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Learning Emotions EEG-based Recognition and Brain Activity: A Survey Study on BCI for Intelligent Tutoring System

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Abstract

Learners experience emotions in a variety of valence and arousal in learning, which impacts the cognitive process and the success of learning. Learning emotions research has a wide range of benefits from improving learning outcomes and experience in Intelligent Tutoring System (ITS), as well as increasing operation and work productivity. This survey reviews techniques that have been used to measure emotions and theories for modeling emotions. It investigates EEG-based Brain-Computer Interaction (BCI) of general and learning emotion recognition. The induction methods of learning emotions and related issues are also included and discussed. The survey concludes with challenges for further learning emotion research.

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Keywords: BCI; Emotions; EEG; Learning; Intelligent Tutoring System

1. Introduction

Emotions or affective states elicited during learning impact learning experience, which promote or restrain the learning. For example, curiosity is expected to occur when students engage in a new topic of interest. Achieving a goal brings about pleasure or satisfaction. Confusion occurs when existing cognitive structure is inconsistent with incoming knowledge. Frustration is elicited if misconception could not be eliminated. Obviously, emotional processes intertwine with cognitive activity and there is considerable overlap in the neural circuitry that supports these two processes[1]. Either in human to human instruction class or Intelligent Tutoring System (ITS), emotions always occur when learners access in learning. In conventional class, human teacher could easily capture the cognitive and affective states of students and accordingly adjusts the speed and contents of the lecture. This adjustment refocuses students' interest and engagement and helps students overcome difficulties and solve problems, making the class efficiently. In recent years, increasing studies have employed many technologies to monitor students' cognitive and affective states and attempted to provide adaptive interfaces and contents accordingly to improve learning efficiency in Intelligent

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Tutoring System (ITS) or online learning. In this work, we survey techniques that have been used to measure emotions and theories for modeling emotions. Among those measures used to detect emotions, Electroencephalograph based (EEG-based) emotion measures have unique potentials and benefits that are distinguished from other methods. In this work, EEG-based Brain-Computer Interaction (BCI) of emotion recognition are mainly focused and discussed. The induction methods of learning and related issues are also included. The survey concludes with challenges for further learning emotion research.

The terminology of learning emotion varies among research in different field, which is affective states in learning, affect[2], emotive states in learning, learning emotions, academic emotions[3], learning-centered affective states[4], etc. The terminology affective states/moods and emotive states are used commonly in Affective Computing. Emotions during learning, academic emotions, and learning-centered affective states are mentioned more in Pedagogy and Educational Technology. In this paper, we use learning emotions to instead other terminologies.

There are two models of general emotions that guide researchers to build emotion recognition systems, namely, the discrete model and the dimension model (as shown in Figure 1). The discrete model refers to the emotional space consisting of basic discrete emotions like joy, anger, surprise, sadness, fear and disgust. The dimensional model divides the emotional space into two main dimensions (Valence and Arousal, VA)[5] or three (Pleasure, Arousal, and Dominance, PAD)[6]. Valence refers to the positive and negative characteristics. Arousal indicates the intensity level of emotion. And Dominance reflects an individual's status, that is, in control or being controlled.

The description and terminology of general emotion models are commonly used to depict learning emotion models, while the latter ones are more specific due to learning situation. Learning emotions models vary based on a variable related to learning (as shown in Figure 1) that is, based on learning activities[3], based on learning session[7], based on learning process[8], based on instructional design[9], and based on learning environment[4]. For example, Pekrun et al.[3] have classified the learning emotions into four categories: achievement, topic, social and epistemic. This taxonomy covers a wide range of emotions that learners experience during learning activities. In this model, learners may have emotions related to 1) outcomes (achievement, like contentment, anxiety and frustration), 2) preferences for certain topics over others (topic, like empathy for the protagonist in a novel), 3) interactions with peers and teachers (social, like pride, shame and jealousy), and 4) processing new information that is encountered (epistemic, like surprise and confusion). Kort et al.[8] proposed a model of the generic learning process, which can be used as internal representations of a learner's cognitive-emotive state while engaged in learning. This emotion model of learning cycle contains the process from constructing learning to un-learning, including negative affect and positive affect. Hopefulness, awe, satisfaction, curiosity, disappointment, puzzlement, confusion, frustration, etc. are mentioned in this model.

Overall, these general emotion models and learning emotion models underlie the emotion recognition system and guide the research to induce emotions.

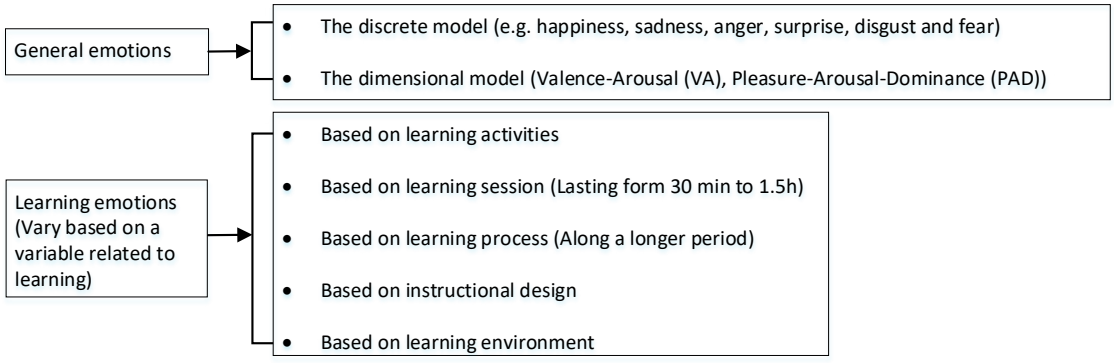

Fig. 1. The Map of Learning Models.