A physiological approach for continuously modeling user emotion in interactive play environments

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Computer games have grown during recent years into a popular entertainment form with a wide variety of game types and a large consumer group spread across the world. As researchers develop novel play environments, computer and console game markets continue to grow rapidly, outperforming the film industry in terms of total revenues in many regions [6]. Although gaming technology has continued to evolve, researchers and computer game developers suffer from a lack of effective evaluation methods. My research interest is in how to quantify emotional experience when engaged with play technologies, by developing an evaluation methodology for entertainment environments that is as robust as methods for evaluating productivity. This paper summarizes a series of experiments used to design this new evaluative methodology.

Motivation

The development of evaluation methodologies in human-computer interaction research (HCI) has been rooted in the sciences of Psychology, Human Factors, Engineering and Computer Science [5]. The idea of emotion, which is equally important to design [5], is still not well understood, especially when the primary goals are to challenge and entertain a user. Traditional measures of user behaviour in productivity environments, such as task performance, are not applicable to play environments since we are not interested in measuring performance; we are interested in measuring what kind of emotional experience is provided by the play technology and environment, regardless of performance [6]. Although traditional usability measures may still be relevant, they are subordinate to the emotional experiences resulting from interaction with the play technology and with other players. An equally important issue for measuring user experience in game environments is that a successful play experience is determined by the process of playing, not the outcome of playing [6]. Any methodological approaches should inform designers of user behaviour both within and after the play experience.

Experiments

Along with several co-authors, I conducted a series of experiments to develop a new method for continuously modeling user emotional state in interactive play environments based on a user's physiological responses. The goal was to develop an evaluation methodology for entertainment environments that: captures usability and playability through metrics relevant to ludic experience; accounts for user emotion; is objective and quantitative; and has a high evaluative bandwidth (continuous measurement). Our approach was to collect physiological data as a direct indication of user experience. We explored the following physiological measures: galvanic skin response (GSR), heart rate (HR), electromyography (EMG) of the face (jaw, forehead, cheek), and respiration.

In an initial experiment we explored how physiological signals respond to interaction with play technologies. We collected a variety of physiological measures while observing participants playing a computer game in four difficulty conditions, providing a basis for experimental exploration of this domain. Collecting and analysing physiological data requires a controlled approach that is hard to balance with the need for ecological validity when measuring behaviour within gaming systems. Guidelines for conducting research in this domain based on results from our initial experiments can be found in [3].

In a second experiment we investigated how physiological signals differ between play conditions, and how physiological signals co-vary with subjective reports [1]. We observed different physiological responses when users played a computer game against a co-located friend versus a computer. When normalized, the physiological results mirrored subjective reports. By integrating the methods in [3], we showed that physiological measures can be used to objectively measure a player's experience with computer games.

In a third experiment we developed a method for mathematically modeling emotion using physiological data. A fuzzy logic model transformed four physiological signals (GSR, HR, EMG smiling, EMG frowning) into the emotional dimensions of arousal and valence. A second fuzzy logic model transformed arousal and valence into five emotional states: boredom, challenge, excitement, frustration, and fun. The modeled emotions' means were evaluated with test data, and exhibited the same trends as the reported emotions for fun, boredom, and excitement, but modeled emotions revealed statistically significant differences between three play conditions, while differences between reported emotions were not significant. The details of the fuzzy logic model can be found in [4] while the validation of the model and its potential use in interactive systems can be found in [2].

Implications of results

In the course of our experiments, we have made significant contributions to affective computing and HCI evaluation methodologies, and have extended the applicability of fuzzy logic to a new domain. Specifically, we provided: a systematic exploration of how the body responds to interactive play environments; rules and guidelines for conducting research in this domain; support that physiological measures can be used to objectively measure a player's experience with entertainment technology; and evidence that normalized physiological measures of experience with entertainment technology correspond to subjective reports.

In addition, our models of emotion provide a continuous metric for evaluation. Modeled emotions provide an objective and quantitative approach to evaluating play technologies, but can also be viewed over an entire experience, revealing the variance within a condition, not just the variance between conditions. This is especially important for evaluating user experience with entertainment technology, because the success during play is determined by the process of playing, not the outcome of playing [6]. Continuously representing emotion is a powerful evaluative tool (with a high evaluative bandwidth) that can be easily combined with other methods. Given a time series of emotional output, researchers can use interesting features in the modeled emotion output to index other evaluative data sources such as video or screen captures of the play environment, or other objective behavioural data.

Future Directions

Our models and results are still preliminary and require further investigation before they are robust enough for deployment outside of a laboratory. Most importantly, we need to employ a better method of scaling the physiological responses to deal with the high variability between individuals. In addition, our models were developed *post hoc*; more research may make these models run in real-time with new users unknown to the system.

We are presently considering other emotional states relevant to interaction with entertainment technology (such as disappointment or pride), which can be described by arousal and valence. Other more complex emotions, such as schadenfreude, are difficult to describe in the emotional dimensions of arousal and valence and require more research to model. In addition, we are looking into other physiological sensors such as EEG and pupil diameter.

Finally, we would like to integrate our approach with other behavioural evaluation methods. Details on these future refinements to the emotional models can be found in [2, 4].

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