Supporting learners with math anxiety: The impact of pedagogical agent emotional and motivational support

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Abstract. In this experimental study, 67 general education community college students worked with one of four animated agents, differing by motivational support (presence, absence) and affective state (positive, evasive), in learning word percentage problems. Student math anxiety level served as a co-variate in the analysis. Results indicated that the presence of agent motivational support had a significantly positive impact on student self-efficacy and student perception of the agent as human-like and engaging.

1 Introduction

Student math anxiety is problematic given its prevalence and negative impact on student performance, avoidance of mathematics courses, and career choice decisions (Betz, 1978; Resnick, Viehe, & Segla, 1982). Research on math anxiety (Morris, Davis, and Hutchings, 1981) suggests that dual components comprise math anxiety, one cognitive and the other emotional (Wigfield & Meece, 1988). The emotional component includes the nervousness, fear, and discomfort felt when doing math-related tasks, whereas the cognitive component includes the worrisome thinking about one's performance and potential negative consequences (Vance & Watson, 1994). Building on this dual component description of math anxiety, this study examined the effects of pedagogical agent emotional and motivational support on adult remedial math student motivation, perception, and learning.

To address the cognitive component of math anxiety, this study employed motivational support with pedagogical agents based on Bandura's (1997) verbal persuasion model, which has proven to be effective to enhance self-efficacy (Baylor & Kim, in press; Baylor, Shen, Kim, & Huang, 2003; Baylor, Shen & Huang, 2003) and women's beliefs toward engineering (Baylor & Plant, 2004). Bandura's approach implements strategies such as verbal suggestions, appraisal of ability, and assessment of activity to engender self-efficacy, or the belief about one's ability to accomplish a task, resulting in less worrisome thinking about one's performance and its potential

negative consequences, i.e., with regard to math anxiety, a decreased amount of the cognitive component of math anxiety.

While there is limited evidence that verbal persuasion is effective via pedagogical agents (e.g., Baylor & Kim, in press), there is no study that has examined the impact of verbal persuasion concomitant with emotional expression. Community college remedial students tend to have high levels of nervousness, fear, or discomfort toward mathematics, due to their prior experiences with math teachers and other influential persons. It would be expected that an agent with a more positive and upbeat affective state would affect them more positively than one with a more negative and evasive state.

These two factors, motivational support and agent emotion, serve as two levels of human face-to-face communication, each aimed at different, yet integrated, parts of the human social-cognitive framework. The question of interest in this study was to determine how these cognitive (e.g. motivational support) and socio-emotional (affective state) components of pedagogical agent communications impact student motivation, learning, and perception of support among students with high math anxiety.

2 Method

2.1 Participants

Sixty-seven GED (General Education Development) students enrolled in a large southeast community college in the United States participated in the study. 55.2% of the participants were male and 44.8% were female; 71.6% of the participants were African-American, 17.9% were Caucasian, and 13.5% were other ethnicity. The participants' average age was 22.33 years (SD=8.75).

2.2 Agent Format

Four three-dimensional animated agents were created by a graphic artist in People Putty© to represent the four conditions, differing by agent affect and motivational support. Since the majority of the participants were African-American, the agents were designed as such, given that prior research shows that learners prefer and are more motivated by working with agents of the same ethnicity (Baylor, Shen, & Huang, 2003).

2.3 Independent Variables

Motivational Support. There are two levels of motivational support for agents in this experimental study: 1) <u>with</u> motivational support; and 2) <u>without</u> motivational support. The two agents in the study shared the same scripts except that the agent

with motivational support had additional motivational comments. The various types of motivational support used in this study were included to promote learning and improve the student's attitude toward learning (Bandura, 1991, 1997; Locke & Latham, 1991). Please refer to Table 1 for examples of the types of motivational support.

Table one: Types of Motivational Support

Type of motivational support	Example
Verbal Suggestion	Try to repeat the four concepts in your mind: principal, rate, time and interest.
Affiliation	I'll be with you all the way.
Positive feedback.	So far you're doing great.
Self-efficacy	Just keep trying. You can do it.
Emotional support	Don't panic. Just take it easy and listen closely.

Affective State. Agent affective state had two levels: 1) positive and 2) evasive. The affective state of the pedagogical agents was controlled by facial expressions and vocal tone quality. The positive state was operationalized to have positive and upbeat facial expressions, with a high-energy voice. In contrast, the evasive state employed more negative and evasive facial expression (e.g., limited eye contact) with a calm and low-energy voice. The agents' facial expressions were controlled using the nine emotional indices in People Putty© software as illustrated in Table 2 below. The two states were validated by a team of researchers as effectively representing the two states.

Table 2: Operationalization of Agent Facial Expressions

People Putty© Emotional Indices	Affective state *Index (1=weak and 5=strong)*	
	Evasive	Positive
Happiness	2	5
Sadness	1	1
Anger	1	2
Mellowness	3	5
Suspicion	1	1
Curiosity	1	5
Ego	3	5
Aggression	3	5
Energy	1	5

2.4 Dependent Variables

Perceived agent persona. The Agent Persona Instrument (API) (Baylor & Ryu, 2003) was used to assess perceived agent persona. The API assesses factors regarding the extent to which the agent was perceived as credible, engaging, human-like, and facilitating of learning. There were 4-9 items per factor and each item was scored on a 5-point Likert-scale with 1 indicating "strongly disagree" and 5 indicating "strongly agree." The Cronbach's alpha for the overall reliability of the instrument was assessed at 0.97.

Self-efficacy. Learners' self-efficacy beliefs about the learning tasks were measured with a one-item question developed according to the guidelines of Bandura and Schunk (1981). The participants answered the question, "How sure are you that you can correctly solve a percentage word problem?" on a scale ranging from 1 (Not at all sure) to 5 (Extremely sure) before and after the intervention.

Learning. Learning was assessed by an open-ended question where the participants had to transfer their knowledge to a new situation. The participants were asked to work out a percentage word problem in steps, as illustrated in the following example:

> Use the four step process to solve the following problem (be sure to show your work and your steps): Nick borrowed $3200 from credit union at a rate of 8% for 6 month. How much total interest did he have to pay back?

The quality of the students' answers were evaluated by two researchers, who scored the students' answers with a detailed scoring rubric on a scale ranging from 1 (completely wrong) to 5 (completely correct). Inter-rater reliability was evaluated as Cohen's Kappa = 0.98.

Instructional Support. To better understand pedagogical agent effectiveness, students were asked "Why or why not did you like to learn from <the agent>?" Two researchers reviewed all of the answers and discerned four main themes: 1) agent was helpful; 2) agent provided self-paced learning; 3) agent was motivational/supportive; and 4) agent was fun. Answers were evaluated qualitatively according these themes and two researchers worked together to code each answer according whether the theme was present or absent. Disagreements were resolved through discussion.

2.5 Co-variate

Math anxiety served as a co-variate to control for participants' math anxiety, and was assessed by the AMAS (Abbreviated Math Anxiety Scale) (Hopko, Mahadevan, Bare, & Hunt, 2003). AMAS is a 9-item 5-point Likert-scale, ranging from 1 (low anxiety) to 5 (high anxiety). The Cronbach's alpha for the overall reliability of the instrument was assessed at 0.90.

2.6 Procedure

Participants in the study were randomly assigned one of four conditions: 1) Positive affective state with motivational support; 2) Positive affective state without motivational support, 3) Evasive affective state with motivational support; and, 4) Evasive affective state without motivational support.

Prior to beginning the module, learners were given a pretest on their anxiety level and self-efficacy toward mathematics. During the experiment, students worked within an agent-based research environment designed to help students learn how to solve percentage word problems. The agent learning environment had three phases (concepts, examples, practice). In the *concepts* phase, learners were taught the basic concepts of percentage word problems and how to use these concepts to solve percentage word problems. In the *example*s phase, learners were guided by the agent through two examples of percentage word problem. In the *practice* phase, learners interacted with the agent to solve a percentage word problem. Figure 1 shows a screen shot of the generic agent (implemented with differing affective state and motivational support). Once participants completed the three phases of the module, they answered questions regarding perceived agent value, anxiety, self-efficacy, instructional support, and learning. The entire module took approximately 40 minutes on average for students to complete.

Figure 1: Generic Agent

2.6 Design and Data Analysis

The study employed a 2 × 2 factorial design, including agent motivational support (with motivational support vs. without motivational support) and agent affective state (positive vs. evasive) as the two factors. For each of the four factors of perceived agent persona and learning, ANCOVAs (Analysis of Covariance) were conducted, using pretest math anxiety as the covariate. For self-efficacy, paired-sample T-tests were conducted to compare pretest self-efficacy with posttest self-efficacy. The significance level of all tests were set as $\alpha = 0.05$. The open-ended questions were coded and evaluated to better understand the agent's role in providing instructional and student support.

2 Results

3.1 Perceived Agent Persona

ANCOVA (Analysis of Covariance) revealed significant main effects for two of four API factors for motivational support: *human-like*, $F(1, 63) = 6.11$, $p<.05$ and *engaging*, $F(1, 63) = 4.19$, $p<.05$. Students perceived the agent with motivational support as significantly more human-like ($M = 3.83$, $SD = 1.02$) and engaging ($M = 4.03$, $SD = 1.09$) than the agent without motivational support ($M = 3.33$, $SD = 1.02$) ($M = 3.65$, $SD = .92$). There were no statistically significant main effects for agent affective state, and no statistically significant interactions.

3.2 Self-efficacy

Paired-sample t-tests were used to compare learner pretest and posttest self-efficacy for each of four conditions. Interestingly, all conditions showed a significant increase in self-efficacy *except for* the condition where the agent had an evasive affective state without motivational support.

Students who worked with the positive + motivation support agent significantly enhanced their self-efficacy from prior ($M=2.43$, $SD = 1.22$) to following the intervention ($M = 3.79$, $SD = 1.37$, $p < .001$). Students who worked with the evasive + motivation support agent also significantly improved in self-efficacy from prior ($M = 3.06$, $SD = 1.53$) to following the intervention ($M = 4.13$, $SD = 1.03$, $p < .001$). Similarly, students who worked with the positive without motivation support agent also significantly improved their self-efficacy ($M=2.42$, $SD = .96$; vs. $M = 3.84$, $SD = 1.43$, $p < .001$).

3.3 Learning

Across all conditions, students performed significantly better on the learning measure than prior to using the program, indicating that the instructional content of the program (which was constant across all conditions) was effective. While the learning scores for students working with the agents with motivational support ($M = 3.76$, $SD = 1.45$) were higher than the students who worked with agents *without* motivation support ($M = 3.44$, $SD = 1.56$), the difference was not statistically significant.

3.4 Instructional support

The most frequent student response was related to the *helpfulness* of the agent. Overall, thirty-four (50.7%) of the students made some reference to the agent as being "helpful" in some way, with comments such as: "he helped make things more clear,"

and “he helped me out in a way I thought nobody would.” Similar frequencies were reported when evaluated according to student ethnicity and gender.

Three of the four agent conditions tended to cite agent helpfulness as a key positive feature of the agent (ranging from 52-65%). This paralleled the quantitative finding regarding student self-efficacy, where these same three conditions significantly improved in self-efficacy. However, students working with the agent with an evasive affective state and without motivational support (i.e., the 4th condition) cited agent helpfulness to a much lower degree (29%); these same students did not improve in self-efficacy as reported previously.

4 Discussion

The evidence suggests that motivational support positively impacted learner self-efficacy, even when the pedagogical agent displayed an evasive emotional state. However, when the pedagogical agent exhibited high emotional energy *without* motivational support, the self-efficacy of the learners also increased, suggesting that the positive affect was sufficient to compensate for the lack of motivational support. Qualitative findings supported the relationship between perceived agent helpfulness and improvement in self-efficacy beliefs. Thus, the perceived “helpfulness” of the agent seems to relate to the ability of the agent to reinforce the student’s belief that the student can in fact perform the learned task, therefore reinforcing the student’s self-efficacy.

The lack of a main effect for agent affective state suggests that the agent’s emotional expression may be secondary, at least in this context, to its verbal persuasion (e.g., motivational support). This suggests that the inclusion of motivational support may result in greater return for improving student motivation. Along this line, the affective state of the agents did not impact student perception of them as perceived as human-like and/or engaging; instead, the presence of motivational support had a significant impact in these areas.

Several factors could have been attributed to the increases in learning across all conditions. First, the learners are, in general, intrinsically motivated to learn the material because it is highly relevant to their goal of passing the GED exam. Another possibility is a novelty effect that many, if not all, of these learners experienced in interacting with a pedagogical agent for the first time, as evidenced by such responses to the open-ended questions as: “it's something different then I had before, I really enjoyed it,” and “it was something new.” This novelty effect may have increased learner attention and focus, and thus impacted their learning.

The fact that learning significantly improved across all treatment levels could also be attributed to the inclusion of effective instructional design strategies in the learning modules (e.g., the inclusion of a step-by-step problem-solving strategy, consistent and coherent language, etc.) as well as the quality and thoroughness of the explanations. This argument is more probable when one considers that the designers involved in creating the learning modules were trained instructional designers with a strong background in teaching remedial math courses.

However, even though sound instructional design may have significantly impacted the immediate learning and performance of the learned task to a new situation, as the results of the study suggest, a learner's belief in his or her own ability to perform the task was not always consistent with the demonstration of successful learning. In other words, the one condition which did not show significant increases in self-efficacy was the condition *without* motivational support and with evasive emotion.

This result suggests that even with sound instruction that there should be a student support mechanism, either motivational or emotional, in place to reinforce a student's learning successes, and thus their self-efficacy, throughout the learning process. Without providing such support, learners may not sustain a belief in their own capabilities to perform the learned task over time.

Providing these types of student support in electronic learning environments could potentially be a critical factor in the future success of any learner. Especially when one considers that the students in the population of interest will be required to demonstrate their learning and perform under high stress testing conditions. These conditions require not only subject matter knowledge, but also require that a person possess a great deal of belief in one's own capability to perform and to demonstrate this knowledge, even more so because of the often stressful testing conditions.

Though not assessed through this study, the long-term effects of providing motivational support might help to sustain learners over the long term to remain engaged in the content and to return to learn within the agent-based learning environment, given that they tend to perceive the agent as more human-like and engaging. Future research could examine the long-term effects of providing pedagogical agent motivational support on sustaining learner engagement and commitment to learning in an agent-based learning environment.

Acknowledgments

This work was sponsored by National Science Foundation Grant # IIS-0218692

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