Social Responses to Virtual Humans: Implications for Future Interface Design

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ABSTRACT
Do human-human social interactions carry over to human-virtual human social interactions? How does this affect future interface designers? We replicated classical tests of social influence known as the social facilitation and inhibition effects. Social facilitation/inhibition theory states that when in the presence of others, people perform simple tasks better and complex tasks worse. Participants were randomly assigned to perform both simple and complex tasks alone and in the presence of either a real human, a projected virtual human, or a virtual human in a head-mounted display. Our results showed participants were inhibited by the presence of others, whether real or virtual. That is, participants performed worse on the complex task, both in terms of percent correct and reaction times, when in the presence of others than when alone. Social facilitation did not occur with the real or virtual human. We discuss these results and their implications for future interface designers.

Author Keywords
Virtual humans, avatars, interface agents, human-computer interaction, social facilitation and inhibition, social influence, experimental studies, social psychology.

ACM Classification Keywords
H.5. [Information Interfaces and Presentation]: Multimedia Information Systems - Artificial, augmented, and virtual realities, Evaluation/methodology; H.5.2 User Interfaces - Evaluation/methodology; J.4 [Social and Behavioral Sciences]: Psychology.

INTRODUCTION
Virtual humans, also referred to as interface agents, act as a new medium to interact with system information. Maes [15] describes interface agents as:

> "Instead of user-initiated interaction via commands and/or direct manipulation, the user is engaged in a co-operative process in which human and computer agents both initiate communication, monitor events and perform tasks. The metaphor used is that of a *personal assistant* who is *collaborating with the user* in the same work environment."

With the emergence of interface agents [16] and virtual characters in everyday applications, understanding how people respond to interface agents is crucial. One way to examine peoples' responses to agents and avatars in a social setting is to look at social psychology literature.

In social psychology literature, one of the classical tests that show how the presence of others affects task performance is social facilitation/inhibition [29, 6, 25]. Social facilitation/inhibition refers to performance enhancement of a simple or well learned task, and performance impairment of a complex or novel task, when completed in the presence of others. Zajonc suggests that this phenomenon is due to the facilitation of dominant responses that occurs under increased physiological arousal [29]. When a person performs a task in the presence of an audience, physiological arousal occurs, facilitating whatever happens to be their dominant response. When a task is easy or well-learned (e.g., simple math problems, such as "Is 2 + 2 = 4?"), the dominant response to the task is likely to be the correct response, thus the presence of others facilitates performance on these tasks. Conversely, when a task is novel or difficult (e.g., complex math problems), the correct response is typically not the dominant response; therefore an increased dominant response will impair, rather than facilitate performance on these tasks. Although most social psychologists are in agreement that social facilitation/inhibition effects are due to the increased arousal that occurs in the presence of an audience, much debate has ensued over the specific cause of this arousal. Some researchers suggest that these effects result from the evaluation apprehension that is experienced in front of an audience [8]. Whereas, Zajonc maintains that the mere presence of others (even in the absence of evaluation) is enough to create physiological arousal [29]; he suggests that this response stems from evolutionarily adaptive tendencies to remain vigilant and alert in the presence of others. Others suggest that this phenomenon is simply due to the fact that an audience distracts attention from the task at hand [2]. In support of this, researchers have found similar facilitation and inhibition effects to occur in response to "nonsocial" distractions, such as loud bursts of noise or lights.

The present study examines if this theory from social psychology carries over to interacting with virtual humans or agents in the context of social facilitation/inhibition. *Directly comparing the results of human-human interaction with human-virtual human interaction may result in a better understanding of social responses to virtual human interfaces and lead to improved interface design.*

RELATED WORK

Social Facilitation and Inhibition

Triplett's first investigation of social influence in 1898 led to the development of many social facilitation theories and studies [25]. These social facilitation theories include Zajonc's drive theory [29], Cottrell, Wack, Sekerak, and Rittle's socialization theory [8], and Sanders, Baron and Moore's [22] attentional conflict theory. Numerous studies have been conducted to test the effect of the presence of others on task performance; Bond and Titus performed a meta-analysis of 241 social facilitation studies and summarized the results of these studies [6].

In a more recent study, Blascovich et al. conducted an experiment on social facilitation based on the biopsychosocial model of challenge and threat [5]. This model states that in goal-relevant situations involving affective and cognitive processes, challenge occurs when the resources from individual experiences meet demands of the situation, whereas for threat, these resources are insufficient to meet demands. In the experiment, the authors measured cardiovascular responses of participants while they either performed a novel or well-learned task alone or in the presence of others. They found that participants performing the well-learned task in the presence of others had an increased cardiac response and decreased vascular resistance, whereas participants performing a novel-learned task in the presence of others had an increased cardiac response and increased vascular resistance. Both of which fit the challenge and threat model. Participants performing the task alone, learned or unlearned, demonstrated no appreciable reactivity from baseline.

Hoyt et al. assessed the utility of using immersive virtual environment technology for social psychological research [12]. Participants mastered one of two tasks and subsequently performed the mastered or non-mastered task either alone or in the presence of a virtual human audience whom they were led to believe were either computer-controlled *agents* or human-controlled *avatars.* The authors found that participants performing in the presence of avatars demonstrated classic social inhibition performance impairment effects relative to those performing alone or in the presence of agents. However, this study introduced a possible confound by having the research assistants physically present in the experimental room in the avatar audience condition. Additionally, the research data did not strongly indicate the effect of audience.

Rickenberg and Reeves ran an experiment to test the effects of different animated character presentation on user anxiety, task performance, and subjective evaluations of two commerce Web sites [21]. They found that the effects of monitoring and individual differences in the way a person thinks about control worked as they do in real life. Users felt more anxious when characters monitored their Web site work and this effect was strongest for users with an external control orientation. Monitoring characters also decreased task performance, but increased trust in Web site content. In the present study, we are interested in *directly* comparing people's responses to a virtual human with their responses to a real human. In addition, we are interested in doing this in the context of social psychology to examine how social interactions between people map to social interaction with virtual humans.

We have previously conducted a study which attempted to replicate the social facilitation/social inhibition effects [28]. Participants first learned a task and were then randomly assigned to perform the same or a novel task either alone, in the presence of a real human, or in the presence of a virtual human. Although the results of the study showed that people reacted to the virtual human similarly to the way they reacted to the real human, our results did not indicate a strong effect and we were able to replicate the inhibition effect with females only. In addition, we found that more women learned the novel task when alone than when being observed by either a human or a virtual human. However, it seemed that male participants were not affected by the presence of an audience, both in terms of inhibition and facilitation. We believe that the weak results from the previous study were largely due to the pattern recognition and number categorization tasks that were used to produce the social inhibition and facilitation effects. Student reactions were variable and a number of participants did not understand the task.

Our current study uses a more well-defined task and a more sensitive experimental design. We chose a task that varied difficulty by using simple and complex math problems. We had evidence that verified the difficulty levels of the items from previous studies with the same student population [9]. Using math problems also eliminates the need for a training phase where participants are required to learn a task. Eliminating the training phase allowed us to treat audience (alone or in the presence of another) as a within subjects variable.

Interface Agents

Reeves and Nass have shown through several studies that people interact, treat, and identify with computers and software agents based on perceived, human characteristics, such as the computer's helpfulness, expertise, and friendliness [20].

A recent trend in computer interfaces has been to include agents or avatars in an attempt to enhance the user experience. Koda and Maes [14] argue that employing a face as the representation of an agent is engaging, makes a user pay more attention, and takes more effort for a user to interact with the system. They also found that realistic faces were better liked and rated more intelligent than abstract faces by the users.

Parise *et al*., investigated how cooperation with a computer agent was affected by the agent's pictorial realism and human likeness. Participants played a game with a talking computer agent that resembled a person, a real dog, a cartoon dog, or with a confederate through a video link. They found that participants cooperated highly with the agent resembling a person and the confederate. Although participants loved the dog and dog cartoon agents, they cooperated significantly less with the dog agents [18].

Baylor *et al.,* investigated the impact of interface agent appearance (age, gender, "coolness") on enhancing undergraduate females' attitudes toward engineering [4]. They found that females reported more positive stereotypes of engineers after interacting with a female agent, but reported that engineering was more useful and engaging when interacting with a male agent. Age interacted with "coolness" such that young cool agents were more effective than young uncool agents, whereas old uncool agents were more effective than old cool agents. In another study, Baylor investigated the impact of a pedagogical agent's gender, realism, and ethnicity on affective and motivational outcomes [3]. The results suggest a need to consider individual differences in learning with social interfaces.

These studies focus on how the appearance of computer agents affects cooperation, changing attitudes, and motivating users. In the present study, we are interested in how the *mere* presence of such an agent might influence task performance. Having an ever-present computer agent, despite its appearance, might have some unexpected results on the user's task performance.

Virtual Humans

Virtual humans have previously been used in the context of social psychology. Slater, *et al.,* conducted studies on the effects and social ramifications of having avatars in virtual environments [24]. They were able to elicit emotions such as embarrassment, irritation, and self-awareness in virtual meetings; and they found that the presence of avatars was important for social interaction, task performance, and presence [24].

In a previous study, we examined the roles of gender and visual realism in the persuasiveness of speakers [26]. Participants were presented with a persuasive passage delivered by a male or female person, virtual human, or virtual character. They were then assessed on attitude change and their ratings of the argument, message, and speaker. The results indicated that the virtual speakers were as effective at changing attitudes as real people. Male participants were more persuaded when the speaker was female than when the speaker was male, whereas female participants were more persuaded when the speaker was male than when the speaker was female. In addition, ratings of the perceptions of the speaker were more favorable for virtual speakers than for human speakers.

Virtual humans are also being used to improve the effectiveness of an Educational Virtual World (EVW) that incorporates different presentation techniques in the Presentation of Education and Training Subjects (PETS) system [7]. The virtual human provides both pedagogical and navigational assistance, and can be tailored to the needs and preferences of the learner.

Researchers have even proposed the use of virtual humans to help children with learning disabilities. In a system named "Buddy", a virtual child acts as a virtual friend for autistic children with a hidden eye tracker and camera to train a child's social attention by reinforcing gaze behavior and encourages the child to look at the animated face's informative area [19]. Virtual humans have also been used by medical students to practice patient interviewing skills using natural methods of interaction with a high level of immersion [13].

In all of these applications virtual humans are meant to aid the user in some way, training, teaching, or even acting as a friend. There is an underlying assumption that the virtual human will only have a positive effect on the user. It is therefore important to fully understand how people response to virtual humans in these social settings. By replicating one of the classical tests of social influence with a virtual human, we hope that the present study will shed some light on this subject.

EXPERIMENTAL STUDY

Building on the lessons learned from our first experiment with social facilitation and inhibition [28], we have designed a follow-up study that uses simple and complex tasks rather than learned and novel tasks. Simple and complex math tasks were chosen because they eliminated the need for a training phase (since we can assume that all college students have some basic math skills); and allowed us to treat task type as a within-subject rather than a between-subject variable. That is, all participants performed both the simple and complex tasks for this experiment. In addition, we were interested in how the level of immersion might influence the results. We compared participants' reactions to a real and virtual human and included a fully immersive condition using a head mounted display (HMD) such that the user is fully immersed in an environment where the virtual human appears in three dimensions.

Social facilitation/inhibition theory simply states that people perform simple tasks better when in the presence of others, and complex tasks worse. For this experiment, we hypothesized that participants' reactions to the presence of the real and virtual human would show social facilitation and inhibition effects.

Several researchers have shown that using an HMD leads to a significantly higher sense of presence in a virtual environment than non-immersive displays [11, 25]. For instance, in an experiment on the fear of public speaking, Slater et al. found that presence tended to amplify participants' responses to a virtual audience (which was either positive or negative) [23]. In other words: People experiencing a higher level of presence were prone to report more negative reactions to a negative audience and more positive reactions to a positive audience. Given the expected higher sense of presence in the immersive condition, we believe that participants will experience higher levels of facilitation and inhibition in the fully immersive virtual human condition than in the projected virtual human condition.

Participants

A total of 85 students (23 males, 62 females, mean age = 23.7, *SD* = 8.28) from the University of North Carolina at Charlotte participated in the study. Volunteers were recruited from the psychology department subject pool, and all received credit points towards their psychology class grade.

Stimulus Materials

Both simple and complex tasks required the participants to verify the accuracy of a series of mathematical equations presented in sentence form. The simple tasks consisted of addition or subtraction problems with one operation presented as a yes or no question, "Is 5 + 2 = 7?" The complex consisted of four operations (addition, subtraction, multiplication, and division), such as: Is (2 x 3) + (4 / 1) - 5 = 5? The numbers used were integers between 1 and 10. For the incorrect examples (such as Is 7 - 3 = 5? Or Is (6/3) + 8 - (4 x 2) = 3), the answer was within two values of the correct answer. Participants were required to verify the accuracy of the statement by making a key press response. Proportion of items answered correctly and the response time were used as measures of task performance.

Pre experimental questionnaires collected data on participant characteristics (such as age, gender and ethnicity, computer use) and measured math anxiety. The math anxiety scale [1] includes 25 items that measure the participants' level of anxiety by asking them to rate how anxious different math-related statements make them feel (such as "Studying for a math test" or "Watching a teacher work on an algebraic equation on the blackboard"). These items are assessed on a 5-point Likert scale (1 - Not at all, 2 – A little, 3 – A fair amount, 4 – Much, 5 – Very Much) and item responses are summed into a math anxiety score. The score was used for screening to make sure that participants in all conditions are equivalent in advance of the experiment. This measure helped determine if there were any preexisting confounding factors among the different groups.

Post experimental questionnaires measured task anxiety and copresence. Task anxiety was measured with one item that asked the participants to rate their level of anxiety on a 7 point numerical scale (1. not at all to 7. a great deal). Copresence refers to the participants' sense of being with another person in the second phase of the experiment. The copresence questionnaire was adapted from the Slater CoPresence Questionnaire [17]. Participants used a 7-point numerical scale (1. not at all to 7. a great deal) to respond to seventeen items (such as "I had a sense of being with the other person...." or "The experience seems to me more like interacting with a person..."). Responses to the items were used to compute two measures: copresence mean and count. The copresence mean is the average rating across all of the items and the copresence count indicates the number of responses that were higher than four.

Apparatus

A Pentium IV 2.4 GHz Dell PC with an nVidia GeForce4 Ti 4200 graphics card served as the graphics generator for the virtual human. The graphics were rendered with OpenGL then projected using a Sony VPL-CX5 data projector.

Stimulus presentation and data collection were controlled by an additional Pentium IV 2.4 GHz Dell PC attached to a 17 inch flatscreen monitor (Figures 1 and 2).

For the virtual human immersive condition, the participants used a head mounted display (HMD) (figure 3a). We used a Virtual Research V8 HMD which has 640 X 480 resolution in each eye. The HMD contains two small screens about two inches in front of the eyes. A 3rdTech HiBall-3100 Tracker was used to track position and orientation. The stimuli screen and virtual human were rendered in the same virtual room. Figure 3b shows the participant's view of the virtual human from the HMD.

We used one of Haptek Corporation's interactive 3-D characters for the virtual human [10]. Haptek also has a library which allowed us to create our own realistic animations and behaviors.

The nature of this experiment requires that the audience, both human and virtual, exhibit only non-verbal gestures and behaviors. In order to make our virtual human, Diana, human-like, we modeled her actions based on the non-verbal behaviors of the human audience in this experiment and executed them at random. These behaviors included coughing, sniffling, yawning, looking around, clearing throat, and shifting in her chair. In addition, Diana displays life-like behaviors such as breathing, blinking, and other subtle gestures. Two speakers at the bottom of the projection screen were used to output the various sounds from Diana (coughing, sniffing, etc.).

Figure 1. Participant with virtual audience.

Figure 2. Participant with real audience.

Figure 3a. Participant in the Virtual Human Immersive condition.

Figure 3b. Participant view of virtual audience in the Virtual Human Immersive condition

Procedure

Pre-Experiment: In the main area of the lab, participants filled out the informed consent form and the pre-experiment questionnaire. They were then given instructions regarding the experimental procedures.

Practice-Session: The participants were taken to the testing room where they were instructed on how to perform the tasks. Specifically, they were told the objective of the tasks, shown how to use the keyboard to respond, and led through a sample trial for each task to familiarize them with the procedures and the tones following the correct and incorrect responses.

Phase I: The first phase of the experiment was the alone condition which involved completion of the simple and complex math tasks while alone in the room. Each task included 25 math sentences with an equal number of correct and incorrect problems randomly arranged. Participants were escorted to the experiment room to perform these tasks and were instructed to return to the main area of the lab when done. The experimenter left the room. After the participants completed phase I, there was a five minute rest period during which the participants received instructions specific to their randomly assigned conditions for phase II. Those assigned to one of the two virtual human audience condition were told that during the task they would be joined by a computer-controlled virtual observer. Those assigned to the human audience condition were told that during the task they would be joined by a female observer.

Phase II: In the human audience condition, the female observer was seated in a chair arranged so that she can observe the participant and the projection screen. In the virtual human projected condition, our virtual human, Diana, was projected on a screen so that she too can 'observe' the participant and the testing screen. In the virtual human immersive condition, Diana was displayed in the HMD. She was seated behind a virtual desk. Diana looked at the screen and at the participant. Her nonverbal responses were intended to indicate some genuine interest in what the participant was doing.

Post-Experiment: Upon completion of the testing phase, participants returned to the main area of the lab, where they filled out a short questionnaire and were debriefed and thanked for their participation.

The experiment took approximately half an hour to complete.

Design

A 3 x 2 x 2 mixed analysis of variance was used to test for the main and interaction effects of each of the variables that are under study

1. Group (Human, Virtual Human Projected, Virtual Human Immersive)
2. Task type (Simple vs. Complex)
3. Audience condition (Alone vs. Audience)

The first variable was manipulated between subjects while the others were repeated measures. Participants were randomly assigned to one of three groups:

1. Human (H)
2. Virtual Human Projected (VHP)
3. Virtual Human Immersive (VHI)

RESULTS

Task Performance Data

Accuracy and response times were automatically recorded for each participant on every trial. Task performance data were computed by summing the number of correct responses across the 25 trials in each condition and converting to percentages. Reaction times measured the time from the presentation of the math question until the participant's response. There was no limit set for response time. Reaction times were trimmed such that responses that were more than two standard deviations from the mean were not included in the analysis; 4.9% of the responses were eliminated for this reason. Mean reaction times were calculated for the remaining responses that were scored as correct.

The task performance data were treated with a 3 x 2 x 2 ANOVA to test for the between subject effect of group (Human, Virtual Human Projected, Virtual Human Immersive), and the within subject effects of task type (Simple vs. Complex) and audience (Alone vs. Audience).

Percent Correct

Table 1 shows the mean percentages for the simple and complex tasks by audience type and group.

As expected, there was a significant main effect for task type, $F(1, 82) = 145.66$, $p < 0.01$, $\eta^2 = 0.64$. Participants performed significantly better on the simple task (M = 94.86%) than on the complex task (M = 83.92%).

There was a significant main effect of audience, $F(1, 82) = 6.86$, $p < 0.01$, $\eta^2 = 0.08$. Participants performed significantly better alone (M = 90.22%) than in the presence of an audience (M = 88.56%).

Figure 4 shows the significant interaction effect of task by audience, $F(1, 82) = 10.46$, $p < 0.01$, $\eta^2 = 0.11$. Participants performed slightly better on the simple task when in the presence of an audience than alone, and much worse on the complex task when in the presence of an audience than alone (see Table 1 for means).

There were no performance differences among the groups (Human, Virtual Human Projected, Virtual Human Immersive), $F(2, 82) = 1.29$, $p = 0.28$; and the group variable was not found to interact with any of the other variables of interest. There was no interaction effect of task x audience x group, $F(2, 82) = 2.24$, $p = 0.11$; or an interaction of task by group, $F < 1$; or an interaction of audience by group, $F(2, 82) = 2.13$, $p = 0.13$. The task by audience effect was not found to vary significantly by group. The differences found in performance are due to the type of task (simple or complex) and the type of audience (alone or in the presence of others).

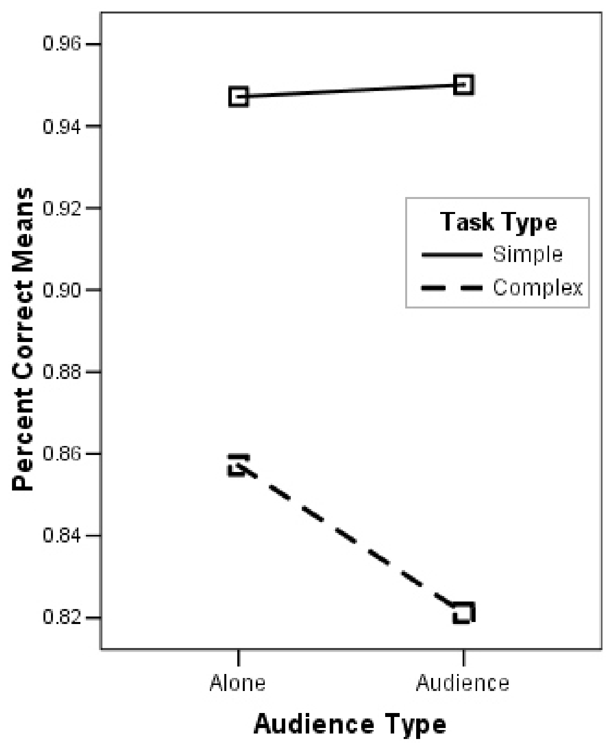

Figure 4. Task by audience interaction for percent correct data.

Reaction Time

Table 2 shows the mean reaction times in milliseconds for the simple and complex tasks by audience type and group.

As expected, there was a significant main effect for task type, $F(1, 82) = 1388.75$, $p < 0.01$, $\eta^2 = 0.94$. Participants responded significantly faster on the simple task ($M = 2226$ ms) than on the complex task ($M = 9851$ ms).

The effect of audience was also significant, $F(1, 82) = 3.35$, $p = 0.04$, $\eta^2 = 0.05$. Participants responded slightly faster alone ($M = 5875$ ms) than in the presence of an audience ($M = 6202$ ms).

Figure 5 shows the significant interaction effect of task by audience, $F(1, 82) = 8.22$, $p < 0.01$, $\eta^2 = 0.09$. Participants responded slightly faster on the simple task when in the presence of an audience than alone, and much slower on the complex task when in the presence of an audience than alone (see Table 2 for means). This result mirrors the result for the per cent correct data. Participants not only performed worse on the complex task when there was an audience present, but they also reacted much slower!

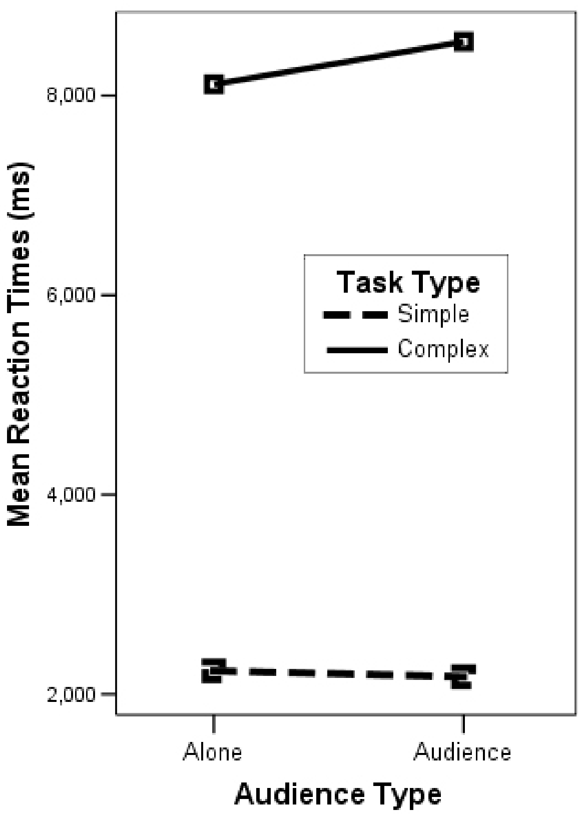

Figure 5. Task by Audience interaction for reaction time data.

There was no main effect of group (Human, Virtual Human Projected, Virtual Human Immersive), $F(2, 82) = 1.31$, $p = 0.28$.; and group did not interact with any of the other variables of interest. There was no interaction effect of task x audience x group, $F < 1$; or an interaction effect of task by group, $F(2, 82) = 1.16$, $p = 0.31$; or an interaction effect of audience by group, $F(2, 82) = 1.42$, $p = 0.25$. Once again, the differences in performance, in terms of reaction time, are not due to group; participants reacted in a similar fashion whether they were watched by a real or virtual human.

	Simple Alone	Simple Audience	Complex Alone	Complex Audience
H[1]	*M* = 94.20	*M* = 94.00	*M* = 86.70	*M* = 78.80
	SD = 5.72	*SD* = 7.05	*SD* = 10.86	*SD* = 12.72
VHP[2]	*M* = 95.17	*M* = 95.86	*M* = 87.17	*M* = 82.62
	SD = 4.46	*SD* = 5.71	*SD* = 10.16	*SD* = 12.25
VHI[3]	*M* = 94.64	*M* = 94.89	*M* = 84.00	*M* = 83.56
	SD = 7.39	*SD* = 5.38	*SD* = 13.46	*SD* = 11.14
All[4]	*M* = 94.72	*M* = 95.01	*M* = 85.72	*M* = 82.12
	SD = 6.08	*SD* = 5.89	*SD* = 11.78	*SD* = 11.91

Table 1. Mean percent correct data by group.
H = Human, VHP = Virtual Human Projected, VHI = Virtual Human Immersive, All = combines all three groups
Sample sizes: $N^1 = 20$, $N^2 = 29$, $N^3 = 36$, $N^4 = 85$

	Simple Alone	Simple Audience	Complex Alone	Complex Audience
H[1]	*M* = 2258	*M* = 1912	*M* = 8076	*M* = 8373
	SD = 684	*SD* = 571	*SD* = 1494	*SD* = 1950
VHP[2]	*M* = 2105	*M* = 2314	*M* = 7790	*M* = 8297
	SD = 677	*SD* = 759	*SD* = 2016	*SD* = 1812
VHI[3]	*M* = 2339	*M* = 2297	*M* = 8472	*M* = 8951
	SD = 735	*SD* = 582	*SD* = 1846	*SD* = 1938
All[4]	*M* = 2240	*M* = 2213	*M* = 8146	*M* = 8592
	SD = 703	*SD* = 660	*SD* = 1836	*SD* = 1902

Table 2: Reaction time data in ms by group.
Sample sizes: $N^1 = 20$, $N^2 = 29$, $N^3 = 36$, $N^4 = 85$

Post Survey Results

Analysis of the post-experiment interviews resulted in the following trends:

- 60.0% of the participants in the human condition, 75.9% of the participants in the virtual human projected condition, and 63.9% of the participants in the virtual human immersive condition felt that they were being watched by another person. The main effect of group was not significant, $\chi^2(48) = 45.10$, $p=0.59$.
- When asked: "What percentage of the time did you feel that you were being watched by another person?" The mean response of the participants in the human condition was 49.6% (*SD* = 50.3), 50.9% in the virtual human projected condition

(*SD* = 43.5), and 47.1% in the virtual human immersive condition (*SD* = 48.7). The main effect of group was not significant, $F < 1$.

The following comments from the participants during the debriefing session illustrate how the participants felt about the virtual human, Diana:

- "When she coughed I felt like I was taking too long, like impatient??"
- "I felt like I was inside a video game!"
- "Diana made me feel anxious, like I have to get the problems done quickly"
- "I did not want [Diana] to think I was stupid"
- "I went a little faster when she was watching me"
- "When I took longer to answer a question, she was trying to peek at what I was doing, and she would clear her throat…"
- "She looked very real, I felt like I was being watched!"

Finally, we made the following observations:

- Several participants commented about Diana sneezing during the experiment, this was very interesting since Diana never sneezed!
- Most of the comments were about the noises that Diana made (e.g. coughing). Participants seemed to think that the noises made her more realistic.

	Computer Use	Math Anxiety	Task Anxiety	Co-presence
H[1]	*M* = 5.55	*M* = 59.40	*M* = 3.90	*M* = 2.70
	SD = 1.67	*SD* = 16.54	*SD* = 1.83	*SD* = 0.89
VHP[2]	*M* = 5.83	*M* = 66.72	*M* = 3.32	*M* = 2.98
	SD = 1.26	*SD* = 19.22	*SD* = 2.00	*SD* = 1.10
VHI[3]	*M* = 5.75	*M* = 65.94	*M* = 4.00	*M* = 3.12
	SD = 1.11	*SD* = 19.36	*SD* = 2.12	*SD* = 1.09
All[4]	*M* = 5.73	*M* = 64.67	*M* = 3.75	*M* = 3.01
	SD = 1.29	*SD* = 18.71	*SD* = 2.02	*SD* = 1.04

Table 3: Means and Standard Deviations of Computer Use, Math Anxiety, Task Anxiety and Co-presence by group. Sample sizes: $N^1 = 20$, $N^2 = 29$, $N^3 = 36$, $N^4 = 85$

Other Variables

Table 3 shows the means for computer use, math anxiety, task anxiety, and copresence by group (Human, Virtual Human Projected, Virtual Human Immersive). There were no significant differences among the groups on any of these measures, *F*s < 1.

In addition, only the math anxiety scores correlated significantly with the percent correct data, $p < 0.01$. No other correlations were found between these variables and the task performance data.

CONCLUSION

This study found that participants were inhibited while performing complex math problems when in the presence of a human, virtual human projected life-size, and a virtual human in an immersive virtual environment. The type of audience present was not a factor, just that there was an audience present. The theory of social inhibition carries over to the virtual human in this study.

Both percent correct data and reaction time data worked in parallel in indicating an inhibition effect. Participants not only performed worse in terms of percent correct while in the presence of others on the complex task, but they also performed much slower.

We were unable to replicate the facilitation effect whereby people perform simple tasks better when in the presence of others. Most likely because of a ceiling effect with the simple math problems, this is a common problem in social facilitation research [6]. Although both the percent correct and reaction time data show trends towards a facilitation effect, the results were not strong enough to claim a facilitation effect.

The immersive condition was expected to lead the highest level of inhibition because of the heightened feeling of presence. This was not the case however; we believe that this may have been due to a problem with the lack of peripheral vision in an HMD (60 degrees diagonal field of view). The nature of the facilitation/inhibition effects are such that you have someone (in your peripheral vision) watching over you while performing task. However, in an HMD, it is possible to block out the view by turning your head. Further research is required to investigate whether this was due to peripheral vision.

The results from this study have implications for future designers of interfaces employing a virtual human. It is crucial for interface designers to understand how people respond and interact with these virtual human interfaces. The results from this study show that virtual humans can indeed inhibit a person while performing a complex task. This should be taken into account when considering a virtual human interface that is intended to aid or facilitate a user in accomplishing a complex or novel task. Designers must be careful that the virtual human interface does not inhibit rather than facilitate the user!

The results from this study, as well as others [20, 21, 26], indicate that many of the rules that apply in human-human interaction carry over to interacting with interface agents and computers. Designers should consider human social interaction theories in developing interface agents.

LIMITATIONS OF THIS WORK

The results of this study are limited to the virtual character employed in our experiment and may not generalize to other types of virtual characters. Further research is needed that examine a larger variety of virtual characters.

Another drawback was the uneven number of male and female participants who were available for the study. More male participants are needed to fully examine the gender effects.

Finally, to achieve more generalizable findings, this study should be replicated with a sample that includes more diverse groups of people, not just college students.

FUTURE WORK

There are a number of remaining questions that could be answered with further research. One of our future goals is to examine possible cross gender interactions by adding a male observer as well as more male participants.

Another future goal is to track the head movements of the participants in the HMD condition. We suspect that the problem of lack of peripheral vision in an HMD made have contributed to the results from that condition. Tracking and logging the head movements of the participants will allow us to visualize and analyze exactly where the participants were looking during the experiment. In addition, to increase participants' peripheral vision, we can use an HMD with a higher field of view.

We are also interested in the effect of the appearance of the virtual human. What if the virtual human's ethnicity as well as gender matched that of the participant? Future work should manipulate the virtual human's age, gender, as well as ethnicity.

Finally, since level of immersion was not a factor in enhancing social influence, future work should explore the effectiveness of simply having the virtual character as part of a desktop display.

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