Can a pedagogical agent help reduce mathematics anxiety?

Q. Wei
Yanghee Kim, Utah State University

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Author(s)  Quan Wei, Western New England University; Yanghee Kim, Utah State University
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Can Pedagogical Agent Help Reduce Mathematics Anxiety?

Introduction

Affective factors in mathematics learning have been studied over the past three decades. Mathematics anxiety was one affective factor that has received greater attention. Hembree (1990) conducted a meta-analysis study on mathematics anxiety and concluded that there is a negative relationship between mathematics anxiety and mathematics performance. Although the cause of mathematics anxiety has not been determined, learners with higher mathematics anxiety are known to show a strong tendency to avoid mathematics, hold negative attitudes towards mathematics, have weak confidence in doing mathematics, and receive lower grades in mathematics courses in general (Ashcraft, 2002; Hembree, 1990; Ma & Xu, 2004). Also, gender difference exists. Girls display a higher level of mathematics anxiety than boys (Ashcraft, 2002; Campbell & Evans, 1997).

In order to help students reduce mathematics anxiety in classroom environments, a number of suggestions have been made, such as structured mathematics instruction, adaptive feedback, good study techniques, positive messages, and successful problem solving experiences (Hackworth, 1992). In addition, a number of clinical therapies have been developed, and their effectiveness has been examined. Among those, systematic desensitization, anxiety management training, and discussion of negative feelings that enable students to be aware of and positively cope with their fear of doing mathematics are recommended as effective methods in reducing mathematics anxiety (Dugas & Robichaud, 2007; Foss & Hadfield, 1993; Hackwory, 1992; Hembree, 1990; Wadlington et al., 1992).

With the rapid development of educational technology, an inquiry is being held into how to simulate such clinical practices in computer-based environments. Pedagogical agents (PAs),
animated life-like characters on the screen, have received increasing attention in education (Elliott et al., 1999; Johnson et al., 2000; Rickel & Johnson, 1999). Studies reported that, after learning from a PA in a computer-based environment, students demonstrate deeper learning, sense of ease and comfort, and higher motivation (Atkinson, 2002; Lester et al., 2001; Moreno et al., 2000; Moreno et al., 2001). The authors speculated that a PA’s capability of expressing emotions might help students with their mathematics anxiety. That is, some mathematics anxiety reduction techniques in the clinical practice might be implemented in the design of a PA so that the PA can stimulate anxious students to be aware of and manage their anxiety to restructure their beliefs about doing mathematics. This study investigated the impact of the anxiety treatment messages presented by a PA in computer-based mathematics learning environments on ninth-grade students’ mathematics anxiety and mathematics learning. Furthermore, the impact of the anxiety treatment messages on students with different prior mathematics anxiety levels (High vs. Medium vs. Low) was examined.

Research Questions

The study seeks to answer the following four research questions:

Q1: What is the impact of anxiety treatment messages provided by a PA on students’
mathematics anxiety?

Q2: Is there an interaction effect of anxiety treatment messages provided by a PA and learners’
prior mathematics anxiety on mathematics anxiety?

Q3: What is the impact of anxiety treatment messages provided by a PA on students’
mathematics learning?

Q4: Is there an interaction effect of anxiety treatment messages provided by a PA and learners’
prior mathematics anxiety on mathematics learning?
Method

Participants

Participants were 128 students enrolled in required introductory algebra in the 9th grade in a high school located in a mountain-west state of the USA. 45.3% of the students were male, and 54.7% of the students were female. 59.4% were Caucasian, 26.6% were Hispanic, 3.0% were African-American, 1.6% were Asian, and 9.4% belonged to other ethnicity groups. The average age of the students was 15.91 (SD = .96).

Materials

Instructional Material.

An online pedagogical-agent-based environment was used as the instructional material. The curriculum covered four topics in introductory algebra, following the Principles and Standards of the National Council of the Teachers of Mathematics (NCTM, 2000). Each topic made up one-class-hour lesson. Lesson 1 covered signed number arithmetic; Lesson 2 dealt with combining like terms and distribution; Lesson 3 covered factoring; and Lesson 4 dealt with graphing linear equations using slope and y-intercept. Each lesson consisted of 4 or 5 subtopics. Each subtopic included two learning phases: Review and Problem Practice. Figure 1 presents the example screens of these two phases.

- Review: At the beginning of every subtopic, students were given a brief review of the concepts that they had learned from their teacher in regular classes. A PA presented the review.

- Problem Practice: After the review, students practiced solving problems guided by a PA, who provided content-related feedback on student’s performance.
Mathematics anxiety treatment messages presented by a PA were modified from Dugas and Robichaud’s (2007) cognitive-behavioral therapy for generalized anxiety disorder. The treatment messages enabled students to be aware of and manage their anxiety while working on mathematics problems. For example, the PA asked the students “When you solve mathematics problems, what do you usually do?” If a student chose an answer, “Spending a long time in reading a mathematics problem before solving it because I am not sure that the way I use to solve the problem was right”, the PA responded like “Well, you may not feel confident about your work while solving the mathematics problems. Everyone’s lives are filled with uncertainty. However, with time and practice, you will find that worry will go away”. If a student chose an answer, “I always feel confident”, the PA told the student to keep doing good work.

**Independent Variables**

There were two independent variables: anxiety treatment messages (treatment vs. control) and students’ prior mathematics anxiety (low vs. medium vs. high). The students in the treatment group received both curriculum content-related information and feedback plus mathematics anxiety treatment messages that presented by a PA. In the control group, the students received only content-related information and feedback. Students’ prior mathematics anxiety had three levels, according to the distribution of participants’ pretest scores of mathematics anxiety ($M =$
28.97, $SD = 10.59$): the scores that were less than one standard deviation below the mean were set as low ($n = 25$); the scores that were greater than one standard deviation above the mean were set as high ($n = 24$); the scores that were in between one standard deviation below and above the mean were set as medium ($n = 79$).

**Measures**

*Mathematics anxiety.*

The subscale of Revised Mathematics Anxiety Rating Scale (RMARS), Learning Mathematics Anxiety, was used to measure students’ mathematics anxiety towards mathematics learning related activities. This instrument consisted of 16 items using five-point Likert scale ranging from 1 “not at all” to 5 “very much”. The pretest was implemented on the first day; the posttest on the last day. The duration between the pre and posttests was a week. Coefficient alpha to test the reliability of the items was .91 in the pretest and .94 in the posttest.

*Mathematics learning.*

Students’ mathematics learning was measured in immediate pre and posttests in each lesson. They were asked to solve a set of short-answer questions in the pretest (6 questions in Lessons 1-3, 10 questions in Lesson 4); at the end of the lesson, they were asked to solve a set of analogous questions (6 questions in Lessons 1-3, 10 questions in Lesson 4).

**Procedures**

The researchers implemented the study in a computer lab of the participating school, in collaboration with algebra teachers, for four days, one lesson per day. Each lesson took about 40 to 50 minutes. The overall procedures were as follows:

- The students were given a brief introduction to the lesson and interfaces. Then, they were asked to put on the headset and listen to the PA, Chris.
• They accessed the lesson web site and typed in their demographic information to start. At log-in, they were randomly assigned to the experimental conditions (treatment or control group).

• They took pretests (a mathematics anxiety test on the first day and a mathematics problem-solving test every day).

• They performed the learning tasks, listening to the content-related and anxiety treatment messages provided by a PA (the anxiety treatment messages only for the treatment group).

• They took posttests (a mathematics anxiety test on the last day and a mathematics problem-solving test every day).

Design and Analysis

A randomized pretest and posttest experimental design was employed. To answer research questions, two repeated ANOVA’s with one within-subjects factor (time) as repeated measures and two between-subjects factors (anxiety treatment messages and learners’ prior mathematics anxiety) were conducted, respectively for mathematics anxiety and mathematics learning. The significant level was set at $\alpha < .05$.

Result

Mathematics Anxiety

First, the result indicated that the anxiety treatment messages provided by a PA did not contribute to decreasing students’ mathematics anxiety. However, there was a significant interaction effect of anxiety treatment messages and students’ prior mathematics anxiety on mathematics anxiety over time, $F (2, 122) = 3.56, p < .05, \eta^2 = .06$. High-anxious students in the treatment group decreased their anxiety (mean decrease of 6.17) more than high-anxious students in the control group (mean decrease of 3.50); medium-anxious students in the treatment group
slightly increased their anxiety (mean increase of 0.74) whereas medium-anxious students in the control group (mean decrease of 3.57) decreased their anxiety; and low-anxious students in the treatment group remained their anxiety unchanged whereas low-anxious students in the control group increased their anxiety (mean increase of 3.33). Second, regardless of the treatment conditions and students’ prior mathematics anxiety, the students overall significantly decreased their mathematics anxiety at the end of the intervention, $F (1, 122) = 3.93, p < .05, \eta^2 = .03$.

Mathematics Learning

The results revealed that the anxiety treatment messages did not contribute to increasing students’ mathematics learning. However, students significantly increased their learning at the end of the intervention, regardless of the presence or absence of treatment messages and students’ prior mathematics anxiety, $F (1, 122) = 86.41, p < .001, \eta^2 = .42$.

Discussion

The study investigated the impact of anxiety treatment messages presented by a PA on mathematics anxiety and mathematics learning. First, the results revealed that the anxiety treatment messages presented by a PA did not contribute to decreasing students’ mathematics anxiety and increasing students’ mathematics learning. This might be because the treatment messages were not individualized but uniform to every student. Second, the anxiety treatment messages helped reduce the mathematics anxiety of high-anxious students but had the negative impact on medium-anxious students. The authors conjectured that the treatment messages might serve as a reminder of anxiety to exacerbate the students’ anxiety rather than help the students manage their anxiety. This finding implies that learners’ mathematics anxiety levels should be a factor to determine the effectiveness of any anxiety treatment efforts. Third, regardless of the treatment messages and students’ prior anxiety, the students in the study overall decreased their
mathematics anxiety and increased their learning after working with a PA. The presence of an agent might be contributive. Yet, to be confident in arguing for agent presence, subsequent research should compare the current agent-based intervention with a control group without the intervention.

The significance of this study is its examination of an attempt to simulate real-world clinical practices in a computer-based environment, through a digital virtual being (a PA). This approach, if shown effective, is much more scalable than the conventional expensive clinical therapy. Reasons for the less-than-desirable impact of the attempt might vary. The curricular learning loads might be too high, the implementation of the treatment messages might not be sufficiently sophisticated, or the duration of the intervention might be too short to expect the changes in a psychological state. At any rate, to continue this line of inquiry, a thorough analysis of clinical procedures must be preceded; then, a pedagogical agent should be adeptly equipped with clinical techniques, with the consideration of both opportunities and limitations of agent technology.

Reference


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