EEG-Based Assessment of Video and In-Game Learning

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Abstract

People often learn game-related information in video games by taking turns playing and watching each other play. This type of in-game learning involves both observation and imitation of actions. However, games are also made to be learnt individually during gameplay. Our study seeks to assess which is more effective for learning: just playing a game yourself or watching somebody play it first. We compare two gameplay situations: playing a digital game before watching a gameplay video and playing a digital game after watching a gameplay video. Using a between-participants design, to measure learning effectiveness we recorded Mu rhythms, which are indirectly linked to mirror neuron activation during *imitation learning*. We also analyze hemispheric frontal alpha asymmetry. Our results indicate that presentation order of the video game matters and players are more aroused when watching a gameplay video before playing.

Author Keywords

EEG; Digital games; Mu rhythm; Physiological evaluation; Games User Research

ACM Classification Keywords

H.5.2. Information interfaces and presentation; K.8.0 [Personal Computing]: General – Games

INTRODUCTION

Learning in video games is essential for creating good gameplay. Raph Koster even argued that the fun of gaming comes from learning how to play [15]. This is sometimes facilitated by tutorials [1]. However, video game players often socialize by taking turns in playing a game and improve their skills by viewing each other playing. It is currently unclear whether learning to play the game individually is effective without this social interaction. In comparison, it may also be possible that learning is most effective in the period after watching someone play. For example, some people might remember gameplay moments with an older brother or sister that involved learning by taking turns playing a game. Here, effective learning is likely facilitated by mirror neuron activity. The firing of mirror neurons facilitates *imitation learning*, where we learn by observing and redoing the actions of others. This is commonly associated with activity of the Mu rhythm.

For game designers, it is important to know whether playing a game is more arousing, and therefore likely more engaging [2]. We wondered whether games are more engaging when you learn to play by yourself or when you watch somebody play the game first. Some games, such as *New Super Mario Brothers Wii*, are using artificial intelligence (AI) to have players watch gameplay actions when a sequence of the game becomes too hard for an individual player. Knowing when to watch gameplay first and when to engage in gameplay yourself would be beneficial to players. Developers could then use these AI techniques to make gameplay more engaging. They could also teach players without interrupting flow and engaging gameplay moments.

RELATED WORK

Observational learning is the ability to acquire new knowledge by observing the behavior of others. Learning through observation and imitation is a strategy that can lead to natural acquisition of behavior [3] and planned acquisition of skills [4]. For example, this strategy has influenced language skill learning and acquisition of skills at playing musical instruments.

A common learning approach in humans is to observe and then mimic the actions of that person until an understanding of the subject is grasped [5]. This is facilitated by the Mirror Neuron System [6] comprising of mirror neurons, which are multimodal association neurons [7] in the brain, and are commonly linked to the activity of the Mu waves, known as Mu rhythm [8]. The Mu rhythm is found over the motor cortex between 8-12Hz [8]. Mu suppression occurs when observing an action performed using hands or mouth (e.g., reaching) [9]. Ulloa and Pineda [9] indicate a strong correlation exists between the perception of an action and action possibilities. Based on this theory, our objective was to compare Mu waves of a player observing a game video and then playing the game and a player playing the game without any reference to the game videos.

The key component of learning is the process of observing the actions of others, understanding their actions and imitating their actions. The process of *imitation learning* is learning accomplished by observing and redoing the actions of others. In a few simple games, some of the rules of the game can be identified through the process of learning by discovery. In others, repetition of certain tasks over time sets to engrave the rules into ones memory. Game literacy necessitates the accumulation of basic gameplay skills affording the playability of new games based on past experience. Very few players tend to read manuals prior to gameplay. However, the trend towards complexity necessitates the need for in-game tutorials or procedures for learning to play while playing. Frustration may also arise from tutorials that are not useful or not completely understood. Frustration can be related to arousal [10]. However arousal during gameplay may result in more engagement [2]. Arousal can be measured using EEG by measuring the difference between two lobes of the brain as frontal hemispheric asymmetry [11].

For investigating learning and arousal, we turned to a real-time physiological evaluation technique, called electroencephalography (EEG). In particular, we measured Hemispheric Frontal Alpha Asymmetry (HFAA) as an indicator of arousal and Mu rhythm as an indicator of learning effectiveness. We also looked at playing time as an indicator of performance. We hypothesize:

H0. Mu rhythm will not be affected by seeing the game played before or trying the game first then seeing someone play. Performance will also not be affected by seeing the video or trying to play first.
H1. Mu rhythm will be suppressed when the person observes someone playing and be pronounced when playing.
H2. Performance will improve if the participant plays the game before watching the video.
H3. Players will show more arousal during gameplay and lower arousal when watching the video.

METHODOLOGY

The study employed a between-participants design. Participants were divided into two groups. One group watched a video of a player playing a game before attempting to play and vice versa. There were 5 trials of each condition presented. Videos and levels were randomized. Participants were given approximately 2 seconds between videos and games. The study was conducted in a controlled environment in the *Game Science Lab* at *University of Ontario Institute of Technology*.

Participants and Procedure

We informed participants about the general procedure and they signed consent forms. No compensation was provided. A demographic questionnaire included questions revolving around gameplay experience, time spent per week playing video games, as well as basic information such as age and gender. Participants ranged in age from 20 to 29. All participants had some experience playing video games. Most participants had no experience playing the stimulus game. Participants were excluded before analysis due to gender, color blindness, history of mental illness or experimenter error. Upon completion of the study, participants were thanked for their time and were debriefed.

Game

For our study, the game needed to have a goal. The player had to be able to imagine themselves completing the tasks necessary to proceed. The participants were given simple instructions. No tutorial, practice trials or hints were given. The game chosen was *Flow* (Big Duck Games LLC, 2012) for iPad, a puzzle game. The game involves connecting nodes without overlapping paths. All nodes must be connected and the game board must be filled to complete the level. Puzzles involve spatial ability, for which gender differences are well-known [12], so that we chose to focus on male participants in this study. The game minimized interaction effects with other variables (e.g., memory effects).

Stimulus Video

People were shown a video of others playing the game to keep the stimuli consistent across players. The video was not instructional and gave no hints. It featured a player playing the game and their mistake made. Each video was approximately a minute in length.

Measures

Performance. Player performance was measured in time it takes to play the level.

Electroencephalography (EEG). EEG was collected using the Emotiv Epoc headset, featuring 14 electrodes with corresponding reference and ground electrodes for a total of 16 electrodes to collect data. The electrodes are positioned according to the 10-20 map. This study will focus of the Mu rhythm between 8-12Hz. The electrodes that overlap the motor cortex were of the most interest and only data from electrodes T7, T8, FC4 and FC5 were used. Initial notch filtering of the EEG data was done to remove 50-60 Hz interference. Data was bandpass filtered to isolate for Mu between 8-12 Hertz. No further filtration was applied. Data was analyzed with Fast Fourier Transform (FFT) to assess the power of the different frequency bands that summate to the raw data. The average of the FFT was taken for each condition. Hemispheric alpha activity [11] was calculated using the absolute value of the difference of the frontal electrodes on each opposing sides: AF3, F3, F7, FC5, FC6, AF4, F8, and F4. EEG was chosen because compared to other measures, such as Galvanic Skin Response (GSR) [13], it is a diverse measure. Future studies will seek to use multiple arousal analyses to give a comprehensive picture of EEG and GSR.

RESULTS

The results of the performance measures, and the EEG were analyzed after subtracting the baseline activity. The EEG data was analyzed using two different methodologies: Frequency analysis and HFAA. Our study seeks to assess the order effects of the stimuli on the measures. Order A is the video-first condition; order B is the play-first condition. The statistical differences between orders were analyzed using a one-way Analysis of Variance (ANOVA) procedure.

Completion Time

The participants' puzzle completion time was also recorded. On average participants in Order A is 9.01 seconds. Participants in order B on average completed the Puzzle in 13.55 seconds. The cumulative mean is 11.28. The ANOVA was not significant F (1, 95) = 3.936, p = 0.067.

EEG Results

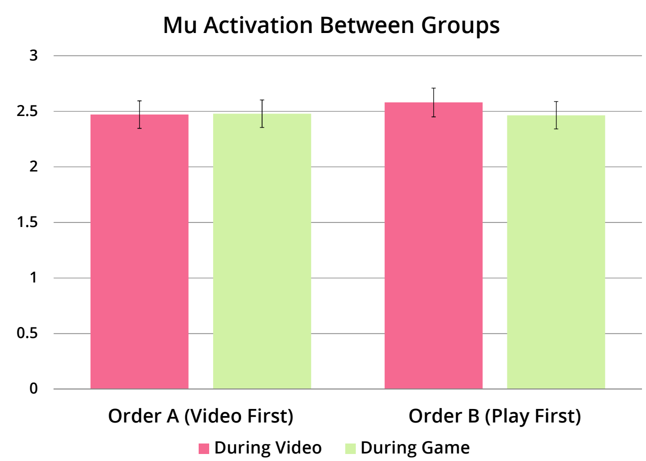

Figure 1. Comparisons using frequency analysis (μV^2).

Play. The cumulative mean of the Mu FFT for each participant in order A is 2.48 μV^2 and the mean Order B is 2.46 μV^2 during play. A one way ANOVA revealed non-significance F(1,95)=0.107; p=0.748, see Figure 1.

Video. The cumulative mean of the FFT of the Mu for order A was 2.47 μV^2. In order B, the cumulative mean for Mu FFT is 2.58 μV^2. To assess the significant difference in Mu FFT depending on order of video and task competition an ANOVA was calculated. The average Mu values of participants using Order A versus Order B were compared. The ANOVA returned a significant score of $F(1,95)=8.183$; $p=0.013$. The average Mu rhythm was significantly different depending on order. Order B has greater Mu activation during the video. Figure 1 shows the comparisons of the Mu frequency based on order in each experimental condition.

Hemispheric Frontal Alpha Asymetry (HFAA)

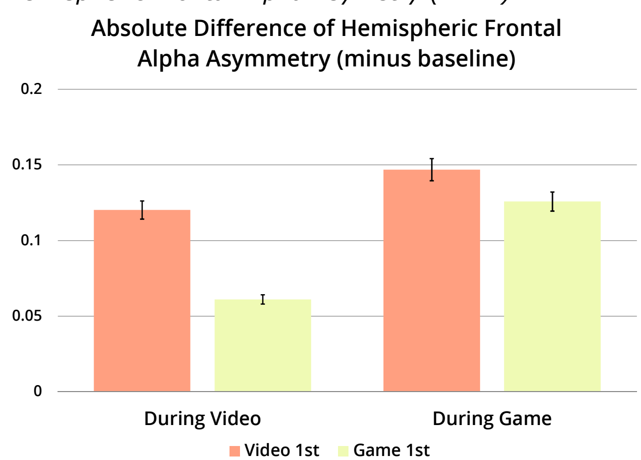

Figure 2. Comparison using HFAA (μV^2).

The average value of the participants' FFT for each lobe was calculated and the absolute value of the difference was taken. The ANOVA was not significant between groups during game play; $F(1, 95) = 0.399$; $p=0.538$. ANOVA was significant during the video; $F(1, 95) = 20.476$; $p<0.001$ (see Figure 2).

Left Lobe. During gameplay the HFAA in the left lobe between groups was not significant $F(1,95) = 0.125$; $p=0.729$. In addition, $F(1,95) = 0.637$; $p=0.438$. Overall, results indicated no significant differences between groups for the left lobe.

Right Lobe. During video between groups comparison of the means showed that the right lobe of the participants $F(1, 95) = 5.569$, $p=0.033$. However during gameplay significant differences between right lobe activation was not found $F(1, 95) = 0.640$, $p=0.437$.

DISCUSSION

The results of the study show that order of watching a person play and playing yourself matters, so it cannot fully support our null hypothesis H0. Part of this might be explained by Koster's fun of gaming theory [15], where learning in games provides fun by trial and error. Similarly, we might enjoy figuring out a game when somebody else plays it. There was a higher rate of firing where Mu suppression was expected. According to our hypothesis H1, this finding is surprising and warrants further study. Performance measures did not indicate differences between conditions. H2 is therefore rejected. The HFAA results show that there is a significant difference in arousal. However, arousal during the video may indicate either increased interest or frustration [10], [11], [14]. Although we are able to reject the null hypothesis, H3 was not conclusive. The HFAA results indicate arousal and should be compared to another measure to best explain this. In addition, significant arousal levels during gameplay were not found [2]. If order can help players learn, then it may also be possible to add more complex mechanisms to games because players may be better able to understand them when they shadow other players or watch them play a difficult part first. Game designers may want to consider the placement of promo or opening videos and game videos to increase the arousal level of players.

STUDY LIMITATIONS AND FUTURE WORK

Future work should include questionnaire to compare with the EEG data [2, 10, 11]. If the stimulus is frustrating it may be introducing a confounding variable to the study. The game used was directed to causal gamers. Future studies will study this effect with more complex games. It may be that the game chosen was simple enough, so no tutorial was necessary. Furthermore, future studies may wish to modify the tasks so that participants can play the game a third time after watching the video in the 'play first' condition.

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