Biomedical Signal Processing and Control 46 (2018) 302–313

Contents lists available at ScienceDirect

Biomedical Signal Processing and Control

journal homepage: www.elsevier.com/locate/bspc

Detecting boredom from eye gaze and EEG

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ARTICLE INFO

Article history:
Received 18 August 2017
Received in revised form 27 April 2018
Accepted 28 May 2018

Keywords:
Boredom
Emotion detection
Emotion-awareness
Eye tracking
Gaze
Electroencephalogram (EEG)

ABSTRACT

The recent proliferation of affordable physiological sensors has boosted research and development efforts of emotion-aware systems. Boredom has received relatively little attention as a target emotion, and we identified a lack of research on the relationship between eye gaze and electroencephalogram (EEG) when people feel bored. To investigate this matter, we first conducted a background study on boredom and its detection by physiological methods. Then, we designed and executed an experiment that uses a video stimulus – specifically designed for this experiment, yet general enough for other boredom research – with an eye tracker and EEG sensor to elicit and detect boredom. Moreover, a questionnaire was used to confirm the existence of boredom. The experiment was based on a hypothesis that participants may feel bored when their gaze deviates from an expected area of interest, thus indicating loss of attention. The results of the experiment indicated correlations between eye gaze data and EEG data with all participants ($N = 13$) when they felt bored. This study can be useful for researchers who have interest in developing boredom-aware systems.

1. Introduction

Emotion-aware computer systems began to gain interest since researchers realized that one-size-fits-all experiences are not sufficient to satisfy the needs of heterogeneous users. In the domain of education, Picard [1] used a piano-teaching computer system to demonstrate the advantages of personalized learning by proposing that the computer could provide appropriate guidance to the learner by observing their emotions. In another example, Chanel et al. [2] applied emotion-awareness to a game so as to maintain the player's engagement. Their goal was to detect the player's emotional state using a categorization scheme comprising three classes: boredom, anxiety and engagement. In order to maintain the player's engagement, they proposed to change the difficulty of the game when the player's emotional state is detected to be boredom or anxiety.

The aforementioned examples illustrate some of the potential affordances that emotion-aware systems enable in experience personalization. Indeed, emotion-aware systems can be used to boost the user's intrigue, motivation, and engagement, while minimizing negative emotions, such as boredom, that may damage the current activity. For example, when a emotion-aware system senses that a user feels boredom during a writing task [3], it can provide proper support to help reducing boredom and thereby increasing engagement, which is a prerequisite for reaching the flow state in the activity at hand [4].

While emotion-aware systems have been constructed to detect and act upon various emotions [5–14], there is one emotion – boredom – which has gained relatively little attention from researchers. One possible reason for this, as Pekrun et al. [15] suggest, is that boredom is "*an inconspicuous, 'silent' emotion, as compared with manifest affective states like anger or anxiety*". Moreover, boredom is a complicated emotion; a bored person can exhibit either high or low arousal [16]. Because of these reasons, elicitation and detection of boredom can be remarkably more demanding than those of more explicit and uncomplicated emotions.

There are three motives for us to choose boredom as the target emotion in this study: (i) boredom can disrupt an activity, such as learning, by preventing focused attention; (ii) boredom may have a negative effect on motivation; and (iii) boredom is a complex emotion, which has attracted comparatively low amount of attention in previous emotion detection research using physiological measurement. Due to these reasons, boredom is an important target emotion for future emotion-aware systems to manage.

Boredom detection methods – and emotion detection methods in general – can be divided into three groups: psychological,

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https://doi.org/10.1016/j.bspc.2018.05.034
1746-8094/

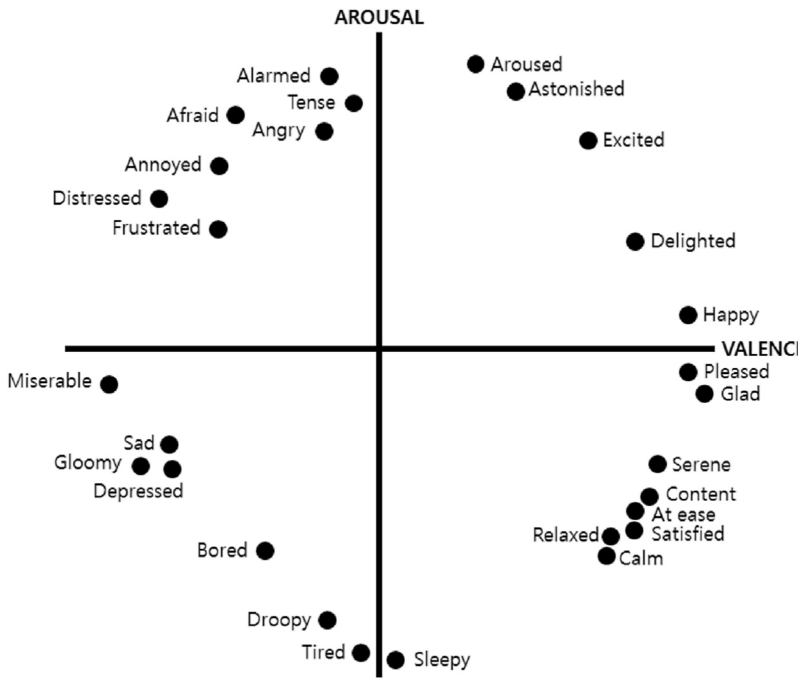

Fig. 1. The Circumplex Model [28].

physiological and behavioral [17]. In this study, we focus on the physiological boredom detection, which concerns measuring various physiological aspects of a participant's response to a stimulus. There have been studies which attempted to detect boredom by physiological methods [18–22], with some of them focusing specifically on the use of eye tracker [23] or electroencephalogram (EEG) [24]. To the best of our knowledge, however, there is a gap in the current understanding of whether there exists a connection between eye gaze and EEG signal when people feel bored.

The purpose of this study is to fill this gap by investigating the relationship between eye gaze and EEG in the context of boredom. We set three hypotheses to frame the study. First, when people get bored, they lose attention to the task at hand [25]. Secondly, when they get bored, their EEG data and gaze data may show distinctive patterns compared to the expected state (e.g. stable EEG, eye fixation at an expected location). Third, due to the first and second hypotheses, a correlation may exist between gaze data and EEG data when people feel bored. Before verifying these hypotheses in an experiment, we first provide explanations of the theoretical underpinnings of emotion modeling and boredom, as well as previously applied methods for collecting and analyzing physiological data for boredom detection. Then, we proceed to present the design and the results of a boredom detection experiment using a video stimulus, an eye tracker, an EEG sensor, and a questionnaire. We designed the video stimulus to be a generic boredom inducing tool that could be used later in other studies related to boredom.

2. Background

2.1. Emotion models

Some researchers developed emotion-aware systems by hand-picking certain emotions [6] or by using dubious terms to express emotions [26]. Such practices can pose validity challenges. Firstly, if the terminology for expressing emotions is not well established, researchers might end up choosing inappropriate terms that may be misunderstood or terms that are not emotions at all. Secondly, the conceptual distance between emotions remains ambiguous if emotions are not represented through an appropriate model. To alleviate these challenges, scientifically validated emotion models have been developed that can be used to classify emotions in emotion-aware systems. Essentially, an emotion model is a structure in which various emotions are categorized according to some criteria. Emotion-aware system developers can utilize emotion models for unambiguous classification of emotions.

Most emotion models have foundations in psychology. Already in 1897, Wundt [27] proposed three dimensions through which emotions can be mapped: "*pleasurable or unpleasurable*", "*arousing or subduing*" (exciting or depressing), and "*strain or relaxation*". In 1980, Russell proposed the Circumplex Model (Fig. 1) in which emotions are distributed in a two-dimensional circular space on two axes: arousal and valence [28]. Arousal on the vertical axis represents the level of excitement (relaxed or aroused) and valence on the horizontal axis indicates the level of emotional state (positive or negative). The Circumplex Model has been used to classify participants' emotions in studies covering various fields [24,29–31].

Russell's Circumplex Model is often used as the basis for emotion-related research but it is not the only emotion model available. According to Grandjean et al. [32], there are three types of emotion models. The models of Wundt and Russell belong to dimensional models, which categorize emotions using various dimensions, such as pleasant–unpleasant, excitement–inhibition and tension–relaxation. Another type is basic emotion models, also known as the Discrete Emotion Theory, which define a set of emotions that form the base of all other emotions. The number of basic emotions vary among these models. For example, Ekman proposed six basic emotions: anger, disgust, fear, happiness, sadness, and surprise [33]. Stevenson et al. used a basic emotion model to prove that the words in Affective Norms for English Words (ANEW) are effective to elicit discrete emotions [34]. ANEW is a set of English words which were rated in terms of valence, arousal and dominance [35]. The third type of emotion models is componential appraisal models, which suggest that our internal state and the state of the world surrounding us are used as inputs for a continuous emotion generation process in our brains [32,36]. Scherer et al. [37] applied an appraisal-based model for mapping of facial expression