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Changes in heart rate and facial actions during a gaming session with provoked boredom and stress☆

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ABSTRACT

This paper presents an experiment aimed at exploring the relation between facial actions (FA), heart rate (HR) and emotional states, particularly stress and boredom, during the interaction with games. Subjects played three custom-made games with a linear and constant progression from a boring to a stressful state, without pre-defined levels, modes or stopping conditions. Such configuration gives our experiment a novel approach for the exploration of FA and HR regarding their connection to emotional states, since we can categorize information according to the induced (and theoretically known) emotional states on a user level. The HR data was divided into segments, whose HR mean was calculated and compared in periods (boring/stressful part of the games). Additionally the 6 h of recordings were manually analyzed and FA were annotated and categorized in the same periods. Findings show that variations of HR and FA on a group and on an individual level are different when comparing boring and stressful parts of the gaming sessions. This paper contributes information regarding variations of HR and FA in the context of games, which can potentially be used as input candidates to create user-tailored models for emotion detection with game-based emotion elicitation sources.

1. Introduction

A general definition of emotions is that they are biologically based action dispositions that have an important role in the determination of behavior [2]. Emotions are multimodal responses to a situation causing changes in expressive behavior [3], e.g. facial activity, and physiological activity [4], e.g. heart rate (HR). Methods for processing such changes to recognize user emotions have been proposed in the domain of human-computer interaction [5], affective computing [6] and game research [7], often involving the mapping of signals into emotional states using machine learning models [8].

In the context of games, a variety of physiological signals have been used to automatically assess different emotional states [9–11]. Significant differences in HR, for instance, are reported at stressful periods of gameplay [12–14], including different levels of game difficulty in *Tetris* [15] and fast/slow conditions in an adapted version of *Pacman* [16]. Additionally the analysis of facial behavior shows that increased activity of the zygomatic [16] and the corrugator [17] muscles, associated with smiling and frowning respectively, are more frequent during particularly emotional game events. The variations of those psychophysiological signals have the potential to be used as sources for emotion detection.

However, while previous work explored the use of games as elicitation sources for recognizing user emotions, relying on the emotional states a person can experience [18] and which physiological signals are better predictors of such states [19], they lack a more user-tailored approach for studying the variations of signals. Emotional states such as stress and boredom are often inducted by administering a game with the same particular setup, e.g. high/low difficulty, to all subjects. People respond differently to media according to their personality [20], and they differ in social, learning and play styles [21]. A game session labeled as stressful, for instance, assumes that all subjects have the same expectations and behave similarly, which dilutes the individuality of each person as some might experience the interaction as not being stressful as intended. Additionally the analysis usually involves the interaction of subjects with some game levels (from the same game) featuring a constant difficulty scale, which does not contemplate the variations of signals in a context where the game difficulty is constantly increasing in the same game level/session.

In this paper, we propose a different approach to explore the relation between facial activity, HR and emotional states, particularly stress and boredom, during the interaction with games. We designed and

☆ This article is an extension of previous work [1].

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carried out an experiment involving games as emotion elicitation sources, which were deliberately designed to cause the aforementioned emotional states in a novel configuration. Our approach consists of recording participants while they play three different games that were carefully designed and developed to have a difficulty level that constantly and linearly progresses over time without a pre-defined stopping point. At the beginning the games are highly predictive, without novelties, changes or surprises and with emphasis on the passage of time during a wait, which leads to an emotional state of boredom [22–24]. The game difficulty is then periodically increased until the subject is not able to cope with the challenges at hand, which happens at different times for different subjects. The ever-growing game difficulty leads to an emotional state of stress towards the end of the interaction.

The purpose of our experiment is to investigate how responses related to physiological activity, i.e. HR, and facial actions (FA), defined by us as being any facial movement different from a neutral face, e.g. lips contraction, relate to emotional states in a game context featuring constant changes in difficulty. As a result, we present an analysis regarding the changes in the HR mean and annotated FA that happened during the phases of the games that were perceived as being boring and stressful. Our main contribution is twofold: firstly we introduce a different structure for emotion elicitation in our games, which account for personal differences among subjects when inducing an emotional state of stress. Secondly we present information, on group and individual level, about the variations of HR and naked-eye recognizable FA that happened during the interactions with such different game structure, especially under situations that were designed to provoke boredom and stress. The aim of this paper is to provide information regarding the variations of HR and FA when compared in boring and stressful moments of a game, which can potentially be used as input candidates to create user-tailored models for emotion detection when games are used as emotion elicitation sources. Additionally we highlight the heterogeneous nature of our group of subjects that have significantly different ages and gaming experiences, which produces a diverse sample for the investigation of changes in HR, FA and emotional states.

2. Related work

2.1. Games and emotional states

A game is defined as a system in which players engage in an artificial conflict, defined by rules, that results in a goal [25]. The difficulty level of the challenge affects the emotional state of players, e.g. moments of boredom or anxiety/stress [24]. A challenge beyond the player's skill to address and overcome it causes anxiety, while the opposite results in disinterest, leading to boredom [26]. An ideal challenge/skill balance produces an optimal experience and concentration state called flow [27], which is vastly connected to engagement/immersion [28] and sense of presence [29]. Game design may also be described as the effort to induce states of flow and presence [30,31].

2.2. Heart rate, stress and frustration

Physiological signals are considered reliable sources of information since they are hard to fake (because of their link to the autonomic nervous system), differently from facial expressions, for instance [32]. The use of physiological signals, such as HR, have been demonstrated as player input for games [33], indication of perceived interest and confusion in mobile applications [34], triangulation of psychophysiological emotional reactions to digital media stimuli [35], and as measurement of frustration in a game [13]. Those approaches rely on physiological arousal [36] and its connection to emotion regulation [37,38]. Vandeput et al. [39] and Garde et al. [40] demonstrate that higher HR and differences in heart rate variability (HRV) are present in mentally demanding tasks when compared to a rest period. Similarly Bousefsaf et al. [10] show that the stress state curve and HR tend to decrease during the rest period and increase during stress sessions, in accordance with previously mentioned works. The standard deviation of HRV has also been reported as significant in the monitoring of arousal, however low and high frequencies of HRV present less weight in the monitoring compared to other signals, e.g. skin conductance [41]. Finally McDuff et al. [42,43] also use HR and its variants in order to measure cognitive stress during computer tasks. According to the authors, the average HR and breathing rate are not significantly different in any case, which differs from the findings of previously mentioned work.

2.3. Facial features and emotional state

The main manifestation of anxiety in the human face involves activities related to eyes (e.g. blinking), mouth (e.g. lip deformation), cheeks, and head movements [44]. The Facial Action Coding System (FACS) [45,46] is a widely used taxonomy for characterizing facial activity, however facial analysis based on Euclidean distances of points has also been reported as successful [47]. Emotion detection based on extracted facial features are often performed by machine learning models [48,49] that achieve significantly different results, which highlights the complexity of correlating facial features and emotions. Heylen et al. [50] report the occurrence of a variety of expressions in a pilot experiment, but most of the time subjects remain with a neutral facial expression. Grafsgaard et al. [51] present brow lowering as a positive predictor of student frustration in the context of a tutoring system, but the same facial activity has been correlated with confusion by previous work. Bailenson et al. [52] show that a machine learning model for emotion detection built from a combination of facial and physiological information is more efficient than a model built with either one alone. Additionally a person-specific model outperforms a model trained with data from all subjects, suggesting that a user-tailored model might be more effective in identifying features (even the more subtle ones) than a general-purpose model.

2.4. Summary

Some of the previously mentioned works rely on subjects performing tasks on a computer, e.g Vandeput et al. [39], Garde et al. [40], or interacting with gamified cognitive tests, e.g. McDuff et al. [43], Bousefsaf et al. [10], Grundlehner et al. [41], to study the relation between signals and emotional states. Those are game-like emotion elicitation sources that are less likely to evoke the same emotions a subject has when interacting with a game, which has decisions and consequences that might produce a deeper emotional involvement. When games (as defined in Section 2.1) are used, they are often commercial off-the-shelf (COTS) games whose difficulty level has been designed to serve and entertain a broad audience, not to induce boredom or stress. Sharma et al. [12], for instance, used three unchanged COTS games in an assessment of computer games as a psychological stressor, which relied on subjects gaming skills to perceive a game as stressful. Similarly Ravaja et al. [14] used an unchanged COTS game to measure phasic emotional responses. Chanel et al. [15] used an unchanged version of Tetris whose level of difficulty for each subject was selected based on repeated interactions with the game followed by analysis of self-reported levels of engagement. It familiarizes subjects with the game and prepare them for the chosen difficulty level. When COTS games are adapted to the needs of researchers, e.g. increased speed in *Pacman* to cause stress [16], subjects interact with pre-defined game modes (e.g. slow, fast and normal mode), which assumes that all players behave similarly and have the same expectations. Finally Rodriguez et al. [13] used a custom-made game designed to induce frustration in the subjects, however the experiment aim was to evaluate emotional regulation strategies in adolecents, not variations of psychophysiological signals in a context involving games as emotion elicitation sources. As opposed to previously mentioned works, our approach consists of using an induced boring to stressful mechanics in