The Influence of Virtual Agents' Gender and Rapport on Enhancing Math Performance

Bilge Karacora[1] (**bilge.karacora@stud.uni-due.de**), **Morteza Dehghani**[2] (**morteza@ict.usc.edu**), **Nicole Krämer-Mertens**[1] (**nicole.kraemer@uni-due.de**), **Jonathan Gratch**[2] (**gratch@ict.usc.edu**)

[1]Department of Social Psychology, University of Duisburg-Essen, Forsthausweg 2, 47057 Duisburg, Germany

[2]Institute for Creative Technologies, University of Southern California, 12015 Waterfront Dr., Playa Vista, CA 90094-2536, USA

Abstract

The purpose of the present research is to investigate whether virtual agents can help enhance participants' performance, effort and motivation in mathematics. We hypothesize that a minimal amount behavioral realism induced by display of rapport is necessary for any social effects to occur in human-computer interaction. Further, we examine whether social facilitation effects occur depending on the gender of the participants and the interacting virtual agents. In a 2x2 between subjects design, participants interacted with a male or female virtual agent that either displayed rapport or no rapport. Our results confirm that gender plays a role when interacting with virtual agents that are capable of establishing rapport. Participants' performance and effort were significantly enhanced when interacting with an agent of opposite gender that displayed rapport**.** Our results have implications on designing agents for education and training purposes.

Keywords: social facilitation, STEM, rapport, virtual agents

Introduction

There is considerable interest in factors that enhance science and math performance. Recently, there has been an upsurge of interest in educational technology that exploits social and motivational factors that enhance math performance in general, and reduce gender inequality in particular (Kim, 2004; Baylor & Ryu, 2003). This work builds on the phenomena that people often treat computers as social actors. Therefore, psychological factors that improve people's performance in traditional face-to-face settings can be simulated by technologies in form of virtual learning companions or virtual instructors. In this paper, we seek to address two related goals. First, we aim to show that certain social psychological phenomena can enhance math performance in a human-computer setting. Specifically, we show that a form of social facilitation can improve performance on standardized math tests. Second, we seek to provide further evidence that people do treat computers as social actors and help elucidate the design principles that foster this effect. We specifically demonstrate that virtual agents must possess a minimum level of behavioral realism to achieve any social effects.

Rapport has been shown as an effective way to create behavioral realism in virtual agents. In social psychology, rapport is described as the establishment of a positive relationship among interaction partners by rapidly detecting and responding to each other's nonverbal behavior (Gratch et al., 2007a). This includes displaying behaviors that indicate positive emotions (such as head nods and smiles), showing mutual attentiveness (such as mutual gaze) and certain coordination behaviors (such as postural mimicry and synchronized movement) (Tickle-Degnan & Rosenthal, 1990). Niewiadomski et al. (2010) reports that when an agent displays appropriate and socially adapted emotional expressions, he is perceived as more human-like than an agent that shows human expressions which are inappropriate or not socially adapted. Garau et al. (2005) conducted a study showing that only participants who interacted with an agent that was responsive to their movements, experienced a sense of personal contact with the agent which influenced them to behave more socially considerate as opposed to interacting with a static or moving but unresponsive agent. This indicates that rapport is an important feature in order for the agent to be perceived as human-like and for any social effects, such as social facilitation, to occur.

Previous research on social facilitation/inhibition illustrates how the presence of others affects an individuals' task performance either positively or negatively (Guerin & Innes, 1982; Zanjonc, 1965; Sanders, Baron & Moore, 1978). Whether or not similar facilitation/inhibition effects occur in presence of virtual agents has been subject to several studies. Rickenberg and Reeves (2000) found that tasks are facilitated or inhibited by the "social" presence of a virtual agent. A study by Zanbaka et al. (2004) indicates that when asked to perform a task, participants reacted similarly to the presence of a virtual agent as they would have in the presence of another human. A follow-up study by Zanbaka et al. (2007) demonstrates that the presence of a virtual agent inhibits the performance of participants on a mathematical task. The limitation of this study was that the sample consisted of only female participants being confronted with an agent of matching gender. Hayes et al. (2010) found a similar decrease in performance with regard to male participants interacting with an agent of the same gender. However, the study demonstrated that when male participants interacted with an agent of the opposite gender their performance improved. The authors argued that participants experienced a stronger feeling of "being in the room with the agent" when interacting with an agent of opposite gender. A post-hoc explanation for Hayes et al.'s findings is that the improvement may have been caused of social facilitation effects.

Experiment

Our goal in this paper is to investigate whether a virtual agent can motivate participants and help to improve their performance in a mathematical task. For this purpose, we examine whether social facilitation effects occur when participants interact with virtual agents and how gender and rapport influence these effects. We extend the previous findings of Hayes at al. (2010) by including both, male and female participants, in an experiment in which they interact with a virtual agent of either matching or opposing gender.

We hypothesize that interacting with a human-like rapport agent of the opposite gender facilitates participants' performance on mathematical tasks. First, we assume that social facilitation effects will cause participants' to show more motivation, invest more effort and achieve a higher improvement of performance when interacting with an agent of the opposite gender. Second, we further expect such social facilitation effects only to occur when rapport is displayed by the agent. The reason is that rapport has been shown to be necessary for an agent to be perceived as a (human-like) social entity, which is required for social effects to occur.

In order to test these assumptions, we designed an experiment in which we manipulated virtual agents' gender and rapport behavior. We recruited male and female participants and had them perform two mathematical tasks, one before interacting with an agent and one during the interaction. Each participant was either confronted with an agent of matching gender or of opposing gender. The agents used in the rapport condition were capable of showing appropriate positive responses such as head nods and smiles in reaction to the participants' verbal and nonverbal behavior. The agents in the no-rapport condition only show minimal unresponsive movements such as breathing or blinking. We explored the effects of our experimental conditions by comparing the participants' performance before and during the interaction with the agent. We also investigated participants' motivation and increase of effort to solve the math problems.

Participants

We recruited seventy-four participants (58.1 % females), from the greater Los Angeles area. Their age ranged from 18 to 34 years with an average age of 23.64 (SD=3.97). 16.2% of participants had high school education, 78.4% collage education and 5,6% went to graduate school. Participants were recruited by responding to recruitment posters posted on craigslist.com and were paid $30. The experiment took about 60 minutes.

Design

We used a 2x2 full factorial between subjects design, with the first variable being the gender of the agent matching the gender of the participant (gender match/gender no match) and the second variable being whether or not the agent displayed rapport (rapport/no rapport). Participants were randomly assigned to one of the four conditions.

Improvement in performance, motivation and increase in effort were measured as dependent variables. We calculated participants' performance improvement by the difference in their performance before and during the interaction with the agent. For this purpose, we subtracted the number of math problems they solved correctly in the second task from the number they solved correctly in the first task. To measure participants' motivational state with regards to the mathematical tasks we used the Situational Motivation Scale (SIMS) by Guay et al. (2000). By subtracting the number of solved math problems in the second task from the number solved in the first task, we calculated the increase in effort. This variable was interpreted as an additional indicator for their situational motivation.

Sample of three questions in the first task:

A) The child care center charges $11 an hour plus a daily $3 drop-off fee. How many hours of childcare did Robert pay for if he dropped his son off 3 days last week and paid $130 at the end of the week?

B) A rental store charges a fine of 25 percent of the usual full-day rental rate for each hour that an item is late. Ryan rented a rototiller for one day for $40. He returned it 3 hours late. How much was his total bill for the rental and the fine?

C) What is the value of the expression $3 + 4 \times 6 – 2(5 \times 8)$?

Sample of equivalent questions in the second task:

A) To do a 12-page report, a word processor charges $26.50. His fee includes a $2.50 delivery charge. How much does he charge per page?

B) Mr. Smith rented a car for 7 days. The car rental charges 500 $ per week and a fine of 15% for each day the car is returned late plus a handling fee of 15 $. He returned the car 2 days late. How much did he have to pay in the end?

C) Evaluate the following expression: 4(12 – 9)2.

Figure 1: Sample of math problems

Mathematical Tasks

Two mathematical tasks were presented to the participants. Each task consisted of a set of 24 math problems comparable to original GRE and SAT math items (for samples of these questions please refer to Figure 1). The math problems were selected out of a larger set of questions pretested with regard to their difficulty. By pretesting the problems we made sure that both tasks have approximate levels of difficulty and require the same sets of skills. Also, tasks had enough number of questions to prevent ceiling effects due to participants finishing all the math problems in less than ten minutes. To avoid an improvement in performance in the second task due to simple learning/practice, the math problems were modified with regard to their wording and surface features. This way the first and the second task appeared distinct from each other while they still each required the same set of skills.

Rapport Agent

Participants interacted with a female or male virtual agent with a human-like appearance. Four different characters were used: two male and two female (Figure 2) to control for possible effects of particular agents. We used the Rapport Agent developed by Gratch et al. (2006). To create rapport with the participant, the agent displayed positive listening behaviors (such as nodding and smiling) that correspond to the verbal and nonverbal behavior of a human speaker. Previous studies of the rapport agent have shown that it is highly capable of creating the experience of rapport comparable with a face-to-face condition (Gratch et al., 2006, 2007a, 2007b). To produce listening behaviors, the Rapport Agent first collects and analyzes audiovisual features from the speaker's voice (silence, speech) and upper-body movements (head nod, smile, eye gaze) in real time. This happens via a microphone and a Videre Design Small Vision System stereo camera, which was placed in front of the participants to capture their movements. Watson, an image-based tracking library developed by Morency (2005), uses images captured by the stereo camera to track the participant's head position and orientation. Acoustic features are derived from properties of the pitch and intensity of the speech signal using a signal processing package, LAUN (Gratch et al., 2006). The Rapport Agent displays behaviors that show that the animated character is "alive" (eye blinking, breathing), and listening behaviors such as posture shifts and head nods automatically triggered by the system corresponding to participants' verbal and nonverbal behavior. This allows the agent to provide contingent feedback while the speaker is speaking by following a response model (Huang et al., 2011) to decide which behavioral response would be most appropriate (such as head nod or smile). The different animations are converted into Behavior Markup Language (BML) (Kopp et al., 2006), send to an action scheduler (to determine the duration of each animation) and passed on to Smartbody, an animation system that blends the different animations naturally into each other (Thiebaux & Marsella, 2007). The commercial game engine Gamebryo then renders the animations and displays them to the user.

Figure 2: Agents used in the experiment

Procedure

After an explanation of the study and obtaining consent, participants were led to a private room where they completed the experiment individually. Participants were seated at a desk with two monitors that were positioned next to each other. They were then instructed to work on a mathematical task for ten minutes, which was presented as a computer-based survey on one of the monitors. The second monitor was turned off at this point. To minimize self-presentation concerns, the anonymity of task performance results and the non-competitiveness of the task were emphasized. The experimenter left the room for the duration of the working period. Participants' answers were not reviewed by the experimenter and they were not given any performance feedback. Next, the experimenter provided detailed (verbal and written) instructions on the following interaction with the virtual agent. It was emphasized that the agent is a computer program and that participants will be alone during their interaction period. The agent was then launched and displayed on the second monitor. The experimenter would leave the room before the interaction started and then would control the virtual agent's speech over a separate computer in a different location, without the participants' knowledge. The agent' nonverbal behaviors were automated by the system according to the condition (rapport/no rapport) as described above. First, the agent asked how the participants estimated their performance on a 5-point Likert-scale (*very poor* to *very good*). Next, they were asked to rate how difficult they thought the math problems were on another 5-point Likert-scale (*easy* to *hard*). This was followed by the second task period that was part of the interaction. The agent would instruct the participants to load the task on the other monitor and work on it for a time period of ten minutes. During that time the agent reminded the participants twice of the time remaining (5 minutes and 1 minute left) and also let them know when time was up. Afterwards, the agent asked the participants to estimate their performance with regard to the second task on the same scale. At the last part of the interaction, the agent interviewed the participants concerning their experiences while working on the tasks and their attitudes towards mathematics in general. Then, the agent would announce the end of the interaction and would disappear from the monitor. Finally, situational motivation and demographic variables were measured in a post survey without the virtual agent visible or the experimenter present. Subsequently, participants were debriefed. During debriefing it was made sure that participants had not been aware during the experiment that the experimenter or any other human was involved and/or had any part in the interaction (for an overview of the study flow, see Figure 3).

Results

We first verified that agent appearance did not affect the results. As anticipated, there were no significant differences between agents with the same gender but different appearances. Therefore, the data was collapsed for further analysis.

There was an overall improvement of performance between the first task when the agent was absent (M = 3.86, SD = 2.72) and the second task when the agent was present (M = 5.49, SD = 3.33, $t(73) = -7.29$, p = 0.001). Also, self-evaluation of participants increased from the first task (M = 2.93, SD = 1.00) to the second task (M = 3.15, SD = 1.08, $t(73) = -2.44$, p = 0.017). Moreover, Participants showed significantly more effort by attempting to solve more math problems in the second task, when the agent was present, (M = 10.01, SD = 3.67) compared to the first task (M = 8.41, SD = 3.49; $t(73) = -4.70$, p = 0.001).

A 2 X 2 ANOVA, with the first factor being the display of rapport by the agent (rapport/no rapport) and the second factor being the gender condition (matching gender/opposing gender) showed a main effect of rapport on the improvement in performance ($F(71) = 4.96$, p = 0.029) (Figure 4). When the agent displayed rapport (M = 2.09, SD = 1.96), participants showed a significantly higher improvement in performance than without rapport (M = 1.21, SD = 1.79; $t(72) = 2.02$, p = 0.047). Specifically, in the opposing gender condition, there was a significant difference between the rapport (M = 2.56, SD = 1.59) and no-rapport conditions (M = 0.87, SD = 1.92), with

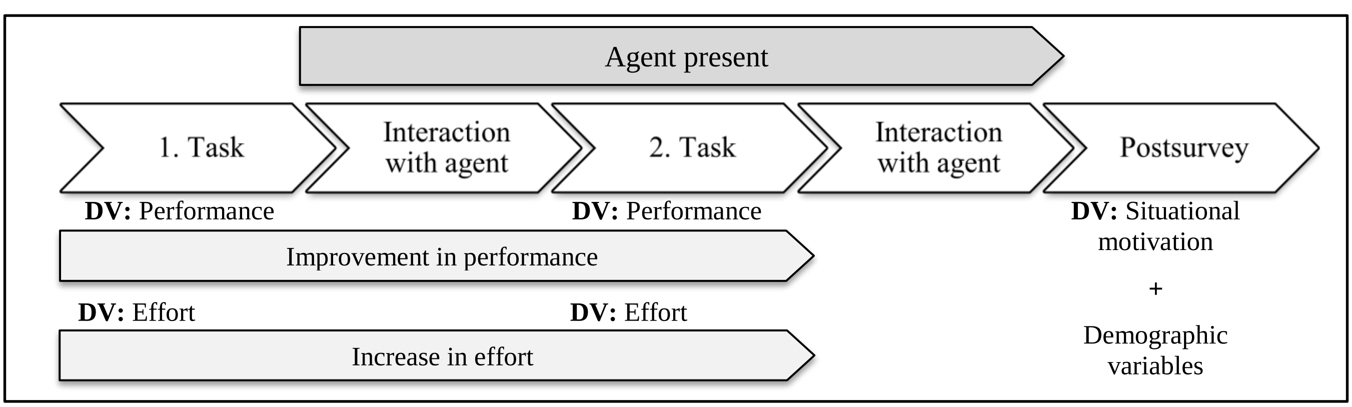

Figure 3: Study Flow

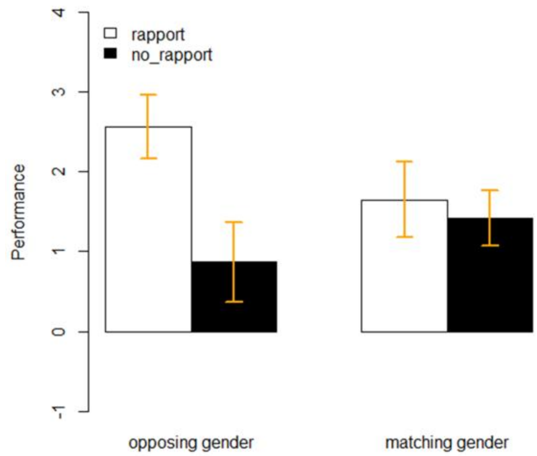

Figure 4: Performance Improvement

significantly higher performance in the rapport condition (t(29) = 2.68, p = 0.012). The difference in improvement in the no-match condition did not reach significance.

We expected performance improvement to occur due to an increase of effort and motivation, thus we used one-tailed t-tests for these two variables. In the opposing gender condition participants invested more effort when rapport was displayed (M = 2.25, SD = 3.17) compared to no displayed rapport (M = 0.27, SD = 3.37, t(29) = 1.69, p = 0.051). In the opposing gender condition, there was a significant trend in increase of motivation between the rapport (M = 63.50, SD = 8.16) and no rapport (M = 56.13, SD = 12.78) condition (t(29) = 1.93, p =.032). Within the matching gender condition the display of rapport did not show any influence on the dependent variables.

Discussion

We expected that facilitation effects to occur when participants interact with a virtual agent of opposite gender and that this will only be the case if the agent displays rapport. The results of this study support these hypotheses. When rapport was displayed, participants' improvement was higher when they interacted with an agent of opposite gender than with an agent of matching gender. The same patterns were found for effort. This indicates that a social facilitation effect only occurs under a certain gender condition, i.e. opposing gender, and when rapport is displayed by the agent. Participants' performance improved most when they interacted with a virtual agent of opposite gender that displayed rapport and it improved least with an agent of the opposite gender who did not display rapport. This indicates that rapport has an effect on participants' improvement in performance only when the agents' gender does not match their own. Research in social psychology has shown that establishing rapport between people and their instructors in face-to face interactions increases desirable outcomes such as motivation and improvement in task success (Granitz et al., 2009; Thomas et al., 1982). Our results show that rapport has a similar positive effect on performance in human-computer-interaction.

Overall, interacting with a virtual agent significantly enhanced participants' performance and effort. Our findings indicate that interacting with virtual agents of opposite gender that are capable of displaying rapport behavior improves participants' performance on mathematical tasks most. It supported participants' motivation and increased their effort to perform well by attempting to solve a higher number of math problems. We hope to further examine whether and how gender differences play a role in this interaction.

Conclusion

In summary, contributions of this work are three-fold. First, the study adds to literature on human-computer-interaction with regard to virtual agents by showing that the agent's gender and rapport are both key factors for achieving desirable outcomes such as motivation, effort and performance with regard to mathematical tasks. Virtual Agents which are capable of establishing rapport can contribute to improve people's performance in mathematics, specifically with regard to standardized math tests. This observation may support the development of useful and effective applications in mathematical education and training, such as virtual instructors, tutors or learning companions. Second, it shows that social facilitation effects occur when interacting with virtual agents of opposing gender. Finally, this work makes a methodological contribution to the fields of experimental psychology and human-computer-interaction.

Acknowledgments

This research was supported by the National Scientific Foundation under grant # IIS-0916858. The first author received support by the PROMOS Program of the German Academic Exchange Service (DAAD).

References

Baylor, A. L. & Ryu, J. (2003). Does the presence of image and animation enhance pedagogical agent persona? *Journal of Educational Computing Research*, 28(4), 373-395.

Garau, M., Slater, M., Pertaub, D. P. & Razzaque, S. (2005). The responses of people to virtual humans in an immersive virtual environment. *Presence: Teleoperators and Virtual Environments*, 14, 104-116.

Granitz, N. A., Koernig, S. K., & Harich, K. R. (2009). Now it's personal: Antecedents and outcomes of rapport between business faculty and their students. *Journal of Marketing Education,* 31(1), 52-65.

Gratch, J., Okhmatovskaia, A., Lamothe, F., Marsella, S., Morales, M., van der Werf, R. J., et al. (2006). Virtual Rapport. *6th International Conference on Intelligent Virtual Agents*. Marina del Rey, CA: Springer.

Gratch, J., Wang, N., Gerten, J., Fast, E., & Duffy, R. (2007a). Creating Rapport with Virtual Agents. In C. Pelachaud, J.-C. Martin, E. André, G. Chollet, K. Karpouzis, & D. Pelé (Eds.), *International Conference on Intelligent Virtual Agents 2007. LNAI 4722* (pp. 125-138). Paris, France: Springer Verlag Berlin Heidelberg.

Gratch, J., Wang, N., Okhmatovskaia, A., Lamothe, F., Morales, M., & Morency, L. P. (2007b). Can virtual humans be more engaging than real ones? In J. Jacko (Ed.). *Human-Computer-Interaction, Part III, HCII 2007. LNCS 4552*, 286–297. Beijing, China: Springer Verlag Berlin-Heidelberg.

Guay, F., Vallerand, R. J. & Blanchard, C. (2000). On the Assessment of Situational Intrinsic and Extrinsic Motivation: The Situational Motivation Scale (SIMS). *Motivation and Emotion*, 24 (3), 175-213.

Guerin, B. & Innes, J. M. (1982). Social facilitation and social monitoring: A look at Zanjonc's mere presence hypothesis. *British Journal of Social Psychology*, 2, 7-18.

Hayes A. L., Ulinski, A.C. & Hodges, L. F. (2010). That Avatar Is Looking at Me! Social Inhibition in Virtual Worlds. In: Allbeck, J. et al. (Eds.). *International Conference on Intelligent Virtual Agents 2010, LNAI 6356*, 454-467.

Huang, L., Morency, L. P. & Gratch, J. (2011). Virtual Rapport 2.0. In: *International Conference on Intelligent Virtual Agents.*

Kim, Y. (2004). *Pedagogical agents as learning companions: The effects of agent affect and gender on learning, self-efficacy, and agent persona.* Tallahassee, FL: United State University.

Kopp, S., Krenn, B., Marsella, S., Marshall, A. N., Pelachaud, C., Pirker, H., Thrisson, K. R. & Vilhjlmsson, H. (2006). Towards a common framework for multimodal generation: the behavior markup language. In: *International Conference on Intelligent Virtual Agents*, 21-23.

Morency, L. P., Sidner, C., & Darrell, T. (2005). Towards context-based visual feedback Recognition for Embodied Agents. *Proceedings of the Symposium on conversational Informatics for Supporting Social Intelligence and Interaction* (pp. 69-72). Hatfield, UK: AISB.

Rickenberg, R. & Reeves, B. (2000). The Effect of Animated Characters on Anxiety, Task Performance, and Evaluations of User Interfaces. *Letters of Computer-Human-Interaction 2000*, 49-56.

Sanders, G. S., Baron, R. & Moore, D. L. (1978). Distraction and social comparison as mediators of social facilitation effects. *Journal of Experimental Social Psychology*, 14, 291-303.

Thiebaux, T. & Marsella, S. (2007). Smartbody: Behavior realization for embodied conversational agents. In: *7th International Conference on Intelligent Virtual Agents.*

Thomas, D., Ribitch, F. & Freie, J.(1982). The relationship between psychological identification with instructors and student ratings of college courses. *Instructional Science*, 11(2), 139-154.

Tickle-Degnan L. & Rosenthal R. (1990). The nature of rapport and its nonverbal correlates. *Psychological Inquiry*, 1(4), 285-293.

Zanbaka, C., Ulinski, A., Goolkasian, P. & Hodges, L. F. (2004). Effects of Virtual Human Presence on Task Performance. In: *Proceedings of the International Conference of Additive Technologies 2004*, 174-181.

Zanbaka C., Ulinski, A., Goolkasian, P. & Hodges, L. F. (2007): Social responses to virtual humans: implications on future interface design. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems 2007*, San Jose, CA, USA, April 28 - May 03, 1561-1570. ACM, New York.

Zanjonc, R.B. (1965): Social Facilitation. *Science*, 149, 269-274.