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Changing Attitudes and Performance with Computer-generated Social Models

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Abstract. Women's under-representation in fields such as engineering may result in part from female students' negative beliefs regarding these fields and their low self-efficacy for these fields. Empirical evidence indicates that computer-generated interface agents are effective in influencing students' interest, motivation, attitudes, and self-efficacy. Hence, in this experimental study, we investigated the potential of interface agents to serve as effective social models for changing attitudes regarding the utility of math and the hard sciences and self-efficacy for these fields. 113 middle-school students interacted with either a female or a male computer-generated interface agent or they did not interact with an interface agent. The findings from this study indicate that interface agents may be used effectively as social models for influencing middle school students' attitudes and beliefs about mathematics and the hard sciences and their mathematical ability. Nevertheless, the efficacy of the agent depended on the characteristics of the agent with the female agent tending to be the most effective regardless of the subject gender.

Keywords. Anthropomorphic interface agents, persuasion, attitude change, computer-based social modeling

1. Introduction

In this experimental study, we investigated the potential of computer-generated agents to serve as effective social models in math and the hard sciences for middle-school students. Participants interacted with either a female or a male computer-generated social model or they did not interact with an interface agent. We investigated the influence of the social interface agents on students' attitude regarding the utility of math and the hard sciences and their self-efficacy for these fields. A math test assessed the implications of the exposure to the agent for students' mathematical ability.

1.1. Gender Differences in Sciences Related Fields

Although there is an evident increase in women's inclusion and success in professions that were traditionally occupied primarily by men, they remain under-represented in the fields such as engineering that require skills in mathematics and the hard sciences [1]. Women's under-representation in fields such as engineering may result in part from female students' negative beliefs regarding these fields and their low self-efficacy with regard to the abilities required for these fields [2].

Self-efficacy refers to the belief that one is competent to meet situational demands [e.g., 3, 4]. Research shows that female engineering students tend to perceive themselves as less competent than their male peers [1]. Those negative self-efficacy beliefs begin early. Girls as young as elementary age tend to underestimate their math ability, even though their actual performance may be equivalent to that of same-aged boys [5-7] and their computation skills are even slightly better in elementary school and middle school [8].

In addition to low self-efficacy, women and girls possess unproductive beliefs about math and the hard sciences, sex-typing science as a masculine pursuit [e.g., 9], and negating the utility of mathematics [6]. Such negative responses to math and the hard sciences may make young women less likely to pursue these areas and may lead them to stop taking classes in these fields from an early age. However, if young women are reached at a young age, it may be possible to change these unproductive beliefs about mathematics and the hard sciences.

1.2. Interface Agents as Social Models

According to Bandura [e.g., 10, 11], much of our learning derives from vicarious experiences. Social modeling of behaviors enables us to learn new behaviors, strengthens or diminishes previously learned behaviors, and reminds us to perform behaviors about which we had forgotten. Social models can also influence people's attitudes [12]. Observing a social model who is similar to the self perform a behavior in a domain provides people with information relevant to their likely self-efficacy in that domain [13]. Therefore, exposure to social models, particularly young, female models who are in the mathematic and the hard sciences fields, may be helpful for improving young women's attitudes and self efficacy regarding math and the hard sciences.

Providing young, female social models in math and the hard sciences to students may be problematic because it would contribute to the already burdensome workloads faced by women in nontraditional fields [14]. In addition, there may exist a possible lack of fit between available social models and the needs of individual students. Therefore, it would be useful to find alternative mechanisms for exposing young women to social models in the mathematics and hard sciences fields.

Interface agents are animated characters that provide teaching or mentoring within a computer-based learning environment. Empirical evidence indicates that interface agents are effective in promoting learning [e.g., 15, 16] and also metacognition [17]. Interface agents have also been found to positively influence student interest, motivation [18-21], and attitudes [22, 23]. Interface agents can also influence self-efficacy [22]. Thus, it may be possible to use interface agents as social models.

Extensive research has demonstrated that people tend to apply human social rules to computer technologies. Further, young women are particularly influenced by the communication and relational aspect of agents and may be more influenced by them than males [21, 24]. Therefore, interface agents, as simulated social models, may be particularly helpful in affecting young female's attitudes and self-efficacy with respect to math and sciences.

1.3. Purpose of Study

The purpose of the current study was to test whether computer-generated agents can serve as effective social models for math and the hard sciences for middle-school students. Participants interacted with either a female or a male computer-generated interface agent or they did not interact with an interface agent. A questionnaire assessed participants' attitudes regarding the utility of math and the hard sciences and their self-efficacy for these fields. A math test assessed the implications of the exposure to the model for students' mathematical ability.

Participants who interacted with an interface agent were expected to indicate more positive attitudes regarding the utility of math and science and greater self-efficacy for math than participants who did not interact with an interface agent. These findings were expected to be particularly strong if the interface agent matched the gender of the participant (i.e., girls would be more influenced by the female interface agent).

2. Method

2.1. Participantsd

Sixty-five females (age M = 13.78, SD = 1.15), and 48 males (age M = 13.87, SD = 1.07) middle-school students participated during a regular scheduled class session. Of the participants, 53.1% were Caucasian, 28.3% were African-American, 1.8% were Asian/Asian American, 8% were Hispanic/Latino, 5.3% were multiracial, 0.9% defined their ethnicity as "other", and 2.7% did not report their ethnicity.

2.2. Research Design and Independent Variables

The study employed a 2 (Participant Gender: male vs. female) x 3 (Interface agent: female vs. male vs. no interface agent) between subjects factorial design. Participants interacted with either a female or a male computer-generated interface agent or they did not interact with an interface agent. All participants filled a questionnaire that was designed to assess their attitudes and self-efficacy regarding engineering-related fields and their mathematical ability.

In previous related work, we found that attractive agents were more influential as social models for engineering [21]. In addition, we found that among the attractive agents, the young and cool were the most influential [22]. Consequently, the agents for the current study were designed to be young (~25 years), cool (as manipulated by the agent's clothing and hairstyle), and attractive (as manipulated by the agent's facial features) and varied in their gender. Previous testing of the agents confirmed that participants perceived them as young, cool, and attractive [22]. The agents (see Figure 1) were created in Poser©.

Figure 1. Female and male young, attractive, and cool agents.

Audio files of human female and male were synchronized with the agents using Mimic2Pro© to create lip-synching and emotional expressions. Several deictic gestures (e.g., pointing a finger) were also included. These gestures were identical for all agents. A fully integrated environment was created using Flash MX Professional©.

2.3. Dependent Variables

Because mathematics and the hard sciences (e.g., chemistry, physics) are strongly related to the field of engineering and are important prerequisites for many types of engineering, we measured participants' attitudes and beliefs regarding these engineering-related fields. The dependent variables were perceived utility, self-efficacy, and career interest in these fields. In addition, we measured the participants' math ability.

The dependent variables were all measured using a 7-point, Likert-type scale. Items for these scales were duplicated, so that half of the items in each scale referred to math and half referred to the hard sciences. Eight items assessed participants' beliefs about the utility of engineering ($\alpha = .87$; e.g., "I would have many good career opportunities if I was a hard science major"). Ten items assessed students' self-efficacy in engineering-related fields ($\alpha = .87$; e.g., "I have always done well in math"). Two items assessed students' interest in having a career in engineering-related fields ($\alpha = .62$; "How likely would you be to take a job in a hard sciences related field?"). Finally, eight multiple-choice questions assessed the participants' math ability.

2.4. Research Environment

Each student was randomly assigned to one of the three conditions (Interface agent: female vs. male vs. no interface agent). In the first two conditions, the assigned agent (set in a coffee shop location) introduced itself and provided a twenty-minute narrative about four female engineers, followed by five benefits of engineering careers. Both the female and the male agents provided exactly the same narrative. This script was validated as effective in Baylor and Plant [21]. Periodically, the participants interacted with the agent to continue the presentation.

2.5. Procedure

The experiment was conducted in a regularly scheduled class session where students accessed the online module through a web-browser (see Figure 2 for screen-shot).

Following completion (or immediately in the case of the control group), participants answered the online post-survey questions.

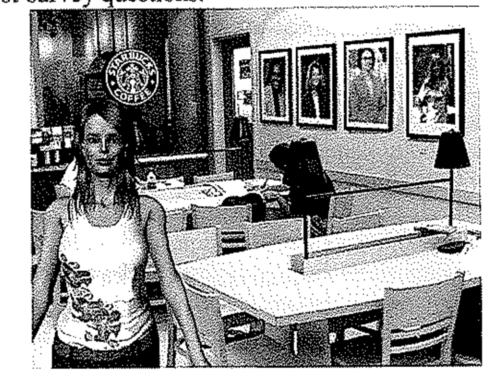

Figure 2. Sample screenshot.

3. Results

To determine the impact of the interface agents and the different impact of the female and male agents, a series of 2 (participants' gender: female vs. male) x 3 (Interface agent condition: female vs. male vs. no agent) between-groups ANOVAs were performed on each of the key dependent variables. Post-hoc tests were conducted where relevant (see table 1).

The analysis for utility revealed a significant main effect of interface agent condition, $F(1, 112)=3.26$, $p < .05$. Participants who interacted with a female computer-generated interface agent expressed significantly more positive beliefs about math and the hard sciences' utility than participants who did not interact with an agent ($d = .64$). The male agent condition fell in between and did not significantly differ from either the no agent or female agent condition.

The analysis for self efficacy revealed a significant main effect of interface agent condition, $F(1, 112)=4.92$, $p < .01$. Participants who interacted with a computer-generated interface agent expressed significantly greater self-efficacy for their performance in engineering-related fields than participants who did not interact with an agent (female vs. no agent, $d = .79$; male vs. no agent, $d = .68$). There was no significant difference between the female agent and the male agent conditions.

The analysis for career interest revealed a significant main effect of interface agent condition, $F(1, 112)=4.71$, $p < .01$. Participants who interacted with a female computer-generated interface agent expressed significantly greater interest in engineering-related careers than participants who did not interact with an agent, ($d = .62$) and than participants who interact with the male agent ($d = .66$). There was no significant difference between the no agent condition and the male condition.

Finally, the analysis for math performance also revealed a significant main effect of interface agent condition, $F(1, 112)=4.09$, $p < .05$. Participants' performance on the math test was significantly higher when they interacted with a female computer-generated interface agent than when they did not interact with an agent, ($d = .66$). Participants who interacted with the female agent also performed marginally better on the math test ($p = .06$) than those who interacted with the male agent ($d = .40$). There was no significant difference between the no agent condition and the male condition.

[illegible]

DV	F	Condition	M	SD
Utility	3.26*	No agent	4.39 [a]	1.64
		Female agent	5.33 [b]	1.28
		Male agent	4.88 [ab]	1.29
Self efficacy	4.92**	No agent	3.44 [a]	.73
		Female agent	4.02 [b]	.74
		Male agent	3.93 [b]	.70
Career interest	4.71**	No agent	2.70 [a]	1.24
		Female agent	3.40 [b]	1.01
		Male agent	2.67 [a]	1.21
Math test scores	4.09*	No agent	3.55 [a]	1.73
		Female agent	4.65 [b]	1.62
		Male agent	4.00 [ab]	1.65

Note: Significance of F values is identified by * at the .05 level and by ** at the .01 level. Differing superscripts indicate significant differences between means on post hoc tests.

4. Discussion

The current work examined whether computer-generated interface agents can serve as effective social models for math and the hard sciences for middle-school students. Participants interacted with either a female or a male computer-generated interface agent [illegible] an interface agent. Supporting our hypothesis, the findings from this study indicate that interface agents may be used effectively as social models for influencing middle-school students' attitudes and beliefs about mathematics and the hard sciences as well as their actual mathematical ability. However, the effectiveness of the agent depended on the characteristics of the agent with the female agent tending to be the most effective regardless of the subject gender.

Specifically, the female agent was significantly better than the no agent condition in influencing both females and males' beliefs about the utility of math and the hard sciences. In addition, females and males students who interacted with the female model performed significantly better on the math test. For both utility and mathematical performance, the male agent fell in between and was not significantly different compared to the female condition and the no agent condition. In addition, for both the females and males' interest in engineering-related careers, the female agent resulted in significantly more interest than both the no agent and the male agent.

However, for the students' self-efficacy, having an agent was better than not being exposed to an agent regardless of the model gender. That is, both the male and the female models were significantly better than the no model in increasing females and males' self-efficacy with regard to their performance in engineering-related fields.

Contrary to our hypothesis, the interface agents influenced females and males [illegible] effective for most of the [illegible] students [illegible] predispose them to view female social models as informative. It is also possible that the female model's positive impact was due to different factors for female and male students. The female students may have identified with the female model and seeing the female model may have led the young women to view these disciplines as welcoming to women. The male students, in contrast, may have been persuaded by the attractive female model that math and science are appealing disciplines where they might meet desirable women, a belief that is generally not a part of the stereotype of these disciplines.

Female computer-generated social models were especially effective for enhancing students' mathematical performance. For female students, exposure to the successful, female social model may have mitigated stereotype threat [e.g., 25, 26]. Stereotype threat is a disruptive concern that one may confirm a negative stereotype about one's social group which can result in impaired performance in relevant situations [26, 27]. Mitigation of stereotype threat is unlikely to explain male students' enhanced performance. However, it is possible that the males associate mathematics with attractive women after receiving the message from the attractive female agent, and this may have increased their motivation to do well in mathematics.

Although the current work provides some evidence of the efficacy of interface agents to improve responses to mathematics and the hard sciences, there were some limitations of the current work. One limitation of this study was that the students who were in the no agent group did not get a substitute treatment prior to filling the survey and answering the mathematical test. Significant results may be due to the existence of a treatment and not the interface agent itself. Nevertheless, for most of the dependent variables, only the female agent was significantly better than the no agent condition, thus, the effects cannot be contributed solely to the existence of a treatment. Another possible limitation was the lack of a pre-test control. A pre-test in this case would have exposed the participants to the content and purpose of the persuasive message, thereby negating the purpose of the study [illegible] expectancy or demand effects). Instead, we utilized a randomly-assigned, between-groups, experimental design. By randomly assigning participants to experimental conditions, we were able to examine differences between the experimental groups without cueing participants to the content of the persuasive message.

In addition, in the current study, we only manipulated the agents' gender. Other characteristics of the agent such as voice (e.g., computer-generated vs. human, tone, accent), persona (e.g., its personality, affective state), and animation (e.g., emotional expressiveness, deictic gestures) were held constant in this study. Future studies should consider such design elements and how they may potentially interact with the agent's gender.

To summarize, we found that computer-generated people can serve as effective social models for math and the hard sciences for middle-school students. In this study we assessed the students' attitudes and beliefs about mathematics and the hard sciences and their mathematical ability using a survey instrument. Of future interest will be measuring how the models actually affect students' choices with regard to their classes and future career.

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