Games User Research using EEG Techniques

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Abstract
In this position paper, we explore electroencephalography (EEG) techniques for games user research, such as frequency analysis, hemispheric asymmetry and event-related potential technique (ERP). We also briefly introduce how to prepare EEG data and what equipment is available for each technique. We hope to outline the benefits of EEG research for the growing array of physiological measures used in games user research.

Author Keywords
EEG, ERP, Games User Research, Neurofeedback, Hemispheric Asymmetry

INTRODUCTION
The purpose of games user research is to improve gameplay and enhance the user experience in games. Traditional user testing approaches can be used to assess player feelings via subjective methods, such as questionnaires and interviews or behavioral observation. However, questionnaires taken during or after game play are subject to validity threats because participants may forget or leave out valuable information and they interrupt the gameplay experience. In addition, some questionnaires do not generate comparable information and can be prone to opinion bias. Additionally, participants may not answer completely honestly, because they fear judgment and do not wish to com-

Figure 1: EPOC Emotiv Wireless EEG headset

Figure 2: Neurosky Mindwave EEG headset.

pletely reveal all their thoughts and opinions, especially when an experimenter is present. Psychophysiological user research addresses some of these concerns. From this field, methodologies such as galvanic skin response (GSR) and electromyography (EMG) are becoming more commonly used in game evaluation. We want to discuss some of the possibilities for using EEG-based player evaluation here.

EEG can be used as an input for a game as well. Currently techniques in the literature are available for both evaluation and for consumer use in games. EEG in comparison to other physiological methods, such as GSR or EMG is more diverse. Depending on the used analysis technique, different information about the participant is made available. Techniques reviewed in this paper include Frequency Analysis, Hemispheric Asymmetry, and Event Related Potential (ERP). We review these techniques for either evaluation or as input where available. Additionally, devices available to both consumers and researchers are suggested for use with the various techniques for user researchers wishing to consider exploring these analyses without buying a clinical grade system. Devices are recommended based on the availability of electrodes necessary for each analysis.

EEG data is recorded using a series of electrodes which sit on the scalp of a participant. The electrodes collect electrical signals and reference against an electrode often located on the mastoid behind the ear, on the ear lobe or on the nose of the participant depending on the setup being used [1, 2]. Additionally, other considerations as epoch length or whether or not to record a baseline depends on data analysis. EEG data, like most physiological data, is not robust, but messy data can be caused by natural movement of the participant (known as artifacts). As a result, artifact removal is usually done to remove blinks, eye movements, chewing and heart beat from the data [1].

FREQUENCY ANALYSIS

Frequency Analysis has been used to input EEG data into a game. Frequency analysis involves decomposing the EEG signal into its component frequency bands [1]. Next, the power of each frequency band is assessed. Depending on the area of interest, simple setups such as the Mindwave or Mindset by Neurosky (see Figure 2) may be used to measure frequency frontally. The EPOC Emotiv (see Figure 1) may be used for measurements across electrodes of the brain. For example, in a study by Salminen et al. [3] EEG of the player was measured while playing a violent video game. Game events such as injury of a player increased theta levels in the occipital area of the brain measured using electrode pairs, including O1 and O2 and Cz reference point.

Frequency analysis of the brain can result in different information based on the area it is measured from. For example theta, often associated with a sleepy, non-aroused state, but midline theta is commonly associated with attentiveness [1]. The alpha rhythm can also be different based on the area it is collected from. Alpha usually representative of relaxation is 8-12 Hz. However the mu rhythm can be measured between 8-12 Hz over the motor cortex and is indirectly related to learning. The mu rhythms are indirectly related to the firing of the mirror neurons during observation or imitation learning [4]. If it is possible to gather more information of how players learn using this technique, then tutorials can be made to be both more comprehensive and enjoyable [5]. With the improvement of tutorials complicated game measures may be used because they are more easily presented.

Neurofeedback
Frequency analysis can be used to measure the player's brain state during gameplay. If the frequency waves are made available to the participant in real time, then it is possible for the participant to regulate their brainwaves to control applications (i.e., neurofeedback [6]).

In an application called Brainball, by Hjelm et al. [7] frequency bands were measured and compared across two participants. The data were used to determine which participant is more relaxed causing a ball to roll across the table to the player, who has a lower relaxation score. The above examples of neurofeedback are not readily accessible to consumers. However, neurofeedback has also been used by in products offered by Neurowear and Neurosky such as Necomimi ears (*Neurowear 2012, NeuroSky 2012*). Necomimi ears move based on the brain state of the person wearing it, and by watching the ears move can get feedback about their brain state. The ears are an example of how EEG can be accessible to a wide age range (14+) of non-experts. Another example of an EEG application made for consumer use is Mindflex, where the EEG inputs to a board-like game. The EEG allows players to control fans, in an attempt to levitate a ball through a variety of obstacles. Applications are being developed for online stores, such as the Neurosky App Store.

HEMISPHERIC ASYMMETRY

Hemispheric asymmetry is an EEG technique that gives the researcher measurement of arousal in response to a stimulus or piece of information. Researchers using this technique will conduct two separate frequency analyses for each hemisphere of the brain and then compare between lobes to get an arousal measure [8].

This technique has been applied to game research. Salminen et al. used it to look at arousal in accordance with in game events and frontal alpha asymmetry [9]. However, researchers should be cautious because the valence of the arousal can also be negative (e.g., frustration) [10]. This technique was also applied to central alpha. Salminen et al. also used this technique to look at violence in video games and found increased theta for killing events in games [3].

Use of this technique may allow for correlation of in game events across games and users arousal. This could allow for a database of in-game events and players brain-state reactions, which can be referenced by game developers. Additionally, it may inspire game developers to create game environments that employ these various techniques.

EVENT RELATED POTENTIAL

The event related potential (ERP) technique is another way of analyzing EEG data. ERP is calculated by averaging the electrodes at the time of the stimulus or presented information to look for patterns or components previously outlined in the literature. For example, the N170 component fires in response to face or face-like stimuli [2]. ERP may be used to provide researchers with interesting information regarding the player’s perception of in game stimuli. For example, if the N170 component was recorded during a game, researchers would be aware of the face stimuli attended to by the player. This may be interesting for social games requiring avatars or for placement of non-player characters.

PITFALLS OF EEG

To start on EEG research, it is necessary to invest in the right equipment. This involves knowing what analyses to conduct before purchasing. Additionally, EEG has weak spatial resolution which can cause source ambiguity [1] and data is subject to noise caused by natural movements of the player while wearing the headset. As a result data must be thoroughly prepared before inputting into a game or analysis. Additionally, EEG provides much data that differ depending on the analysis used. As a result, researchers and developers must know EEG thoroughly before applying the technique [2, 3]. Additionally, secondary measures may be necessary to insure proper assessment of the EEG activity [9]. In conclusion, EEG can be analyzed using, for example, Frequency Analysis, Neurofeedback, Hemispheric Asymmetry, and ERP. Different techniques can be used to either evaluate or input information in to video games. EEG may be used for creative and novel games that are better enjoyed by players.

FUTURE WORK

Despite pitfalls of EEG, future work in this area, such as using mu rhythms for learning applications or evaluating player arousal using hemispheric frontal alpha asymmetry will provide valuable information on the mental state of participants during gameplay. Additionally, further work using ERP may allow for novel gaming applications. In the future, my work will involve using ERP as both an evaluation and input. In addition, I would like to use ERP to make more creative puzzles for video games based on game understanding.

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