An Introduction to EEG Analysis Techniques and Brain-Computer Interfaces for Games User Researchers

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ABSTRACT
Games User Research (GUR) can provide meaningful insights into the study of games. As a part of GUR, we focus on the area of cognitive psychology and discuss electroencephalography (EEG) as an evaluation technique for games. We want to introduce game researchers to EEG when studying the cognitive side of player experience and discuss how it can benefit game studies. In this paper, we review EEG techniques before providing researchers with information about general EEG setup and methodology, EEG data collection, preparation, and analysis. Techniques reviewed have been used in medical applications, research, brain-computer interaction (BCI) and human-computer interaction (HCI) applications. In addition, future ideas for applications of EEG techniques in game studies are discussed. We outline how to use different EEG analysis techniques for game research and it is our hope to make these techniques more understandable for the game studies community and to demonstrate their merit for games user research.

Keywords
EEG, User experience, player experience, video games, affective technology, EEG technology.

INTRODUCTION
Successful games (e.g., critical and commercial successes) are often described with adjectives such as *engaging*, *immersive* or *exciting* (Ermi and Mäyrä 2005; Ijsselsteijn and Kort 2007). Players might report playing them to “lose track of time” or “be completely focused” (Brockmyer, J.H., Fox, C.M., Curtiss, K.A., McBroom, E., Burkhart, K.M., Pidruzny 2009). Games that do not engage players or create optimal experiences are often considered failures (i.e., they do not achieve high sales and/or good reviews), costing businesses and video game players time and money. They also cause game developers frustration. Researchers have attempted to measure and to predict how to create good and engaging gameplay experiences, but there is currently no guarantee for the commercial and critical success of a video game. However, Games User Research (GUR) takes hints from psychology to take playtesting to a scientific level, where it is

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possible to maximize the chances of a game to be considered a success (Mirza-Babaei et al. 2013).

GUR often uses post-gameplay methods such behavioural observation, player interviews, focus groups and questionnaires (Nacke 2013). To discuss all of these methods is beyond the scope of this paper. We will briefly discuss some questionnaires before focusing on physiological evaluation methods. The Game Engagement Questionnaire (GEQ) (Brockmyer, J.H., Fox, C.M., Curtiss, K.A., McBroom, E., Burkhart, K.M., Pidruzny 2009)**,** for example, is used to help researchers better understand the overall player experience or the summation of the player's thoughts and feelings. Recently, Takatalo et al. attempted to make a more comprehensive questionnaire called Presence Involvement Flow Framework (PIFF) by examining features previously studied in the literature (Takatalo, Kawai, Kaistinen, Nyman, Häkkinen 2011). However, questionnaires and other methods that are administered to players after gameplay are sometimes called into question because of their validity and reliability threats, meaning that researchers are asking players to *recall* feelings. This technique becomes complicated when seeking information on particular (e.g., perpetually occurring) gameplay events. In addition, stopping players during gameplay may interrupt their game flow and affect their feedback. Ideal game evaluation techniques provide real-time feedback to researchers during a game and can be timed to record important events.

Physiological evaluation such as using skin conductance, heart rate or electroencephalography (EEG) can be used for real-time evaluation (Cacioppo, Tassinary, Berntson 2007). This paper focuses on the use of EEG as a real-time evaluation tool for aspects of player experience during gameplay (Salminen, Mikko j., Kivikangas, Matias, Ravaja, Niklas, and Kallinen, Salminen, Kivikangas, Ravaja, Kallinen 2009) and as a tool for Brain-Computer Interface (BCI) applications (Krepki, Blankertz, Curio, Müller 2007; Nijholt, Erp, Heylen 2008). Although EEG was traditionally used for medical applications, EEG has also been used for research. EEG methodology has been used to evaluate parts of user experience and to interact with computing systems, most often for users with interaction constraints.

A disadvantage of EEG is that has limited spatial resolution in comparison to functional Magnetic Resonance Imaging (fMRI) techniques. Researchers sometimes report EEG results as a function of the collection area. Although the electrodes record the signal from a particular scalp location, it is not guaranteed that the findings originate from the measured areas of the skull. Signals may originate from neighbouring areas of the brain and be recorded by other electrodes. This becomes more problematic when looking at signals originating from the lower brain such as the basal ganglia (Teplan 2002). However in comparison to fMRI, EEG has great temporal resolution, which fMRI cannot compete with. As a result, EEG can be used to study the effects of stimuli as a function of time. In addition, data can be looped back to a computing system in real time for BCI and human-computer interaction (HCI) applications. This is best exemplified by neurofeedback studies discussed later in this paper. HCI and BCI applications are also designed to be accessible for consumer and non-medical use. As a result, EEG is better in both cost effectiveness and accessibility (Buzsaki 2009; Logothetis 2008; Luck 2005; Poldrack 2006).

DATA COLLECTION

EEG is recorded through a series of electrodes. Electrodes should align to the 10-20 map of electrode placement, a reference map commonly used to align electrodes to scalp locations corresponding to brain lobe areas. The electrical activity recorded by all electrodes (corresponding to neural activity) is often referenced against one or two reference points. Reference points may include, for example, the center of the scalp, nose, or mastoids. Alternative reference methods may include calculating the average as a global reference or using Driven Right Leg (DRL) and Common Mode sense (CM). The electrical activity of each electrode is subtracted from the reference point to obtain information about the brain of the participant. Once obtained the information can be analyzed using different techniques such as frequency analysis, hemispheric asymmetry, event related potential (ERP), or connectivity. The technique used depends on the information sought as specified by the hypothesis of the research that is carried out (Cacioppo, Tassinary, Berntson 2007; Coan and Allen 2004; Coben and Hudspeth 2008; Luck 2005).

Equipment

There are many different companies producing EEG equipment for data collection that vary in reference points or number of electrodes. Recordings may be done with a dense electrode array of 132 electrodes (Krepki, Blankertz, Curio, Müller 2007), 62 electrode caps (Aftanas, Varlamov, Pavlov, Makhnev, Reva 2002), 19 electrodes caps (Kouijzer, Moor 2009), 16 electrodes as in the consumer-price EPOC Emotiv system (Ekanayake 2010), 10 electrode caps (Salminen, Ravaja 2008)) or even as few as 1 electrode and references as in the consumer-price Neurosky systems (Schild, LaViola, Masuch 2012). Introducing multiple electrodes can increase spatial resolution but increase the cost of the system and it may also increase complexity of the analysis, depending on the technique used. In contrast, certain evaluation techniques may not be possible with the available electrode arrangements. For example, hemispheric asymmetry techniques cannot be used with a single electrode system. However, in most cases, a high-density electrode system is not required for frontal frequency analysis. Researchers need to consider the best system to use based on the purpose of the study proposed and the analysis technique to be utilized, which we will discuss below (Buzsaki 2009; Cacioppo, Tassinary, Berntson 2007; Coan, Allen 2004; Luck 2005; Thatcher 2012).

PREPARATION OF EEG DATA

EEG data can be analyzed in alternative ways to provide different information about the brain state. However, EEG is not a robust measure and can yield less than the expected amount of information if not collected properly (e.g., more artefacts, noise). The significance of the findings can also be affected by improper treatment of the data during analysis; for example, the accuracy of a time stamps can affect where you search for a brain response (Cacioppo, Tassinary, Berntson 2007; Luck 2005).

Time Stamps

EEG techniques look at the brain state following a change in the environment or in stimuli. As a consequence, it is important to have an indication of event time or stimulus presentation to run an analysis. Averaging over time with no events or incorporating resting state into the average analysis can change the significance levels of the results. Time stamps are especially important for event-related potential technique (ERP) analysis because of the sensitivity of the components to a time within milliseconds post stimulus or after the presentation of an event. For example, the N170 (a component of ERP analysis) is found in adults 170ms after the presentation of a face or face-like stimuli (Luck 2005).

Baseline

It may be necessary to have a baseline for comparison depending on the design of the experiment. This may be collected as an eyes-open baseline or an eyes-closed baseline based on the experimental protocol being used. The processing of visual input might influence alpha and arousal activity levels and this should be taken into account when considering eyes-open or eyes-close as a baseline. (Buzsaki 2009; Cacioppo, Tassinary, Berntson 2007; Luck 2005).

Artefact Removal

Researchers attempt to collect clean data to minimize the amount of artefacts or noisy data collected. Some precautions that are common include minimizing muscle movement and head turning; keeping light settings consistent, ensuring electrode contact with the skull of the participant, running the experiment in a separate room free of distractions. Other precautions can including attempting to reduce bridging, the return of identical recordings between electrodes, by keeping the moisture, which conducts electrical signals to a minimum. Researchers also often measure the head of the participant using landmarks like nasion (the dip between the eyebrows) and the inion (on the back of the skull) to ensure strict adherence to the 10-20 system for electrode placement. Pilot studies should be run to check if the data collected is usable before running a full experiment (Luck 2005). However—despite best efforts—noise and artefacts may still be recorded.

Artefact removal involves omitting messy data that is not the result of brain signals. Artefacts can be caused by blinks, lateral eye movements, muscle activity and movement. Artefact removal also includes reduction of noise caused by electrical currents near the experimental set up from the data. Artefact removal may be necessary to ensure the internal validity and reproducibility of the study. For example, artefacts can cause artificial results (Luck 2005).

A common method of removing artefacts is visual inspection. This involves the researcher looking through the data for peaks, messy sections, rectangular patterns associated with lateral eye movements or other patterns associated with artefacts (Aftanas, Varlamov, Pavlov, Makhnev, Reva 2002; Ibric, Dragomirescu, Hudspeth 2009; Nacke, Stellmach, Lindley 2010; Salminen, Ravaja 2008; Ulloa, Pineda 2007). Visual inspection produces clean data. However; there is the threat of compromised inter-rater reliability, because this method is somewhat subjective. Therefore, individual differences exist. In addition, researchers may accidently remove real data. This technique lacks efficiency; it also requires time and effort from the experimenter. Some researchers combine visual artefact removal techniques with statistical analysis of the peak to ensure that only outliers and not valuable data is being removed from the EEG recordings (Kouijzer and Moor 2009). This technique does alleviate some concerns of visual artefact inspection; but is still time-consuming and can also be affected by individual differences between researchers when identifying components for statistical analysis.

Other researchers use electroculography (EOG) channels near the eyes to identify artefacts (Aftanas, Varlamov, Pavlov, Makhnev, Reva 2002; Krepki, Blankertz, Curio, Müller 2007; Wilson, Russell 2007). This technique makes artefacts arising from eye movements more salient. It also reduces the chances of removing significant data because data that has peaks that are not reflected in the EOG channels are not removed.

Researchers may also employ programs to artefact the data. In their 2012 study, Malik et al. used *Neuroguide* software (Malik, Pauzi, Khairuddin 2012). Researchers may also wish to employ a combination of the above techniques depending on their tolerance for artefacts (Aftanas, Varlamov, Pavlov, Makhnev, Reva 2002). In contrast, researchers may also choose not to artefact data before analysis. This process can be time consuming, so that some researchers do not artefact (Hwang, Kim, Jung, Kim, Lee, Im 2011). Researchers studying BCI and HCI application may also choose not to artefact because it does not suit the final application of their results (Nijholt, Erp, Heylen 2008).

The decision regarding which approach to artefacts will be used depends on both the researcher and the sensitivity of the data to artefacts. Therefore decisions to artefact or not must be made on a case-by-case basis. Researchers should be able to justify the concluding decision.

Filtering

Filtering can result in cleaner data and affect the significance of the finding. However, filtering can also distort the data and must be considered carefully before use (Luck 2005).

Notch filters are often utilized because electrical equipment near the experimental setup can cause 60 Hertz interference, which can introduce artefacts to the data. As a result, researchers may choose to notch filter at 50 to 60 Hertz (Cacioppo, Tassinary, Berntson 2007; Luck 2005). Band Pass Filters limit the upper and lower ranges of the frequency ranges being used in the study. Researchers should also ensure that the sampling rate is at least twice as high as the highest frequency (Cacioppo, Tassinary, Berntson 2007; Luck 2005).

Component analysis such as Principal Component Analysis (PCA) and Independent Component Analysis (ICA) are powerful techniques for identifying components to be removed, such as artefacts caused by muscle movements or electrical noise. It allows the artefact removal process to be more automatic but can distort the data (Cacioppo, Tassinary, Berntson 2007; Luck 2005; Thatcher 2012).

ANALYSIS TECHNIQUES

EEG utilizes a number of techniques to analyze data.. Analyses that depend on power of a frequency band or decomposition of the EEG signal include frequency analysis, neurofeedback, hemispheric asymmetry and synchrony techniques. ERP techniques are used to look at the brain changes after an event or stimulus presentation. Lastly, synchrony and power change are of interest during connectivity studies or studies that further explore the connections within the brain. The analysis will dictate the specifications of the equipment and setup. It will also affect the study design and statistical analysis. The chosen analysis must reflect the research question. The presented paper will review different analysis techniques and how they may be used to explore different hypothesises

Frequency Analysis

Questions involving the brain state of the user may employ frequency analysis. In frequency analysis the EEG data is divided by frequency bands determined by separating the signal in to its component waves. A common approach to this analysis would be to use a Fast Fourier Transform (FFT). Information obtained by this analysis depends on the area of collection. For example, for skull collection, the alpha band consisting of 8-13 Hertz frequency, and can be an indication of a drowsy or relaxed state (Cacioppo, Tassinary, Berntson 2007; Salminen, Ravaja 2008; Ulloa, Pineda 2007).

Delta band is defined from 1-4Hz. The theta band is from 4-12Hz and can be associated with sleepiness. The alpha band is 8-13Hz and is often associated with a relaxed state. The beta band is from 13-30Hz and can represent concentration. Lastly, the gamma band is from 30-50Hz (Nacke, 2013).

This method has previously been used classically to study sleep; where the differences in sleep level are associated with different frequency bands. In a study by Landolt et al. (1995) frequency bands were examined to assess the effect of caffeine of the depth of sleep of the participant. The study revealed that caffeine reduces the prevalence of the low frequency delta activity (Landolt, Dijk, Gaus, Borbély 1995).

This methodology was employed by Salminen and Ravaja in 2008, to study the effects of violence on players playing a first person shooter. The events recorded for the analysis, as stimuli, involved shooting and injuring other players. The results showed that in response to violent events there is an increase in oscillatory theta activity (Salminen, Ravaja 2008). The study was limited to only one game, so conclusions drawn were not referenced against a null condition of non-violence. Future continuations of this study may want ensure the results are reproducible against a more rigorous null criteria.

Pre-calculated frequency measures for entertainment and relaxation are available for Neurosky MindWave and MindBand headsets. Although built in and usable; Neurosky has not released the calculations of the two variables and therefore it is not available to use these formulas for academic purposes.

In a paper by Schild et al, (2012) looking at player experience, these formulas were used and compared to questionnaire data from the GEQ (Brockmyer, J.H., Fox, C.M., Curtiss, K.A., McBroom, E., Burkhart, K.M., Pidruzny 2009) after playing a game. The resulting data from the EEG contrasted the results of the questionnaire. This is likely due to the use of the non-released formulas in the analysis (Schild, LaViola, Masuch 2012).

Additionally, a study by Crowley et al. also utilized the measures of relaxation and attention from the *Neurosky* headset. The researchers were particularly interested in the brain state of the participant during mistakes (Crowley, Sliney, Pitt, Murphy 2010). Another approach to the same problem could involve using Error Related Negativity (ERN) (Holroyd, Coles 2002) discussed later on in the paper. However, use of this methodology would require a change in equipment.

Using EEG data and frequency based analysis to manipulate physical prototypes is an application of *BCIs*. *Brainball* is a game played by two players on a table which employs a physical ball. The object of the game is to keep the ball away from your end of the table. If the ball rolls towards your opponent, you are declared the winner. To meet the objective it is necessary to relax. Thinking about winning or about game strategies will only benefit your opponent. The game uses EEG input to determine the player's relaxation level using frequency analysis. For ensuring the winner is in a relaxed, meditative or peaceful state, the theta, alpha and beta levels of the players are compared against each other. This application is a demonstration of the ways EEG can be used to manipulate physical objects (Hjelm 2003). However, the authors do not explain the creation of the table and no particular research objectives were set for this design.

In the previously cited works the overall frequency of the brain was analyzed. However, depending on the research question, researchers may to choose to analyze signals from only few areas of the skull by limiting the electrodes. For example, theta frequency can signify sleepiness or drowsiness while midline theta can represent concentration (Cacioppo, Tassinary, Berntson 2007).

The *mu* rhythm is collected in the alpha frequency range of 8-12 Hertz over the motor cortex. To specifically look at this rhythm only; data from electrodes overlapping or near the motor cortex (i.e., horizontally between the ears) is used. The mu rhythm fires when observing an action preformed using the hand or mouth and is suppressed when the participant mirrors that action (McFarland, Miner, Vaughan, Wolpaw 2000; Nyström, Ljunghammar, Rosander, Hofsten 2011; Ulloa, Pineda 2007).

In a similar study, McFarland et al. (2000) studied the mu rhythm. The researchers used topography as part of their analysis (McFarland, Miner, Vaughan, Wolpaw 2000). Topographies allow for visualization of the decomposition of the signal into component frequencies overlaid on a depiction of the skull. The topographies allow for visual identification and removal of artefacts, and it also allows for the visual identification of information (Cacioppo, Tassinary, Berntson 2007).

Researchers have also looked at mu rhythms to study learning in video games. They showed that learning depends on the order of watching the game played first versus playing the game before watching the video. The results also indicated that the order of play also affected arousal (Wehbe, Kappen, Rojas, Kapralos, Nacke 2013).

Neurofeedback

Presenting the brain state of the participant to the participant in a compressive way will allow them to alter their brain state according to the feedback provided. This premise is the foundation of neurofeedback. Often studies employ a visualization to inform users of their brain state (Gevensleben, Holl, Albrecht, Vogel, Schlamp, Kratz, Studer, Rothenberger, Moll, Heinrich 2009), but one may also use a physical representation (Hjelm 2003). Often neurofeedback techniques measure meditation or relaxation using frequency analysis (Cahn, Polich 2006). *Brainball* is an example of neurofeedback because it informs the participant of their current brain state (relaxation) and allows the participant to act on that information (Hjelm 2003). Individuals can also learn and benefit from neurofeedback. Research has shown that this technique can alter an individual’s brain in measurable way (Ibric, Dragomirescu, Hudspeth 2009).

Neurofeedback has also been used widely for clinical purposes. Neurofeedback has been used to help children with Attention Deficit Hyperactivity Disorder (ADHD) or Attention Deficit Disorder (ADD) (Gevensleben, Holl, Albrecht, Vogel, Schlamp, Kratz, Studer, Rothenberger, Moll, Heinrich 2009; Lubar, Swartwood, Swartwood, O’Donnell 1995; Masterpasqua, Healey 2003) as well as children with Autism Spectrum Disorder (ASD) (Kouijzer, Moor 2009).

Hemispheric Frontal Alpha Asymmetry

Hemispheric Frontal Alpha Asymmetry as involves frequency analysis. This technique involves looking at hemispheric activity of the opposing lobes of the brain. This may include comparing statistical power of the frequency analysis of a wave in the right hemisphere versus the left (Cacioppo, Tassinary, Berntson 2007). Further statistical tests can be used to analyze the data by lobe, to look for significant differences in activation between lobes. Coan & Allen outline a protocol that can be followed (Coan, Allen 2004).

This technique has been applied to user experience and gaming. Salminen et al. (2009) looked at Super Monkey Ball2 and examined game events (i.e., falling off the track) to determine their effects on the player. The researchers propose that games that are more arousing are more engaging. Therefore, this technique can provide a measure of player experience. This methodology is useful because the player does not have to be disrupted to get feedback (Salminen, Mikko j., Kivikangas, Matias, Ravaja, Niklas, and Kallinen, Salminen, Kivikangas, Ravaja, Kallinen 2009). Hemispheric Frontal Alpha Asymmetry can also be used as a measure of negative emotions such as stress or aggression. Researchers have examined the use of hemispheric frontal alpha asymmetry during task completion of impersonal stimuli versus interpersonal or socially induced stressful conditions. The study concluded that this technique can be used of an indication of these negative emotions during both events (Verona, Sadeh, Curtin 2009). Studies employing this technique should employ a second measure, such as a questionnaire, to interpret the data accurately (Wehbe, Kappen, Rojas, Kapralos, Nacke 2013).

Synchronization

Event-Related Synchronization (ERS) and Event-Related Desynchronization (ERD) are techniques that can be used to provide more information about the participant's brain state in association with a time event. Different methods of quantification have been used. This technique has been employed by Aftanas et al. (2002) the separated alpha bands and theta band were studied during emotional arousal (Aftanas, Varlamov, Pavlov, Makhnev, Reva 2002) This technique may be able to help us better understand the brain state and arousal levels of a participant during gameplay at a time-locked event. For an in-depth review refer to (Pfurtscheller, Lopes da Silva 1999). Durka et al. (2004) also discuss this method and can be valuable reference to researchers looking to employ this technique. The researchers also provide some guidelines at the conclusion of the paper (Durka, Zygierewicz, Klekowicz, Ginter, Blinowska 2004).

Event Related Potential Technique (ERP)

Questions that involve cognitive understanding may be answered using event related potential technique. Researchers employing this methodology look at different components or patterns that appear post stimulus or after an event. This technique uses time markers to identify the point of the stimulus is presentation. Researchers often record a couple hundred milliseconds post stimulus around 800 ms seconds after. Researchers then search for the expected component within the time range. For instance, the P300 component is a component that occurs 300 ms post a visual stimulus. When looking for this component pattern one would record an overlapping time section and expect the peak to occur 300ms post presentation of the visual stimulus (Luck 2005).

A common approach to the analysis of this technique involves summating the data from individual electrodes. In other words, data pre- and post- stimulus is examined by summing the curves after removing artefacts. Random fluctuations will be resolved through this process leaving only systematic differences. Patterns of activation previously established in the literature are sought to make inferences about the cognitive state of the participant. The appearance of the component can also depend on the population being studied. As an example, the N170 component appears 170ms post presentation of a face or face-like stimuli but in children it appears around 250ms post stimuli (Luck 2005).

Stimuli or events are not always concrete. ERP analysis can be used to study more abstract concepts such as creativity and insight (Dietrich, Kanso 2010; Dietrich 2004a, 2004b). In addition, components can also include patterns that occur indirectly or as a result of cognition following task or stimuli. For example, Error Related Negativity (ERN) is a negatively occurring peak that occurs after an error is made. Error related negativity is robust and does not discriminate between tasks and increases with the severity of the error (Holroyd and Coles 2002).

In a study by Tangermann et al. P300 and N200 components were studied as participants responded to visual stimuli. The end application was a photo browser. For this reason the independent variable was the highlighting of the photos to attract user attention. Dependent measures included performance and ERP analysis of the P300 and N200 components (Tangermann, 2011).

Another BCI application was used for computer security and authentication. The researchers propose that EEG can be used to authenticate users. The researchers believe that EEG will be a more secure method of authentication because passwords can employ the use of the implicit memory system (Martinovic, Davies, Frank, Perito 2012). Implicit memory, or more specifically procedural memory, is a component of memory that is not immediately accessible, but manifests during task completion (Galotti 2008). The researchers had participants complete a two-hour training playing a game—Guitar Hero—which requires players to press buttons in sequence to earn points. The researchers show that the P300 component can be used for multiple individuals as an authentication strategy. The authentication can be completed by playing the game, despite the fact that users were unable to recite the password or even portions of the password (Martinovic, Davies, Frank, Perito 2012). However in the article, researchers do not address the problem of memory decay and also do not test how often the user will need to complete training or authenticate in order to continuously keep the password stored implicitly.

ERP analysis also has been used as an evaluation technique. In a study by Li et al. in 2008, fatigue during stereoscopic 3D was quantitatively measured using ERP analysis (Li, Seo, Kham, Lee 2008).

Berlin Brain Computer Interface

Krepki et al. (2007) introduce Berlin Brain Computer Interface (BBCI) as a protocol for use of EEG for BCI applications using a combination of ERP analysis and neurofeedback techniques. Participants in this study attempt to use EEG in a game like format as a possible control mechanism. Researchers suggest that further development and use of this system may contribute to future applications for special populations, such as brain controlled wheel chair (Krepki, Blankertz, Curio, Müller 2007). BBCI has been applied by Lalor et al. (2005) who used ERP of visual stimuli for immersive game control (Lalor, Kelly, Finucane, Burke, Smith, Reilly, McDarby 2005).

Connectivity and Coherence

When two or more regions of the brain fire synchronously, they are said to be functionally connected despite the absence of physical connection (Delorme, Mullen, Kothe, Akalin Acar, Bigdely-Shamlo, Vankov, Makeig 2011; Nolte, Bai, Wheaton, Mari, Vorbach, Hallett 2004; Thai, Longe, Rippon 2009). Unlike other EEG techniques, functional connectivity technique is not exclusive to EEG. Other techniques such as functional Magnetic Resonance Imaging (fMRI) (Koshino, Kana, Keller, Cherkassky, Minshew, Just 2008) and Diffusion Tensor Imaging (DTI) (Sundaram, Kumar, Makki, Behen, Chugani, Chugani 2008) also employ functional connectivity.

The brain is able to change in response to stimuli. Connectivity techniques can be used to show real time changes in the brain state in response to stimuli (Hwang, Kim, Jung, Kim, Lee, Im 2011). This can allow researchers insight to the affects of gaming on brain in real-time.

Connectivity has been applied as an evaluative measure of user experience. Malik et al. (2012) looked at brain states during game play on large screens. Researchers separated data into frequency bands. The researchers then state: *"We used three EEG measures: absolute power, coherence and phase lag to analyse further analyzed data"* They report significant findings in absolute power in the occipital, partial frontal and motor regions. (Malik, Pauzi, Khairuddin 2012). However, this study does not vary the screen size as an independent variable; instead the task completed by the participants was completed on a large screen with no comparable screen condition. Future studies manipulating screen size would be a natural follow up and would also look at user experience from a human computer interaction perspective such as in Ivory et. al. 2009.

DISADVANTAGES OF EEG

As shown above EEG can provide researchers and developers which a unique view of the brain state of a participant which may appeal to researchers. However EEG has its disadvantages as well. Compared to fMRI, EEG has poor spatial resolution. This may lead to source problems or the inability to pinpoint the exact location the signal is arising from. However compared to fMRI, EEG offers better temporal resolution or the ability to better understand what time the event occurred in relation to a stimuli (Luck 2005; Cacioppo, Tassinary, Berntson 2007).

One of the disadvantages that can be most prohibitive to researchers is the robustness of the signal. EEG continues to be vulnerable to artefacts or noisy data. However other physiological techniques also have similar problems. Researchers must take proper precautions to ensure that the data collected is clean or the study may not yield usable results (Cacioppo, Tassinary, Berntson 2007; Luck 2005).

Like all physiological techniques EEG also suffers from the one-to-many, many-to-one problem. In other word due to the complexity of the human body there can be many origins of each signal or a single signal may be the product of many physiological processed (Fairclough 2009).

FUTURE IDEAS

Combinations of different frequency techniques may allow for more dynamic gameplay. Techniques, such as ERP is not commonly used as an application for gaming. Using ERP as input for the game will allow researchers to create more complex puzzles and more engaging gameplay. In addition, during EEG gaming researchers can also examine user experience and use information to enhance gameplay based on their level of cognitive understanding. Other techniques such as connectivity may also allow researchers to look at cooperation in gaming and assess the use of different areas of the brain during gaming to create a more challenging experience without cognitively overloading the user (Haroz, Whitney 2012; Wilson, Russell 2007).

CONCLUSION

EEG is versatile and can be used as an evaluative measure of user experience or contribute to Brain Computer Interface (BCI) applications. Overall, researchers must prepare their experimental protocol to reduce artefacts and maximize the quality of the data. Techniques, such as frequency analysis, hemispheric asymmetric, synchronization, event related potential technique and connectivity can provide different information. Applications of these different techniques can also be applied to BCI applications and human computer interfaces. In conclusion, despite the sensitivity of the methodology; electroencephalography (EEG) can provide researchers with insight into the participant's brain state and cognitive functioning.

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