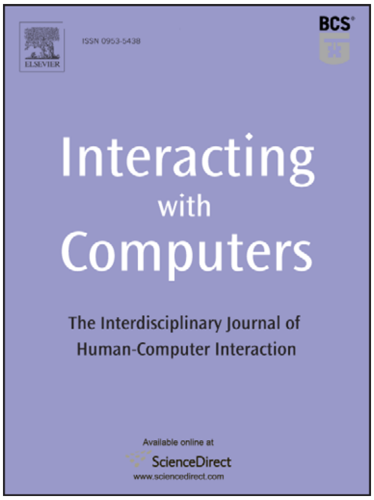

More Than a Feeling: Measurement of Sonic User Experience and Psychophysiology in a First-Person Shooter Game

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PII: S0953-5438(10)00039-1
DOI: 10.1016/j.intcom.2010.04.005
Reference: INTCOM 1744

To appear in: *Interacting with Computers*

Received Date: 21 September 2009
Revised Date: 1 April 2010
Accepted Date: 6 April 2010

Please cite this article as: Nacke, L.E., Grimshaw, M.N., Lindley, C.A., More Than a Feeling: Measurement of Sonic User Experience and Psychophysiology in a First-Person Shooter Game, *Interacting with Computers* (2010), doi: 10.1016/j.intcom.2010.04.005

Running head: MEASUREMENT OF SONIC USER EXPERIENCE IN GAMES

More Than a Feeling: Measurement of Sonic User Experience and Psychophysiology in a First-Person Shooter Game

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More Than a Feeling: Measurement of Sonic User Experience and Psychophysiology in a First-Person Shooter Game

1. Introduction

Research efforts are beginning to unravel the epistemological, ontological and methodological nature of user experience (UX) to foster a better general understanding and give rise to structural models of this concept (Law, Roto, Vermeeren, Kort, & Hassenzahl, 2008). In addition to the structural efforts involved in creating models of UX, discussions of UX measurement techniques and experimental results from UX studies form the basis of our growing understanding of this research field. While digital games have been the focus of some of these efforts (Bernhaupt, IJsselsteijn, Mueller, Tscheligi, & Wixon, 2008; Nacke, 2009b), qualitative and quantitative studies of UX in games are still few in number, especially where sound is concerned. This is partly because of the shortage of research on what UX measurement techniques can be applied to evaluate the affective experiences of digital gaming and how. Digital games are designed for entertainment; hence, the emotional and affective aspects of UX when interacting with games concern game developers directly. Emotions in games act as a motivator for the cognitive decisions players make during gameplay and they drive UX in games (Nacke, 2009a; Nacke & Lindley, 2009). In this paper, we outline the motivation and hypotheses for an empirical study investigating effects of sonic UX in digital games. The methodology and results of the empirical study are reported and discussed and, in particular, correlations between subjective experience and physiological data are analyzed. Finally, we conclude on the suitability of psychophysiological measurement for assessing sonic UX in games and give an outlook onto our future work in this area. Our long-term motivation in pursuing this experimental line is to investigate a player's experience of sound in games to work towards a model of such experience, which should function as a practical guide for game sound design - especially addressing the potential of new technology. Thus, by presenting our measurement methodology and results, we hope to provide a foundation upon which a structural model of sonic UX in games can be built in future research.

1.1 Psychophysiological measurement and the dimensional emotion model

Psychophysiology uses physiological signals, recorded with electrodes on the skin, to obtain information about a user's emotional and mental state. Traditionally, these signals were explored in the areas of neuroscience, medicine or biomedical engineering but they have recently been introduced to human-computer interaction (HCI) research (Fairclough, 2008; Mandryk & Inkpen, 2004). The measurement is not particularly obtrusive and has been used to covertly assess emotional reactions of users engaged with interactive entertainment products such as digital games (Nacke & Lindley, 2008; Ravaja, 2004). Two approaches have emerged in HCI research and are starting to gain popularity because of their relatively easy deployment and analysis. Facial electromyography (EMG) describes the measurement of subtle electrical activation of face muscles and is a good indicator of pleasant or unpleasant emotion (Bradley & Lang, 2007). Electrodermal activity (EDA) is a very common psychophysiological measurement method due to its very easy application (Boucsein, 1992). EDA is regulated by production of sweat in the eccrine sweat glands, where increased sweat gland activity is related to electrical skin conductance level (SCL), and is associated with physical arousal (Lykken & Venables, 1971).

To evaluate EDA and EMG measurements, dimensional theories are *de facto* standards used in psychophysiological research. One of the most influential dimensional models in emotion assessment, the circumplex emotional model, was developed by Russell (1980). In this model, emotions are divided along two axes formed by valence (i.e., tone; from pleasant to unpleasant) and arousal (i.e., bodily activation; from deactivation to activation). Emotional words defined by everyday language, such as tension (unpleasant activation), boredom (unpleasant deactivation), serenity (pleasant deactivation), and delight (pleasant activation) can be classified within the dimensional space and correlate to ratios of valence and arousal. Results from EMG are usually placed somewhere along the valence dimension (in correlation with the affect words mentioned before) and EDA results are used as indicators along the arousal dimension. However, there are no clear threshold values for positive or negative valence and the interpretation of psychophysiological measures is usually subjective. There have also been several adaptations of the model (Posner, et al., 2009; Posner, Russell, & Peterson, 2005). Russell (2003) argued that the emotional experience a person feels is a cognitive interpretation of their automatic physiological response. Using affective images and words as stimuli makes a classification of emotions in this model generally more straightforward than using a complex stimulus like a digital game.

Nevertheless, several experiments using psychophysiological analysis of players have been reported using digital games as stimuli (Mandryk, Inkpen, & Calvert, 2006; Nacke & Lindley, 2008; Ravaja, Saari, Salminen, Laarni, & Kallinen, 2006). In all of these studies certain elements of play (such as collocation of players or challenge level of the gameplay) have been under investigation. In addition to gameplay mechanics or social factors, visual and sonic elements of games influence and shape UX in games. Thus, UX in games should be analyzed separately for each influencing factor (visual or sonic) if psychophysiological analysis is to yield significant results. By focusing on the measurement of sonic UX and psychophysiology in a game, our goal is to advance the theoretical understanding of UX and sound in games. However, one limitation of current psychophysiological studies is that they cannot precisely classify UX in games since many experiential phenomena in games have no or only fuzzy definitions (e.g., flow, immersion, presence; see empirical study below) and lack standardized quantitative measurements. Hence, one purpose of this study is to provide a correlation between subjective UX estimates (collected with a questionnaire) and physiological data.

1.2 Toward measuring sonic UX in games

In digital games, an important part of UX is the conscious design of sound and music to affect aesthetics, feedback and rewards for players (Lord, 2004). Audio signals in games guide the interaction within a virtual game world and can be used to provide vital elements of gameplay, such as the interaction feedback in Guitar Hero (RedOctane, 2005). While this sonic UX in games may be shaped by sound and music cues, the enticing nature of these stimuli is currently understudied, as is UX in digital interactive entertainment in general. Digital games use the potential of visual information for aesthetic appeal and for elements of game design more than audio information (a few exceptional examples such as Silent Hill 2 (Konami, 2001) or Dead Space (Electronic Arts, 2008) excluded). Our experiment uses game sound definitions defined by Grimshaw and Schott (2008) because they mirror the practice of separate volume controls for sound and music typically found in the console interfaces for the genre of games studied here: references to ‘sound’ in this study refer to diegetic sound (sound that originates from the game environment, its objects and its characters); references to ‘music’ refer to the non-diegetic musical soundtrack.

Research has shown that arousal is likely to have a mediating effect on responses to sound, where especially the effect of environmental noise on health and performance has come under scrutiny (Glass & Singer, 1972). Noise was demonstrated to inhibit attention and lead to weak performance while showing an excess in arousal levels. However, the results of sound effects on psychophysiological measures are mixed. Wolfson and Case (2000) report a study, which investigated the influence of color (red/blue) and music volume (loud/quiet) on performance scores, heart-rate, and questionnaire responses. They found that music volume alone had little influence on the psychophysiological and survey measures but the combination of red color and loud music led to perceptions of excitement and successful playing. In another study, Grimshaw, Lindley, and Nacke (2008) analyzed the effects of audio on UX as well as psychophysiological measures in the FPS game *Half-Life 2* (Valve Corporation, 2004). They treated audio as a single independent variable, using sound and music as different levels of the same variable. However, a one-way repeated-measures analysis of variance (ANOVA) showed no significant results for physiological measures. We assume that a separate analysis of game sound and music could have an effect on psychophysiological variables. Thus, we propose and test the following hypotheses using a 2×2 experimental design with sound (on and off) and music (on and off) as separate independent variables:

H1: When sound is present EMG and EDA levels increase, when sound is absent EMG and EDA levels decrease

H2: When music is present EMG and EDA levels increase, when music is absent EMG and EDA levels decrease.

In addition, based mainly on Wolfson and Case's (2000) results, we hypothesize about an interaction effect of music and sound on EDA measures:

H3: When both music and sound are present, EDA levels increase when playing a first-person shooter (FPS) game, when both music and sound are absent EDA levels decrease.

IJsselsteijn, Poels, and de Kort (2008) theorized that *immersion*, *flow*, *tension*, *competence*, *negative affect*, *positive affect*, and *challenge* are important elements of gameplay experience and developed a Game Experience Questionnaire (GEQ) to assess these elements; this will be used in our study. Preliminary results linking these dimensions to frontal EEG asymmetry during cooperative and competitive play were presented recently (Salminen, Kivikangas, Ravaja, & Kallinen, 2009). The most discussed gameplay experience factors in game-related literature are immersion (Jennett, et al., 2008) as well as presence (Lombard & Ditton, 1997) and flow (Csíkszentmihályi, 1990). While presence could arguably be a better term for immersion (Schubert, Friedmann, & Regenbrecht, 2001; Slater & Wilbur, 1997) – since it is often defined as a state of mind (i.e., being transferred to a virtual location) or a characteristic of people’s experience rather than a characteristic of the technology – we chose to use the term immersion in this study, because this construct is explicitly used in the GEQ measure that was employed in this study (IJsselsteijn, et al., 2008). In the GEQ, immersion is defined as sensory and imaginative immersion based on the Sensory-Challenge-Imaginative (SCI) model of Ermi and Mäyrä (2005), which differentiates between sensory (i.e., audiovisual quality and style), challenge-based (i.e., challenge level of gameplay), and imaginative immersion (i.e., imaginary or fantastical themes and storytelling) (IJsselsteijn, et al., 2008). Thus, sensory immersion concerns the audiovisual quality and style of games; imaginative immersion describes the absorption in the narrative of a game or identification with a character, which is understood to be synonymous with feelings of empathy and atmosphere (Nacke & Lindley, 2009). However, challenge-based immersion bears significant similarities to the flow concept described next.

Flow is defined as a holistic sensation and positive peak experience (Csíkszentmihályi, 1990). Hence, complete mental absorption in an activity is fundamental to this concept which makes flow an experience mainly elicited in situations with high cognitive load, probably accompanied by a feeling of pleasure. Tension is described by IJsselsteijn et al. (2008) as a negative experience relating to the difficulty of a game and the competition a player feels. Next, they describe competence as an experience of positive control over the game, where players feel they can successfully apply their skills. Negative affect characterizes the effect of boredom and distraction players feel when they are not challenged enough by a game. Positive affect, on the contrary, characterizes fun and enjoyment in playing a game. Finally, challenge is an ambiguous experience that is characterized by the difficulty of the game, effort of playing, the feeling of learning, and mental stimulation. Having briefly discussed these GEQ dimensions, we aim to study the effects of sound and music on game-playing experience and the correlation between subjective GEQ responses and objective physiological data. In more detail, our research questions for our study are:

RQ1: What are the effects of sound and music on game-playing experience?

RQ2: Which dimensions of gameplay experience correlate with physiological measurements?

The experimental study reported here was designed to record both subjective (i.e., questionnaires) and objective (i.e., psychophysiological sensors) responses. More specifically, we used electromyography (EMG) and electrodermal activity (EDA) to try to account for the valence and arousal dimensions of affect (Bradley & Lang, 2007; Lang, 1995; Russell, 1980).

2. Method

2.1 Design

We employed a 2 × 2 repeated-measures factorial design with sound (on and off) and music (on and off) as independent variables, using a counterbalanced order of sound and music settings in the same game. The independent variables were three EMG measures (orbicularis oculi activity [eye], zygomaticus major activity [cheek], and corrugator supercilii activity [brow]), EDA level, and seven dimensions of subjective experience (for details, see section 2.5.3 Game Experience Questionnaire) (IJsselsteijn, et al., 2008). Questionnaire item order was randomized for each participant.

2.2 Participants

Data were recorded from 36 undergraduate students (66.7%) and university employees. Participants were recruited from a Swedish university campus and through student-union Internet forums; they were also offered a small compensation (*100 SEK*) for their participation. Their age ranged between 18 and 41 (M = 24, SD = 5). Twenty-nine participants were male. All participants played digital games regularly and 94.4% reported they play games at least once a week. Sixteen participants started playing digital games when they were between 6-12 years old, 8 when they were between 12-18 years, and 3 when they were older than 18 years.

2.3 Materials

The game used in this study was a specially designed modification of *Half-Life 2* (Valve Corporation, 2004) that featured three sequential rooms each with a more difficult combat situation including more and stronger enemies and less ammunition and fewer health items. The game was designed so that all enemies in one room had to be eliminated to advance to the next room, allowing for clearly increasing combat challenges in each subsequent room.

Although *Half-Life 2* allowed the control of game audio features internally (e.g., soundscapes), sound and music were controlled externally for this experiment. For example, the experimenter turned a music track on or off (depending on the experimental condition) immediately before the participants started to play. The game-internal sound was turned on or off (again, depending on the condition) by the experimenter using commands: a software trigger controlled whether the game engine would play game sound or not. For the logging of psychophysiological data, in-house software was used (Nacke, Lindley, & Stellmach, 2008).

2.4 Procedure

Individuals were invited to the laboratory where experiments ran in two-hour sessions. After a brief description of the experimental procedure, each participant filled out two forms. All participants had to give informed consent before commencement of the experiment. Individuals were then seated in a comfortable chair; the electrodes were attached. During a resting period of 3-5 minutes, individual physiological baseline measurements were recorded. Individuals were then asked to play under each of the sound and music conditions in a counter-balanced order. We refer to the various conditions of sound as sound on/off and music as music on/off. The experimenter instructed individuals to play to the end of the game level. Play sessions lasted a maximum of 10 minutes each, after which players were interrupted if they had not completed the game level. Participants had to restart the game level in each experimental condition. Between each condition, participants had a short break of 2-3 minutes to fill out the GEQ (IJsselsteijn, et al., 2008).

2.5 Measures

<<insert Figure 1 about here >>

2.5.1 Facial EMG. We recorded the activity from left-hand-side muscle regions orbicularis oculi (OO, eyelid), corrugator supercilii (CS, brow), and zygomaticus major (ZM, cheek) muscle regions (Fridlund & Cacioppo, 1986), using BioSemi flat-type active electrodes (11mm width, 17mm length, 4.5mm height) electrodes with sintered Ag-AgCl (silver/silver chloride) electrode pellets with a contact area 4 mm in diameter. Figure 1 shows the location of the EMG electrodes on the facial muscle sites in an annotated photograph. The electrodes were filled with low-impedance highly conductive Signa electrode gel (Parker Laboratories, Inc.). The raw EMG signal was recorded with the ActiveTwo AD-box at a sample rate of 2 kHz and using ActiView acquisition software. EMG was processed with BESA software (MEGIS GmbH, München) using a low-cutoff-filter (30 Hz, Type: forward, Slope: 6 dB/oct) and a high-cutoff-filter (400 Hz, Type: zero phase, Slope: 48dB/oct). Data were considered to be invalid when there was no signal for long periods (e.g., electrode fell off). These data were excluded from further analysis: this was the case for seven participants. Therefore, for the psychophysiological analysis (EDA and EMG), 29 cases were used. EMG data were rectified and exported together with EDA data at a sampling interval of 0.49 ms for statistical data analysis using SPSS for further analysis.

2.5.2 EDA. Electrodermal activity was measured using two passive Ag-AgCl (silver/silver chloride) Nihon Kohden electrodes (1µA, 512 Hz). The electrode pellets were filled with TD-246 skin conductance electrode paste (Med. Assoc. Inc.) and attached to the thenar and hypothenar eminences of a participant’s left hand (Boucsein, 1992).

2.5.3 Game Experience Questionnaire. Different components of game experience were measured using the GEQ (IJsselsteijn, et al., 2008). It combines several game-related subjective measures (with a total of 36 questions): *immersion*, *tension*, *competence*, *flow*, *negative affect*, *positive affect* and *challenge*. Each dimension has 5 items (except immersion which has 6 items). Each item consists of a statement on a five-point scale ranging from 0 (not agreeing with the statement) to 4 (completely agreeing with the statement). Example statements are “I forgot everything around me” (Flow), “I was good at it” (Competence), “I felt that I could explore things” (Immersion), “I felt frustrated” (Tension), “I had to put a lot of effort into it” (Challenge), "I enjoyed it" (Positive Affect), and "I was distracted" (Negative Affect). The questionnaire was developed based on focus group research and subsequent survey studies (IJsselsteijn, et al., 2008; Poels, de Kort, & IJsselsteijn, 2007). The GEQ has been used in several studies together with psychophysiological equipment (Nacke & Lindley, 2009; Salminen, et al., 2009) and it is of sufficient quality to accurately report gameplay experience (the values of of Cronbach's alpha ranged from .71 to .89 in the original study (IJsselsteijn, et al., 2008)).

3. Results

We present the results of a two-way repeated-measures factorial ANOVA using sound and music as independent variables with two levels (on = audible or off = inaudible) and facial EMG (brow, eye, cheek), EDA, and GEQ dimensions as dependent variables. A few values in the psychophysiological dataset were missing or outliers (due to recording problems such as electrodes falling off). Therefore, before the analysis, average values of psychophysiological measures were normalized using logarithmic transformation, a standard procedure for the normalization of physiological data (Ravaja, 2004). Only statistically significant findings are reported.

3.1 Results of EMG

<<insert Table 1 about here >>

The descriptive statistics for normalized EMG measurements at different facial locations (eyelid [OO], brow [CS], and cheek [ZM]) are shown in Table 1. Using the tonic data (in this context, we understand tonic as measured over a period of time albeit responding to an experimental condition), we tested significant differences between the factors sound and music. Thus, we separately carried out 2 × 2 ANOVAs for each EMG measure. None of the ANOVAs showed statistical differences for EMG measurements. Thus, it must be assumed that neither sound nor music, nor the interaction of sound and music, had a significant effect on EMG measurement.

3.2 Results of EDA

<<insert Table 2 about here >>

The descriptive statistics for normalized EDA measurements (using logarithmic transformation) under sound and music conditions are reported in Table 2. No threshold values existed to classify EDA results as either activation or deactivation in the arousal dimension (Lang, 1995; Russell, 1980). Conditions with higher arousal values could, however, indicate a more exciting UX than in other conditions. Therefore, a 2 × 2 ANOVA tested the effects of the independent variables, as for the results of EMG, no significant effects were found. Thus, we assumed that neither sound nor music, nor the interaction of sound and music, had a significant effect on EDA measurement. With the aforementioned EMG results our full hypotheses H1 and H2 were not supported by these results. Additionally, H3 had to be rejected.

3.3 Results of Game Experience Questionnaire

<<insert Table 3,4 about here >>

Table 3 shows the descriptive statistics for each GEQ dimension under each sound and music condition that was used in the experiment reported here. Similar to our treatment of the physiological data, we tested the effects of sound and music (RQ1) with a 2 × 2 ANOVA and found a main effect of sound on all 7 dimensions of the GEQ and an interaction effect of sound and music on tension and flow. Table 4 shows the results from the ANOVA. Thus, absence or presence of sound seemed to influence all subjective GEQ dimensions, but this effect was qualified by an interaction effect on tension and flow (cf. Table 4). As we can see in Table 3, the more positive or neutral dimensions of the GEQ (Flow, Positive Affect, Competence, Immersion, Challenge) were experienced more positively when the sound of the game was playing, while the more negative dimensions (Negative Affect, Tension) were experienced less negatively. The opposite was the case when sound was turned off. Therefore, game sound seemed crucial for a subjective, positively rated game experience.

In addition to a main effect of sound, an interaction effect of *sound* × *music* on the GEQ dimensions *tension* and *flow* was found. This effect was further investigated with simple-effect analysis (see Table 5). The effect of music was significant at each level of sound and vice versa on tension and flow.

<<insert Table 5, Figure 2 about here >>

As shown in Figure 2, flow was rated highest when sound was on and music was off but received the lowest scores when both were turned off. When sound and music were on, the flow rating was a slightly lower than in the *sound on/music off* condition. The experience ratings were even lower when sound was turned off and music remained on (albeit not as low as when both sound and music were turned off). Turning on music seemed to dampen flow experience which was more polarized (positive and negative) when the differences of sound were taken into account.

<<insert Figure 3 about here >>

Figure 3 shows the interaction effect of sound and music on tension ratings. For tension, music seemed to be the polarizing factor: When music was on and sound was on, tension was experienced lowest while when music was on and sound was turned off tension was experienced highest. There was not much difference when music was off. When both music and sound were turned off, tension ratings were a bit higher than when sound was on and music was off.

3.4 Correlation between Physiological Data and Survey Responses

Finally, addressing RQ2 about which dimensions of gameplay experience correlated with physiological measurements, we calculated Pearson's *r* for GEQ values and psychophysiological results (after assuring the normal distribution with a Kolmogorov-Smirnov test). Different patterns of correlation emerged from the analysis (see Table 6). In the condition *sound on/music off*, competence correlated negatively with EMG OO and EMG CS, while flow had a negative correlation with EDA. In the condition *sound off/music off*, we found several positive correlation patterns. Immersion correlated with EMG CS and EMG ZM, flow with EMG ZM, positive affect with EMG CS, and challenge with EMG ZM. No significant correlations were found for *music on/sound on*. Lastly, with *music on/sound off*, flow again correlated positively with EMG ZM activity, and immersion negatively with EDA.

<<insert Table 6 about here >>

4. Discussion

Unfortunately, as with the study of Grimshaw et al. (2008), we did not find any main effects of either sound or music on tonic psychophysiological data. Therefore, our three hypotheses H1-H3 could not be supported by these results. In general, this leads us to question whether tonic linear analysis is the correct way of analyzing the psychophysiological data collected in our experiment. Indeed, it is one of the controversies regarding the use of psychophysiological methods (Cacioppo, Tassinary, & Berntson, 2007; Nacke, 2009a): Do they yield suitable results for complex stimuli? The results of a study by Mandryk, Inkpen, and Calvert (2006) for example would suggest this, since significant psychophysiological differences were found when playing against a computer versus playing against a friend (and in another experiment for differences in the challenge level of a digital sports game). One point they noted in their discussion is the difference between phasic responses to game events versus a tonic activity level of the psychophysiological data and that there was no way of assuring how much influence of phasic responses was accumulated in the tonic averages for each experimental condition. Thus, a more promising approach to psychophysiological analysis in digital games might be the focus on phasic psychophysiological player responses in digital games and the alteration of a single game event (Ravaja, Turpeinen, Saari, Puttonen, & Keltikangas-Järvinen, 2008). Hence, a venture of future research could be focusing on phasic psychophysiological analysis of sound and music attached to game events. This would then require the experimental design to account for changes in sound and music for a single game event that happens repeatedly during an experimental playing sessions (i.e., regular game events such as firing a gun or killing an enemy would be suitable).

In addition, we could hypothesize that the interpretation of tonic data can be subjective and it might be that psychophysiological measurements are not an optimal method for assessing the role of sound in digital games. There are many factors potentially affecting the interpretation and experience of perceptual stimuli: prior experience of the stimuli, cultural and societal experience and milieu, age, gender and present mood, for example, not to mention cross-modal relationships between vision and hearing. To provide an example related to sound, the accepted automotive model of sonic ‘sportiveness’ differs between Germany (Porsche) and Italy (Ferrari) (Cleophas & Bijsterveld, in press). Thus, it may well be the case that more precise interpretations of tonic data can be achieved through cross-correlation with expanded qualitative methods, which take into account the above factors.

Nevertheless, we did find a significant main effect of game sound (on/off) on GEQ dimensions. The main effect of sound showed that on five dimensions of experience, regardless of music, the presence of sound led to higher subjective ratings of positive GEQ dimensions and lower ratings of negative GEQ dimensions. Without sound providing audible feedback, players experienced the game as tenser and less pleasant. This suggests that sound led to a better gameplay experience. A reason for this could be that the auditory feedback (provided by sound) made players feel more positive about their playing experience. Brewster and Crease (1999) suggested that enhancing menus with sound feedback made them more usable. In line with this argument, our results suggest that using sound feedback in games can make them indeed more playable. However, it has to be noted that background confirmatory sound effects are a complex communication form of human-computer interfaces and many task variables are involved in creating an interactive experience and perception (Edworthy, 1998). The interaction effect of sound and music on flow ratings might suggest a polarizing effect of music, weakening the positive effect of sound on flow. Music, on the other hand, seemed to disturb players when present with in-game sound. However, without sound present, music had a positive effect on flow.

The interaction effect of sound and music on tension ratings pointed to music as a polarizing factor for tension. When music was playing and sound was on, the tension of the player was lowest, indicating that sound and music when audible at the same time had a soothing effect on the player while, when music was on and sound was off, players might have been frustrated since they lacked auditory feedback and were distracted by the music playing in the background. The first-person perspective posits a player as being *in* a game world while the scenario is that of the “hunter and the hunted:” In such a situation, as in reality, the lack of clues as to the possibilities or threats inherent in the environment can be disturbing. The tension found in the condition *music on/sound off* may be explained not only by the lack of informative sound cues but also, firstly, by the perceptual mismatch between the world that the eyes see and the world that the ears hear and, secondly, by the lack of sonic response and feedback to player actions.

Two limitations of this study are a lack of an established theory of gameplay experiences that could provide a frame for deeper analysis and a lack of experimental results on sonic UX in games to which these findings could be compared. In general, not many studies have addressed correlations between user experience and psychophysiological measures (Mandryk, et al., 2006). The correlations that we have found between psychophysiological measures and GEQ dimensions are a first step in this direction (RQ2, see Table 6). However, the results were neither currently showing a clear direction nor did they allow drawing a single conclusion. For example, EMG OO is usually used to indicate positive emotions and high arousal, but was negative in our correlation (sound on) to competence (which should be a positive GEQ dimension). Another finding from the correlation analysis was the negative relationship between flow and EDA (sound on), and immersion and EDA (music on). Flow and immersion could be those factors more likely being related to mental concentration effort in games (naturally leading to lower EDA) and not so much to excitement (leading to higher EDA). The results from the GEQ support the idea that players' experiences and sound design influence each other and thus future studies, which should use less complex but still game-like sound stimuli (presented at a phasic game event level), could strengthen this relationship with psychophysiological results. To overcome the theoretical limitation of this work, future studies should consider triangulating the psychophysiological data with interviews and other kinds of qualitative data that will provide a richer frame of interpretation for these quantitative results.

5. Conclusion and Future Work

In summary, we have found that the most pleasant conditions for playing games are playing with sound on, but the positive effect of sound depended on the presence or absence of music for the experiences of tension and flow. A methodological result of the research presented in this paper is the understanding that tonic analysis might be worse than event-focused phasic psychophysiological analysis for hypothesis-driven psychophysiological UX research. In addition, the correlation of psychophysiological activity and subjective responses will be an analysis strategy to concentrate on in future studies. We also see a lot of potential in cross-correlation of subjective and objective measures in terms of attentional activation. This could be for example the exploration of brain wave (i.e., EEG) data to find out more about the cognitive underpinnings of gameplay experience and thus potentially separating experiential constructs from an affective emotional attribution and attributing them to cognitive and attentional factors. Experiments might be designed to answer the question: Does attention guide UX or vice versa? Others might investigate sound and affect in game genres other than FPS.

There is some way to go before a comprehensive model of a player's experience of game sound (let alone general UX in games) will be achieved – one providing the basis for game sound design guidance and taking into account the potential for new technology. Currently, game sound design as it is experienced in-game is generally static and undynamic. Pre-recorded audio samples are triggered through a player's interaction but undergo no real-time processing according to the player’s emotional or affective state. Developing technology (e.g., consumer devices such as the NIA and Emotiv headsets) and experimental game sound processes (e.g., procedural audio) point the way to richer and a more personalized player's experience through biofeedback combined with the real-time synthesis of sound. The creation of affective, on-the-fly sounds according to players’ psychophysiological state (and, perhaps, a cultural/societal profile defined *a priori*) can be used to enhance or counteract that state. This is an essential future challenge for affective computing in games as well as for measurement of sonic UX in games. Such a sound design paradigm has implications in other fields too: relational-agent design, experimental psychology, psychiatric therapy, to name a few. Before such a model of structural game sound experience is realized though, there is much fundamental and experimental work to be done.

Future challenges here will include refining the experimental methodology based on past experimental studies (Mandryk, et al., 2006) that clearly distinguish experimental stimuli, while still being embedded in a gaming context, so that the measurements and results obtained remain ecologically valid and thus more readily informative for game and sound design. The multi-method combination and correlation of subjective and objective quantitative measures seems a good starting point from which to create and refine more specific methods for examining the impact of sound and music in games, but this could be expanded to take into account more factors. In the future, we hope to see more UX evaluations using physiological logging of players' behavior and emotion to create a comprehensive view of gameplay experience: this could improve our understanding and inform the creation of a structural model of UX in general.

6. Acknowledgments

We would like to express our gratitude to Sophie Stellmach and Dennis Sasse for helping with this study. Part of this research was funded by the European Commission (Contract: FP6-NEST-28765). We also thank all our participants.

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Captions for Tables and Figures (attached)

Table 1

Tonic averages (standard deviations) of EMG measurements

Table 2

Tonic averages (standard deviations) of EDA (physiological arousal) measurement

Table 3

Averages (standard deviations) of GEQ responses

Table 4

Results from 2×2 ANOVA carried out on GEQ dimensions

Table 5

Results from simple-effect analysis

Table 6

Correlation analysis of GEQ dimensions and psychophysiological measures

Figure 1. Facial locations and nomenclature of EMG electrodes.

Figure 2. The effect of sound and music on the GEQ dimension flow.

Figure 3. The effect of sound and music on the GEQ dimension tension.

Table 1

Tonic averages (standard deviations) of EMG measurements

	Sound			
	On		Off	
EMG Location	Music On	Music Off	Music On	Music Off
Eyelid (OO)	1.88 (.38)	1.85 (.35)	1.89 (.41)	1.79 (.30)
Brow (CS)	1.93 (.24)	1.88 (.26)	1.92 (.31)	1.88 (.26)
Cheek (ZM)	2.00 (.40)	1.99 (.35)	2.03 (.42)	1.94 (.34)

Note. Tonic EMG measurements were normalized as ln[μV], *N* = 29. OO = orbicularis oculi, CS = corrugator supercilii, ZM = zygomaticus major.

Table 2

Tonic averages (standard deviations) of EDA (physiological arousal) measurement

	Sound			
	On		Off	
Measure	Music On	Music Off	Music On	Music Off
EDA	.71 (.19)	.74 (.20)	.73 (.21)	.75 (.19)

Note. Tonic EDA was normalized in log μS.

Table 3

Averages (standard deviations) of GEQ responses

	Sound			
	On		Off	
GEQ Dimension	Music On	Music Off	Music On	Music Off
Immersion	1.53 (1.08)	1.51 (1.01)	1.13 (.95)	.85 (.79)
Flow	2.10 (1.28)	2.37 (.94)	1.72 (1.32)	1.50 (1.12)
Competence	2.18 (1.21)	2.24 (.93)	1.88 (1.10)	1.57 (1.06)
Positive Affect	2.06 (1.11)	2.16 (.93)	1.61 (.93)	1.49 (1.00)
Tension	.97 (1.12)	1.41 (.81)	1.94 (1.13)	1.57 (1.13)
Challenge	2.18 (1.08)	2.19 (.69)	1.96 (.85)	1.60 (.81)
Negative Affect	.86 (.86)	1.06 (.62)	1.63 (1.02)	1.71 (1.10)

Note. Each GEQ dimension listed above contains 5 items (except immersion with 6 items), each item consists of a statement on a five-point scale ranging from 0 (not agreeing with the statement) to 4 (completely agreeing with the statement).

Table 4

Results from 2×2 ANOVA carried out on GEQ dimensions

Factor	GEQ Dimension	F (1,35)	*p*	η_p^2
Sound				
	Immersion	17.10	< 0.001	0.33
	Tension	11.64	0.002	0.25
	Competence	7.49	0.01	0.18
	Negative Affect	23.73	< 0.001	0.40
	Positive Affect	11.77	0.002	0.25
	Flow	16.32	< 0.001	0.32
	Challenge	9.04	0.005	0.21
Sound × Music				
	Tension	10.63	0.002	0.23
	Flow	4.70	0.04	0.12

Note. Only statistically significant (*p* < .05) results are reported.

Table 5

Results from simple-effect analysis

Effects		F (1, 35)	*p*	η_p^2
Tension				
	Effect of Music at *Sound on*	88.26	< 0.001	0.72
	Effect of Music at *Sound off*	107.86	< 0.001	0.76
	Effect of Sound at *Music on*	105.86	< 0.001	0.75
	Effect of Sound at *Music off*	109.08	< 0.001	0.76
Flow				
	Effect of Music at *Sound on*	173.85	< 0.001	0.83
	Effect of Music at *Sound off*	72.39	< 0.001	0.67
	Effect of Sound at *Music on*	103.22	< 0.001	0.75
	Effect of Sound at *Music off*	164.32	< 0.001	0.82

Note. Only statistically significant (*p* < .05) results are reported.

Table 6

Correlation analysis of GEQ dimensions and psychophysiological measures

GEQ Dimensions	Sound	Music	EMG OO	EMG CS	EMG ZM	EDA
Competence	On	Off	-.40	-.42		
Flow	On	Off				-.42
Sensory and Imaginative Immersion	Off	Off		.38	.40	
Flow	Off	Off			.40	
Positive Affect	Off	Off		.34		
Challenge	Off	Off			.36	
Sensory and Imaginative Immersion	Off	On				-.37
Flow	Off	On			.36	

Note. Only statistically significant (2-tailed, $p < .05$) correlations are reported. For the condition *sound on, music on*, no significant correlations were found.

Figure 1

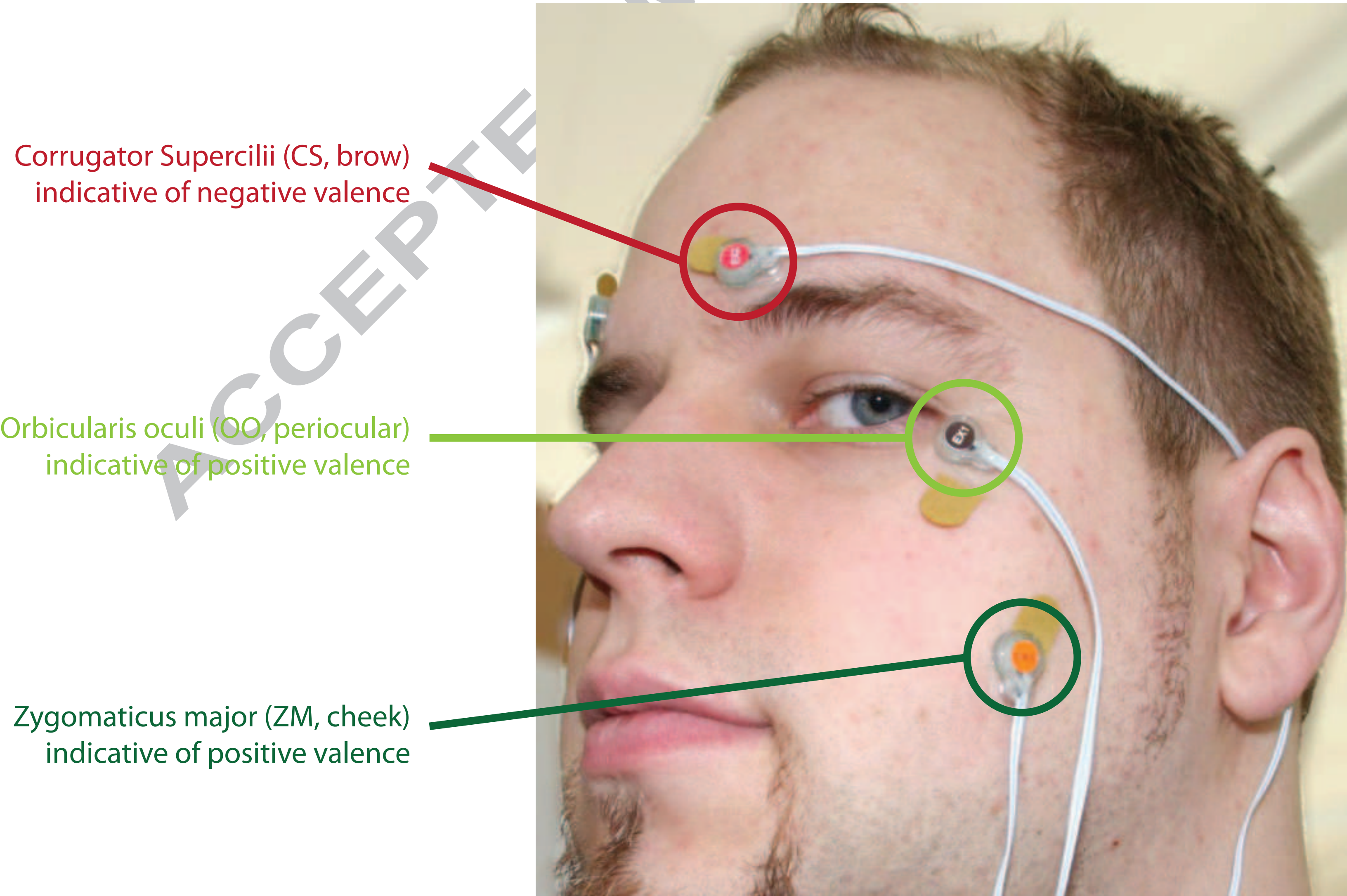

Corrugator Supercilii (CS, brow)
indicative of negative valence
Orbicularis oculi (OO, periocular)
indicative of positive valence
Zygomaticus major (ZM, cheek)
indicative of positive valence

Figure 2

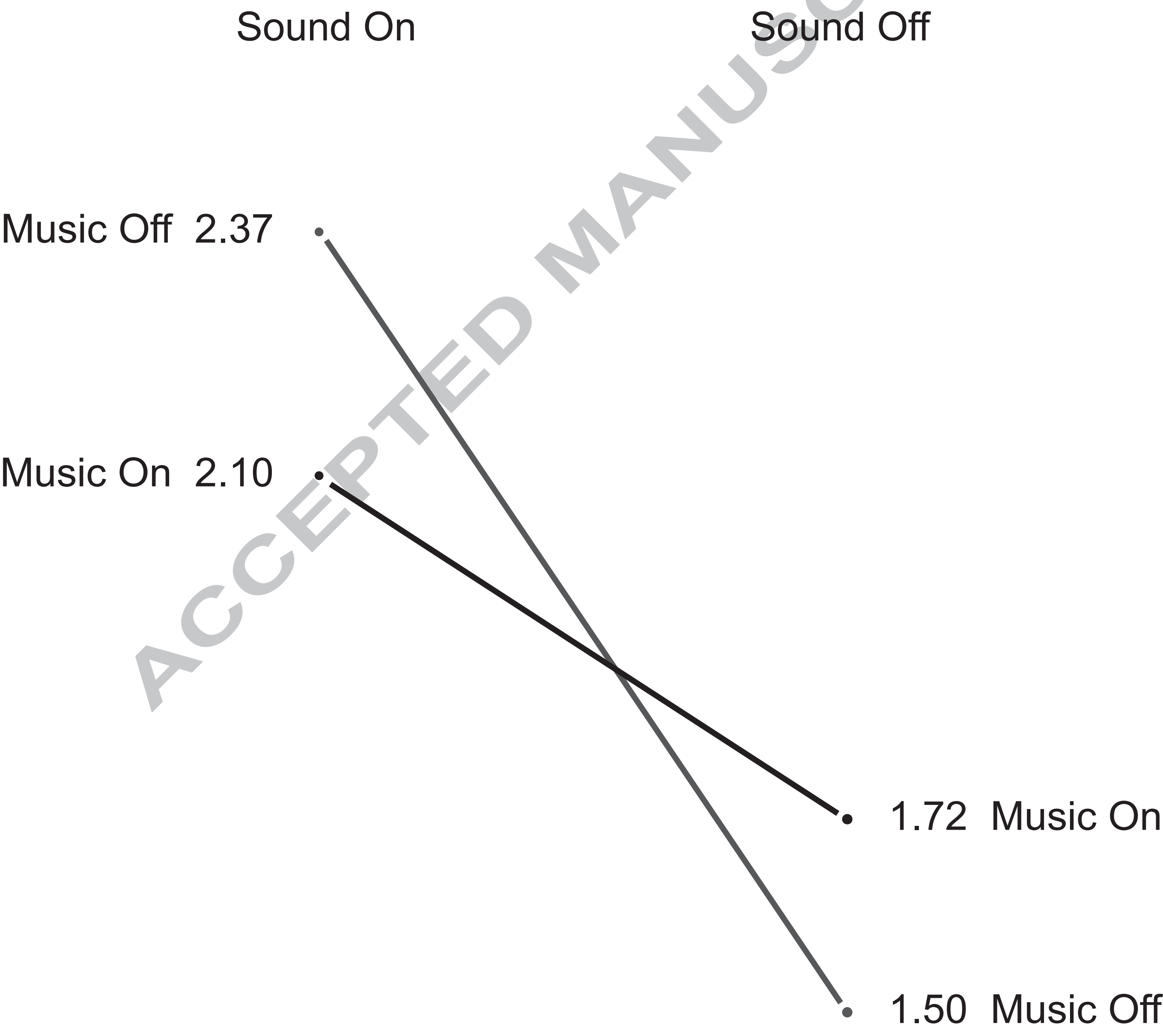
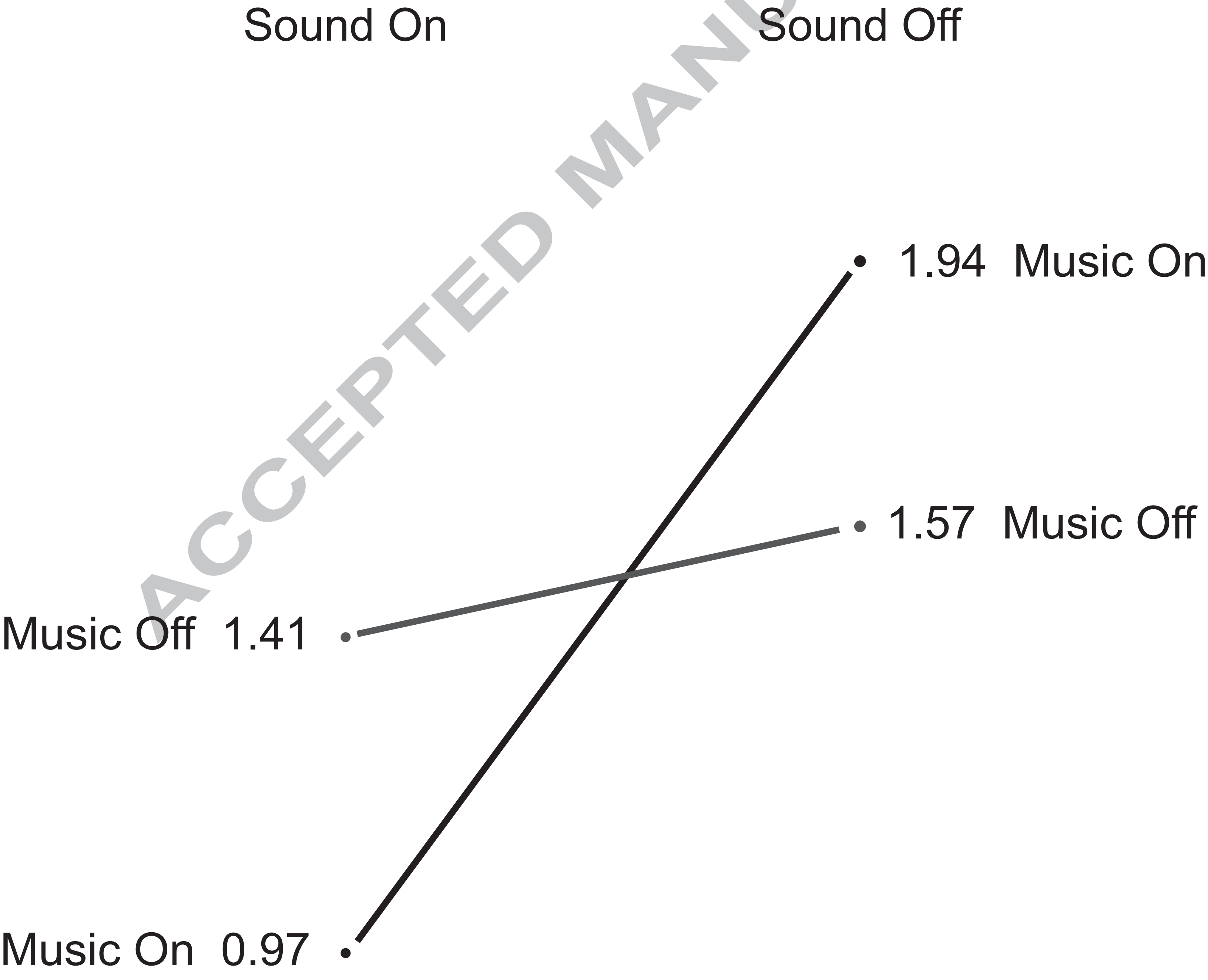

Sound On
Sound Off
Music Off 2.37
Music On 2.10
1.72 Music On
1.50 Music Off

Figure 3


Sound On
Sound Off
1.94 Music On
1.57 Music Off
Music Off 1.41
Music On 0.97

Abstract

The combination of psychophysiological and psychometric methods provides reliable measurements of affective user experience (UX). Understanding the nature of affective UX in interactive entertainment, especially with a focus on sonic stimuli, is an ongoing research challenge. In the empirical study reported here, participants played a fast-paced, immersive first-person shooter (FPS) game modification, in which sound (on/off) and music (on/off) were manipulated, while psychophysiological recordings of electrodermal activity (EDA) and facial muscle activity (EMG) were recorded in addition to a game experience questionnaire (GEQ). Results indicate no main or interaction effects of sound or music on EMG and EDA. However, a significant main effect of sound on all GEQ dimensions (immersion, tension, competence, flow, negative affect, positive affect, and challenge) was found. In addition, an interaction effect of sound and music on GEQ dimension tension and flow indicates an important relationship of sound and music for gameplay experience. Additionally, we report the results of a correlation between GEQ dimensions and EMG/EDA activity. We conclude subjective measures could advance our understanding of sonic UX in games, while affective tonic (i.e., long-term psychophysiological) measures of sonic UX in games did not yield statistically significant results. One approach for future affective psychophysiological measures of sonic UX could be experiments investigating phasic (i.e., event-related) psychophysiological measures of sonic gameplay elements in digital games. This could improve our general understanding of sonic UX beyond affective gaming evaluation.