a number of factors such as task complexity, type of presence, and the context of evaluation seem to moderate the strength of the presence effect (Aiello & Douthitt, 2001). The present study was not designed to distinguish among the major social facilitation theories. Instead, we wished to examine *whether* the social facilitation effect can be evoked by virtual humans under conditions that map on to the signature finding with real humans. The key hypothesis is that the presence of a virtual human enhances simple task performance and impairs complex task performance.

Experiment Design

The experiment tasks needed both breadth and depth to test the social facilitation effect but at the same time be applicable to the realm of virtual humans. Hence, the following two criteria were used for selecting experimental tasks.

1) Is the task something that a user might do with the assistance of a virtual human?
2) Is the task scalable in terms of difficulty?

With respect to the first criterion, virtual humans can assist users in many different tasks. Some tasks can be opinion-like (e.g., choosing what to bring on a trip) while others can be more objective (e.g., implementing edits in a document) (Catrambone, Stasko, & Xiao, 2004). These tasks are "high-level" cognitive tasks. Hence, low level sensory motor tasks were excluded from this experiment.

With respect to the second criterion, the present study examined differences in task performance between simple and complex tasks.

Using these two criteria, the present study incorporated the following three cognitive tasks: anagrams, mazes, and modular arithmetic. These three tasks provided a good mixture of verbal, spatial, mathematical, and high level problem solving skills. All three tasks were cognitive tasks and had an objective and therefore, were within the range of tasks that a virtual human might assist. It was also possible to produce both easy and difficult instances of these tasks. As part of a larger study, participants also did an additional task, the Tower of Hanoi; it was done after the other tasks were completed and was a between-subject task and excluded from the analyses below.

Anagram Task

Social facilitation (due to a human being present) in anagram tasks has been studied in the context of electronic performance monitoring (EPM), a system whereby every task performed through an electronic device may be analyzed by a remotely located person (Davidson & Henderson, 2000). The social facilitation effect was clearly observed in the presence of EPM; easy anagrams being performed with greater proficiency and difficult anagrams

being performed with less proficiency. In the present study, anagrams were divided into two categories (easy or difficult) using normative solution times from Tresselt and Mayzner's (1966) anagram research.

Maze Task

Research has suggested that participants tend to perform better in the presence of a human on simple maze tasks (Rajecki, Ickes, Corcoran, & Williams, 1977). In the present study, simple mazes included wide paths and few blind alleys so that the correct route was readily perceivable, whereas difficult mazes included narrow paths with many blind alleys. Materials for the maze task were similar to the ones of Jackson and Williams (1985). Participants were given a maze and a cursor on the screen and were asked to draw a path to the exit.

Modular Arithmetic Task

The object of Gauss's modular arithmetic is to judge if a problem statement such as $50 \equiv 22 \pmod 4$ is true. In this case, the statement's middle number is subtracted from the first number (i.e., $50 - 22$) and the result (i.e., 28) is divided by the last number (i.e., $28 \div 4$). If the quotient is a whole number (as here, 7) then the statement is true. Difficulty of the task was manipulated by controlling the number of digits presented to participants for the first two numbers of a given problem; one for an easy task ($7 \equiv 2$) and two (with borrowing) for a difficult task ($51 \equiv 19$). Beilock, Kulp, Holt, and Carr (2004) claimed that modular arithmetic is advantageous as a laboratory task because it is unusual and, therefore its learning history can be controlled.

Method

Participants

One hundred and eight participants were recruited from the Georgia Institute of Technology. Participants were compensated with course credit.

Materials

Participants did all tasks (anagrams, maze, and modular arithmetic) on a computer. Java application and Java script were used to implement the tasks on the computer. An additional computer was used to present the virtual human. Haptek Corporation's 3-D character was loaded on this computer (Figure 1); the appearance of the virtual human was held constant. The character displayed life-like behaviors such as breathing, blinking, and other subtle facial movements. The monitor was positioned so that the virtual human was oriented to the task screen and not the participant and was located about 4 feet from the task monitor and about 3.5 feet from the participant. This is also the location where the human observer would sit.

Figure 1: Virtual Human in the present study.

Design and Procedure

The present study was a 2 x 3 within subject design. The complexity factor had two levels; simple and complex, and the presence factor had three levels; alone, presence of a human, and presence of a virtual human. These two within subjects factors were crossed to produce six types of trials: participants doing a simple task alone, a simple task in the presence of a human, a simple task in the presence of a virtual human, a complex task alone, a complex task in the presence of a human, and a complex task in the presence of a virtual human. Every participant experienced multiple instances of each of the six trial types.

The order of the presence factor was varied across participants using a Latin Square. That is, some participants did the first set of tasks in the presence of a human (H), the next set in the presence of the virtual human (VH), and the third set alone (A). The other two orders were A -> H -> VH and VH -> A -> H.

Within a particular presence situation (e.g., virtual human), participants did a block of anagrams, a block of mazes, and a block of modular arithmetic problems. Task order was manipulated using a Latin Square resulting in three possible orders (anagram -> maze -> mod arith; maze -> mod arith -> anagram; mod arith -> anagram -> maze).

Within each task block, participants conducted a combination of easy and difficult trials for that particular task (e.g., anagrams). The number of easy and difficult trials was the same (six) in each block; however, the order of easy and hard trials was one of the three predetermined pseudo-randomized orders.

In the anagram tasks, a five letter anagram appeared on the screen and the participants were asked to solve the anagram quickly and accurately by typing in the answer using the keyboard and then pressing the Enter key. Completion time and error rates were measured.

In the maze tasks, a maze appeared on the screen. Participants were asked to move the cursor by dragging the mouse through each maze and find the exit as fast as possible. Completion time was measured.

In modular arithmetic tasks, a problem statement (e.g., $50 \equiv 20 \pmod 4$) appeared on the screen. Participants were asked to decide whether the statement was true or false by pressing the corresponding button in the keyboard. There was a "Y" marked key corresponding "true" and an "N"

marked key corresponding "false". Response time and error rates were measured.

Each participant was briefed on each task prior to the actual experiment. Briefing consisted of a demonstration by the experimenter and four hands-on practice trials for the participants so that they could familiarize themselves with the computer and the task.

For conditions involving a human or a virtual human, the participants were told that a human or a virtual human was there to "observe" the task and not the participant. Specifically, when a human was present, participants were told:

> An observer will be sitting near you to observe the tasks you will do. The observer will be present to learn more about the tasks and try to catch any mistakes we made in creating the tasks. The observer is not trying to learn how you go about working on the tasks and, in fact, will not be allowed to communicate with you while he is sitting here.

When a virtual human was present, participants were told:

> A virtual human will observe the task. The virtual human is an artificial intelligence that attempts to analyze events that happen on the computer screen. The virtual human will be present to learn more about the tasks and try to catch any mistakes we made in creating the tasks. The virtual human is not trying to learn how you go about working on the tasks and, in fact, will not be allowed to communicate with you while he is present.

Results

A three-way repeated-measures ANOVA (complexity factor, presence factor, and task factor) was initially conducted and was followed by simple effects analyses. Analysis was conducted on response times because it has been the most frequently measured dependent variable in social facilitation research (Bond & Titus, 1983). The pseudo order and the Latin Square orders had no effect on task performance and all results were collapsed over these variables.

Data were transformed into z-scores for each task to perform the analysis involving complexity, presence, and task. The results (summarized in Figure 2) show that the effect of presence on task completion time was conditional upon the combination of the task and task complexity, resulting in a significant three-way interaction of Presence x Task type x Complexity ($F(4, 324) = 4.39$, $MSE = .23$, $p < .01$). Of particular importance, the results show that combined across task types (anagram, maze, and modular arithmetic), if the task was easy then completion times in the presence of the virtual human and the real human tended to be faster than in their absence, whereas, if the task was hard then mean completion times were slower in the presence of the virtual human and the real human than in their absence. This observation is supported by a Presence x Complexity interaction that is consistent with the social facilitation effect, $F(2, 162) = 53.0$, $MSE = .21$, $p < .001$.

Significant two-way interactions were found between complexity and task type, $F(2, 162) = 42.7$, $MSE = .56$, $p < .001$, and between presence and task type, $F(2, 162) = 6.66$, $MSE = .21$, $p < .001$. There was a main effect of complexity (easy, hard), $F(1, 81) = 807.77$, $MSE = .99$, $p < .001$, and presence (alone, virtual human, human), $F(2, 162) = 8.6$, $MSE = .21$, $p < .001$, but no main effect of task type, $F < 1$.

Post hoc Analyses for Each Task Type

The three-way Presence x Task x Complexity interaction suggests that each task type should be further analyzed for the relationship between presence and complexity. We conducted a post hoc Dunnett's test to compare each presence condition to the alone condition separately for each task type. For each task type, the social facilitation effect for virtual humans was demonstrated and, for each task type, the social facilitation effect for humans was demonstrated. The analyses for each of the above observations are presented below.

Virtual Human vs. Alone. For the anagram task, response time for easy tasks was shorter in the virtual human condition than the alone condition, t(214) = 3.17, MSE = .36, p < .001, and the response time for hard tasks was longer in the virtual human condition than the alone condition, t(214) = 3.09, MSE = .25, p < .01 (see Figure 2a). For the maze task, response time for easy tasks was shorter in the virtual human condition than the alone condition, t(214) = 2.60, MSE = .02, p < .01, and the response time for hard tasks was longer in the virtual human condition than the alone condition, t(214) = 1.90, MSE = .25, p < .05 (see Figure 2b). For the modular arithmetic task, response time for easy tasks was shorter in the virtual human condition than the alone condition, t(214) = 2.00, MSE = .05, p < .05, and the response time for hard tasks was longer in the virtual human condition than the alone condition, t(214) = 4.33, MSE = .21, p < .001 (see Figure 2c).

Human vs. Alone. For the anagram task, response time for easy tasks was shorter in the human condition than the alone condition, $t(214) = 4.57$, $MSE = .23$, $p < .001$, and the response time for hard tasks was longer in the human condition than the alone condition, $t(214) = 3.48$, MSE = .48, $p < .001$ (see Figure 2a). For the maze task, response time for easy tasks was shorter in the human condition than the alone condition, $t(214) = 3.71$, $MSE = .03$, $p < .001$, and the response time for hard tasks was longer in the human condition than the alone condition, t(214) = 2.14, $MSE = .30$, $p < .05$ (see Figure 2b). For the modular arithmetic task, response time for easy tasks was shorter in the human condition than the alone condition, $t(214) = 2.00$, $MSE = .04$, $p < .05$, and the response time for hard tasks was longer in the human condition than the alone condition, $t(214) = 7.81$, $MSE = .31$, $p < .001$ (see Figure 2c).

Virtual Human vs. Human. For the anagram task, response time for easy tasks was shorter in the human condition than the virtual human condition, $t(214) = 1.75$, $MSE = .08$, $p < .05$, but the response time for hard tasks was not significantly different, $t(214) < 1$ (see Figure 2a). For the maze task, response time for easy tasks was shorter in the human condition than the virtual human condition, $t(214) = 2.21$, $MSE = .01$, $p < .05$, but the response time for hard tasks was not significantly different, $t(214) < 1$ (see Figure 2b). For the modular arithmetic task, response time for easy tasks was not significantly different, $t(214) < 1$, but the response time for hard tasks was longer in the human condition than the virtual human condition, $t(214) = 4.56$, $MSE = .36$, $p < .001$ (see Figure 2c).
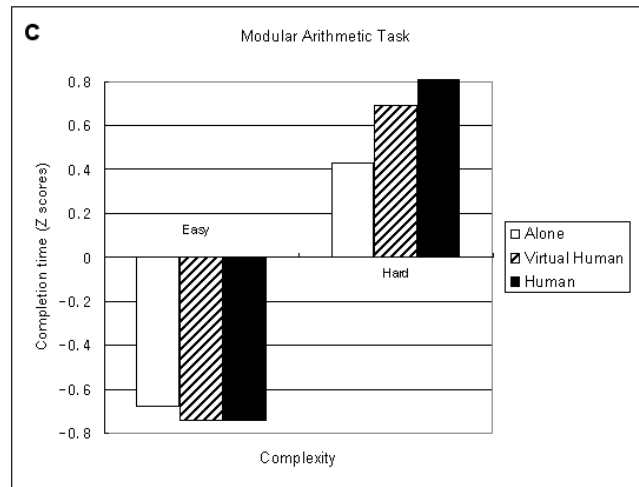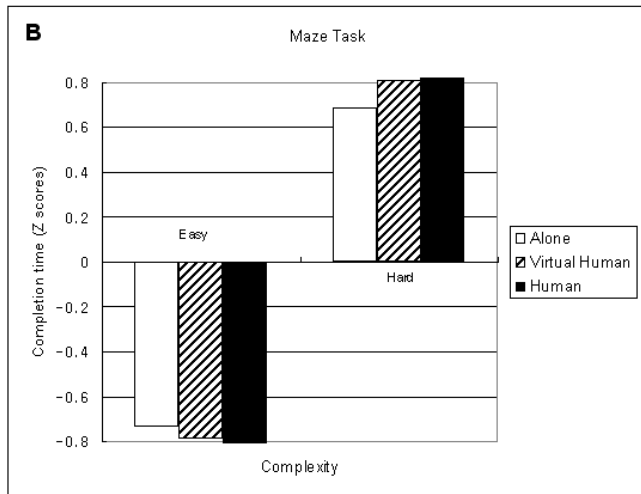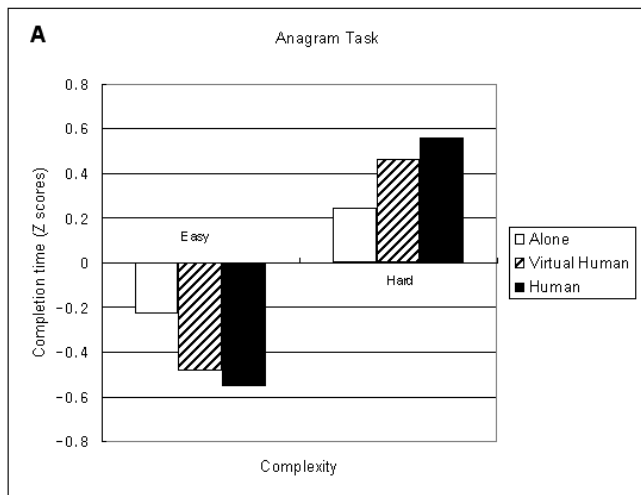
Figure 2: Mean completion time in seconds for each condition for the different tasks (n = 108).

Discussion

The key hypotheses in this study were supported: For easy tasks, performance in the virtual human condition was better than in the alone condition, and for difficult tasks, performance in the virtual human condition was worse than in the alone condition. We replicated the social facilitation effect of humans and expanded this effect to the presence of virtual humans.

How would a presence of virtual human evoke a social facilitation response? Drive theory (Zajonc, 1965) would argue that the presence of a virtual human elevated the participants' drive levels. This increased drive supposedly enhances performance of easy tasks and inhibits difficult tasks. The evaluation apprehension theory (Cottrell, 1972) would argue that participants were concerned with how the virtual human would evaluate them and this increased drive level. However, these theories are built on findings with humans and might have limitations in explaining social facilitation of virtual humans.

It is worth considering how the presence of a virtual human is similar to or different from the presence of a human. What factors might lead someone to treat a virtual human as a person versus treating the virtual human as a program? On the one hand, users might unconsciously regard virtual humans as social entities (Nass et al., 1994). On the other hand, users are aware of the limitations of virtual humans based on their knowledge with computer systems.

We suggest that the social nature of human-virtual human interaction is somewhere between human-human interaction and human-computer interaction. Users' behaviors when interacting with virtual humans are different from when they interact with windows, menus, and icons. Yet, users react to virtual humans in the same way as to humans under certain conditions (Xiao, 2006). The present results seem to support this idea. For easy tasks participants were fastest in the presence of a human and slowest when alone; the virtual human trials fell in the middle although the difference

between the human and virtual human trials was not significant for the modular arithmetic task. Similarly, for hard tasks participants were fastest alone and slowest with a human present; the virtual human trials fell in the middle. The difference between the human and virtual human trials was not significant for the anagram and the maze task. The present experiment was not designed to explore differences due to the presence of virtual human and human, but future studies can begin to do this.

The results have implications for the design of instructional systems as well as other systems involving human-computer interaction. They suggest that designers of such systems should consider that users behave differently in the presence of virtual humans and that the nature of the behavior depends on the task (such as task difficulty). A design decision to present a virtual human should be a deliberate and thoughtful one. An ever-present virtual human might make users uneasy, thus diminishing performance for a challenging task. Presenting a virtual human only when it is called upon by a user or when a task is easy might be a good idea.

Conclusion

This study examined whether the social facilitation effect can be evoked by virtual humans. The study found that virtual humans do produce the social facilitation effect: for easy tasks, performance in the virtual human condition was better than in the alone condition, and for difficult tasks, performance in the virtual human condition was worse than in the alone condition. This was observed for a range of verbal, spatial, and mathematical tasks. Designers and practitioners of interaction systems should be mindful about the likely social nature of virtual humans.

Reference

Aiello, J. R. & Douthitt, E. A. (2001). Social facilitation from Triplett to electronic performance monitoring. *Group Dynamics*, 5, 163-180.

Beilock, S. L., Kulp, C. A., Holt, L. E., & Carr, T. H. (2004). More on the fragility of performance: Choking under pressure in mathematical problem solving, *Journal of Experimental Psychology: General*, 133(4), 584-600.

Bond, C. F. & Titus, L. J. (1983). Social facilitation: A meta-analysis of 241 studies. *Psychological Bulletin*, 94, 265-292.

Catrambone, R., Stasko, J., & Xiao, J (2004). ECA user interface paradigm: Experimental findings within a framework for research. In C. Pelachaud & Z. Ruttkay (Ed.), *From brows to trust: Evaluating embodied conversational agents*, 239-267. NY: Kluwer Academic/Plenum Publishers.

Collier, G. (1985). *Emotional Expression*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cottrell, N. B. (1972). Social Facilitation. In C. McClintock (Ed.), *Experimental Social psychology*, 185-236.

Davidson, R. & Henderson, R. (2000). Electronic performance monitoring: A laboratory investigation of the influence of monitoring and difficulty on task performance, mood state, and self-reported stress levels, *Journal of Applied Social Psychology*, 30(5), 906-920.

Glantz, K., Rizzo, A., & Graap, K. (2003). Virtual reality for psychotherapy: current reality and future possibilities. *Psychotherapy: Theory, Research, Practice, Training*, 40(1/2), 55-67.

Hill, R. W., Gratch, J., Marsella, S., Rickel, J., Swartout, W., & Traum, D. (2003). Virtual humans in the mission rehearsal exercise system. *Kynstlich Intelligenz*, 17(4), 32-38.

Jackson, J. M. & Williams, K. D. (1985). Social loafing on difficult tasks: Working collectively can improve performance. *Journal of Personality and Social Psychology*, 49, 937-942.

Jeong, S., Hasimoto, N., & Makoto, S. (2004). A novel interaction system with force feedback between real- and virtual human: an entertainment system: "virtual catch ball", *Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology*, 61-66.

Lester, J., Converse, S., Kahler, S., Barlow S., Stone, B., & Bhogal, R. (1997). The persona effect: affective impact of animated pedagogical agents. *Proceedings of the SIGCHI conference on Human Factors in computer systems*, 359-366.

Nass, C., Steuer, J., & Tauber, E. (1994). Computers are social actors. *Proceedings of the ACM Computer Human Interaction 1994 Conference*, 72-78.

Rajecki, D. W., Ickes, W., Corcoran, C., & Lenerz, K. (1977). Social facilitation of human performance: mere presence effects, *The Journal of Social Psychology*, 102, 297-310.

Reeves, B. & Nass, C. (1996). *The Media Equation*. New York, NY: Cambridge University Press.

Rickenberg, R., & Reeves, B. (2000). The effects of animated characters on anxiety, task performance, and evaluations of user interfaces. *Proceedings of the ACM Computer Human Interaction 2000 Conference*, 49-56.

Tresselt, M. E., & Mayzner, M. S. (1966). Normative solution times for a sample of 134 solution words and 378 associated anagrams. *Psychonomic Monograph Supplements*, 1, 293-298.

Walker, J., Sproull, L., & Subramani, R. (1994). Using a human face in an interface. *Proceedings of the Conference on Human Factors in Computers 1994*, 85-91.

Xiao, J. (2006). *Empirical studies on embodied conversational agents*. Doctoral dissertation, Georgia Institute of Technology, Atlanta, GA.

Zajonc, R. B. (1965). Social facilitation. *Science*, 149, 269-274.

Zanbaka, C. Ulinski, A., Goolkasian, P., & Hodges, L. F. (2004). Effects of virtual human presence on task performance. *Proceedings of the International Conference on Artificial Reality and Telexistence*, 174 – 181.