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Using Startle Reflex to Compare Playing and Watching in a Horror Game

Karen L. Blackmore

William Coppins

Keith V. Nesbitt

School of Design, Communication & IT
University of Newcastle
Callaghan NSW 2308
+61 2 4921 5206

karen.blackmore@newcastle.edu.au; will.coppins@gmail.com;
keith.nesbitt@newcastle.edu.au

ABSTRACT

Human startle reflex has been identified as a valid physiological measure of valence and arousal, providing a useful mechanism for evaluating player engagement in video games. In this research, we use electromyography (EMG) recording of the startle reflex of participants to explore the impact of playing, versus watching a play through, of a game. Participants in the research played and watched Parsec Studio's *Slender: The Eight Pages*, a freely available video game within the horror genre. Experiments were conducted both with participants both playing and watching the game, with results showing a statistically significant difference in startle responses between the two conditions. The results suggest that the fear state of the game is enhanced through player interaction and increased attention.

Categories and Subject Descriptors

• Human-centered computing → Laboratory experiments • Human-centered computing ~ Laboratory experiments.

Keywords

Affective processing; startle reflex; engagement; eye blink; horror genre.

1. INTRODUCTION

While the role of video games in the emotional development of children and adolescents has been a popular societal topic, the widespread adoption of games in both entertainment and learning contexts amongst a broadening demographic poses deeper questions regarding the effect games are having. In particular, what aspects of games make them enjoyable, addictive or engaging, and how can games, or their interactivity, elicit emotional involvement from players? This area of enquiry involves an understanding of human emotions and emotional responses.

Additionally, much of the prior research into the psychological impacts of video games has focused on the effects of excessive use, and whether or not there exists a tendency for video games to encourage violent behavior [1]. In essence, previous research

efforts into video game psychology have served only to answer the fundamental question of whether video games are “good” or “bad”. Understanding the contextual aspects of games and gameplay that lead to greater player engagement and immersion extends beyond this good/bad dichotomy, and remains a key goal for game designers. This includes games for entertainment and serious purposes, as well as those within specific genres.

Amongst the many game genres in existence, the horror-genre, and particularly the survival-horror genre, presents a complex interplay of structural game characteristics and gameplay to engage players. Survival-horror games are often distinctly different from other horror-themed games in the way they treat the pacing of the protagonist's progress, and the importance of combat. Survival horror games tend to feature a de-emphasis on combat, instead favoring scenarios that require hiding, running, and solving puzzles [2]. Protagonists are often under-armed or prepared, with ammunition (if there is any at all) sparse, not only making the character more vulnerable, but introducing resource rationing and inventory management as a crucial part of the game's design [3]. In addition, level designs are often poorly lit and claustrophobic, to provide suspense and challenge to the player through deprivation of situational knowledge [4],[3].

The horror genre traditionally relies upon the twin concepts of horror and terror, described by Varma [5] as “sickening realization” and “awful apprehension” respectively. It is proposed that these two concepts cannot occur without the perception of threat to oneself [6]. In this research, the game *Slender: The Eight Pages* [7] was used for its focus on terror, which is usually partnered with suspense [6]. While this game ends in, and occasionally features, a horror trope known as a “jump scare” (a traditionally employed shock tactic in horror video games which embodies the principle of “horror”), most of the gameplay involved deals with “terror”. This “awful apprehension” of a coming event is suitable to be measured via the startle reflex, which is very effective at measuring a user's valence through their low level response to in-game stimulus [8]. Although the overall research we conducted considered player's emotional experience of the game with and without sound, we focus on the differences between playing and watching the game in this paper.

In the following section, we discuss the role of emotions, and provide detail on the use of the startle reflex for measuring affective processing. In Section 3, we outline the methods used to recruit participants, capture data and process the recorded physiological measurements. This is followed by the presentation of results in Section 4, and finally a discussion of findings, limitations and possible future work in Section 5.

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2. EMOTION AND AFFECT

Emotions are biologically based action dispositions, theorized to be systematic responses that occur when a highly motivated action is delayed [9]. Additionally, Hebb [10] proposed that an emotion is the result of a novel circumstance preventing the completion of behavior. Essentially, emotions can be considered an involuntary response with primitive origins.

Emotional expression is incredibly varied and complex, however most theorists endorse an approach to emotion that features three components; 'subjective feeling', 'expressive behavior', and 'physiological arousal' [11]. While these multiple emotional components are noted, simpler models to capture the motivational basis of emotion have evolved that consider the motivational basis of emotion using a very simple, two-factor model featuring affective valence and arousal [12] (Figure 1). This dimensional theory of emotion holds that all emotions can be located on a two-dimensional space, as a function of valence and arousal [13]. In this two-dimensional model, valence represents a user's emotional reaction to a stimulus, reflecting the degree to which it is a pleasant or unpleasant experience (positive and negative valence, respectively). Arousal indicates the level of activation associated with the experience, from very excited and energized, to sleepy, calm, and/or disinterested [13].

Figure 1 - Graphical representation of the valence/affect model [12]

Psychophysiological investigations suggest that some emotional states, such as valence and arousal, may be objectively measured with physiological measurements such as facial electromyography (EMG) [14], heart rate [15] and galvanic skin response [16], [17]. For instance, these measures have all been used to study the physiological effects of video games on users [18]. Each of these measures has relative advantages and disadvantages depending on individual research circumstances.

According to Lang [12], facial electromyography (EMG) is the primary physiological index of valence. More specifically, EMG measurement of the human startle reflex has been shown to reliably measure emotional states related to fear and pleasantness, and is not determined by arousal or attention [19]. The research presented in this paper therefore focuses on the measurement of valence in response to stimuli to better understand emotional responses by measuring the intensity of the reflex response.

The human startle reflex is a non-invasive measure of central nervous activity that typically occurs when an individual encounters a sudden, surprising change in their environment [20]. It is a reflex reaction that occurs without voluntary control and is characterised by protective body reactions, such as eye-blinks and stiffening of neck posture. In evolutionary terms, it likely provides a defensive response to threatening stimuli and is associated with the fright, fight and flight response. Elements of the startle response, such as the eye-blink, are modulated with an individual's emotional state; eye-blinks being larger when individuals are highly aroused and in unpleasant emotional states compared to blinks associated with low arousal and positive affect [21].

The startle reflex is typically measured using facial electromyography (EMG). EMG activity increases with the contractions of various facial muscles that are closely linked with positive or negative emotions. It has been established that increased activity of the *zygomaticus major* (cheek) and *orbicularis oculi* (eye) facial muscles correspond to high arousal conditions, whereas the *corrugator supercilii* (brow) muscle corresponds to low-arousal conditions, during affective imagery [21] (Figure 2). Surface EMG recording electrodes over the *orbicularis oculi* muscle is the most frequently used method in human startle reflex studies to measure valence [20].

Figure 2 - Organisation of the startle reflex eyeblink and physiological indicators [21, pg.441]

The usefulness of the startle reflex to measure emotional state or affect in users has lead to its adoption in game studies. For example, in one study, researchers used various physiological indicators including heart rate, skin conductance, and the startle reflex to gauge the immersion of participants while playing a bespoke level of Half-Life 2 [22]. Similarly, Ravaja, Saari, Salminen, Laarni and Kallinen [13] examined the emotional valence and arousal psychophysiological responses to different video game events among 36 young adults who played Super Monkey Ball 2 (Sega Corporation, Tokyo, Japan), finding that instantaneous game events elicited reliable psychophysiological responses indexing these emotional responses.

3. METHOD

Adopting a combination of quantitative and experimental methods, this research used surveys and experiments in which

physiological measures were captured, alongside pre-and-post questionnaires (Figure 3). The methodology used in this research was conducted under approval of the University of Newcastle's Human Research Ethics Committee (Reference No: H-2014-0221).

Figure 3 - Research Methodology

Participants were required to fill out an initial demographic questionnaire, with added questions on the participant's prior experience to horror-genre video games. They were then required to watch two five-minute pre-recorded screen captures (VIEW) of gameplay of a horror-genre video game (Parsec Productions' *Slender: The Eight Pages*) - one with all sound enabled, and one with all sound disabled, randomly ordered for each participant - while attached to a EMG recording equipment. Participants then engaged in two five-minute actual play (PLAY) of the same game under the same conditions. Afterwards, participants filled out a post experiment questionnaire to gather their thoughts of the gameplay, as well as their opinion on their own immersive experience.

Details of participant recruitment, survey instruments and startle reflex EMG recording and processing are provided in the following sections.

3.1 Participant Recruitment

Potential participants were made aware of the project via recruitment posters, which were posted on notice boards around

the Callaghan campus of the University of Newcastle. Invitations to participate were also sent via email, and through word of mouth.

As a result, participants consisted primarily of undergraduate students at the University of Newcastle. Students were eligible for participation if they fell within the ages of 18 to 60. In addition, the participants were required to have normal or corrected to normal vision, and not suffer from any problems in visual or auditory perception in order to experience the game and its accompanying sounds competently.

3.2 Startle Reflex Recording

The recording of the human startle reflex in this research follows the guidelines for human startle eye blink electromyography studies developed by Blumenthal et al. [20] for the Society for Psychophysiological Research. Startle reflex responses were obtained using sudden acoustic white noise pulses while the participant viewed a demonstration of, and then played, the game. An Arcam FMJ Amplifier was used to both convey the game sound and deliver the startle pulse. The game sound varied between 63-70 dB during experiments whereas the acoustic startle pulse was delivered at a constant 105 dB. The pulse was delivered at random intervals across the five minute experiment period, at no less than 30s apart, containing frequencies in the 20 Hz to 20 kHz range at 105 dB, with a rise time of less than 10 microseconds.

In order to measure the EMG response, a disposable ECG electrode was placed under the left eye, below the lower eyelid in line with the pupil in a forward gaze over the *orbicularis oculi*. A second electrode was also placed 1-2cm laterally to the first, and a third 'isolated ground' electrode was placed on behind the ear - an electrically inactive point (Figure 4).

Figure 4 - Placement of electrodes on test participant

According to the guidelines set out by [20], a valid startle pulse cannot exist within 500ms of a game event. This was accounted for in the demonstration play through, as the individual startle pulse recording for the demonstrations was customized to suit the gameplay events. However, the pulse recording used for a participant's play through, due to the inherently random nature of the player's actions, required manual indication of pulses invalidated by game events in the post-processing phase.

The EMG signal, recorded using an AD Instruments Bio Amp in conjunction with Labchart 8 software, was sampled at 4000Hz with a range of 500 μ H. During data capture, a low pass band filter at 50Hz and a high pass filter at 0.3Hz were used. Finally, a 50Hz notch filter was applied, and the signal was inverted. The EMG response and the acoustic stimulation pulses were recorded in Labchart using Channels 2 and 4 respectively. A macro was created within Labchart to synchronize the pulses and recordings.

3.3 EMG Post-Processing

The recorded EMG signals and acoustic pulses were exported from Labchart in an appropriate format for data analysis in Matlab R2014b (8.4.0.150421) from Mathworks Inc. [23]. The raw EMG signal imported into Matlab was expressed in volts (V) at a sample rate of 250 microseconds (μ s) per time step. The raw signal was converted to (mV) to conform to reporting standards [20], [24]. Following this, full wave rectification (absolute value) was applied to the biphasic signal to determine the total energy (both positive and negative) contained in the signal.

A time interval of 150ms before the time window of each startle acoustic pulse was used to derive a mean EMG baseline for each response. Individual baselines for each response were used to negate the effect that disturbance in the electrode lines might have occurred over the duration of an experiment [20], [25], with 150ms considered adequate for obtaining a reliable measurement [25]. The rectified EMG signal was then processed to extract the peak amplitude in the period from 20-120ms following the end of each startle acoustic pulse. The actual peak response amplitude, and the peak amplitude less the baseline amplitude, was recorded for each startle for statistical analysis.

The final step was to classify each pulse/EMG recording epoch (trial) by visually interpreting the EMG data using the scoring approach detailed by Blumenthal, et al. [20]. For each trial, a decision was made as to whether; a) the baseline period was contaminated with noise or movement artifact, or an involuntary blink, and thus a stimulated blink could not be quantified and thus the trial should be rejected, or b) if a response within the 20-120ms latency window occurred, and if not, the trial should be recorded as a nonresponse, or c) a valid response occurs in a trial that has not been rejected, and is thus scored as valid. An example of a "Valid", "Rejected" and "No Response" EMG signal are shown in Figure 5.

Figure 5 - Examples of response epochs classified as 'valid', 'rejected' and 'no response'

3.4 Survey Instruments

Two questionnaires were used as part of this research. Firstly, a Pre-Questionnaire was used and administered before the main experiment trials, with the purpose of gauging a participant's familiarity with the genre. This was later used in order to measure

the effect of any experience bias. This survey was heavily based upon a similar survey [26], which was also used to gain an insight into a player's familiarity with the chosen genre, and video games as a whole. It is slightly adapted with the addition of questions from a questionnaire developed by Grimshaw, Lindley and Nacke [17], which served to add the dimension of a player's confidence, and their self-rated familiarity with video games. Grimshaw, Lindley and Nacke used this questionnaire to gauge a participant's familiarity with the subject area, as well as gather demographic information, and for this reason it was well suited for adaptation in this research.

A second questionnaire was administered after the participant had completed the four experiment trials of the video game, and is focused upon the player's retrospective opinion on their own sense of immersion while playing the game. It is based heavily upon a questionnaire developed by Jennet et al. [27] in their work titled "Measuring and Defining the Experience of Immersion in Games", in which the questionnaire is used to measure a participant's sense of immersion. Four questions were omitted from the original survey as they were irrelevant to the horror genre of video games. For example, "It was as if I could interact with the world of the game as if I was in the real world" was deemed irrelevant as the original study used Valve's *Half-Life 2*, a game that features a large amount of interactivity in a realistic environment. *Slender: The Eight Pages*, by comparison, does not.

4. RESULTS

4.1 Participant Characteristics

In total, 15 people participated in the experiments. The participants recruited for this research were of mixed gender, with a majority male (10) compared to female (5). The sample was biased towards a younger age bracket due to the recruitment taking place entirely on the University of Newcastle's Callaghan campus. Twelve (12) of the participants were between the ages of 18-25, and 3 between the ages of 26 and 40.

In terms of education background, the majority of participants held bachelor degrees (10 of 15), with one participant studying at a postgraduate level, and the remainder currently studying the Higher School Certificate, at TAFE, or another course. All participants were familiar with PC gaming, with most (9 of 15) additionally familiar with console based games, and 7 of 15 familiar with mobile games. Of the 15 participants recruited, 9 indicated they played video games the maximum amount of time per week available on the scale within the survey at 25+ hours. Two indicated the minimum amount of 0-5hrs, the rest falling between 10-15hrs and 15-20hrs a week (Figure 6).

Figure 6 – Graph of number of hours per week of game play by participant (%)

Overall, the participant pool was mixed in its familiarity of the horror genre, which was measured on a scale from 1 to 10, with 1 indicating low familiarity and 10 indicating maximum familiarity. Responses were spread relatively evenly across 1-8. The majority of participants (8 out of 15 - 53.5%) rated themselves as very confident with video games in general; with 6 (40%) indicating medium confidence, and 1 (6.5%) indicating low confidence.

4.2 Startle Reflex/EMG Results

As described in the Method section, manual visual interpretation of a plot of each baseline/pulse/response epoch was undertaken, with a determination on the validity of each response made. Following this process, each of the 6-7 responses to a startle pulse within each experiment was recorded as either 'valid', 'rejected' or 'no response'.

This classification revealed some differences in the response validity based on the experiment conditions. The sound on/sound off condition revealed little variation, however, comparatively large differences exist in the view/play condition (Figure 7 and 8). A larger percentage of valid responses occurred when participants played the game (60%) compared to viewing the game play-through (15%). Similarly, fewer responses were rejected for experiments where participants played the game (7%) compared to viewing (19%).

These results indicate that less of a correlation exists between sound and non-sound modes of delivery, and more of a correlation between methods of engagement, suggesting that player attention is much less affected by the state of sound than hypothesized in the overall research. Furthermore, these results also suggest a potential for greater inhibition or attenuation of the reflex in the more passive viewing mode than the playing mode.

Figure 7 - Percentage of Response Types by Sound Condition (On/Off)

Figure 8 – Percentage of response types (Valid/Rejected/No Response)

A chi-square test of independence was performed to examine the relation between response types (valid, rejected and no response) and the view/play experiment conditions. The relation between these variables was significant, $\chi^2 (2, N = 382) = 82.79, p < .000$. A higher number of valid EMG startle responses are recorded under game play conditions than game view.

Analysis of the peak EMG response (20-120ms post pulse) and variance were conducted on only those responses classified as valid. A summary of the valid responses for each of the experiment conditions is provided in Table .

Table 1 – Summary of valid EMG responses for each experiment condition

	N	Average Response (mV)	Average Variance
All	42	4.121	981.453
Sound On	22	10.482	1134.448
Sound Off	20	-2.876	816.690
View	15	6.585	1103.384
Play	27	2.752	946.616

Further analysis of the Play/View experiment conditions was used to explore the effect of the presence or absence of sound on participants' affective experience of the game. A result worth noting is the clear trend that exists between the modes of engagement. Participants recorded significantly higher magnitude startles in response to viewing the game than playing it. This suggests that they were less affected by the startle reflex pulse when playing the game, compared to very startled reactions when watching.

Why exactly this occurs is not clear. The expected result would be that players participating in the game environment – in keeping with currently established and used definitions of presence and flow – would experience a greater sense of immersion and be more readily startled by the probe [6]. However, the opposite may also be true – part of a sense of immersion is an exclusion of outside stimulus, which may include the startle probe [17].

The variation in average peak response for sound on/sound off conditions was also examined (Figure 9 and 10). The statistical significance of the difference in the means in the sound on/off conditions for the play and view experiments was tested using a Student's T Test for independent samples. Given the small sample sizes ($n=7-14$) and large variances evident in the data, equal variances could not be assumed and thus the unequal variances

form of the test was used. An independent-samples t-test was conducted to compare the effect of sound and no sound in the game viewing condition. There was no significant difference in the scores for sound on ($M=13.9$, $var=1388.6$) and sound off ($M=-1.7$, $var=638.2$) conditions; $t(12) = 2.18$, $p = 0.35$. Similarly, an independent-samples t-test was conducted to compare the effect of sound and no sound in the game playing condition. There was no significant difference in the scores for sound on ($M=8.5$, $var=935.0$) and sound off ($M=-3.46$, $var=565.0$) conditions; $t(24) = 2.06$, $p = 0.26$.

Figure 9 – Average peak response (mV) by sound condition for playing experiment

Figure 10 – Average peak response (mV) by sound condition for watching experience

Thus while peak amplitude differences in both conditions are evident, the sample size is too small to allow significance to be formally tested.

5. CONCLUSION

A significantly higher proportion of participants exhibited valid EMG startle responses while actually playing the game compared to viewing a play-through of the game. The startle response, which is considered an aversive reflex, is enhanced during a fear state and is diminished in a pleasant emotional context [19]. However the amplitude of the reflex has been found to vary in response to either attention allocation or the emotional context [19]. The play condition can be considered to require more attention, as participants need to use controls to navigate through the game world. The larger number of valid EMG responses in this mode suggests that the fear state of the game is enhanced through player interaction and increased attention. Sound appears

to play a lesser role in this process. However, further analysis is required to fully validate these results.

During the experiments, participants watched playthroughs of the game before playing the game themselves. This ordering was to negate the need for a training mode, and to control for variability in the sound conditions. The sound on and sound off conditions within these modes was randomized. There is therefore the potential that the difference in playing versus watching may contain bias from the ordering of the modes. Future work should address this by randomizing the playing and watching modes.

The human startle reflex is non-trivial to capture, analyse and interpret effectively. There are numerous potential sources of EMG signal bias [20], which have been differentially accounted for in this research. A key limitation of the research lies in the attempted adaption of a standard experiment design that uses still images, to one using game play visual provocation. Although some evidence on the efficacy of measuring startle reflex in a similar way for film exists [28], this medium provides an observational, and comparatively passive experience for participants [29]. The implications of using a less passive provocation for measuring startle response are not well defined.

During the experiments, participants watched playthroughs of the game before playing the game themselves. This ordering was to negate the need for a training mode, and to control for variability in the sound conditions. The sound on and sound off conditions within these modes was randomized. There is therefore the potential that the difference in playing versus watching may be due to bias from the ordering of the modes. Future work should address this by randomizing the playing and watching modes.

However despite this potential bias, existing research suggests that the startle reflex exhibits stability across time [30]. Thus the noted differences in valid and average peak responses in this study are attributed the differences in actual experiment conditions rather than the ordering of the play/view modes. The results indicate attenuation of the reflex while playing versus viewing the game, and there is also greater attenuation in sound off conditions. Considering existing models of affective processing [31], these results suggest that the presence of sound, and the watching experience, provide comparatively negative emotional stimuli.

The research presented in this paper provides a useful framework for further study of structural game elements using both survey and physiological measures. The complex nature of the startle reflex, and its role in quantifying affect in game environments, provides an interesting and potentially fruitful course for future work. In the first instance, the research presented in this paper would be greatly enhanced by increasing the sample size. This may lead to statistically significant results. Areas for future work could also include, but are not limited to:

- Analysis of specific ingame events and associated sound on player affect using video recordings of participant experiments
- Extending the game genre considered in the experiment to another, or considering the differences between the presence and absence of sound across genres
- Utilizing the immersion survey used in this research, and a larger sample size, to quantify the impact of sound in games using a between group experiment design

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