Social Facilitation Effects of Virtual Humans

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Objective: To investigate whether virtual humans produce social facilitation effects. **Background:** 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 in the social psychology literature as *social facilitation.* The present study investigated whether virtual humans can evoke a social facilitation response. **Method:** Participants were given different tasks to do that varied in difficulty. The tasks involved anagrams, mazes, and modular arithmetic. They did the tasks alone, in the company of another person, or in the company of a virtual human on a computer screen. **Results:** 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. **Conclusion:** As with a human, virtual humans can produce social facilitation. **Application:** The results suggest that designers of virtual humans should be mindful about the social nature of virtual humans; a design decision as to when and how to present a virtual human should be a deliberate and informed decision. An ever-present virtual human might make learning and performance difficult for challenging tasks.

INTRODUCTION

Interest in virtual humans or embodied conversational agents 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), engineering (Zorriassatine, Wykes, Parkin, & Gindy, 2003), clinical practice (Glantz, Rizzo, & Graap, 2003), and the 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) argued 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 et al. (1994) and the work of other researchers (e.g., Lester et al., 1997; Nass, Moon, & Carney, 1999; Reeves & Nass, 1996) suggest that there is a striking similarity between how humans interact with each other 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 question of interest is whether virtual humans can elicit a social facilitation effect, in

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which the mere presence of another person can facilitate or inhibit task performance. Various researchers have offered theories to account for this effect (e.g., Cottrell, 1972; Zajonc, 1965; for an 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 as performance impairment on a complex or novel task. Humans behave differently, and presumably process information differently, when there is someone else near than when they 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 be 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 to focus when a task is easy, thereby enhancing performance.

Only a handful of studies have investigated whether social facilitation can be produced by 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 with 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. (1994) claimed that this enhancement in task performance was attributable 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. In addition, spending more time with the talking face did not necessarily enhance 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 presentations of virtual characters 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 attributable to virtual humans. Participants first learned a task and were then randomly assigned to perform the same task or a novel task alone, in the presence of a real human, or in the presence of a virtual human. In general, Zanbaka et al. (2004) were unable to replicate the social facilitation effect. As they noted in their paper, a ceiling effect may have been one reason their research failed to replicate the social facilitation 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).

In sum, there have been difficulties with the dependent measures used in prior studies investigating social facilitation with virtual humans. 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). Thus, the present study was designed to examine whether the social facilitation effect can be evoked by virtual humans under conditions that map onto 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.

METHOD

Tasks

The experimental tasks needed both breadth and depth to test the social facilitation effect but, at the same time, needed to be applicable to the realm of virtual humans. Hence, the following two criteria were used for selecting experimental tasks: (a) Is the task something that a user might do with the assistance of a virtual human? (b) 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), and 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, sensorimotor 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 used 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 they were within the range of tasks with which 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, after the other tasks were completed; this was a between-subjects task and excluded from the following analyses.

Anagram task. Social facilitation (attributable to a human being present) in anagram tasks has been studied in the context of electronic performance monitoring, 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 (see also Davidson & Henderson, 2000).

Maze task. Research has suggested that participants tend to perform better in the presence of a human on simple maze tasks (Rajecki, Ickes, Corcoran, & Lenerz, 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 ≡ 22 (mod 4)," is true. In this case, the statement's middle number is subtracted from the first number (i.e., 50 – 22) and the result of this (i.e., 28) is divided by the last number (i.e., 28 ÷ 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 ≡ 2) and two for a difficult task (51 ≡ 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. In the modular arithmetic tasks, problem statements were given to the participants. Easy problems consisted of single-digit no-borrow subtractions, such as "7 ≡ 2 (mod 5)"; hard problems consisted of double-digit borrow subtraction operations, such as "51 ≡ 19 (mod 4)." These were similar to the ones of Beilock et al. (2004).

Participants

One hundred 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 lifelike 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, not to the participant, and was located about 4 feet (~1.2 m) from the task monitor and about 3.5 feet (~1 m) from the participant. This is also the location where the human observer would sit.

Design and Procedure

The present study was a 2 × 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, in which participants did 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 → modular arithmetic; maze → modular arithmetic → anagram; and modular arithmetic → 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 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 to find the exit as fast as possible. Completion time was measured.

In modular arithmetic tasks, a problem statement, such as "50 ≡ 20 (mod 4)," appeared on the screen. Participants were asked to decide whether the statement was true or false by pressing the corresponding button (*Y* for "true," *N* for "false") on the keyboard. Completion 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.

Figure 1. Virtual human in the present study.

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, 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 doing. 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 completion times because it has been the most frequently measured dependent variable in social facilitation research (Bond & Titus, 1983). The pseudo order and Latin square factors were tested to examine whether they had an effect on performance. 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 × Task Type × 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, 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 × 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 × Task × 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 these observations are presented next.

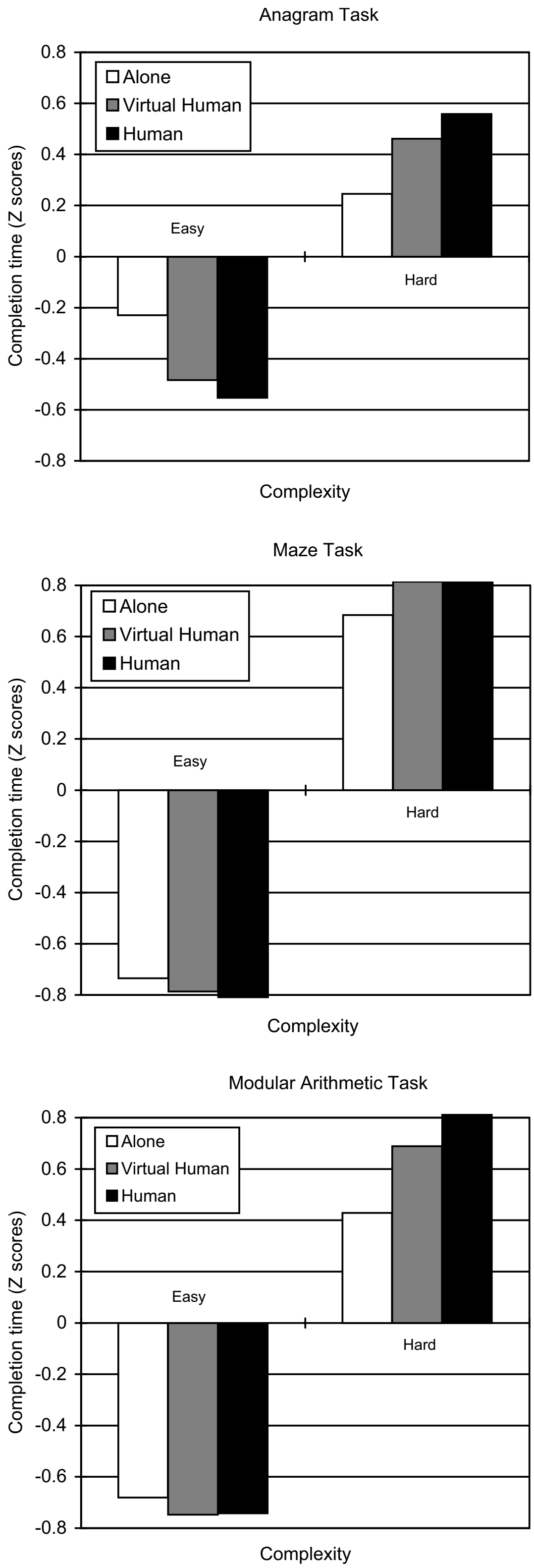

Figure 2. Mean completion time in seconds for each condition for the different tasks ($n = 108$).

Virtual human versus alone. For all three tasks (anagram, maze, and modular arithmetic), pairwise comparisons show that completion time for easy tasks was shorter in the virtual human condition than in the alone condition, and that completion time for hard tasks was longer in the virtual human condition than in the alone condition (see Figure 2); anagram easy: $t(214) = 3.17$, $MSE = .36$, $p < .001$; anagram hard: $t(214) = 3.09$, $MSE = .25$, $p < .01$; maze easy: $t(214) = 2.60$, $MSE = .02$, $p < .01$; maze hard: $t(214) = 1.90$, $MSE = .25$, $p < .05$; modular arithmetic easy: $t(214) = 2.00$, $MSE = .05$, $p < .05$; modular arithmetic hard: $t(214) = 4.33$, $MSE = .21$, $p < .001$.

Human versus alone. For all three tasks, pairwise comparisons show that completion time for easy tasks was shorter in the human condition than in the alone condition, and completion time for hard tasks was longer in the human condition than in the alone condition (see Figure 2); anagram easy: $t(214) = 4.57$, $MSE = .23$, $p < .001$; anagram hard: $t(214) = 3.48$, $MSE = .48$, $p < .001$; maze easy: $t(214) = 3.71$, $MSE = .03$, $p < .001$; maze hard: $t(214) = 2.14$, $MSE = .30$, $p < .05$; modular arithmetic easy: $t(214) = 2.00$, $MSE = .04$, $p < .05$; modular arithmetic hard: $t(214) = 7.81$, $MSE = .31$, $p < .001$.

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 the presence of a 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 that this increased drive level. However, these theories are built on findings with humans and might have limitations in explaining social facilitation by 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 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. The present results can not speak directly to these issues, but future research might fruitfully address them.

The results have implications for the design of instructional systems as well as for 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, as compared with when they are alone, 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. The results contribute to the foundational theory of human-computer interaction. Designers and practitioners of interaction systems should be mindful about the likely social nature of virtual humans.

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