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Examining Learners' Academic Achievement Emotions during Science Learning with an Intelligent, Hypermedia Multi-Agent System[1]

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Abstract. We used Pekrun et al.'s (2002) AEQ measure to investigate the relationship between college students' (N = 105) trait emotions and their emotional experiences with MetaTutor, an intelligent, multi-agent, hypermedia environment for learning about the human circulatory system. We also examined the relationship between learners' self-reported emotions and learning outcomes using their proportional learning gains. We also examined whether learners' emotional experiences significantly different between MetaTutor's two pedagogical agent (PA) scaffolding conditions: prompt and feedback (PF) and control (C). Results revealed that learners' trait and state emotions significantly differed, but that no significant differences existed between the two pedagogical agent conditions. We also found that emotions were not generally related to learning outcomes. These findings suggest that MetaTutor may have a dampening effect on learners' negative achievement emotions and prompts further study into the potential relationship between learning and the experience of neutral states.

Keywords. Emotions, mutli-agent systems, self-regulated learning, tutoring, scaffolding, and pedagogical agents.

Objectives and Theoretical Framework

Effective learning and students' experience of emotions are critically related (D'Mello et al., 2009; McQuiggan & Lester, 2009; Pekrun et al., 2011; Woolf et al., 2009). The interdisciplinary field of Affective Computing (Picard, 1997, Calvo & D'Mello, 2012) has arisen over the past decade to study emotions in computer-based learning environments (CBLEs), such as intelligent tutoring systems (ITS). ITSs are CBLEs that use artificial intelligence (AI) to respond and adapt to learners as they interact with the learning environment. ITS-learner interactions are handled by one or several embodied pedagogical agents (PAs) who provide learners with prompts (e.g., to use learning strategies, such as taking notes or coordinating informational sources) and feedback (e.g., on students' use of learning strategies, such as whether a page the student indicated was relevant to their sub goal is indeed relevant) that scaffold their learning and self-regulatory processes.

For affective computing research in ITSs, the objective is to design systems with embodied pedagogical agents (PAs) that use AI algorithms to detect, model, and adapt to fluctuations in learners' emotional states, in order to dampen negative emotions and

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facilitate positive emotions because of their impact on learning and problem-solving (e.g., Azevedo & Chauncey Strain, 2011; D'Mello, & Graesser, 2013; Conati & Maclaren, 2009; Harley, Bouchet, & Azevedo, 2012, in press; Lester, McQuiggan, & Sabourin, 2011; Rodrigo & Baker, 2011; Woolf et al., 2010). Despite the recent surge in interdisciplinary research on affective computing, little is known about many important facets of learners' emotional experiences with ITSs, such as how learners' emotions fluctuate over the learning session and whether they are related to the emotions learners' typically experience while studying. Additionally, few experimentally controlled studies have been conducted evaluating the influence of different PA scaffolding strategies on learners' emotions, despite a considerable amount of variance in the strategies deployed both within and between different ITSs (D'Mello, Lehman, & Graesser, 2011; D'Mello & Graesser, 2013; Harley, Bouchet, & Azevedo, 2012, in press; Rodrigo & Baker, 2011;). For example, MetaTutor has two PA conditions with different levels of adaptivity (see MetaTutor and Materials for more information).

This study, which has three primary *objectives,* attempts to address these gaps in the literature. The *first objective* of this study was to examine the relationship between learners' trait (more habitual, re-occurring emotions such as trait test anxiety) and concurrent and retrospective state emotions during their interactions with MetaTutor. MetaTutor is an intelligent, multi-agent, hypermedia environment for learning about the human circulatory system (Azevedo et al., 2010, 2012, in press). State emotions are emotions strongly tied to the learning activity, such as enjoyment while studying interesting material, and can be further distinguished as concurrent state emotions (the emotions learners are experiencing during the learning activity) and retrospective state emotions (the emotions learners report having experienced during the learning activity shortly after) (Pekrun, Goetz, Titz, & Perry, 2002). We used Pekrun's achievement emotion questionnaire (AEQ) and theory of control value achievement emotions (Pekrun et al., 2002, 2006, 2011) to accomplish this and our other objectives. Pekrun (2002, pp.4), in line with other emotional theorists (e.g., Gross, 2010), defines achievement emotions as "a set of interrelated psychological processes including affective, cognitive, physiological, and motivational components". Our *second objective* was to examine whether significant differences in learners' emotional experiences existed between MetaTutor's two PAs scaffolding conditions: prompt and feedback (PF) and control (C). Our *third objective* was to examine whether a relationship between learners' self-reported emotional experiences and learning could be identified.

Method

Participants

105 undergraduate students (65% female) from one large public university and one small, private university in North America participated in this two-session experiment. Participants were randomly assigned to one of two experimental conditions ($N = 50$ in PF; $N = 55$ in C). Participants were between 18 and 31 years old ($M = 20.85$; $SD = 2.63$) and were enrolled in various undergraduate programs, with 4.8% coming from biology or medical programs. Participants' self-reported GPAs ranged from 1.1 to 4.0 ($M = 3.21$; $SD = 0.50$). Participants were paid up to $40 for completion of the two-session four-hour experiment. Participants in the small, private university in North America had the option of receiving course credit for the first session of the experiment (1 hour).

MetaTutor and Materials

MetaTutor. In this study we used MetaTutor, a multi-agent ITS and hypermedia-learning environment which consists of 38 pages of text and static diagrams organized by a table of contents displayed in the left pane of the environment (see Figure 1; Azevedo, Moos, Johnson, & Chauncey, 2010). The version of MetaTutor used in this experiment was comprised of material (text, images, knowledge assessments) on the human circulatory system, which it is designed to teach participants about during their interaction with the system. MetaTutor's main interface consists of a timer, which indicates how much time remains for participants to learn about the human circulatory system, an SRL palette, where participants can initiate interactions (e.g., make metacognitive judgments regarding the relevance of the content, or enactment of a learning strategy such as summarizing science material) with one of four PAs depending on the action chosen. An electronic notepad is available for participants to take notes and access them at any time during the learning session, except during the post-test. MetaTutor also includes a dialogue history box which participants can open to review their previous interactions with the PAs (e.g., feedback on whether their proposed sub goal was too broad or too specific). Self-report questionnaires (e.g., AEQ) were administered using a Google Docs form embedded in the MetaTutor learning environment.

One of the four PAs is always visible in the upper right-hand corner of the learning environment, and each is responsible for specific tasks, such as certain self-regulatory processes, during the learning session. Specifically, Gavin the Guide provides guidance for participants in the learning environment and administers knowledge assessments and self-report measures, Pam the Planner prompts and scaffolds planning processes (e.g., prior knowledge activation, setting sub-goals), Mary the Monitor prompts and supports participants in their monitoring processes (e.g., judgment of learning), and Sam the Strategizer prompts participants to engage in learning strategies and ensures their use (e.g., note-taking, summarizing).

The PAs instructional strategies varied in nature, detail, and amount of scaffolding provided by the PAs in each of MetaTutor's two conditions. In the PF condition, learners were prompted by the PAs to use specific self-regulatory processes (e.g., metacognitively monitor their emerging understanding of the topic), and were given feedback about their use of those processes. The timing of the PAs' prompts was determined by various factors regarding the interaction between the learner and the agents (e.g., time on the page, time on current sub-goal, number of pages visited, relevancy of current page for the sub goal). In the C condition, participants did not receive prompts or feedback from the PAs.

Academic Emotions Questionnaire. The AEQ was used to assess the cognitive, motivational, and physiological components of emotions. The measure consists of 24 scales, which assess three classes of emotions: class-related, learning-related, and test-related. In the current study we used only the learning-related scale, which consisted of eight classes of learning-related emotions (i.e., enjoyment, hope, pride, anger, shame, anxiety, hopelessness, and boredom) assessed through 75 items. The AEQ is a flexible measure and the wording and instructions can be altered in order to assess learners' trait (more habitual, re-occurring emotions, such as trait test anxiety), course-specific, or situation specific (i.e., state achievement) emotions. Here, we used the instructional

manual (Pekrun et al., 2002) to adapt the AEQ in order to measure learners' learning-related (i.e., studying) trait and state (concurrent and retrospective) emotions with MetaTutor. The AEQ uses a 5-point Likert response scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). A sample item from the before studying section is "I look forward to studying". A mean score was derived for each learning-related trait emotion. Coefficient alphas for the learning-related scales ranged from .53 to .93.

Pre-test and post-test. Two equivalent 25-item multiple-choice tests on the human circulatory system were used in this study. Participants completed one version of the test as the pretest during session 1 and the other as the post-test during session 2. The order participants received the tests in was counter-balanced. The pretest was designed to assess participants' prior knowledge of the circulatory system and the post-test was designed to assess their knowledge about the circulatory system after interacting with MetaTutor for a one hour learning session. Each of the 25 multiple-choice questions included four foils: a distractor, near-miss, thematic, and correct answer alternatives. Both versions of the tests included text-based (which participants could respond to using one sentence within the content) and inferential items (which required participants to integrate the information from two sentences within the content).

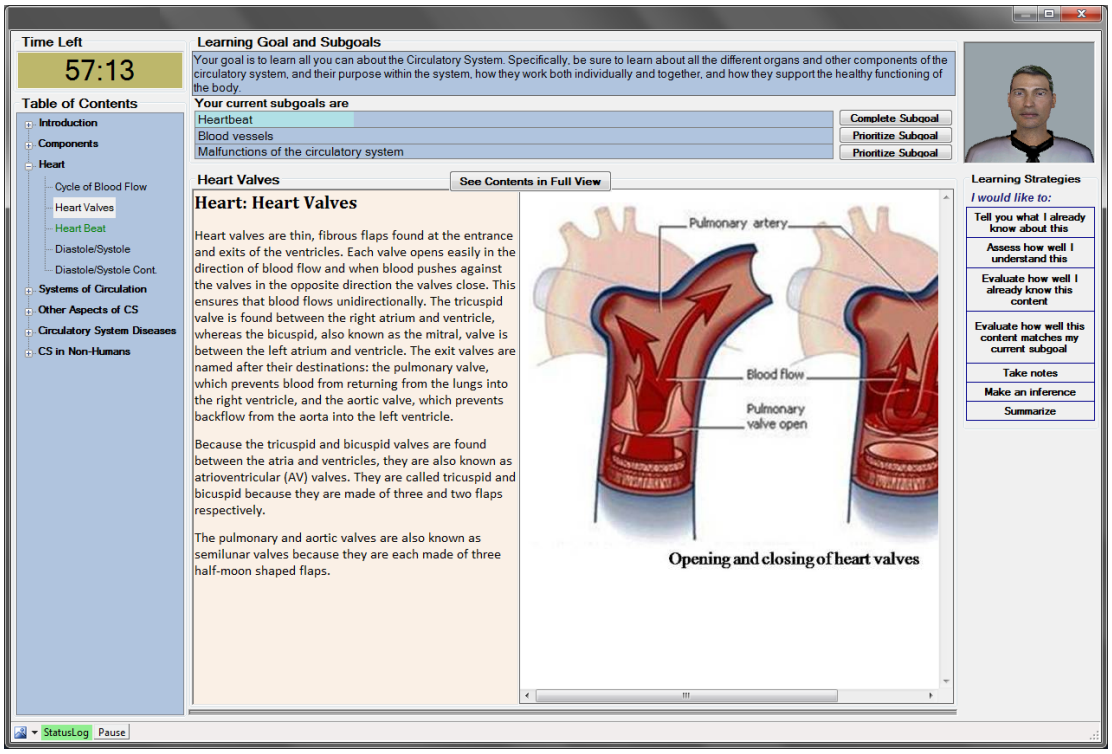

Figure 1. Screenshot of MetaTutor Interface

Experimental Procedure

The experiment consisted of two sessions (session 1 lasted approximately 30 minutes and session 2 lasted approximately three hours), which were separated by a maximum of three days or a minimum of one hour to avoid participant fatigue. During session 1, participants read and signed an informed consent form and were administered

several self-report questionnaires (e.g., demographics, mini-IPIP, AEQ-trait emotions) and a pretest assessing their knowledge of the human circulatory system. All participants completed the session individually on a desktop computer with a Core 2 Duo 2.80 GHz processor, 2GB of RAM and Windows XP, using a 17" monitor with a 1024x768 resolution. Participants were compensated up to $10 at the end of session 1 ($10/hr.) or given extra course credit.

During session 2, participants were shown an introductory video presenting information regarding the MetaTutor learning environment, including training on how to use different components and navigate through the system as well as how to verbalize their thinking (i.e., using a think-aloud protocol) whenever necessary throughout the experiment. A research assistant was present throughout the entire experiment and prompted participants to think-aloud if they were silent for more than three seconds (based on Azevedo et al., 2010; Ericsson & Simon, 1993). Participants were also provided with instructions on how to set and create their own sub-goals (e.g., path of blood flow) based on their overall learning goal[2]. Each participant was given an hour to learn as much as possible about the circulatory system using MetaTutor.

Halfway through the learning session, participants were prompted by one of the PAs (Gavin) to fill out the learning-related, concurrent state AEQ measure. After they finished filling it out participants were given the opportunity to take a five-minute break, though not all participants chose to take it. At the end of session 2, participants were asked to complete a post-test on the human circulatory system and the learning-related, retrospective AEQ measure. Lastly, all participants were debriefed and received up to $40 for participating in the study. A large amount of data was collected during Session 2, including additional questionnaires (e.g., AGQ), video, audio, screen recording, eye-tracking, log file, and physiological (e.g., GSR) data, however they are not reported in this paper. Sessions One and Two occurred at least one hour apart from each other and no more than four days apart.

Data Analysis

In order to examine learners emotions we conducted eight repeated measures ANOVAs (one for each emotion subscale the AEQ assessed) where time of administration of the AEQ (1 = trait, 2 = concurrent state, and 3 = retrospective state) was the within-subjects variable, PA scaffolding condition was the between-subject variable, and scores on the AEQ subscale (e.g., pride, enjoyment) were the dependent variables for each model. Except for hope and boredom, which were only assessed during the trait and concurrent state administrations (based on Pekrun et al., 2002), all emotions were assessed during all three administrations of the AEQ.

A series of bivariate correlations were also run examining the relationship between learning, using participants' proportional learning gain score ((posttest score − pretest score) / (1 – pretest); D'Mello et al., 2010) and each of the achievement emotions for each AEQ administration. Several cases produced solution outliers and were therefore deleted from the analyses (Tabacknick & Fidell, 2007). One additional participant was removed from all analyses because he/she selected the same maximum score (5) across

[2] To learn about all the different organs and different components of the circulatory system and their purpose within the system, how they work both individually and together and how they support the healthy functioning of the body.

all items for all emotional scales of the AEQ retrospective state emotion measure, which suggested inattention to the items.

Results

Research Question 1: What is the Relationship Between Learners' Trait and Concurrent and Retrospective State Emotions During Their Interactions with MetaTutor?

The repeated measures ANOVAs revealed a significant main effect of AEQ administration for all emotional states (see Table 1). Table 1 reveals that while all of the emotional states significantly varied over administration, large effects sizes (Cohen, 1988, partial eta squared; $\eta^2_p = 0.26$) were found for pride, shame, and enjoyment across the AEQ 1 through 3, and hope between the administration of AEQ 1 and 2.We used Fisher's least significant difference (LSD) test to make pairwise comparisons to determine if significant differences existed between the administration of the measures and examined the descriptive statistics to determine the direction of the differences (see Table 2). An examination of the descriptive statistics and pairwise comparisons revealed that learners' self-reported trait emotions were significantly higher for all emotions than concurrent state or (where applicable) retrospective emotions ($p < 0.05$), with the exception of hopelessness, which did not significantly differ for learners between their trait and retrospective scores. Learners' concurrent state emotions also significantly differed between their trait emotion and retrospective emotion scores ($p < 0.05$), with the exception of enjoyment.

Table 1

Summary of Repeated Measures ANOVAs for AEQ Measure and Follow-Up Pairwise Comparison Differences Using LSD Correction

Variable	*df*	*MS*	*F*	*p*	η^2_p
Shame	1.63, 168.05	19.52	47.50	0.000**	0.32
Anxiety	1.76, 181.50	14.61	29.50	0.000**	0.22
Anger	2, 206	11.58	25.02	0.000**	0.20
Pride	1.85, 190.37	35.91	86.41	0.000**	0.46
Enjoyment	1.86, 192.03	12.50	37.40	0.000**	0.27
Hopelessness	1.76, 179.46	3.07	8.32	0.001**	0.08
Boredom	1, 103	2.04	4.18	0.043*	0.04
Hope	1, 103	14.82	41.61	0.000**	0.29

* $p < 0.05$, ** $p < .01$

Table 2

Means, Standard Deviations, and Pairwise Comparisons For Each Administration of the AEQ by Emotion Scale

AEQ Scale	*Administration*			*Pairwise Comparisons (LSD)*		
	1	*2*	*3*	*AEQ 1 & 2*	*AEQ 1 & 3*	*AEQ 2 & 3*
	M (SD)	*M (SD)*	*M (SD)*	*M (SE)*		
Shame	2.60(0.85)	1.84(0.73)	2.06(0.89)	-0.76(0.08) **	0.53(0.09)**	-0.23(0.06) **
Anxiety	2.84(0.77)	2.13(0.73)	2.48(1.00)	0.70(0.08)**	0.36(0.11)**	-0.35(0.08)**
Anger	2.22(0.70)	1.91(0.90)	1.55(0.92)	0.30(0.09)**	0.66(0.10)**	0.36(0.10)**
Pride	3.93(0.60)	2.81(0.80)	3.24(0.98)	1.12(0.08)**	-0.69(0.10)**	-0.43(0.08)**
Enjoyment	3.52(0.58)	2.90(0.75)	3.00(0.91)	0.63(0.07)**	0.51(0.09)**	-0.11(0.12)
Hopeless	1.93(0.76)	1.62(0.75)	1.87(0.85)	-0.30(0.08)**	0.06(0.09)	-0.24(0.06)**
Boredom	2.57(0.82)	2.37(1.05)	NA	0.20(0.10)*	NA	NA
Hope	3.70(0.68)	3.16(0.83)	NA	0.53(0.08)**	NA	NA

* $p < 0.05$, ** $p < .01$

Note: The AEQ uses a 5-point Likert response scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

Research Question 2: Do Significant Differences in Learners' Emotional Experiences Exist Between MetaTutor's Two PA Scaffolding Conditions?

The repeated measures ANOVAs failed to reveal a significant main effect of condition or interaction effect between PA condition and administration of AEQ ($p < 0.05$).

Research Question 3: Does a Relationship Between Learners' Self-Reported Emotional Experiences and Learning Exist?

In order to assess the relationship between learners' achievement emotion scores and their learning outcomes with MetaTutor, we calculated learners' proportional learning gain score and ran a series of bivariate correlations using the Pearson's correlation coefficient where the critical alpha level was set at $p < .05$. We found no significant correlations between learners' proportional learning gain and trait emotion AEQ scores; one significant negative correlation between learners' scores on the hope subscale of the state AEQ and proportional learning gain, $r(103) = -.196$, $p < .05$; and for the AEQ retrospective emotion sub scale we found a significant negative correlation between learners' proportional learning gains and anxiety, $r(103) = -.228$, $p < .05$ and hopelessness, $r(102) = -.224$, $p < .05$.

Scientific Contributions of the Study

In summary, we found (1) that learners' scores on the different AEQ measures significantly differed, (2) that no significant differences existed between PA conditions for the concurrent state or retrospective state AEQ measures' subscales, and (3) that the relationships between learners' emotions as assessed by these measures were either not significantly related or were significantly negatively related, in the cases of learners' pride (concurrent state emotion), hopelessness (retrospective state emotion) and anxiety (retrospective state emotion) to their proportional learning gains on the circulatory system posttest.

Our first set of results demonstrates that the emotional experiences learners had with MetaTutor were different than those they typically experienced while studying. This result reveals an emotional dampening effect for learners during their interactions with MetaTutor where they report less strong experiences of both negative and positive emotions. What stands out, however, is the finding that learners experienced lower levels of negative emotions (e.g., boredom and anxiety) than they typically did while studying, which suggests that there are qualities of this ITS that have dampening effects for negative emotions. This has positive implications for students learning given that negative emotions such as boredom and anxiety distract and disparage students from learning. Positive emotions are known to facilitate learning, however, their presence is not required for students to learn. Therefore it is not practical to consider their low levels or absence as evidence that something is amiss. Furthermore, given the context of MetaTutor, as a discipline-specific learning environment unrelated to the discipline most learners (95.2%) typically study, it is logical that learners experienced weaker embodiments of positive emotions such as pride and enjoyment, especially since MetaTutor does not incorporate any game-like elements that could potentially enhance or make it intrinsically motivating to interact with (McQuiggan & Lester, 2009). This context makes it unlikely that most learners will make strong appraisals of task value, which is known to lead – in conjunction with appraisals of control – to the experience of negative achievement emotions (Pekrun, 2006). Therefore, the fact that students tended to experience modest levels of emotions during their interactions with MetaTutor should be regarded as an adaptive outcome.

It is also interesting to note in this set of results that learners' retrospective emotions, in all applicable cases except for anger, returned closer to their typical (studying) trait emotion levels, although they still differed significantly (except for enjoyment). These findings suggest that learners' experienced a meaningful shift in their emotions at some point during the second half of their learning session with MetaTutor. One explanation is that the post-test measure which learners filled out at the end of their learning session prior to filling out the AEQ retrospective state emotion subscale accounted for a large portion of this difference. This is a likely explanation because of the particular emotions (anxiety, shame, hopelessness, and pride) that returned to a higher intensity level and differed significantly from the concurrent state emotions. It is likely that learners who were either uncertain of their performance on the post test or thought they didn't do as well as they wanted to could experience anxiety, shame, or hopelessness, while those who felt optimistic about their results may have felt proud of themselves. It is also possible that students experienced these emotional intensity fluctuations as a result

of their progress in the second half of the learning session. For example, students may have felt less pride during their learning session at the half-way mark than they typically reported feeling during studying because they felt they still had a lot to learn and were uncertain of their ability to complete their sub goals. At the end, it is possible that these students who did complete their sub goals or simply felt they learned a meaningful amount, may have then felt proud when prompted to reflect back on their learning session. Future research distinguishing these two options is required and could prove valuable to understanding learners' emotional trajectories over time while learning with MetaTutor.

Our second result is consistent with and expands upon prior research with MetaTutor (Harley, et al., 2012, in press) where no significant differences in learners' emotions between PA conditions were identified. Harley et al. (2012) used automatic facial expression recognition software (FaceReader 4.0) to analyze learners' emotions during a sub phase of their interactions with MetaTutor. Harley et al., (in press) aligned a later version of the facial expression recognition software (FaceReader 5.0) to measure learners' emotions across the learning session and align it with learners' concurrent self-reported emotions on a 19-item emotion questionnaire. These re-occurring findings provide supporting evidence that the increased scaffolding that PAs provide in the PF condition may not help promote more positive emotions, but that this condition does not arouse more negative emotional states in learners. This finding reflects more positively on MetaTutor than some other, similarly non-emotionally adaptive, ITS analyses of differences between tutorial scaffolding prompts and feedback (D'Mello et al., 2009).

Finally, only three emotions across all of the AEQ measures and subscales were significantly related to learners' proportional learning gains. While this finding is not consistent with prior research using the AEQ (Pekrun et al., 2011), the authors are not aware of any research done using the AEQ with ITSs which represent distinct studying environments. It is possible, as Harley and colleagues (2012) propose, that learners may be better predisposed to learn with ITSs while in a more emotionally flat or neutral state, which could explain our lack of findings, as neutral states were not measured. Another likely explanation for the lack of relationship between emotions and learning is the lack of variance in learners' proportional learning gains (M = 29.93; SD = 45.47) stemming from a ceiling effect in the mean pretest scores (M = 18.96 [/ 25]; SD = 4.11). Current research is being conducted collecting new data with more challenging items.

In summary, the results of this study are helpful in providing specific information about learners' achievement emotions in the context of an ITS. Most importantly, the results suggest that there are elements of MetaTutor that dampen learners' experience of negative emotions during their interactions with it across both conditions relative to their trait studying emotions. Moving forward, we will compare and hope to replicate or improve upon learners' emotional experiences with MetaTutor as we evaluate new PA conditions (Bouchet, Harley, & Azevedo, in press).

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