Chapter 108
Toward a Feature-Driven Understanding of Students' Emotions during Interactions with Agent-Based Learning Environments: A Selective Review

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ABSTRACT

This selective review synthesizes and draws recommendations from the fields of affective computing, intelligent tutoring systems, and psychology to describe and discuss the emotions that learners report experiencing while interacting with agent-based learning environments (ABLEs). Theoretically driven explanations are provided that describe the relative effectiveness and ineffectiveness of different ABLE features to foster adaptive emotions (e.g., engagement, curiosity) vs. non-adaptive emotions (e.g., frustration, boredom) in six different environments. This review provides an analytical lens to evaluate and improve upon research with ABLEs by identifying specific system features and their relationship with learners' appraisals and emotions.

INTRODUCTION

The last few decades have witnessed an explosion in the study of the complex role of emotions in a multitude of learning contexts (Azevedo & Aleven, 2013; D'Mello, 2013; Calvo & D'Mello, 2010, 2011, 2012; Harley, in press; Pekrun & Linnenbrink-Garcia, 2014). Amidst the application of traditional and cutting-edge methods to computer-based learning environments (CBLEs),

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however, many fundamental questions remain unanswered: How do students feel about interacting with specific types of CBLEs? Does the incidence of discrete emotions vary between similar types of environments? What features support or hinder learners' experience of adaptive emotions within these environments? This review is unique in attempting to answer these questions as they relate to a type of CBLE, namely agent-based learning environments (ABLEs; which feature pedagogical agents) and in so doing address these gaps in the research literature (Calvo & D'Mello, 2010; D'Mello, 2013). Understanding how and why learners' feel they way they do toward ABLEs is important because of the relationship between learning and emotions in which emotions can both support (e.g., enjoyment, hope) and hinder learning (e.g., boredom, anxiety; Pekrun, 2011; Pekrun, Daniel, Perry, Goetz, Stupinsky, 2010; Pekrun, Goetz, Frenzel, Petra, & Perry, 2011).

Agent-Based Learning Environments

ABLEs are a type of computer-based learning environment (e.g., multi-agent systems, intelligent tutoring systems, serious games) used to help students learn various educational and professional topics such as science, math, computer literacy, and cultural sensitivity. These environments use artificial intelligence (AI) to respond and adapt to learners' individual needs as they interact with the system and, in some cases, train and foster students' cognitive, emotional, and metacognitive self-regulatory skills (Arroyo, Burleson, Tai, Muldner, & Woolf, 2013; Azevedo & Aleven, 2013; Azevedo et al., 2013; Conati & Maclaren 2009; D'Mello & Graesser, 2013; D'Mello, Lehman, Pekrun, & Graesser, 2014; Kinnebrew, Biswas, Sulcer, Taylor, 2013; Sabourin, Mott, & Lester, 2011). ABLEs can provide students with the opportunity to interact with educational material in a variety of forms including text, diagrams, videos, and interactive simulations. Many also contain a variety of embedded digital learning tools such as structured or unstructured note-taking features and open learner models that provide learners with opportunities to structure and monitor their learning progress (Azevedo et al., 2013; Feyzi-Behnagh et al., 2013).

ABLEs are unique from other computer-based learning environments because of their use of pedagogical agents (PAs) represented by an animated character (usually a 3D human head and torso) that serve several functions such as providing immediate and tailored prompts and feedback (e.g., hints, summaries, encouragement, and evaluations) to support student learning. Pedagogical agent-learner interactions are handled by one or several embodied PAs that vary along numerous dimensions including presence or absence of natural language processing, speech, facial expressions, gestures, gross motor behaviors, gender, and race. Several of these dimensions have been shown to influence learners' interactions, reaction to, and their opinions of PAs (Arroyo et al., 2013; Baylor & Kim, 2009). Furthermore, relationships between learners' individual differences (e.g., personality traits, gender) and PA characteristics have been found (e.g., PAs with different pedagogical interventions, gender; Arroyo et al., 2013; Harley et al., under review). For example, Arroyo et al. (2013) found that female students expressed positively valenced emotions most often and engaged in more productive behaviors when they interacted with female PAs as opposed to male students who had better learning outcomes when no PAs were present and the worst performance and affective outcomes when they interacted with female PAs.

Research has found that the visual presence of PAs does not distract students (i.e., produce a *split-attention effect*) from learning (Craig, Gholson, & Driscoll, 2002; Moreno, Mayer, Spires, & Lester, 2001). Moreover, in addition to the advantages that computer-based learning environments provide learners with (e.g., individualized feedback and low-stakes assessment) the presence of a PA has been found to have a positive effect on learners' perception of their learning experience as well