SOCIAL FACILITATION EFFECTS OF VIRTUAL HUMANS

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I dedicate this thesis to my parents, for their never-ending support.

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SUMMARY

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 name derives from the "good" side of the effect). Different theories have been proposed to explain this effect.

The present study investigated whether people respond to a virtual human the same way they do to a real human. Participants were given different tasks to do that varied in difficulty. The tasks involved anagrams, mazes, modular arithmetic, and the Tower of Hanoi. They did the tasks either alone, in the company of another person, or in the company of a virtual human on a computer screen.

As with a human, virtual humans 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. Implications for the design of instructional systems as well as other systems involving human-computer interactions are discussed.

CHAPTER 1

INTRODUCTION

Interest in virtual humans or embodied conversational agents (ECAs) is growing in the realm of human computer interaction. Many believe that interfaces based on virtual humans have great potential to be beneficial. 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 user's command than simply displaying "I don't understand." on the screen. The text requires the user to read, which may be disruptive to the main task the user is involved in (Catrambone, Stasko, & Xiao, 2004).

Virtual humans can work as an assistant such as a travel agent or investment advisor and deal with any tasks that require managing vast amounts of information (Catrambone et al., 2004). Personified interfaces are also known to be engaging and appropriate for entertainment tasks (Koda, 1996). In clinical settings, virtual humans can be useful as well. Some studies noted that exposure to a virtual audience may be helpful in diminishing the fear of public speaking (Anderson, Rothbaum, & Hodge, 2003). Virtual humans have also been adopted in the development of virtual classroom scenarios for the assessment and rehabilitation of Attention Deficit Hyperactivity Disorder (ADHD) (Rizzo, Buckwalter, & Zaag, 2000).

However, humanized computer interfaces are not welcomed by all researchers. Apparently, simply adding human characteristics to an interface does not guarantee a more usable and useful interface. For example, Lanier (1995) claimed that ECAs disempower users by not providing a clear indication of who is responsible for a system's actions. Shneiderman and Maes (1997) noted that ECAs may increase user anxiety, reduce user control, and destroy a user's sense of accomplishment. Ironically, the presence of a face seems to lead users to assume an ECA is more intelligent than it is (Catrambone et al., 2004).

It is clear that rigorous empirical study within a systematic research agenda is necessary to obtain a clearer understanding about the utility and usability of virtual humans. It is also important to consider the social dimension of the interaction between users and virtual humans. How do users interact with virtual humans? Do people respond to a virtual human as we do to a real human?

Apparently, there is a striking similarity between how humans interact with one another and how a human and a virtual human interact. A study by Nass, Steuer, and Tauber (1994) used the following experimental paradigm to investigate the social context of interacting with virtual humans:

1. Select a social science finding which concerns behavior toward humans.
2. Change "human" to "computer" in the statement of the theory.
3. Replace humans with computers in the method of the study.
4. Provide the computer with characteristics associated with humans.
5. Investigate whether the social rule still applies.

Nass et al. (1994) applied this approach into their studies and claimed that individuals' interactions with computers are fundamentally social. Their evidence suggests that users can be induced to elicit social behaviors even though users assume machines do not possess emotions, feelings, or "selves". Further research suggested that people respond to computer generated personalities in the same way they tend to respond to human personalities (Moon & Nass, 1996; Nass & Lee, 2000).

One prominent social phenomenon is the social facilitation effect. The idea is that the presence of another person can facilitate or inhibit task performance. In other words, we behave differently when there is someone else near than when we are alone. 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. Would this phenomenon be equally observed with virtual humans?

This question of whether the social facilitation effect transfers equally to a virtual human is crucial in designing effective ECAs. A review of research on ECAs concluded that three factors are critical in evaluating the effectiveness of an ECA: user, features of the ECA, and task (Catrambone et al., 2004).

A sub-factor within the features of ECA is 'presence'. Is 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. Likewise, users might exceed in task performance if the task is simple or easy.

The present research studied such issues based on a review of current social facilitation theory, followed by an in-depth analysis of some empirical studies that have investigated social facilitation effects of virtual humans. Finally, an experiment was conducted to effectively examine social facilitation effects due to virtual humans.

CHAPTER 2

SOCIAL FACILITATION THEORY

Social facilitation theory is one of the oldest theories in psychology. While a large body of research has been conducted over more than 100 years, the development of social facilitation theory has been fragmented (for a most up-to-date review, see Aiello & Douthitt, 2001). No single theory has emerged that can effectively account for this phenomenon. Currently, there are three prominent explanations: drive theories, evaluation apprehension, and cognitive process on performance (Guerin, 1993).

Drive (or Arousal)

Zajonc (1965) noticed that some social facilitation studies found performance enhancements in the presence of others while other studies found performance impairments. He proposed a theory based on the Hull-Spence drive theory (Spence, 1956) to explain these differences in performance. In the presence of others, individual drive levels are elevated. This increased drive enhances emission of dominant responses and inhibits emission of subordinate responses. Hence, when a task is well learned, the dominant response is likely to be correct resulting in enhanced performance. Conversely, when a task is not well learned, the dominant response is likely to be incorrect resulting in impaired performance.

Zajonc (1980) also emphasized that although other factors (evaluation apprehension, etc.) might influence individual reactions to the presence of others, they were not necessary to evoke social facilitation. He claimed that mere presence of others was not only necessary but sufficient for social facilitation.

Evaluation Apprehension

Cottrell (1972) asserted that mere presence was not enough to elevate drive levels and would not necessarily cause social facilitation effects. He proposed that only when individuals were concerned about how others would evaluate them would drive levels increase, resulting in social facilitation or impairment of task performance. In addition, prior evaluation experiences caused people to develop a drive reaction, that is, a learned drive.

Cottrell's theory is similar to Zajonc's in its assertion that drive was a mediator between the presence of others and performance effects. Cottrell's theory differs from Zajonc's in terms of what triggers the increment in drive levels.

Cognitive Processes

Several theories emphasize distraction in the way individuals process information in the presence of others (Baron, Moore, & Sanders, 1978). Baron proposed that attention conflict can produce drive-like effects on performance such that it can facilitate simple tasks and impair complex ones. He suggested that this attention conflict can have social or nonsocial causes, and three conditions are likely to trigger the conflict: (a) the distraction is very interesting or hard to ignore, (b) there is pressure to complete the task quickly and accurately, and (c) attending to the task and the distracter simultaneously is difficult or impossible.

Research on Social Facilitation of Virtual Humans

There are only a handful of studies that 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 as 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 whether the questionnaire task in their study was meant to be a simple task. Secondly, spending more time with the talking face does not necessary mean enhancement in task performance. This may simply mean that it took longer to listen to a question than to read it and the study did not address this issue.

The study by Walker et al. (1994) also compared responses to two different talking faces. Participants who answered questions spoken by a stern face, spent more time, made fewer mistakes, and wrote more comments, compared to subjects who answered questions spoken by a neutral face. Walker et al. suggested that the presence of another person apparently produces evaluation reminders and therefore leads people to try harder. They posited that the more expressive face (the stern face) produced the most evaluation reminders between the conditions. Yet the nature of the link between expressiveness and the degree of evaluation reminder is unclear. No reference has been made to substantiate this claim and there is no study that has investigated the relationship between the expressiveness of a face and the effect of social facilitation.

Sproull, Subramani, Kiesler, Walker, and Waters (1996) have also looked into this matter using a questionnaire study. Similar to Walker et al.'s study, participants responded to a talking face versus a text display. They attempted to investigate people's arousal and attention level to see the effects of social facilitation. Arousal was captured by asking participants “How relaxed did you feel?” and “How confident did you feel?” during use of the system. Attention level was measured by recording information on how much time participants spent in each section of the experiment, the number of items they skipped in the scales, and the number of words participants wrote in the task. Participants reported to be more aroused (less assured and relaxed) in the face conditions than in the text condition. However, the results provided only partial support for facilitated attention. While participants took longer to respond in the face conditions, they also skipped more questions. As stated, “This difference suggests that subjects were less careful in the face conditions, but also suggests they were avoiding certain questions.” (Sproull et al., 1996, p. 113)

The major problem with Sproull et al.’s (1996) research is their exclusive focus on drive level (arousal and attention). Drive based theories (Cottrell, 1972; Zajonc, 1965) are only a part of theories that attempt to explain the social facilitation effect. Even in social psychology, it is not agreed whether drive based theories are the true cause for social facilitation. In our context, we are not even sure if this social phenomenon can be invoked by the presence of virtual humans. Thus, before investigating the cause it is reasonable to examine whether social facilitation will occur due to the presence of virtual humans.

Zanbaka, Ulinski, Goolkasian, and Hodges (2004) attempted to investigate social facilitation due to virtual humans and replicated the social facilitation effect in the presence of a virtual human. 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.

The reason that Zanbaka et al.'s (2004) research failed to replicate the social facilitation effect was, as quoted 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).

CHAPTER 3

EXPERIMENT DESIGN

As mentioned earlier, there is no single unified theory that can parsimoniously account for the social facilitation effect. Regarding Zajonc's (1965) claim that mere presence is sufficient enough to invoke the social facilitation effect, there is yet no agreement. Cottrell's (1972) evaluation theory is also challenged by researchers and as Bond and Titus (1983) noted, "Evaluation potential increased the effect of presence. However, in nearly as many cases, it reduced the effect" (p. 278). It is not clear why results have been so inconsistent. 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, it is not reasonable to pursue this research from just one perspective. For example, the first two studies in human computer interaction investigated the social facilitation effect from the drive based theories (Cottrell, 1972; Zajonc, 1965) exclusively. It is limiting to examine social facilitation in such a way when the validity of drive based theories is questionable even for interaction between humans. Therefore, the present study was not designed to distinguish or support any of the three major social facilitation theories.

I wished to examine whether the social facilitation effect can be evoked by virtual humans. Thus, the important question to ask pertained to the only fact that has been consistently observed in social psychology: the presence of other(s) enhances simple task performance and impairs complex task performance. Therefore, this study addressed the following question: Does the presence of a virtual human lead to enhanced task performance in simple tasks and impaired task performance in complex tasks?

The design of tasks was crucial for this experiment. Tasks had to give 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?

Virtual humans can assist users in virtually any task. Some tasks can be opinion-like (e.g., choosing what to bring on a trip) while others can be more objective (e.g., providing hints when solving a quiz) (Catrambone et al., 2004). However, it was reasonable to think that these tasks require high-level cognition. Hence, low level sensory motor tasks were excluded from this experiment.

2) Is the task scalable in terms of difficulty?

The present study examined difference in task performance between simple and complex tasks. Hence, the experiment should be able to scale the difficulty of tasks.

Using these two criteria, the present study incorporated the following four cognitive tasks: anagrams, mazes, modular arithmetic, and the Tower of Hanoi. These four tasks provided a good mixture of verbal, spatial, mathematical, and high level problem solving skills. All four 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.

Anagram Task

Social facilitation 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. Anagrams were divided into two categories (easy or difficult) using normative solution times from Tresselt and Mayzner's (1966) anagram research. This experiment replicated their study in the presence of virtual human.

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). This is an example of the social facilitation effect. Simple mazes included wide paths and few blind alleys so that the correct route is readily perceivable, whereas difficult mazes included narrow paths with many blind alleys.

Modular Arithmetic Task

The object of Gauss's modular arithmetic is to judge if problem statements 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 of this (i.e., 28) is divided by the last number (i.e., 28 ÷ 4). If the dividend 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; one for an easy task and two for a difficult task.

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. A number of researchers have examined how mental arithmetic is learned and rule based algorithms are used to solve math problems (for a review, see Beilock et al.). However, this study was not interested in such issues but rather, whether people perform differently in the presence of a virtual human.

Tower of Hanoi Task

The Tower of Hanoi is a well-structured and a well-studied problem. Research has focused on its isomorphs and problem representations (e.g., Hayes & Simon, 1977; Kotovsky & Fallside, 1989; Kotovsky, Hayes & Simon, 1985; Simon & Hayes, 1976; Zhang & Norman; 1994). While no research had examined the social facilitation effect in the Tower of Hanoi task, the present study included this task and controlled the difficulty of the task by manipulating the number of disks.

It is worth mentioning that this puzzle is well known to students of Computer Science as it appears in virtually any introductory book on data structures. Such students were excluded in the experiment. Also, once participants learn the essence of this problem (the nature of recursive function) subsequent problems will be drastically easier to solve. Therefore, this task was manipulated as a between subjects factor while the others were manipulated as a within subjects factor.

CHAPTER 4

METHOD

Participants

One hundred and eight participants were recruited from the Georgia Institute of Technology. Participants who have had prior exposure to a data structure course were excluded from the experiment. Participants were compensated with course credit.

Materials

The present study used a computer that participants interacted with for all four tasks. Java application and Java script were used to implement tasks on the computer.

Materials for the anagram tasks (Appendix A) were similar to the ones of Davidson and Henderson (2000). Anagrams was pulled from both easy and difficult word lists (Appendix B) generated based on mean solution time in Tresselt and Mayzer's (1966) anagram research. Materials for the maze task (Appendix C) were similar to the ones of Jackson and Williams (1985). Participants were given a maze and a cursor on the screen to find the exit. In the modular arithmetic tasks, predetermined problem statements were given to the participants (Appendix D). Easy problems consisted of single-digit no-borrow subtractions (e.g., $7 \equiv 2 \pmod 5$) and hard problems consisted of double-digit borrow subtraction operation (e.g., $51 \equiv 19 \pmod 4$). These were similar to the ones of Beilock et al. (2004). In the Tower of Hanoi tasks, three poles were displayed with three (easy condition) or five disks (difficult condition) to move around (Appendix E).

An additional computer was used for the presence of virtual human condition. Haptek Corporation's 3-D character was loaded on this computer (Appendix F). 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 (Appendix G).

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 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. For the mazes, anagrams, and modular arithmetic tasks, every participant experienced multiple instances of each of the six trial types, for the Tower of Hanoi task, each participant participated in only one of the six trial types (i.e., one trial).

A series of task blocks was presented to each participant (Figure 1). Each row in Figure 1 represents the order a participant received. Each task block varied by the type of task and the type of presence (e.g., conducting an anagram task alone). A Latin square is used to determine the order of these blocks. Within each task block, participants conducted a combination of easy and difficult trials for a particular task (e.g., anagrams) in a particular type of presence (e.g., alone). While the number of easy and difficult trials was the same, the order was matched to one of the three predetermined pseudo-randomized orders.

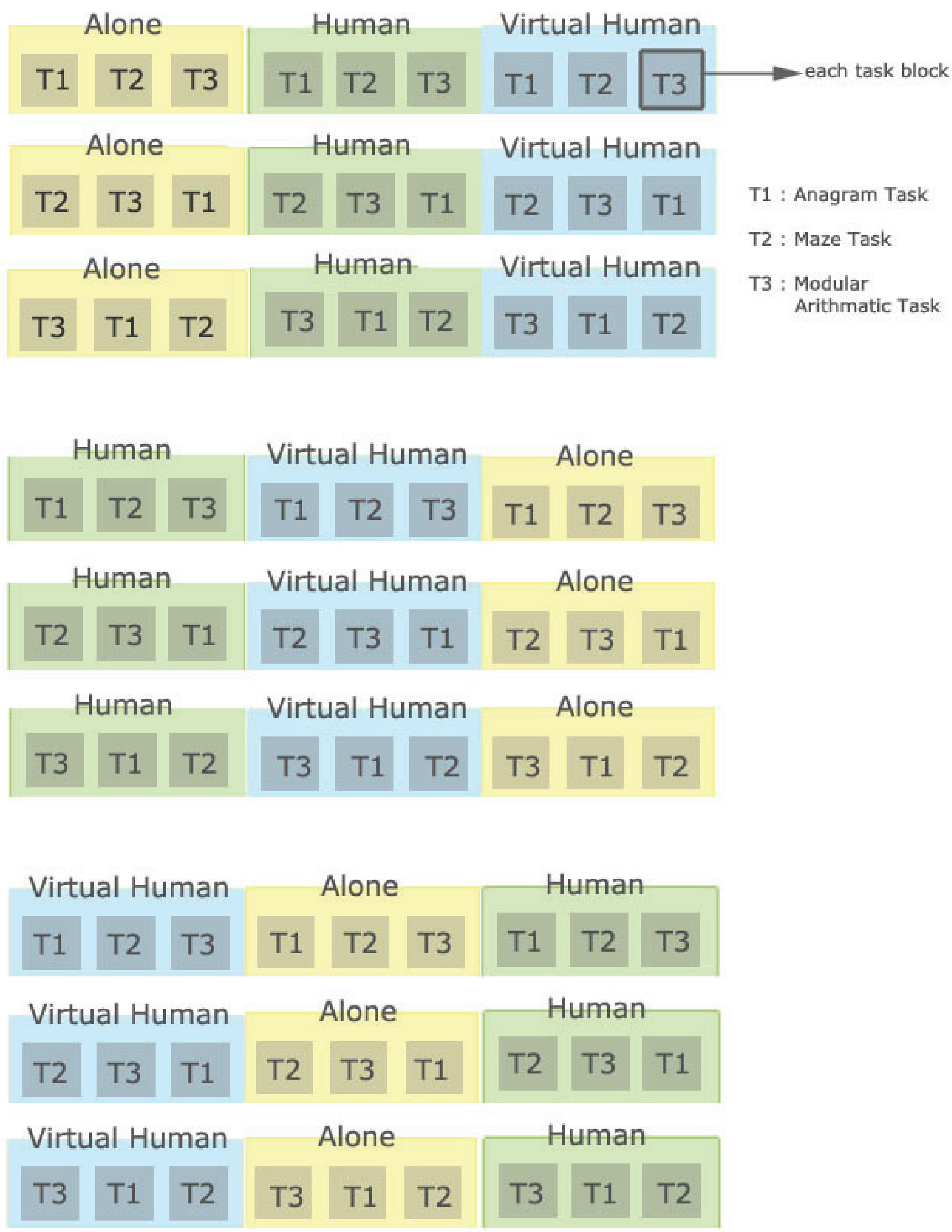


Figure 1. *Task Design Map*. There were nine possible trials orders, each of which is represented as a row in the figure. This was crossed with three predetermined pseudo-randomized orders which resulted in 27 trial orders.

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 keyword. 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 is 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”. Reaction time and error rates were measured.

In the Tower of Hanoi task, three poles and a tower of three disks (easy condition) or five disks (difficult condition) appeared on the screen. Disks were stacked in increasing size on the far left pole. Participants were asked to transfer the entire tower to the far right pole, moving only one disk at a time without ever placing a large one onto a smaller. This rule was told explicitly to the participants and they were forced to comply (i.e., the program did not allow participants to move a large disk onto a smaller.). Completion time and the number of moves were recorded.

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 can 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 is there to “observe” the task and not the participant

(Appendix H). Literature review revealed that there has been no study on how gender, age, or race affects social facilitation. While future research might want to look at effects of such variables, the appearance of the agent was not intended to represent a particular gender, age, or race and was held constant in the present study.

CHAPTER 5

RESULTS

Statistical analyses were performed by taking the following steps: (1) three-way ANOVA (complexity factor, presence factor, and pseudo orders), and (2) simple effect analysis to examine the social facilitation effect. Analysis among the three dimensions was conducted to examine a main effect and any possible interactions. Analysis was conducted on reaction time because it has been the most frequently measured dependent variable on well learned tasks (Bond & Titus, 1983). Although the order was randomized and effects should distribute equally across conditions, the pseudo order factor was tested to make sure it did not have an effect by itself.

Anagram Task

Pseudo order and the Latin square order had no effect and all results were collapsed over these variables.

ANOVA Analysis on reaction time (See Table 1) indicates that there was a main effect of complexity (easy, hard), $F(1, 81) = 166.49$, $MSE = 285.94$, $p < .001$, but no main effect of presence (alone, virtual human, human), $F(2, 162) = .009$, $p > .92$. A significant two-way interaction between complexity and presence was found, $F(2, 162) = 17.41$, $p < .001$.

Table 1. Mean reaction time in seconds including incorrect responses for each condition (*n* = 108). Percent correct is inside the parentheses.

	Presence		
Complexity	Alone	Virtual Human	Human
Easy	20.0, *sd* = 20.0 (93%)	14.9, *sd* = 9.8 (94%)	13.5, *sd* = 10.6 (95%)
Hard	29.7, *sd* = 19.1 (70%)	34.1, *sd* = 22.1 (65%)	36.0, *sd* = 23.1 (65%)

Simple Effects Analysis The interaction between complexity and presence suggests analyzing simple effects at each level (See Table 2).

Table 2. *p* Values for Testing Hypothesis

Comparisons	*p* Values
Easy Task	
Alone vs Virtual Human	< .05
Alone vs Human	< .001
Hard Task	
Alone vs Virtual Human	< .05
Alone vs Human	< .05

In accordance with the social facilitation literature, the reaction time in easy tasks was expected to be faster in the human condition than the alone condition and the reaction time in hard tasks was expected to be slower in the human condition than the alone condition. This was supported.

The social facilitation effect of virtual human was also demonstrated. The reaction time in easy tasks was faster in the virtual human condition than the alone condition and the reaction time in difficult tasks was slower in the virtual human condition than the alone condition.

Maze Task

Pseudo order and the Latin square order had no effect and all results were collapsed over the variables.

ANOVA Analysis on reaction time (See Table 3) indicates that there was a main effect of complexity (easy, hard), $F(1, 81) = 619.83$, $MSE = 269.41$, $p < .001$, but no main effect of presence (alone, virtual human, human), $F(2, 162) = 1.54$, $p > .21$. A significant two-way interaction between complexity and presence was found, $F(2, 162) = 5.61$, $p < .01$.

Table 3. Mean completion time in seconds for each condition ($n = 108$).

	Presence		
Complexity	Alone	Virtual Human	Human
Easy	12.8 (*sd* = 6.8)	11.7 (*sd* = 5.3)	11.3 (*sd* = 3.4)
Hard	42.1 (*sd* = 14.4)	43.3 (*sd* = 19.4)	45.1 (*sd* = 18.6)

Simple Effects Analysis The interaction between complexity and presence suggests analyzing simple effects at each level (See Table 4).

Table 4. *p* Values for Testing Hypothesis

Comparisons	*p* Values
Easy Task	
Alone vs Virtual Human	< .05
Alone vs Human	< .05
Hard Task	
Alone vs Virtual Human	< .05
Alone vs Human	< .05

In accordance with the social facilitation literature, the completion time in easy tasks was expected to be faster in the human condition than the alone condition and the completion time in hard tasks was expected to be slower in the human condition than the alone condition. This was supported.

Social facilitation effect of virtual human was also demonstrated. The completion time in easy tasks was faster in the virtual human condition than the alone condition and the completion time in difficult tasks was slower in the virtual human condition than the alone condition.

Modular Arithmetic Task

Pseudo order and the Latin square order had no effect and all results were collapsed over the variables.

ANOVA Analysis on reaction time (See Table 5) indicates that there was a main effect of complexity (easy, hard), $F(1, 81) = 432.01$, $MSE = 15.36$, $p < .001$, and presence (alone, virtual human, human), $F(2, 162) = 26.88$, $p < .001$. A significant two-way interaction between complexity and presence was found, $F(2, 162) = 38.06$, $p < .001$.

Table 5. Mean reaction time in seconds including incorrect responses for each condition ($n = 108$). Percent correct is inside the parentheses.

	Presence		
Complexity	Alone	Virtual Human	Human
Easy	3.00, $sd = 1.4$ (99%)	2.69, $sd = 0.7$ (99%)	2.72, $sd = 0.9$ (99%)
Hard	8.07, $sd = 3.3$ (93%)	9.26, $sd = 3.9$ (89%)	10.92, $sd = 5.1$ (88%)

Simple Effects Analysis The interaction between complexity and presence suggests analyzing simple effects at each level (See Table 6).

Table 6. *p* Values for Testing Hypothesis

Comparisons	*p* Values
Easy Task	
Alone vs Virtual Human	$< .05$
Alone vs Human	$< .05$
Hard Task	
Alone vs Virtual Human	$< .001$
Alone vs Human	$< .001$

In accordance with the social facilitation literature, the reaction time in easy tasks was expected to be faster in the human condition than the alone condition and the reaction time in hard tasks was expected to be slower in the human condition than the alone condition. This was supported.

Social facilitation effect of virtual human was also demonstrated. The reaction time in easy tasks was faster in the virtual human condition than the alone condition and the reaction time in difficult tasks was slower in the virtual human condition than the alone condition.

Tower of Hanoi Task

ANOVA Analysis on reaction time (See Table 7) indicates that there was a main effect of complexity (easy, hard), $F(1, 102) = 139.7$, $MSE = 5908.11$, $p < .001$, but no main effect of presence (alone, virtual human, human), $F(2, 204) = 1.68$, $p > .19$. An interaction between complexity and presence was not found, $F(2, 204) = 2.04$, $p > .14$.

Table 7. Mean completion time in seconds for each condition (*n* = 108). Number of steps to complete the task is inside the parentheses.

	Presence		
Complexity	Alone	Virtual Human	Human
Easy	33.6, *sd* = 40.5	33.9, *sd* = 22.1	30.1, *sd* = 32.9
	(52)	(32)	(31)
Hard	171.9, *sd* = 112.1	208.5, *sd* = 107.3	241.7, *sd* = 90.2
	(116)	(115)	(115)

Simple Effects Analysis Simple effects were analyzed to test the hypothesis.

Table 8. *p* Values for Testing Hypothesis

Comparisons	*p* Values
Easy Task	
Alone vs Virtual Human	> .98
Alone vs Human	> .75
Hard Task	
Alone vs Virtual Human	> .29
Alone vs Human	< .05

In accordance with the social facilitation literature, the completion time in easy tasks was expected to be faster in the human condition than the alone condition and the completion time in hard tasks was expected to be slower in the human condition than the alone condition. This was partially supported. While the completion time in hard tasks was significantly slower in the human condition, the completion time in easy tasks was not significantly faster.

Social facilitation effect of virtual human was not demonstrated. The completion time in easy tasks was not significantly faster in the virtual human condition than the alone condition nor the completion time in difficult tasks was significantly slower in the virtual human condition than the alone condition.

CHAPTER 6

DISCUSSION

The key hypotheses in this study were generally 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. However, an exception was observed for the Tower of Hanoi task. For this task, the social facilitation effect was partially supported in the human condition, but it was not supported in the virtual human condition.

The design of the Tower Hanoi task might have contributed to this exception in the findings. It was the only between-subject task in the experiment. Because each participant participated in only one condition (e.g., easy – alone task, difficult – virtual human task), individual differences might have influenced the results. In addition, this one trial task was given at the end of the experiment, meaning boredom effects might have influenced the participants. The directionality of the means (e.g., in the difficult task, mean completion time in the human condition > mean completion time in the virtual human condition > mean completion time in the alone condition) showed a trend in the expected direction which suggested that with more accurate tuning of the task, the social facilitation effect might be observed for the Tower of Hanoi as well.

In this study, we replicated the social facilitation effect of humans and expanded this effect to the presence of virtual humans. Why would we behave differently when there is a virtual human near than compared to when we are alone? Nass et al. (1994) claimed that an individual's interactions with computers are fundamentally social.

However, there was no interaction in this experiment. Yet, participants still behaved socially in a mere-presence-like circumstance. This study leaves a variety of questions to be pursued in future studies: Is the social facilitation effect a result of conscious (or unconscious) belief that the virtual human is human-like? Or is it a result of the virtual human being realistic, that is, animated and expressive? How does task play a role in social facilitation of virtual humans?

The drive theory (Zajonc, 1965) would argue that the presence of a virtual human elevated the participants' drive levels. This increased drive enhanced easy tasks and inhibited difficult tasks. The evaluation apprehension theory (Cottrell, 1972) would argue that the participants were concerned with how the virtual human would evaluate them and this increased the drive level. Finally, the cognitive distraction theory (Baron, Moore, & Sanders, 1978) would propose that the presence of the virtual human distracted the participants that made attending to the task and ignoring the virtual human difficult. However, as mentioned earlier, there is no single unified theory that can parsimoniously account for the social facilitation effect with humans. The social facilitation effect of virtual humans may be explained by a combination of these theories.

The results have implications for the design of instructional systems as well as other systems involving human-computer interactions. They suggest that designers of such systems should be mindful about the social nature of virtual humans. They should understand that the users behave differently in the presence of virtual humans and that the nature of the behavior depends on the task, more specifically on the task difficulty.

One of the limitations of this study is related to the location of the virtual human. The virtual human in this study was located in a separate monitor with a distance from the monitor that presented the tasks. However, most of the current ECAs are located within the task space (i.e., ECAs are presented with the task in the same monitor). This limits the generalizability of the study. Future research may address this issue.

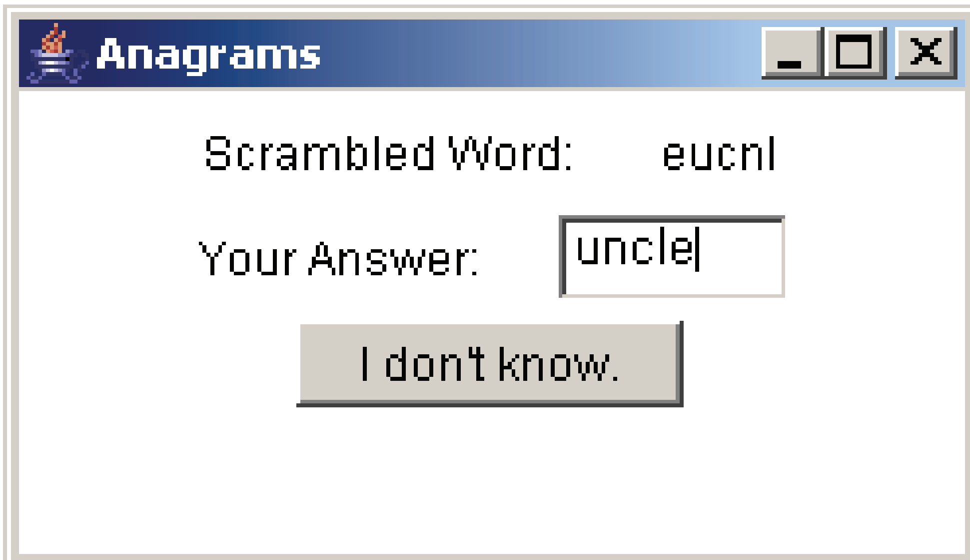
CHAPTER 7

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 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 social nature of virtual humans.

APPENDIX A

ANAGRAM TASK



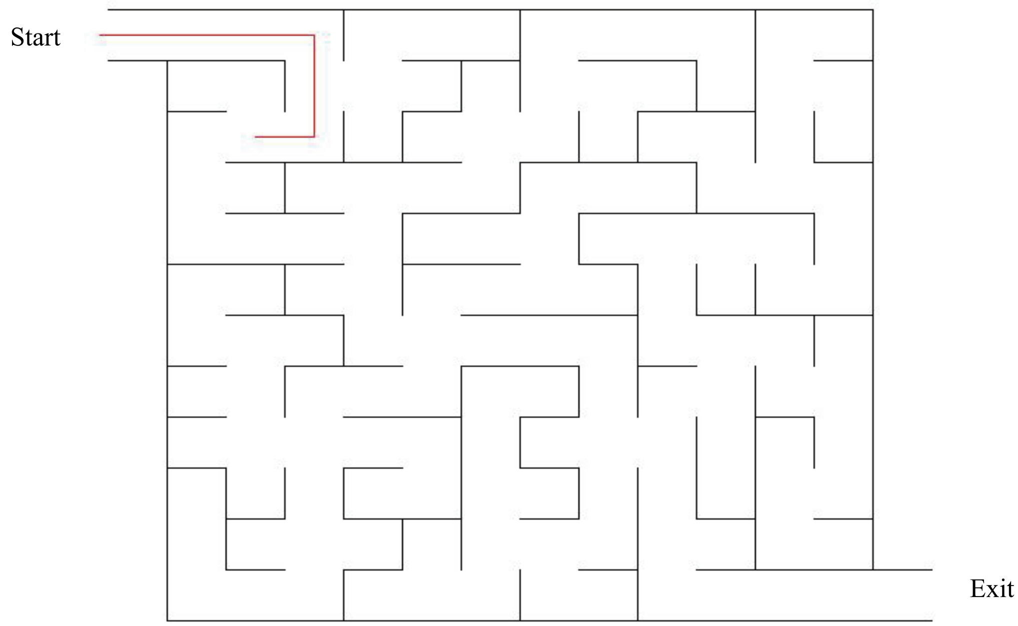
APPENDIX B

WORD LIST

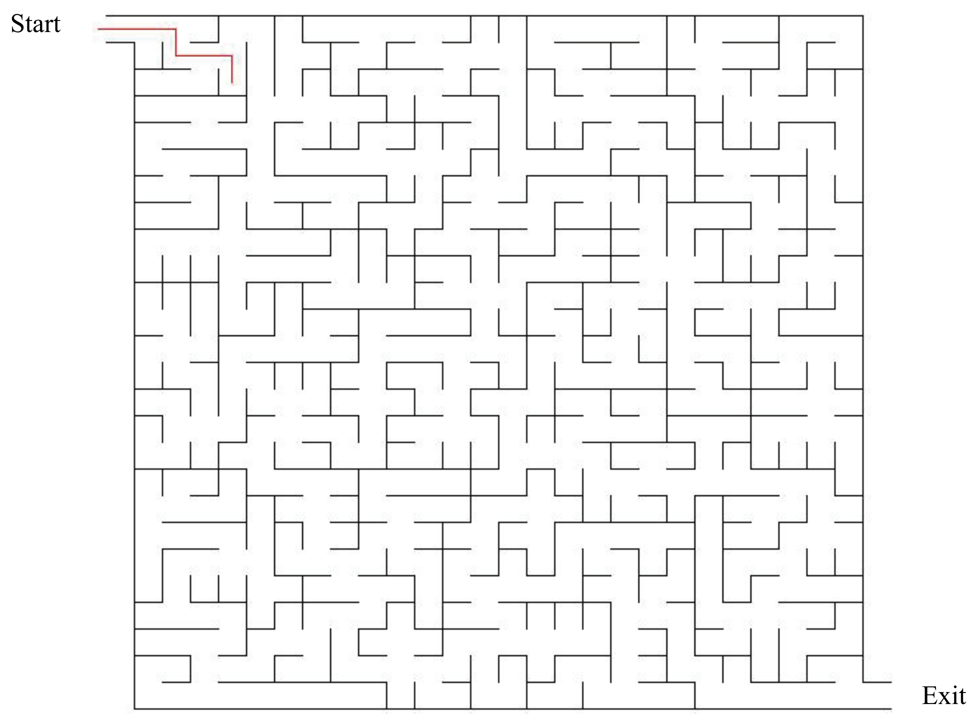
Easy Words (n = 18)		Difficult Words (n = 18)	
Solution Words	Anagrams	Solution Words	Anagrams
judge	egujd	audit	dtuai
water	aewtr	pause	speua
beach	beahc	apron	oapnr
voice	eocvi	uncle	eucnl
model	odelm	panic	pncia
train	ntrai	scale	elcsa
labor	orlab	cobra	obrac
house	euohs	guard	augdr
drink	nrdki	value	aeuvl
guide	iuegd	tango	tanog
fault	ultfa	adopt	dpaot
climb	milbc	noble	bnloe
giant	ntgia	flirt	ltifr
chair	ihrca	tonic	ciotn
cloth	lcoht	birth	rhtib
baton	tonba	music	iumcs
sugar	ugars	wagon	gawno
month	ohtnm	habit	taibh

APPENDIX C

MAZE TASK



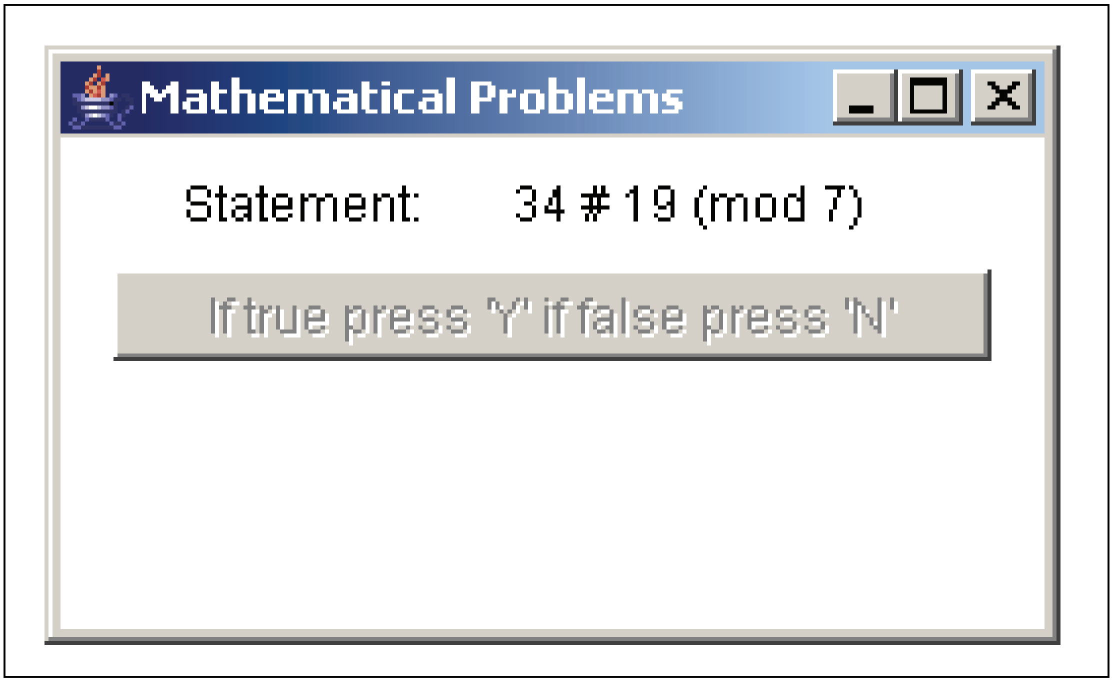
Easy Maze



Difficult Maze

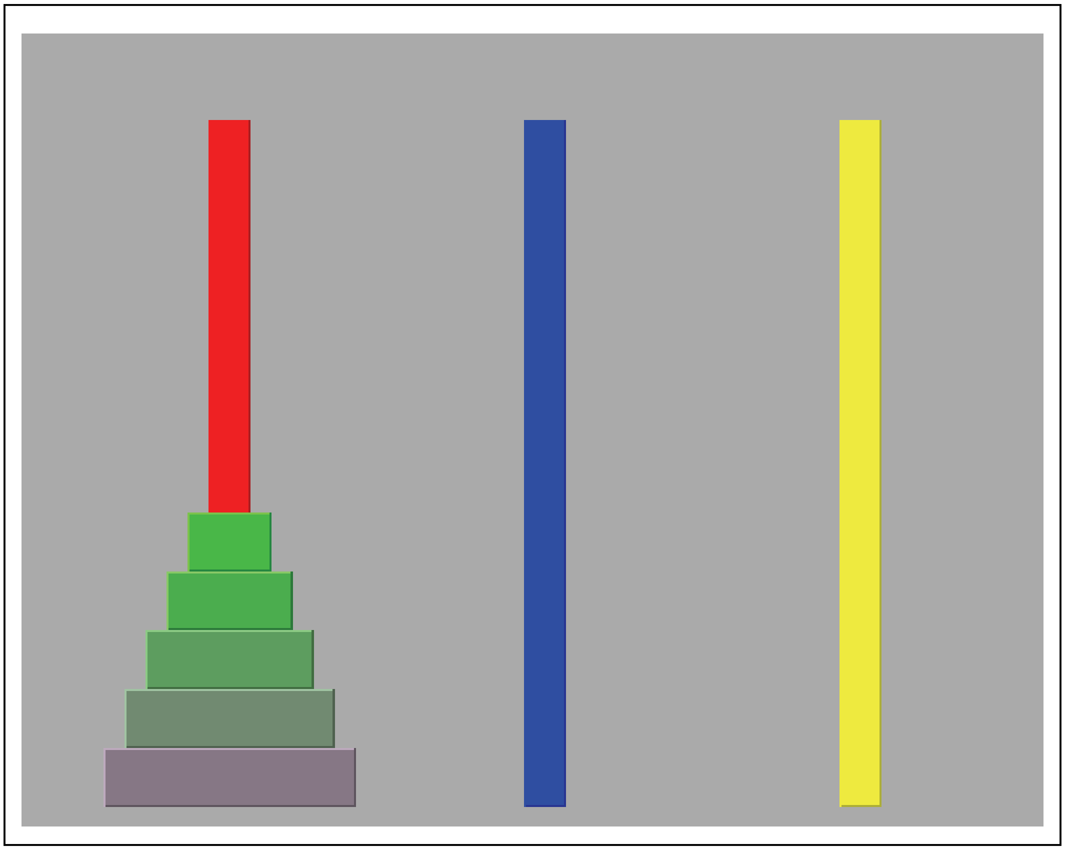
APPENDIX D

MODULAR ARITHMETIC TASK



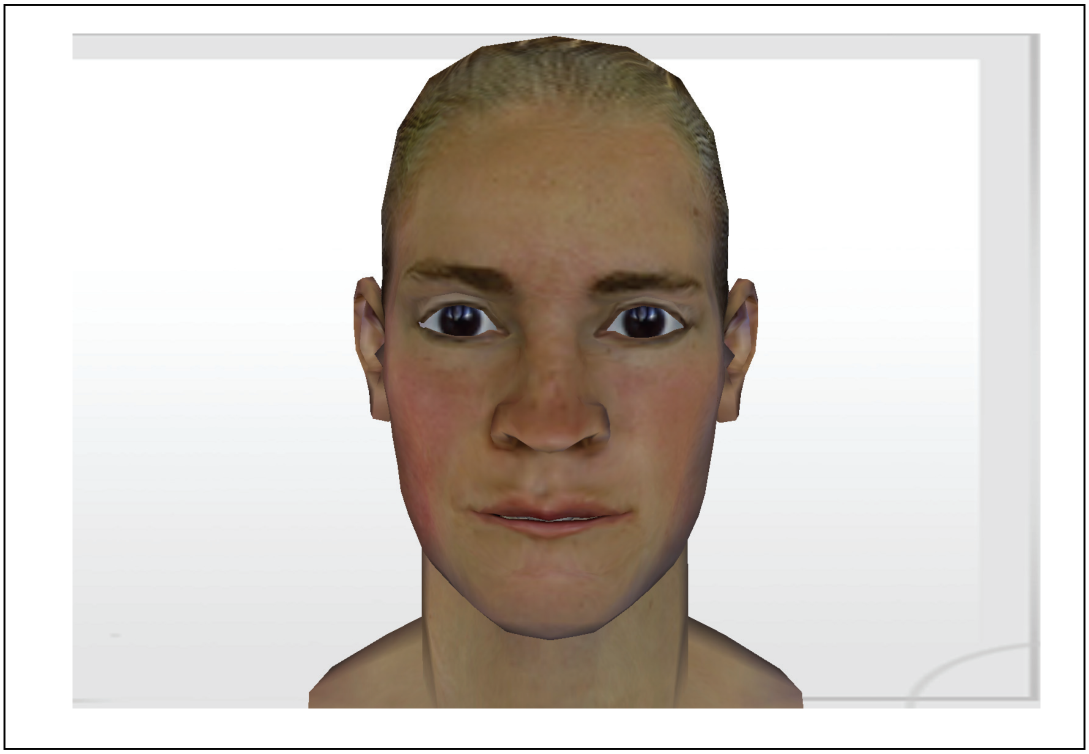
APPENDIX E

TOWER OF HANOI TASK



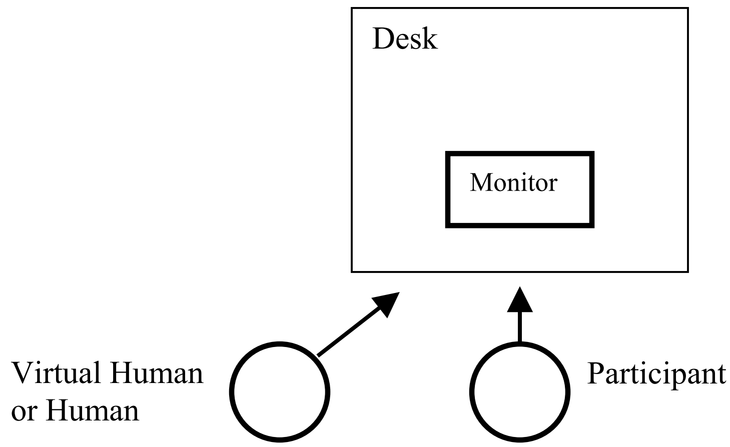
APPENDIX F

VIRTUAL HUMAN IN THE PRESENT STUDY



APPENDIX G

EXPERIMENT LAYOUT



APPENDIX H

SCRIPT FOR THE HUMAN OR THE VIRTUAL HUMAN CONDITION

The Human Condition

An observer will be sitting near you to observe the tasks you will be 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.

The Virtual Human Condition

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.

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