Decomposing Immersion: Effects of Game Demand and Display Type on Auditory Evoked Potentials

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Abstract
Immersion is used to describe the degree of psychological engagement with a computer game. A study was performed to investigate the relative contribution of game demand (easy, hard, impossible) and display type (small 5″ display, large TV display, head-mounted display) on the experience of immersion. Fifteen participants played a racing game in a range of conditions. Players' experience of immersion was captured via a subjective questionnaire and evoked cortical potentials to an auditory oddball task. Results indicated that slow wave potentials were sensitive to task demand, i.e. impossible demand reduced attention to the game. There was also a weak effect of display type at both frontal and central sites that was indicative of greater immersion for the large TV screen compared to other display types. This study provides preliminary data on the decomposition of immersion into sensory and cognitive components.

Keywords Immersion; Games; ERP

ACM Classification Keywords
K.8.0 Personal Computing: General - Games

Introduction

The current paper is concerned with the measurement of immersion via gameplay in a digital world [12]. An analysis of immersion [8] emphasized the propensity for players to "lose" themselves in gaming activity. Jennett and colleagues [8] also characterized immersion in terms of reduced awareness of sensory stimuli associated with the external (i.e. non-game) world; they also argued that increased immersion distorted time perception as well as promoting a sense of presence [11] in the virtual world. Other analyses [5] have posited a distinction between categories of immersion, such as sensory immersion (the contribution of audiovisual characteristics on immersion), cognitive immersion (the effect of game demand on immersion) and imaginative immersion (the impact of characterization and narrative on immersion).

The experience of immersion in a computer game is based on two fundamental psychological phenomena: selective attention and intrinsic motivation. The first refers to the prioritization of incoming sensory stimuli related to gameplay. Given that attentional capacity is finite [19], it is logical that the ability of the player to perceive non-game related stimuli is often compromised. The motivational properties of computer games are best characterized in terms of self-determination [16], i.e. motivation to play is sustained because the experience is innately interesting, satisfying and rewarding.

There is evidence that sensory immersion [5] is driven by audiovisual properties of gaming hardware. For example, larger screen sizes have been associated with increased immersion across a number of studies [7; 18; 17]. The influence of challenge immersion [5] is more difficult to assess. Several researchers [2; 14] have characterized optimal states of challenge in terms of flow states [4]; others have reported how immersion is influenced by the degree of cognitive challenge experienced by the player [3]. With respect to challenge immersion, the motivational intensity model [20] includes a 'tipping point' where the investment of effort into task activity may abruptly decline due to a perception of unachievable demand. It has been argued that challenge immersion may be maximized just prior to this tipping point [6]. The goal of the current study is to investigate the contribution of both sensory and challenge immersion by manipulating the type of display and level of game demand. Our study is designed to contrast the effect of three screen types (5″ small screen, large LCD screen, head-mounted display) upon sensory immersion. We also manipulated cognitive immersion by exposing our participants to easy, hard and impossible levels of demand.

Event-related potentials (ERP) were used to measure immersion in the context of the auditory oddball paradigm [10]. This methodology involves exposing the player to non-game related auditory stimuli as a secondary task whilst they are primarily engaged with gameplay; in this case, participants heard a series of discrete tones including a subset of "oddballs" which differed from the majority of tones in pitch. This approach to capturing residual attentional capacity has been used successfully to index game demand [1] and presence experience [9]. In line with the paper published recently by Kober and Neuper [9], we anticipated that increased immersion would reduce the amplitude of late negative slow waves (SW) to the auditory oddball data, i.e late negative SW are associated with central cognitive processing.

Specifically, we expected the head-mounted display (HMD) to reduce the magnitude of SW, as this pattern is indicative of less attention to the tones, which is interpreted as greater sensory immersion in the game. With respect to cognitive demand, we expected the magnitude of the SW response to be reduced during hard game demand as this condition represents the peak of challenge immersion compared to the easy or impossible versions of the task.

Methodology

Fifteen volunteers (8 male; mean age 24.2 years, S.D.= 3.95) participated using an ethically approved protocol. We used a mixed 3x3 experimental design incorporating visual display type as a between-subjects factor (either head-mounted display, LCD-TV or LCD small screen) and video game difficulty level (easy, hard and impossible) as a within-subjects factor. Three groups (N=5) played the Playstation3 game "WipeoutHD Fury". Each group used a single, full-HD display modality – either a Samsung LE40B550 40" LCD TV (large LCD display), a Silicon Micro Display ST1080-10V1 head-mounted display (HMD), or a Lilliput 569GL, 5" LCD camera monitor (small display).

Our oddball task closely resembled a "classic" ERP methodology [13]. Audacity's pure tone generator (audacity.sourceforge.net) was used to create ninety 1KHz "standard" and twenty 2KHz "oddball" beep tones (with virtually instantaneous auditory rise-times), which were played-back randomly in collective blocks of 110 tones using E-Prime v2.0. We mixed the beep tone audio via the mixing console such that the tones played were audible within WipeoutHD's normal audio soundtrack. We recorded EEG responses to the standard and oddball tones from 64 EEG channels in an extended 10-20 system montage using a Biosemi ActiveTwo ADC-12 amplifier. EEG was recorded at 1024Hz, and referenced post-hoc to linked earlobes. We removed gross artifacts and eye blinks from the EEG and band-pass filtered between 0.1 and 30Hz post-hoc, averaging the standard and oddball tones separately.

We opportunistically invited 15 non-experimental (i.e. pilot) volunteers to play the game for approximately 40 minutes to observe their abilities under different difficulty settings. Under the "Easy" game condition, participants had to achieve a finishing position from 5th to 8th in the novice setting of game difficulty. Participants were expected to finish in one of the top three positions in the "Hard" setting (which was achievable for all participants based on performance during training but only approx. 50% of the time). The level of game difficulty was increased to elite for the Impossible condition which meant that all participants inevitably finished in either 7th or 8th position.

The subjective gaming experience was quantified using the Immersive Experience Questionnaire (IEQ) [8] (appendix B from the source).

RESULTS

We divided the late positive component regions of the ERP into regions SW1 and SW2 in line with previous work [9]. Region SW1 spanned 400-650ms, while SW2 spanned 650-832ms. Analyses were conducted at the vertex Cz and frontal Fz electrode sites, beginning with large ANOVAs for SW1 and SW2 comprising tone type (2), display modality (3) and task difficulty (3). Display modality emerged as a strong effect across all tone types, with mean amplitudes largest during the LCD-TV condition at the Cz site (e.g. $F(1,12)=11.09, p<0.01$). Oddball-tone data was analysed separately, where a more marginal effect of Display modality remained present during the earlier SW1 region at Cz ($F(2,12)=3.652$, $p<0.06$) and Fz ($F(12,12)=3.82$, $p<0.06$), although post-hoc testing could no longer definitively identify the source. During the later SW2 region at Fz, a main effect of task difficulty was present ($F(2,24)=7.06$, $p<0.01$). Post-hoc tests showed mean amplitudes varied significantly at frontal sites during the "Impossible" condition (vs. Easy, $t(14)=2.60$, $p<0.02$ and vs. Hard $t(14)= -3.93$, $p<0.01$).

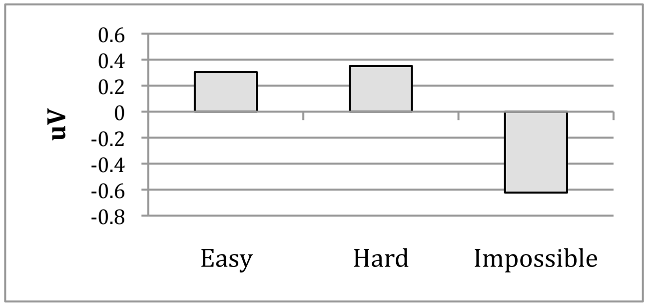

Figure 1. Mean amplitude of SW2 component at Fz over three levels of task demand (easy, hard, impossible).

Data from the IEQ questionnaire showed the Appendix B variant was sufficiently reliable (Cronbach's Alpha = 0.79) and showed an effect of task difficulty ($F(2,24)=5.84$, $p<0.01$). Overall immersion scores were highest during the "Hard" race condition (vs. Easy, $t(14)= -3.0$, $p<0.01$, and vs. Impossible $t(14)=2.50$, $p<0.03$). There was no effect of display type.

DISCUSSION

The purpose of the experiment was to use ERP measurement to distinguish the impact of display type and task demand on immersion. The analysis of the IEQ questionnaire revealed a main effect of game difficulty, i.e. the hard game caused the highest level of subjective immersion. We hypothesized that challenge immersion would peak in line with maximal levels of game demand where success was possible, i.e. challenge is reduced in the easy and impossible conditions because success is easily attained in the former and unachievable in th latter [20]. We were surprised that display type had no significant effect on mean IEQ scores as it was anticipated that the HMD display would result in the highest level of immersion.

Slow negative wave (SW) components of the ERP have been associated with attentional resources [15], i.e. higher amplitude is associated with greater allocation of attention resources. In the case of the current study, we measured SW magnitude to a secondary stimulus (auditory oddball) to index residual attention during game play. Therefore, the absence of a negative SW component during the LCD condition indicated that low attentional resources were allocated to the auditory oddball in this condition – and sensory immersion in the game was highest with the large LCD display. The prominent negative SW component for the 5" LCD display is interpreted as a relative reduction of sensory immersion, i.e. attentional resources continue to be invested in the auditory oddball.

The same logic applies to interpretation of the prominent negative SW2 component during the Impossible demand condition shown in Figure 1. In this case, attentional resources to the auditory oddballare highest because game immersion is low, i.e. because the game was impossible to win. This finding was supported by the motivational intensity model [20], i.e. attention to the game is minimized when likelihood of success is low. However, it was expected that the magnitude of SW2 would distinguish between easy from hard levels of game demand.

There were some weaknesses in the design of the study. Data was only collected from fifteen participants and so the results should be viewed as preliminary. In addition, time restrictions and concern about fatigue in our participants meant that each test session yielded only 80 oddball tones for analysis; in comparison with traditional ERP paradigm (i.e. elementary cognitive tests), this number is quite low and may have led to greater variability in our data.

The purpose of the study was to use ERP analysis in combination with the simultaneous manipulation of sensory and challenge aspects of immersion. The results indicated that cognitive immersion exerted the strongest influence on the subjective experience of our participants. The ERP analysis pointed to an effect of cognitive immersion (game demand) that was specific to SW2 at the frontal site (Figure 1). The influence of display type (sensory immersion) appeared to exert aninfluence on SW1 across both frontal and central sites. It was anticipated that the HMD condition would lead to greatest sensory immersion, but the large LCD screen appeared to exert a stronger influence on both SW components. This effect may have been created by perceptual differences in display type (e.g. a large field of view) or increased immersion may have promoted by the inherent familiarity of the hardware (console plus television screen). Future research will seek to explore the impact of sensory immersion by employing a graded approach as opposed to crude comparison used in the current study, i.e. to manipulate perceptual qualities of the display in a precise fashion. We also intend to extend the current database by including more participants in testing and possibly expanding the number of trials per participant.

Conclusion

The experiment presents some preliminary results on the use of ERPs to decompose immersion into elements associated with sensory experience (display type) and challenge (game demand). With respect to subjective experience, challenge immersion was the dominant factor. We found some evidence that ERPs from frontal site responded to challenge immersion.

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