Guidelines for Affect Elicitation and Tracking in High Intensity VR Exergaming

Soumya C. Barathi
University of Bath
Bath BA2 7AY, UK
sbcb20@bath.ac.uk

Michael Proulx
University of Bath
Bath BA2 7AY, UK
M.J.Proulx@bath.ac.uk

Eamonn O'Neill
University of Bath
Bath BA2 7AY, UK
maseon@bath.ac.uk

Christof Lutteroth
University of Bath
Bath BA2 7AY, UK
c.lutteroth@bath.ac.uk

CHI'20,, April 25–30, 2020, Honolulu, HI, USA
ACM 978-1-4503-6819-3/20/04.
https://doi.org/10.1145/3334480.XXXXXXX

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

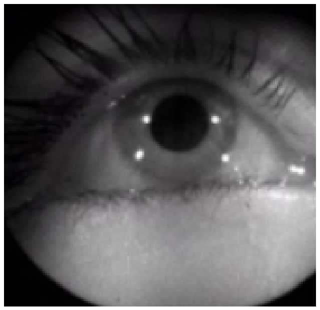

Figure 3: Imagery from an eye tracking enabled head-mounted display

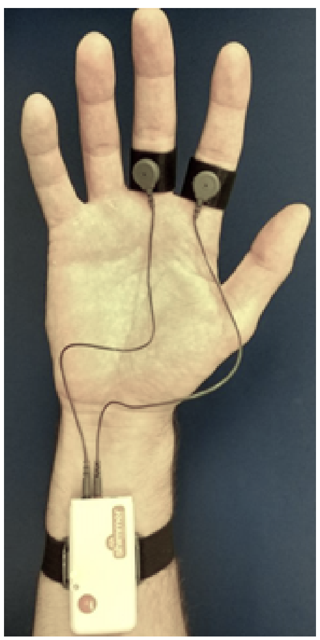

Figure 4: Skin conductivity monitor

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.

Acknowledgements

Soumya C. Barathi's research is funded by the UK's EPSRC Centre for Doctoral Training in Digital Entertainment (CDE), EP/L016540/1 and the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 665992. Eamonn O'Neill's and Christof Lutteroth's research is partly funded by CAMERA, the RCUK Centre for the Analysis of Motion, Entertainment Research and Applications, EP/M023281/1.

REFERENCES

[1] Soumya C Barathi, Michael Proulx, Eamonn O'Neill, and Christof Lutteroth. 2020. Affect Recognition using Psychophysiological Correlates in High Intensity VR Exergaming. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, 1–15.

[2] Martin J Barwood, Neil JV Weston, Richard Thelwell, and Jennifer Page. 2009. A motivational music and video intervention improves high-intensity exercise performance. *Journal of sports science & medicine* 8, 3 (2009), 435.

[3] Daniel T Bishop, Costas I Karageorghis, and Georgios Loizou. 2007. A grounded theory of young tennis players' use of music to manipulate emotional state. *Journal of Sport and Exercise Psychology* 29, 5 (2007), 584–607.

[4] W Boucsein. 2012. Electrodermal activity: Springer Science+ Business Media. (2012).

[5] Kimberly A Brownley, Robert G McMurray, and Anthony C Hackney. 1995. Effects of music on physiological and affective responses to graded treadmill exercise in trained and untrained runners. *International Journal of Psychophysiology* 19, 3 (1995), 193–201.

[6] Maurizio Codispoti, Vera Ferrari, and Margaret M Bradley. 2006. Repetitive picture processing: autonomic and cortical correlates. *Brain research* 1068, 1 (2006), 213–220.

[7] Jeffrey F Cohn. 2006. Foundations of human computing: facial expression and emotion. In *Proceedings of the 8th international conference on Multimodal interfaces*. 233–238.

[8] Jeffrey F Cohn, Karen Schmidt, Ralph Gross, and Paul Ekman. 2002. Individual differences in facial expression: Stability over time, relation to self-reported emotion, and ability to inform person identification. In *Proceedings. Fourth IEEE International Conference on Multimodal Interfaces*. IEEE, 491–496.

[9] Hugo D Critchley. 2002. Electrodermal responses: what happens in the brain. *The Neuroscientist* 8, 2 (2002), 132–142.

[10] Fabien D'Hondt, Maryse Lassonde, Olivier Collignon, Anne-Sophie Dubarry, Manon Robert, Simon Rigoulot, Jacques Honoré, Franco Lepore, and Henrique Sequeira. 2010. Early brain-body impact of emotional arousal. *Frontiers in human neuroscience* 4 (2010), 33.

[11] ISO DIS. 2009. 9241-210: 2010. Ergonomics of human system interaction-Part 210: Human-centred design for interactive systems. *International Standardization Organization (ISO). Switzerland* (2009).

[12] Paul Ekman. 1993. Facial expression and emotion. *American psychologist* 48, 4 (1993), 384.

[13] Don C Fowles, Margaret J Christie, Robert Edelberg, William W Grings, David T Lykken, and Peter H Venables. 1981. Publication recommendations for electrodermal measurements. *Psychophysiology* 18, 3 (1981), 232–239.

[14] James J Gross and Robert W Levenson. 1995. Eliciting emotions using films. *Cognition and Emotion* 9, 1 (1995), 87–108.

[15] John M Henderson, Wonil Choi, Steven G Luke, and Joseph Schmidt. 2018. Neural correlates of individual differences in fixation duration during natural reading. *Quarterly Journal of Experimental Psychology* 71, 1 (2018), 314–323.

[16] John M Henderson and Steven G Luke. 2014. Stable individual differences in saccadic eye movements during reading, pseudoreading, scene viewing, and scene search. *Journal of Experimental Psychology: Human Perception and Performance* 40, 4 (2014), 1390.

[17] Harrie F Hess and Jerry V Diller. 1969. Motivation for gambling as revealed in the marketing methods of the legitimate gambling industry. *Psychological Reports* 25, 1 (1969), 19–27.

[18] Sungpyo Hong, Joanna Narkiewicz, and Randy H Kardon. 2001. Comparison of pupil perimetry and visual perimetry in normal eyes: decibel sensitivity and variability. *Investigative ophthalmology & visual science* 42, 5 (2001), 957–965.

[19] Robin Hunicke, Marc LeBlanc, and Robert Zubek. 2004. MDA: A formal approach to game design and game research. In *Proc. AAAI Workshop on Challenges in Game AI*, Vol. 4. 1722.

[20] Costas I Karageorghis, Leighton Jones, and Daniel C Low. 2006a. Relationship between exercise heart rate and music tempo preference. *Research quarterly for exercise and sport* 77, 2 (2006), 240–250.

[21] Costas I Karageorghis, David-Lee Priest, Peter C Terry, Nikos LD Chatzisarantis, and Andrew M Lane. 2006b. Redesign and initial validation of an instrument to assess the motivational qualities of music in exercise: The Brunel Music Rating Inventory-2. *Journal of sports sciences* 24, 8 (2006), 899–909.

[22] Dacher Keltner, Paul Ekman, Gian C Gonzaga, and Jennifer Beer. 2003. Facial expression of emotion. (2003).

[23] Sylvia D Kreibig. 2010. Autonomic nervous system activity in emotion: A review. *Biological psychology* 84, 3 (2010), 394–421.

[24] Arlen C Moller, Brian P Meier, and Robert D Wall. 2010. Developing an experimental induction of flow: Effortless action in the lab. *Effortless attention: A new perspective in the cognitive science of attention and action* (2010), 191–204.

[25] Pedro Silva Moreira, Pedro Chaves, Nuno Dias, Patrício Costa, and Pedro Rocha Almeida. 2018. Emotional processing and the autonomic nervous system: a comprehensive meta-analytic investigation. (2018).

[26] Larissa Müller, Arne Bernin, Sobin Ghose, Wojtek Gozdzielewski, Qi Wang, Christos Grecos, Kai von Luck, and Florian Vogt. 2016. Physiological data analysis for an emotional provoking exergame. In *2016 IEEE Symposium Series on Computational Intelligence (SSCI)*. IEEE, 1–8.

[27] Larissa Müller, Arne Bernin, Andreas Kamenz, Sobin Ghose, Kai von Luck, Christos Grecos, Qi Wang, and Florian Vogt. 2017. Emotional journey for an emotion provoking cycling exergame. In *2017 IEEE 4th International Conference on Soft Computing & Machine Intelligence (ISCMI)*. IEEE, 104–108.

[28] Larissa Müller, Sebastian Zagaria, Arne Bernin, Abbes Amira, Naeem Ramzan, Christos Grecos, and Florian Vogt. 2015. Emotionbike: a study of provoking emotions in cycling exergames. In *International Conference on Entertainment Computing*. Springer, 155–168.

[29] Lennart E Nacke and Craig A Lindley. 2010. Affective ludology, flow and immersion in a first-person shooter: Measurement of player experience. *arXiv preprint arXiv:1004.0248* (2010).

[30] Lennart E Nacke, Sophie Stellmach, and Craig A Lindley. 2011. Electroencephalographic assessment of player experience: A pilot study in affective ludology. *Simulation & Gaming* 42, 5 (2011), 632–655.

[31] Simon Niedenthal. 2009. What we talk about when we talk about game aesthetics. (2009).

[32] Pedro A Nogueira, Rui Rodrigues, Eugénio Oliveira, and Lennart E Nacke. 2013a. A hybrid approach at emotional state detection: Merging theoretical models of emotion with data-driven statistical classifiers. In *Proceedings of the 2013 IEEE/WIC/ACM International Joint Conferences on Web Intelligence (WI) and Intelligent Agent Technologies (IAT)-Volume 02*. IEEE Computer Society, 253–260.

[33] Pedro A Nogueira, Rui Rodrigues, Eugénio Oliveira, and Lennart E Nacke. 2013b. A regression-based method for lightweight emotional state detection in interactive environments. In *XVI Portuguese conference on artificial intelligence (EPIA)*.

[34] Jamie L Rhudy, Klanci M McCabe, and Amy E Williams. 2007. Affective modulation of autonomic reactions to noxious stimulation. *International Journal of Psychophysiology* 63, 1 (2007), 105–109.

[35] Kenzo Sato and Richard L Dobson. 1970. Regional and individual variations in the function of the human eccrine sweat gland. *Journal of Investigative Dermatology* 54, 6 (1970), 443–449.

[36] K Sato and F Sato. 1983. Individual variations in structure and function of human eccrine sweat gland. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* 245, 2 (1983), R203–R208.

[37] Jocelyn C Scheirer, Rosalind W Picard, Nancy Tilbury, and Jonathan Farringdon. 2002. Sensing and display of skin conductivity. (July 2 2002). US Patent 6,415,176.

[38] Meike K Uhrig, Nadine Trautmann, Ulf Baumgärtner, Rolf-Detlef Treede, Florian Henrich, Wolfgang Hiller, and Susanne Marschall. 2016. Emotion elicitation: A comparison of pictures and films. *Frontiers in psychology* 7 (2016), 180.

[39] Sandy Wolfson and Gill Case. 2000. The effects of sound and colour on responses to a computer game. *Interacting with computers* 13, 2 (2000), 183–192.