Addressing Affective States with Empathy and Growth Mindset

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ABSTRACT

We present results of a randomized controlled study that compared different types of affective support messages delivered by pedagogical agents. Results suggest that using a character that is empathic and emphasizes the malleability of intelligence and the importance of effort provides useful results in student learning, while reducing boredom and anxiety. Emphasizing success and failure ("That is correct/wrong") appears to be detrimental to learning and interest and promotes anxiety. We examine a variety of student affective, cognitive and engagement outcomes in an intelligent tutoring system for mathematics.

Keywords

Empathy, Affect, Growth Mindset, Pedagogical Agents.

1. Introduction

Ideally, digital learning environments should manage the delicate balance between motivation and cognition, promoting both interest and deep learning. Students' emotions can positively or negatively influence achievement outcomes; e.g., confidence, boredom, confusion, stress, and anxiety all influence student achievement [1][2] and affective predispositions such as low self-concept and pessimism diminish academic success [3][4][5][6]. As far as science, technology, engineering, and mathematics (STEM) topics are concerned, females, minorities, and students with learning disabilities experience more frustration and anxiety when solving problems than do their peers [7][8][9]. It is not surprising that these students also anticipate more barriers in STEM activities and more bias in their self-assessments [10][11]. Understanding how the environment might address negative emotions is especially important since it is experienced by most students, at various points in their learning.

Teachers attend to the affective needs of individual students [12][13], but they have limited means to recognize and respond to students' affect in a typical classroom. Given the reality of already burdened teachers and school systems, individualized education may only be achieved through adaptive tutoring technologies that supplement traditional classroom instruction.

Interest has emerged in affect-aware technologies, given the pivotal role that affect and motivation play in the success of learning activities. The overwhelming majority of this work to date, however, has focused on modeling affect, i.e., designing computational models capable of detecting how students feel while they interact with intelligent tutoring systems (ITS) [14][15][16][17][18]. While modeling affect is a critical first step in providing adaptive support tailored to students' affective needs, very little work exists on systematically exploring the impact of interventions on students' performance, learning, affect, and attitudes, i.e., how an environment might respond to students' emotions (e.g., frustration, anxiety, and boredom) as they arise.

One way to address students' affective state is to respond in affective terms, e.g., messages that support students' motivation to persist working on a task. However, which messages should a tutoring system, or pedagogical agent, send to students? How should pedagogical agents respond to affective states or traits of negative valence (e.g., frustration, confusion, anxiety, and lack of interest)? Should students be praised when they do well? This research focuses on how a system should address students when they are not doing well, when they make mistakes or when they show disengagement

We consider different possibilities for messages that animated affective characters deliver in a tutoring system. The testbed for our work is MathSpring[1], an intelligent tutor (ITS) for mathematics that personalizes math problems, provides helps using multimedia, and effectively teaches, helping students to improve in standardized test scores [19].

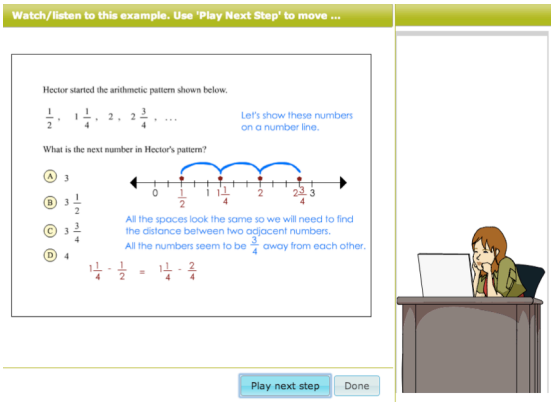

Figure 1. Learning companions use gestures to offer advice and encouragement (character currently showing high interest). Students can ask for hints within practice problems. Animations, videos, and worked-out examples (shown here) add to the spoken hints about the steps in a problem.

2. BACKGROUND RESEARCH

Praising Success. The traditional way for an ITS to respond to students is to report the correctness or incorrectness of their work and to congratulate them verbally or with a 'thumbs up' gesture when the work is correct; when the work is incorrect, a character might move its head from side to side or not show excitement.

Training Growth Mindset. Dweck's growth mindset theory [20][21] suggests that sudents who view their intelligence as an immutable internal characteristic tend to shy away from academic

[1] MathSpring is freely available at *http://mathspring.org*

challenges; whereas students who believe that intelligence can be increased through effort and persistence tend to seek out academic challenges. Students who are praised for their **effort** are much more likely to view intelligence as being **malleable**; and their self-esteem remains stable regardless of how hard they may have to work to succeed at a task. Additonally, praise for effort encourages perseverance. In our past work, we integrated learning companions (Figure 1) into *MathSpring*, which were able to train attributions for "success/failure", suggesting that effort is the cause for student success, and that mistakes are merely an indication that more effort needs to be exerted in the future to master this skill. About 20 different messages transmitted the idea that intelligence is malleable, perseverance and practice are needed to learn, that making mistakes is an essential part of learning, and failure is not due to a lack of innate ability (Table 1).

Table 1. Examples of messages spoken by the characters.

Condition	Message Example
Empathy	"Don't you sometimes get frustrated when trying to solve math problems? I do. But guess what. Keep in mind that when you are struggling with a new idea or skill, you're learning something, and you are becoming smarter."
Growth Mindset	"Keep in mind that when you are struggling with a new idea or skill, you're learning something, and you are becoming smarter."
Success/Failure	Correct → "Excellent job!" Incorrect → "Wrong. Shall we work it out on paper?"

In controlled randomized studies with hundreds of students, students in general and especially certain groups of students (females and students with learning disabilities) reported increased confidence levels and decreased frustration when working with learning companions that trained growth mindset in this way, compared to not receiving learning companions. In addition, student enjoyment, self-concept, and interest were higher compared to students not given learning companions, suggesting that such affective pedagogical agents can impact students' emotional states [7][9].

Empathic Learning Companions. To date, the Mathspring learning companions have not responded to learners' emotional states and have acted in a counseling manner regardless of student emotion. As a result, and despite positive significant effects for the overall population of students, characters seemed to have been "harmful" to a group of students (e.g., high achieving males), who had higher affective baselines at pretest time; the characters seem to have been distracters for this group of students. Characters were more effective for lower achieving students [9] and for female students in general [7]. These results suggest that affective characters should probably be different for students who are not presently frustrated or anxious (often high achieving males). One possibility is that the behavior of the **characters be adaptive to the affective state of the student**. For example, the empathic characters could verbally and visually display empathy after a student has reported a negative emotion in a two-phase process: The character would: (1) be empathic to a student's emotion saying that *they* are feeling that same way (e.g., "Sometimes I get [frustrated] when solving math problems") and (2) resolve the situation by training failure attributions and growth mindset, (e.g., "however, struggling in problems is actually a good thing, because it means that we are learning something new and becoming wiser", see Figure 2).

D'Mello and Graesser carried out close research work on empathic characters in AutoTutor, a conversational tutor that uses 3D companions to hold dialog in natural language with the student [22]. Affective AutoTutor maps dynamic assessments of learners' affective and cognitive states with tutor actions that address boredom, confusion, and frustration, which are sensed by monitoring conversational cues and other discourse features, gross body movements, and facial features [23]. AutoTutor responds with dialog-moves with emotional facial expression and emotionally modulated speech. For example, in response to a student's mild boredom it states: "This stuff can be kind of dull sometimes, so I'm gonna try and help you get through it." and in response to a student's confusion, "Some of this material can be confusing. Just keep going and I am sure you will get it". In comparison to a non-affective tutor, AutoTutor improved learning for low-domain knowledge learners, but was less effective at promoting learning for high-domain knowledge learners. Learning gains increased with the affective tutor whereas students' plateaued with the non-affective tutor [24]. The affective tutor resulted in a greater positive change in perceptions than did the non-affective one, and affective response was effective during the second session of use, but not during the first session [27].

Our research questions included: a) Can we achieve similar benefits using 2D characters (HTML-based) that are less realistic than 3D characters and do not use a natural language approach?; b) Are the benefits to student learning and emotion due to empathy of the companion, i.e., what kind of benefits would a less empathic, but still highly motivational companion afford?; and c) What are the results on learning and emotion of using an empathic or less empathic companion in comparison to a control companion

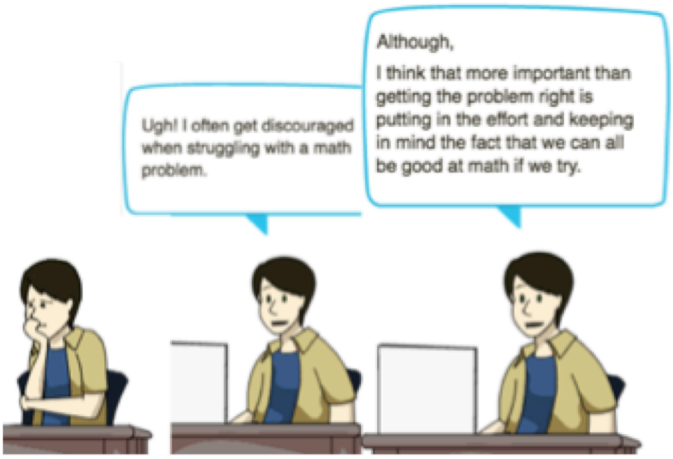

Figure 2. Learning companion empathizing to self-reported anxiety in three stages: visual acknowledgement of anxiety (left); verbal acknowledgement (middle); connector and resolution via growth mindset message (right).

that indicates only success or failure?

3. METHODS

We conducted a randomized controlled study during June 2014, with seventy-one (N=71) 7th grade students in an urban district in California.

Conditions. All conditions asked students to self-report the following emotions in a five point scale: frustration (unipolar emotion scale) and confidence/anxiety (bipolar scale)

approximately every five minutes in between math problems (MathSpring does not interrupt students while solving problems).

Students were randomly assigned to three conditions of characters delivering messages. All messages were given both in audio and written form, to guarantee the likelihood that they were exposed to the message. The conditions were: 1) *Success/Failure Condition*: provided traditional success/failure messages and some basic metacognitive support when students made mistakes (e.g., suggest that student asks for a hint after acknowledging the answer was incorrect); 2) *Growth Mindset Condition*: trained attributions for success and failure by emphasizing the importance of effort/perseverance and instilling growth mindset; 3) *Empathy Condition*: delivered empathic messages after the emotion is self-reported (and until the next emotion self-report five minutes later), in the following way:

a. If the last emotion reported had positive valence, the character visually reflected the positive emotion with a certain probability at each problem;
b. When the last emotion reported had negative valence, and with a certain probability, the character first visually reflected the negative emotion; second, it reported an empathy message such as "Sometimes these problems make me feel [frustrated]", third, a connector such as "on the other hand", last, resolved with a growth mindset message such as "I know that putting effort into problem solving and learning from the hints will make us learn and grow our intelligence".

Table 2. Outcome variables measured in this experiment[2]. The questions on the pre- and post-test were answered in a 5-point scale, going from "not at all" to "very much".

Math Test Performance- Students % score on math questions that are representative of the content covered in MathSpring. **Math value-** Measure of how important students think math is. "Compared to most of your other activities, how important is it for you to be good at math?" **Math liking**- Measure of how much students like math. "Do you like your math class?" **Learning Orientation-** Do students have a mastery/learning or performance orientation? "Some math classes have extra-credit projects. What kind of extra projects would you most like to do?" (1 if answered "An extra-credit project where I could learn about things that interested me." 0 otherwise) **Learning Goal**- Measure of how much of a learning goal students have when doing math (2 questions). "When you are doing math exercises, is your goal to learn as much as you can?" **Performance Approach Goals – "**Do you want to show that you are better at math than your classmates?"
Frustration- Measure of how frustrating students find math. Average of "Do you get frustrated when solving math problems?" and "Does solving math problems make you feel frustrated?" **Confidence-** Measure of how confident students feel in their ability to do math. "Do you feel confident that you will eventually be able to understand the mathematics material?" **Anxiety-** Measure of how anxious math makes students. Average of "Do you get anxious while solving math problems?" and "Do you worry that math class is much too difficult for you?" **Interest-** Measure of students' interest in math. "Are you interested when solving math problems?" **Boredom-** Measure of how boring students find math. "Do you feel bored to just think of your math homework assignments?" **Excitement-** Measure of how exciting students find math. "Do you feel that solving math is exciting?"

[2] The affective survey was based on instruments by [21][22][25][26]

There were some important details regarding the three conditions, namely: 1. The Success/Failure condition provided a response after getting the answer correct, and also after the second mistake made (as the first incorrect attempt triggered flashing the hint button); 2. The growth mindset condition provided one of a series of growth mindset messages after the second mistake (as the first incorrect attempt also made the hint button flash), and occasional growth mindset messages at the beginning of a new problem; however, the growth mindset condition occassionally provided some success/failure messages, as we did not want the characters to "preach" too much at every incorrect/correct attempt; for this same reason, the characters acted any response with a certain probability; 3. The empathy condition "empathized" at the beginning of a new problem with a certain probability, using both empathy and growth mindset messages as described before; however, it also used some success/failure messages as well as growth mindset messages after correct and second incorrect attempts, similar to the Growth Mindset Condition.

4. RESULTS

We analyzed the system log's descriptive statistics to determine which messages each group had received. All students were presented with Success/Failure messages to some extent, but students in the Growth Mindset condition should have been presented with more messages regarding growth mindset training (reflections of effort and meaning of mistakes) and students in the Empathy condition should have had access to empathy messages, along with some degree of growth mindset messages and success/failure messages.

Table 3. Means and Standard Deviations of total number of messages of different kinds, seen by students in each condition.

Condition	Total Empathy Messages Seen	Total Growth Mindset Messages Seen	Total Success/Failure Messages Seen
Empathy (N=14)	8.7 (3.0)	16.8 (7.4)	21.6 (12.1)
Growth Mindset (N=11)	0 (0)	20.9 (8.9)	28.8 (10.9)
Success/Failure (N=12)	0 (0)	0 (0)	33.7 (14.7)

Procedure. Students received a pre-test on day 1, used the system on days 1, 2 and half of the 3rd day, and took a post-test starting at the middle of the 3rd day. The measures used on the pre-and post-tests are shown in Table 2. Both pretest and posttest included mathematics questions, one for each area of knowledge covered in the tutoring system. The experiment was carried out at a distance (researchers were not present at the moment of the study). Instead, teachers were instructed to run the software. Students were matched with a character of their same gender, as this had resulted in a higher learning in previous studies with middle school students, and we expected that adding a gender mis-match would add further noise to our data [7]. As measuring gender effects was not the main goal of our study, we decided to match students to a character of their same gender.

First, we measured the total number of messages seen, Table 3. Only students in the "Empathy" condition saw expressions of empathy given by characters (either visual, verbal, or both), and that students in both the "Empathy" and "growth mindset" conditions had access to (verbal) growth mindset messages. All groups saw some level of "Success/Failure" messages, with the

Success/Failure condition seeing slightly more Success/Failure messages, on average.

We next analyzed pre to posttest gains. Unfortunately, we lost pre- and post-test data because of technical issues, which left us with N=37 students with full data.[3] We also had to match pre- and post-test data with within tutor data. Due to the low number of cases per each of the three conditions (total N=37), we decided not to carry out a cross-sectional between subjects comparison. Instead we analyzed partial correlations between exposure to the different messages indicated above and outcome variables (Table 2). We analyzed partial correlations between the total number of messages seen and a variety of post-test measures, while controlling for the corresponding pre-test measure, time spent in the tutor and total exposure to the character. The partial correlations between the total number of messages seen of each type and the post-test measures, each controlling for the corresponding pre-test measure, is shown in Table 4. We also accounted for exposure to the tutor (time spent in tutor overall) and exposure to the characters (total amount of visual or verbal character messages that the student was exposed to).

Table 4. Partial Correlations Between Specific Message Type and Post Test Measures for N=37 students, after accounting for the corresponding pre-test baseline, exposure to the tutor (time spent in tutor), and exposure to the characters (total messages heard of any kind delivered by the characters).

Variable Measured After Using MathSpring	Total Empathic Messages Seen[1]	Total Growth Mindset Messages Seen[2]	Total Success/Failure Messages Seen[3]
Math Post-Test Performance	0.34*	0.31+	-0.39*
Math Valuing Posttest	0.13	0.13	-0.16
Math Liking Posttest	0.25	-0.11	-0.14
Learning Orientation Posttest	0.10	0.26	-0.20
Performance-Oriented Goals	-0.24	-0.34*	0.33+
Frustration Posttest	-0.17	-0.09	0.17
Confidence Posttest	0.11	-0.10	-0.04
Anxiety Posttest	-0.43*	-0.16	0.40*
Interest Posttest	-0.16	-0.19	0.21
Boredom Posttest	-0.48**	-0.11	0.41*
Excitement Posttest	-0.22	-0.02	0.18

+p<0.1, *p ≤ 0.05, ** p ≤ 0.01

[1] Only students in the empathy condition had values higher than zero for this variable

[2] Students in the success/failure condition had zero values for this variable

[3] Students in all conditions had values higher than zero for this variable

We can observe significant correlations between the frequency of exposure of specific kinds of messages and outcomes. A significant correlation between math posttest and empathic messages received (after partialing out for incoming knowledge as expressed in the math pretest and general exposure to the tutor and characters) indicates that students **learned more as they received more empathic messages**. A near significant correlation between growth mindset messages seen and math posttest performance indicates a similar trend of learning more as more growth mindset messages are seen. On the other hand, **success/failure messages are negatively correlated** to math posttest suggesting that the more success/failure is emphasized, the less learning will be exhibited.

A significant correlation between performance-approach orientation and growth mindset messages received indicates that more exposure to growth mindset messages is related to **lower performance-oriented** goals; on the other hand, high frequency of success/failure messages appears to increase performance-oriented goals. After accounting for students' incoming math anxiety and general exposure to tutor/characters, the levels of **anxiety** reported by students after using the tutor were negatively correlated to exposure to empathic messages, suggesting that seeing **more empathic messages would help to decrease students' anxiety**. Conversely, high frequency of success/failure messages is correlated to higher anxiety reports. Similarly, after accounting for baseline boredom towards math and exposure to the tutor and characters, **boredom** reported at posttest time **was negatively correlated to exposure to empathic messages**, and instead, boredom was positively correlated to the frequency of success/failure messages received.

5. DISCUSSION

Some of our results align to expectations in the literature: characters delivering growth mindset messages (e.g., helping students to focus on personal progress and reflect on their errors) reduced performance-approach goals (e.g., to beat classmates in comparison to a norm instead of a self-referenced focus). This suggests that growth mindset messages work according to what they were supposed to accomplish. What was not expected was that growth mindset messages would provide an apparent boost in student math learning. Similarly, we expected that empathic characters would help decrease students' anxiety and boredom. This is consistent with results from D'Mello and Graesser [27], though for the overall tutoring session and with using simpler 2D characters instead of 3D characters. Learning companions that showed empathy helped with students' negative affective states, in particular anxiety and boredom. Again, we did not necessarily expect that exposure to empathic messages would yield higher math performance and learning, but having characters deliver empathic messages appears to provide a boost in student math learning with the tutor. More importantly, we did not expect that success/failure messages would be so harmful to students. Regardless of whether messages indicated success or failure, the more students are exposed to these kinds of messages, the higher boredom and anxiety they develop, the higher performance-oriented goals they develop, and the lower learning they exhibit at posttest time. Note students in all conditions received success/failure messages, with students in the success/failure condition receiving these messages the most.

In response to our initial research questions we have the following answers: a) we can achieve similar learning and emotional benefits with a 2D HTML-based character that is less realistic and does not process natural language; b) learning and emotional benefits are due to empathy, first, and second, some (less important) benefits are due to growth mindset (motivational) messages, specifically directed at performance/learning orientation; and c) a tutor that indicates only success or failure is harmful to students, at least in comparison to other messages that emphasize the learning process and the importance of effort.

[3] The data loss had to do with the pre/post-test surveys not being launched correctly by the software and incomplete student surveys in Survey Monkey, in which students failed to correctly enter their usernames or when mistakes occured when typing.

We conclude that characters within learning environments, such as intelligent tutoring systems, are either explicitly or implicitly powerful transmitters of affective messages, with repercussions that can be shown in students' affective states, predispositions and math learning.

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