Guidelines for Affect Elicitation and Tracking in High Intensity VR Exergaming

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Abstract
This position paper provides an overview of advances made in affect elicitation and tracking. We provide guidelines for evoking underwhelming, overwhelming and optimal affective states and tracking the affective state using psychophysiological measurements in high intensity VR exergaming. We discuss the research challenges that need to be addressed to implement affective high intensity VR exergaming.

Author Keywords
VR exergaming; affect elicitation; psychophysiological measurements; affect tracking; guidelines

CCS Concepts
•Human-centered computing → Human computer interaction (HCI);

Introduction: The Role of Affect Elicitation and Tracking in HCI Research
Affective computing is a rapidly growing field in HCI. It is the study of developing affectively intelligent systems that can identify emotion and accordingly adapt their interaction for better personalisation and user experience. The foundation of affective computing is accurate and instantaneous recognition of affective state. Identifying effective affect elicitation techniques is an essential step to develop and test affect

Figure 1: Players exert themselves on an exercycle

recognition methods.

The vast literature in affect recognition shows that the affective state can be identified and tracked by various methods such as, for example, facial expression recognition and psychophysiological correlates. However, recognising the affective state in the context of VR exergaming with conventional methods can be challenging. This is because psychophysiological measurements are extremely sensitive to movement and perspiration, which cannot be avoided in VR exergaming. This position paper discusses guidelines to evoke different affective states and successfully identify their affective state in light of our findings reported in our recent research paper [1]. We also contemplate the challenges that need to be overcome to build affectively adaptive high intensity VR exergames.

Overview of Advances in Affect Elicitation and Tracking

Affective states and user experience

Affective state is defined as a mental experience caused by neurophysiological variation linked to feelings with positive or negative valence. We consider affect as a two-dimensional model based on Russell's affect grid model, which describes affect along the dimensions of valence and arousal. User experience is defined as perceptions and responses resulting from the use of a system [11], so it is reflected in the current affective state of the user. Studies generally rely on tedious self-reported questionnaires at the end of an experiment to gauge user experience, which does not serve the purpose of dynamically adapting the system based on the user experience.

Affect elicitation and user experience simulation

Effective affect elicitation is an integral part of psychological studies. Studies use a variety of ways to induce different

Figure 2: High intensity racing game

affective states. One of the most widely used methods in affective studies is the use of standardised collection of pictures called IPAC (International Affective Picture System) [6, 34, 10]. Another extensively used method in emotion research to induce emotion is film clips, which are dynamic in nature and combine visual and auditory stimuli [38, 14]. Similar to affect elicitation in psychological studies, many gaming studies have attempted to induce different user experiences. Moller et al. invoked overwhelming, underwhelming and optimal player experiences by tweaking the game intensity [24]. Nacke et al. induced different player experiences, flow, immersion and boredom via game level design modifications [29]. These studies show that media are powerful affective stimuli.

Game aesthetics is defined as the sensory phenomena encompassing visual, aural, haptic and other elements that the player encounters in the game [31]. It is very powerful as it is capable of evoking desirable emotional responses in the player [19]. Visual and aural stimuli such as bells, sirens, flashing lights and dramatic hues can increase aesthetic satisfaction in a game by providing feedback to the

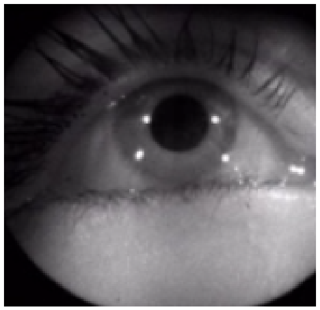

Figure 3: Imagery from an eye tracking enabled head-mounted display

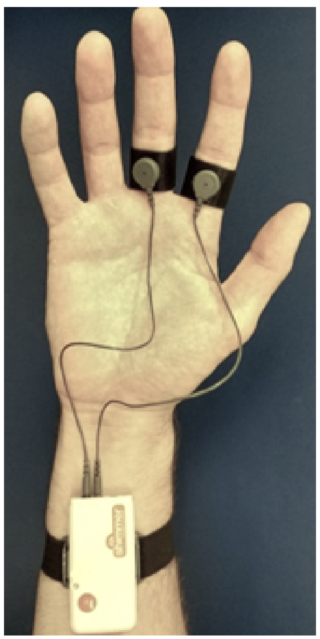

Figure 4: Skin conductivity monitor

player and acting as a reward for continued participation [39, 17]. Several studies show the ergogenic effect of music in sports and high intensity exercise performance by shifting attentional focus away from agonising exercise induced bodily sensations [5, 3, 2, 21]. Motivational tracks include a high tempo beat over 120 beats per minute and a strong rhythm to enhance energy and induce bodily action [20]. Based on these studies we evoked underwhelming, overwhelming and optimal states in high intensity VR exergames by varying the aesthetics and gameplay.

Affect tracking and gauging user experience

The cross-cultural studies of Ekman et al. show that facial expressions are reliable indicators of affective state [22, 12]. Affective state can be tracked by recognising facial expressions [7]. However, there is a variation of 25% [8] or more in emotion expression which likely occurs due to culturally specific prescriptions of emotion display rules, temperament, personality, and socialization [7]. This could potentially mean that psychophysiological measurements which indicate the biological underpinnings of emotional processing controlled by the autonomic nervous system are more reliable indicators of affective state as they are reflexive and involuntary [23, 25]. Several studies have been successful in identifying and monitoring the affective state reflecting the user experience by using neuropsychophysiological sensors such as heart rate variability, skin conductivity, EEG, and fMRI, which indicate increased autonomic nervous system activity [29, 30, 33, 32].

Player experience tracking in high intensity VR exergaming

Neuropsychophysiological sensors are extremely sensitive to perspiration and extensive movements, which cannot be avoided while playing an exergame. Previous studies have identified player experience in moderate intensity non-VR exergames by using facial expressions, GSR, temperature, respiration and movement [27, 28, 26]. However, this cannot be applied for high intensity VR exergames, which only require half the time commitment of moderate intensity exercise. This is because high intensity exercise is more physically exerting than moderate intensity exercise, leading to higher perspiration and extensive movement, which could corrupt these psychophysiological measurements. Furthermore, recognising facial expressions is challenging in VR exergaming because players are usually wearing a headset covering half their face. The challenge of tracking player experience in high intensity VR exergaming is to find robust psychophysiological measurements that reflect the player's experience without being overly affected by perspiration and movement. Studies show that pupil dilation, blink rate and eye movements are potential measures of affect. Skin conductivity may be suitable for tracking affect in high intensity VR exergames because the eccrine glands on palms and soles are more sensitive to affect than exertion induced perspiration [4, 13, 9] and affective responses typically precede the appearance of sweat.

Guidelines for Affect Elicitation and Tracking in High Intensity VR Exergaming

Different affective states can be evoked in high intensity VR exergames by using game aesthetics and gameplay to create underwhelming, overwhelming and optimal exergaming scenarios. When tracking the affective state using psychophysiological correlates, it is important to ensure that the game mechanics, exercise protocol, equipment, ambient lighting and overall game environment in all the exergaming scenarios stay the same to avoid confounding factors.

An 'optimal' exergaming scenario can be created by using appealing music and optimally challenging gameplay. An ‘underwhelming’ exergaming scenario can be created by using minimal aesthetics without any sound effects and no gameplay. An ‘overwhelming’ exergaming scenario can be created by using stressful and annoying sound effects and extremely challenging gameplay.

Pupil dilation, blink rate and skin conductivity are suitable psychophysiological measures for high intensity VR exergaming. Furthermore, unconventional measures such as performance and gaze fixations are speculative indicators of affect. Ray casting can be used to detect the gameplay-related components corresponding to the point of gaze, such as a timer and speed indicator. A low rate of gaze fixations on gameplay-related components indicates that the player was focusing more on the outer VR environment or staring at nothing instead of paying attention to the game. Because all the exergaming scenarios use the same exercise protocol, the noise in the skin conductivity measurements due to movement artefacts and exercise induced sweat will be similar and comparable.

Our findings confirmed that different psychophysiological measures vary in their ability to indicate affective valence and arousal. For example, skin conductivity is mainly a measure of arousal, and blink rate is more useful for predicting valence than arousal.

We observed that skin conductivity was affected by systematic individual differences in eccrine activity [35, 36]. Similarly, gaze fixations varied in terms of fixation length [15, 16] and pupil dilation measurements had varying individual pupillary sensitivity [18]. These individual differences can be compensated by normalising the variables using standard z-score transforms. Pupil dilation and gaze fixations measurements can be centred at the participant mean and scaled by dividing them by a participant’s standard deviation. Similarly, skin conductivity can be divided by the standard deviation to produce a measure of arousal.

Conclusion: The Road Ahead to Affective High Intensity VR Exergaming

Although we have successfully identified and evaluated that skin conductivity and pupillometry measurements are suitable to use in the context of high intensity VR exergaming, we must tackle the following research and engineering problems to implement affective high intensity VR exergames:

1. Instantaneous recognition of affect is still a challenge: Our studies show that there is correlation between psychophysiological measurements and self-reported player experience measurements over a period of 5 minutes. The next step is to ensure there is a correlation between instantaneous psychophysiological measurements and instantaneous self-reported user experience measurements. This step is essential to build a dynamic affectively adaptive high intensity VR exergame because each sprint session in the high intensity exercise protocol we use lasts for only 30 seconds. Therefore, in order to be effective in adapting exergame intensity according to the affective state, the system has to recognise the affective state instantaneously.

2. Psychophysiological sensors: Our studies show that psychophysiological sensor data must be preprocessed by using normalisation to compensate for individual differences. This was done after the experiment data was recorded. In order to enable dynamic adaptation of the exergame according to the affective state, the elaborate process of preprocessesing must be done instantaneously while the measurements are collected.

3. Stabiles and labiles: It has been reported that some people ("stabiles") are not stimulated much by external events or internal thoughts [37], making it hard to measure affect. Similarly, some people have high skin conductance responses in the absence of external stimuli ("labiles"). Although we did not encounter these phenomena in our study, studies with bigger sample sizes are necessary to investigate these challenges.

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