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Measuring Learners' Unfolding, Discrete Emotional Responses to Different Pedagogical Agent Scaffolding Strategies

Jason M. Harley, François Bouchet, and Roger Azevedo
McGill University, Dept. of Educational and Counselling Psychology, Montréal, Canada
jason.harley@mail.mcgill.ca

Abstract. This study investigates learners' discrete emotional responses to a pedagogical agent's (PA) tutorial scaffolding strategies during their interactions with it while setting three sub goals for their learning session with MetaTutor. 24 undergraduate students from a large, research-intensive university participated in this study and were randomly assigned to one of the two scaffolding conditions (Feedback and Non-Feedback). Results revealed that the PA scaffolding strategy exerted a significant main effect on participants' embodiment of positive emotions (happiness) and that there was a significant interaction effect of PA scaffolding strategy and sub goal (within subjects measure) on participants' embodiment of neutrality. These results support the design of a tutorial strategy that is able to both scaffold learning and support adaptive emotional regulation.

Objectives and Theoretical Framework

Research in psychology, educational psychology and computer science has found that a preponderance of emotions exist and critically impact students' motivation, learning, performance, identity development and health in academic and learning settings (McQuiggan & Lester, 2009; McQuiggan, Mott, & Lester, 2008; Schutz & Pekrun, 2007; Woolf, Burleson, Arroyo, Dragon, Cooper, et al., 2009). Accordingly, there has been a surge in research investigating emotion, emotion regulation, detection, measurement, and analysis in a variety of domains, including the interdisciplinary field of intelligent tutoring systems (ITS). Investigating emotions in the context of ITS and serious games (many of which incorporate tutors) has led to strides in both emotional measurement (Calvo & D'Mello, 2010; Zeng, Pantic, Roisman, & Huang, 2009) and systems containing emotionally embodied and sensitive computer agents (McQuiggan & Lester, 2009; McQuiggan et al., 2008; Woolf et al., 2009). These systems have focused on examining the roles that artificial intelligence (AI) can play in facilitating learners' experience of positive emotions, which are essential to facilitating positive learner-tutor relationships and learning outcomes.

The *purpose of this study* was to investigate the effect of two different pedagogical agents' (PA) tutorial scaffolding strategies on students' proportions of discrete (e.g. happiness, anger) emotions during the sub goal setting task of the learning session with MetaTutor. These scaffolding strategies were deployed in two separate conditions. The first condition was a non-feedback condition, where the PA: prompted students to set three sub goals; be mindful of their overall learning goal (to learn all they can about the circulatory system); either accepted or rejected students' proposed sub goals; proposed to re-word the sub goal if it was too broad; and proposed a randomly chosen alternative, appropriate sub goal in the case of all other failed attempts (e.g. if the sub goal was

irrelevant or too specific). The second was a feedback condition, in which participants were additionally given information related to the relevancy and proximity of their proposed sub goal to one or more of the seven ideal sub goals and the PA only proposed an alternative sub goal after three successive and unsuccessful attempts or if the sub goal was too specific (See Figure 1). The emotions examined in this study were Ekman and Friesen's (1972; 1992) six universal, basic emotions, which include: happiness, surprise, anger, sadness, disgust and fear, in addition to neutral. The theory of basic emotions holds that these emotions are experienced, embodied and recognizable in all human cultures through distinct universal signs, such as facial expressions, and that changes in emotional states occur rapidly (unless an emotion is repeatedly evoked), automatically, and unintentionally (Ekman, 1992). However, emotions can also be consciously manipulated through emotional regulation, a process through which one can attempt to influence the emotions one experiences, when one experiences them and how one experiences them (Gross, 2002). Accordingly, our second objective in this study was to examine participants' unfolding emotional states as they progressed through the sub goal setting task. In examining students' unfolding emotions, we can identify periods in which students may experience a breakdown in their ability to regulate their emotions, which can in turn inform emotionally adaptive scaffolding strategies for PAs.

Method

Participants

Participants included 24 undergraduate students (67% female) from a large public university in North America. Participants were randomly assigned to one of two experimental conditions, where, for the purposes of this study, they interacted with a PA, which deployed one of the two aforementioned scaffolding strategies for the goal-setting phase of the learning session with MetaTutor.

MetaTutor and Materials

MetaTutor is a multi-agent intelligent tutoring system and hypermedia-learning environment which consists of 41 pages of text and static diagrams organized by a table of contents displayed in the left pane of the environment (See Figure 1). The version of MetaTutor used in this experiment is comprised of material on the human circulatory system, which it is designed to teach participants about during their interaction with the four PAs embedded in the system. In this study we used FaceReader™ 3.1, a software program designed by Noldus™ that analyzes participants' facial expressions and provides a classification of their emotional states using an Active Appearance Model to model the participants' faces and an artificial neural network with seven outputs corresponding to Ekman and Friesen's 6 basic emotions in addition to neutral, to classify the embodiment of learners' emotions. We used FaceReader's pre-calibration and general model 1 settings in this study to analyze participants' faces. A Microsoft LifeCam™ was used to record the participants' faces during their interaction with MetaTutor. In accordance with FaceReader's guidelines, the camera was mounted above the monitor of the computer participants were using in order to capture their faces, but not obstruct the screen; videos were imported into FaceReader as WMV3 files with a resolution of 800 x 600 and a frame rate of 15 frames per second.

Experimental Procedure

On day one of the MetaTutor experiment, participants completed a demographics questionnaire, and pretests on the human circulatory system as well as on their understanding of Self-Regulated Learning. Day One of the experiment generally took 20 to 30 minutes for participants to complete. On day two, participants interacted with MetaTutor for two hours, after which they immediately completed a posttest on the human circulatory system. Prior to the beginning of the learning session, participants were instructed in a think-aloud protocol, the Tobii T60 eye-tracker was calibrated to each participant individually and audio and video capture equipment were tested and activated. Several tutorial videos featuring instructions from either a human agent or a combination of a human and PA were shown to the participant at the beginning of the session to explain how to navigate the system.

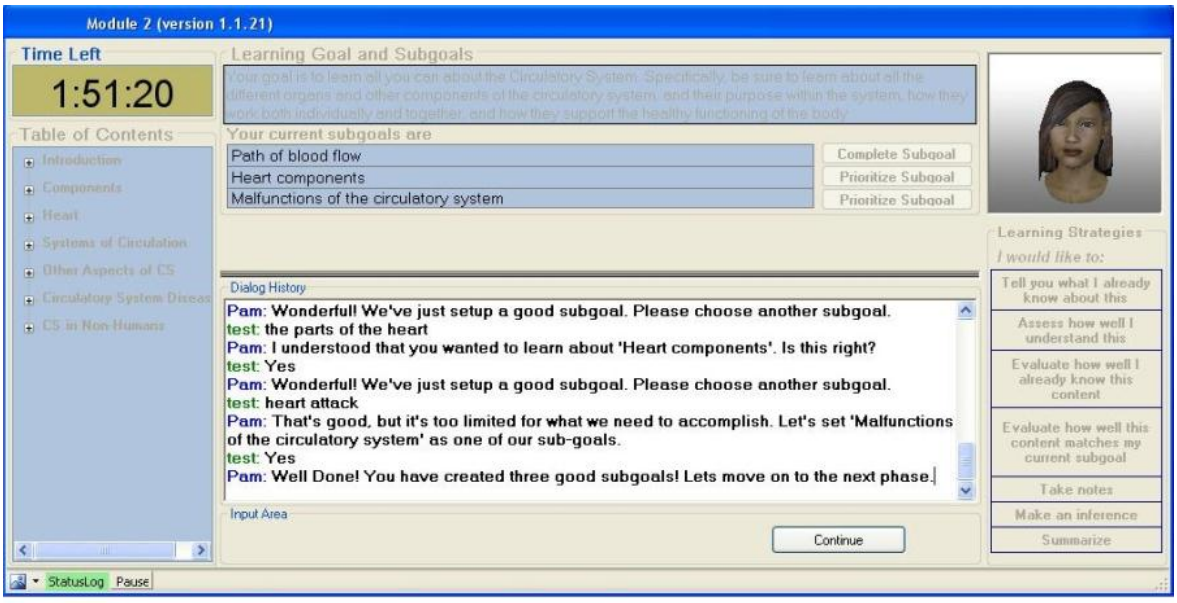

Figure 1. Screenshot of MetaTutor Interface and Goal Setting Learner-PA Interaction Example for the Feedback Scaffolding Condition

The goal setting phase of this study could take up to approximately 15 minutes and included, in addition to the sub goal setting task itself, the self-introduction of the PA, prior knowledge activation (PKA), where the PA requested participants to tell it everything they know about the circulatory system and a brief introductory video instructing participants on how to set an appropriate sub goal and the PAs role in this process. The sub goal setting task is the focus of our study and ranged between one minute and twelve seconds and three minutes and forty five seconds. This difference in time is due to participants' varying abilities to set sub goals for learning as much as they could about the circulatory system at an appropriate level of detail as well as the scaffolding strategy deployed by the PA. Ideal sub goals outline, at a level of detail that is not too broad or too specific, something the participant wishes to learn about and understand regarding the circulatory system (the main goal, which the sub goals are organized around).

Data Analysis

Total frequency scores for each of the 7 emotional states for each sub goal setting task for each participant were extracted from the FaceReader logs. Though the time period examined in this study was short, individual participants' data yielded summed (across emotions) frequency counts ranging for 999 to 3,052. In total this study examines 40,817 judgments of emotional states made by FaceReader across participants and conditions. The total frequency scores represented the frequency with which each emotional state was the dominant emotional state (had the highest intensity level according to FaceReader) during each sub goal setting attempt. In order to run inferential statistics on the emotional data and make comparisons between participants' embodiment of emotions, we transformed the frequencies into proportions and ran 7 different 2x3 repeated measures ANOVAs; one for each emotional state. Proportions do not sum up to 100% because we included classification failures (frames where FaceReader couldn't identify the emotion – usually because the participant was typing and looking at the keyboard). Each of these inferential statistics measured participants' proportions of a single discrete emotion (the dependent variable) between the two scaffolding strategies (the between subjects variable) and across the 3 different sub goal setting attempts (the within subjects variable) of the sub goal setting task.

Results

The proportions of each of the discrete emotions between the two conditions as well as across the conditions (total) are presented in Table 1. These proportions demonstrate that participants' embodied more negative than positive (happiness) or neutral (neutral, surprise) emotions during the sub goal setting task. Figure 2 displays a histogram of the proportions of each discrete emotion for each condition.

Table 1.

Proportions of Discrete Emotions by Tutorial Strategy and Across Tutorial Strategies

Sample	Proportions of Discrete Emotions						
	Neutral	Happiness	Sadness	Anger	Surprise	Fear	Disgust
Feedback	8.90	3.49	10.93	23.61	22.82	1.15	8.61
Non-Feedback	14.37	14.53	8.05	34.81	17.05	1.22	2.32
Total	11.18	8.09	9.73	28.28	20.41	1.17	5.99

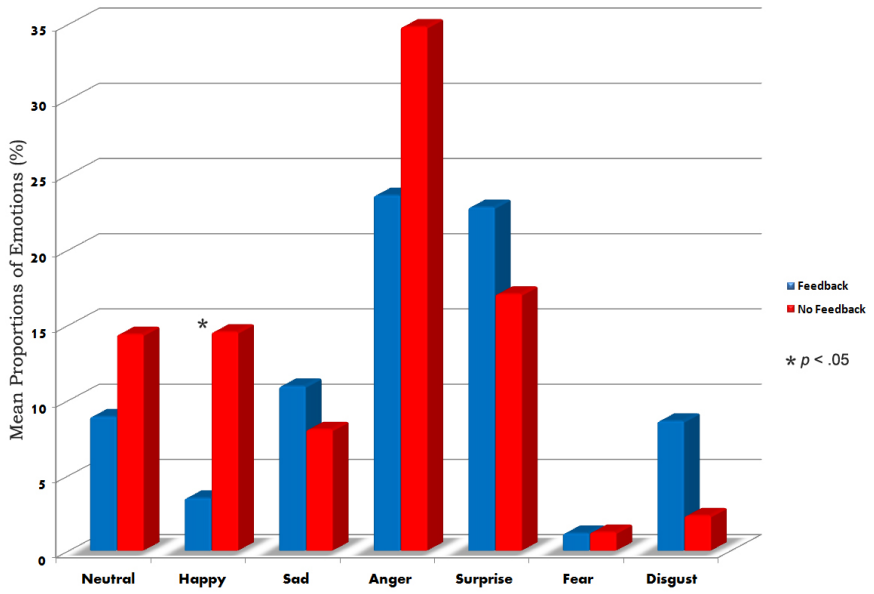

Figure 2. Proportions of Discrete Emotions by PA Scaffolding Strategy

For our 7 different repeated measures 2x3 ANOVAs, the one examining happiness revealed that there was a significant main effect of the tutorial scaffolding strategy on participants' embodiment of happiness, $F(1, 22) = 7.27$, $p < .05$, *partial* $n^2 = 0.25$. By looking at the descriptive statistics comparing the means of participants' proportional embodiment of happiness, we can see that participants experienced greater mean proportions of happiness in the Non-Feedback ($M = 15.28$; $SE = 3.04$) rather than the Feedback scaffolding condition ($M = 3.7$; $SE = 3.04$). The repeated measures 2x3 ANOVA examining neutral revealed a significant interaction effect for scaffolding strategy and sub goal, on participants' embodiment of neutral, $F(2, 44) = 3.28$, $p > .05$, *partial* $n^2 = 0.13$, which had a marginally significant linear contrast trend, $F(1, 22) = 4.17$, $p < .053$, *partial* $n^2 = 0.16$. By looking at the descriptive statistics in Table 2, we can see that participants' embodiment of neutral was generally higher in the Non-Feedback scaffolding condition, but that in the third sub goal attempt, participants proportions of neutral dropped below the mean level of those in the Feedback condition. Although no other significant main effects for sub goal nor the interaction were found, $p > .05$, by looking at the descriptive statistics for the interaction effect of scaffolding strategy and sub goal for happiness (see Table 3) we can see that the mean proportion of happiness approximately doubled in the third sub goal attempt, where for neutral it was more than halved from the previous sub goal setting attempt.

Table 2.

Marginal Means and Standard Errors for the Interaction Effect of Sub Goal and Scaffolding Strategy on Neutral

Tutorial Strategy	SG	*M*	*SE*
Feedback	1	9.85	4.27
	2	8.59	5.03
	3	10.13	3.33
Non-Feedback	1	16.93	4.27
	2	18.28	5.03
	3	8.27	3.33

Table 3.

Marginal Means and Standard Errors for the Interaction Effect of Sub Goal and Scaffolding Strategy on Happiness

Tutorial Strategy	SG	*M*	*SE*
Feedback	1	4.12	3.44
	2	2.58	3.37
	3	4.34	5.61
Non-Feedback	1	11.41	3.44
	2	11.83	3.37
	3	22.61	5.61

Scientific Contributions of the Study

In summary, we found that students' in both tutorial scaffolding conditions embodied higher proportions of negative than positive or neutral emotions. Our results also demonstrate that participants experienced higher proportions of positive and neutral emotions in the non-feedback scaffolding strategy than in the feedback strategy during their interaction with MetaTutor. These findings are similar to those of D'Mello, Craig, & Graesser (2009) who reported that negative emotions, including frustration, boredom, and confusion represented the majority of emotions experienced by learners during their learning session with AutoTutor. Furthermore, D'Mello et al. (2009) reported that negative tutor feedback was positively correlated with confusion and frustration. This finding may help explain our results, given that participants' received more negative feedback in the Feedback condition than the Non-Feedback condition due to a greater number of attempts for each sub goal. These findings also provide evidence of meaningful shifts in emotions within a relatively short and identifiable period of time; between the second and third sub goal attempt. This shift may represent either a breakdown in emotional regulation from neutral to a negative emotion or the onset of emotional regulation, where students up regulated their emotions from neutral or negative emotions to happiness. Tracing the individual trajectories of participants' emotions is a direction for future investigation of this research question.

In summary, these results provide further evidence that PAs designed to scaffold students' learning and learning-related skills and process need to also deploy emotionally adaptive strategies that are able to detect students' emotional states and leverage positive emotions through strategies such as the perceived provision of empathy or the promotion of self-efficacy (McQuiggan, et al., 2008; McQuiggan & Lester, 2009; Woolf et al., 2009). Without such interventions, participants may be expected to continue to experience more negative than positive emotions during their interactions with PAs, regardless of changes in tutorial scaffolding strategies (D'Mello, Craig, & Graesser, 2009; Harley, Bouchet & Azevedo, in press).

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