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The Impact of Health-Related User Interface Sounds on Player Experience

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Abstract

Background. Understanding how **sound** functions on informational and emotional levels within **video games** is critical to understanding **player experience** of games. **User interface sounds**, such as **player-character health**, are a pivotal component of gameplay across many video game genres, yet have not been studied in detail.

Method. To address this research gap in user interface sounds, we present two studies: The first study examines the impact of the presence or absence of **player-health sounds** on player experience. The second study explores the impact of the **types of sound** used to indicate player health. We use mixed methods with **qualitative** and **physiological measures**.

Results. Our results reveal that despite the presence of visual cues, sound is still important to **game design** for conveying health-related information and that the type of sound affects player experience.

Keywords

game sound, games user research, multimodality, physiological evaluation, player experience, user interface sounds

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Introduction

Sound in video games serves many purposes: It may inform players that an enemy is nearby, that they have obtained an important item, that they are under fire, or that they need to find some form of health replenishment to avoid an otherwise imminent death. It can evoke emotion, induce emotion, and encourage engagement in the game. Designing sound for contemporary games can be a complex process. It involves creating multiple variations of sounds to avoid repetition. In the sound mix, designers prioritise sounds, so that the soundscape is supportive of playability (i.e., optimising a player's understanding and ability to interact within the game environment) and player experience (i.e., how immersed or engaged players are). Despite the vital influence of sound in the design of video games, there is a lack of formal scientific studies investigating the impact of sound on player experience.

Although video game sound evaluation is important, it is complicated in practice. User testing has limitations when evaluating game sound, because it is difficult to account for erroneous variables such as player control (e.g., overall volume, mix between speech/sound effects/music), audio output variation (e.g., stereo/surround, headphones/speakers), and external environment effects (e.g., background noise). Beyond detecting the absence of sound, many players lack conscious awareness of how sound (or the music; Hébert, Béland, Dionne-Fournelle, Crête, & Lupien, 2005) is functioning within the game. However, sound not only provides information to support player interaction, but also plays a vital role in driving emotional engagement (Collins, 2008, 2011; Perron, 2004). The many functions of game sound (Collins, 2007), coupled with difficulties in evaluating it, reveals a genuine and immediate need for new user testing approaches capable of managing these issues.

We address this need by presenting two novel user testing studies of game sound that contribute to advancing our understanding of game sound in general and of player-health user interface sounds in particular. The health of the player-character is arguably the most important resource in nearly all action games (notably first person shooters and role playing games: When health drops too low, the character will die and the player will have to begin again from a save point. Informing the player about the status of their health (notably, of impending virtual death) is an important function of the game's user interface and sound design. Information about character health is usually graphically presented on-screen with either hearts or a health indicator that changes when the player's health increases or decreases. Usually, a critical warning sound alarms players when the health gets to a precariously low level. Often, this is a beeping warning, sine-wave-like sound, but also character-body sounds (breath, heartbeat) increasing in pace. Occasionally, musical cues (e.g., music tempo increases in *Street Fighter 2: The World Warrior* (Capcom, 1991)) or vocal warnings (e.g., *Killer Instinct* (Midway, 1994)) are used.

Previous studies have shown that sound in games plays a significant role in player experience (see below). However, it has not been shown whether all of the sounds in the game are contributing to that experience, or if only some sounds are contributing, while others are redundant or even counterproductive. As one step towards understanding the role that individual types of sound may play in games, in this paper, we seek to understand the effect of player-health related user interface sounds on player experience.

Background: Sound Research in Games

While still an emerging field of research, there are a limited number of existing studies concerning video game sound and user experience that help us to frame and inform our work. Some studies explore sound design in games from an observational angle with respect to the game genre (Garcia, 2012; Garner, Grimshaw, & Nabi, 2010), but our approach was informed by formal studies of sound modality.

Relevant studies explored the impact of sound-on against sound-off in a video game, using many types of games from first-person shooter games (Grimshaw & Schott, 2008; Nacke, Grimshaw, & Lindley, 2010), slot machine games (Dixon et al., 2014), and real-time strategy and stealth games (Jørgensen, 2008). The measurement approaches ranged from using physiological measures to surveys and observation. Each of these studies has posited that the presence of sound has a discernible impact on both gameplay performance and enjoyment across all genres examined. We can assert that the absence or presence of sound therefore has some effect on player experience. However, we have yet to determine the exact associations between particular aspects or features of game sound and specific experience qualities. As described above, interface sounds have not been separated from existing sound studies, and it remains to be determined if interface sounds contribute to the player's enjoyment of the game or the experience of the game (i.e., player experience).

The substitution of the sound or music that featured in the original iteration of a game with bespoke alternatives has been studied by Dixon et al. (2014) in the context of slot machine games, and also by Wharton and Collins (2011) using the action role-playing game *Fallout 3* (Bethesda Softworks, 2008). These studies found significant impact on the player's overall experience, such as physiological response, altering the speed with which they play, or affecting subjective enjoyment ratings, suggesting that it is not merely the presence of sound that matters, but the presence of a particular type of sound that is contextually significant to the game. As a caveat, the study by Nacke et al. (2010) reported an impact of sound-on/sound-off only on subjective experience measures and not on physiological measures. Auditory User Interfaces Studies of the informational functionality of sound outside the area of games are relatively plentiful and most certainly useful, in that they are indicative of specific acoustic and psychoacoustic variables that could be tested within a game context. For example, the field of sonification explores the use of sound to explicate complex data sets (Kramer, 1994). Studies into auditory interfaces across a variety of settings explored using audio to convey information to a user as a design component (Gaver, 1986). Receiving conflicting information across multiple sensory modalities during a task causes users to perform worse. However, synchronised sound that is semantically consistent with a visual display, increases user performance (Oakley, Brewster, & Gray, 2000; Pao & Lawrence, 1998).

Auditory Interface Sounds

In user interfaces, a distinction is made between auditory icons and earcons (Brewster, 1998). Research concerning auditory icons and earcons provides insights into our existing understanding of how sound can influence both player experience and in-game behaviour. An auditory icon is a sound that is presented with the intention of providing information about an object or event (Gaver, 1986). For example, when knocking on an object, the noise that it makes can give an idea of what material the object is constructed from (i.e., whether it is solid or hollow, as well as how forceful the knock was). Our inferences from auditory icons depend on how well we have learned to interpret the nuances in the sound we hear (see Goldstein, 1989; Welch & Warren, 1980). Auditory icons thus encode a wide range of information in a form understandable for most people (Blattner, Sumikawa, & Greenberg, 1989). Earcons, by contrast, possess no pre-existing semantic association or meaning that we can immediately interpret. An earcon is established when the listener forms a semantic bridge between the sound and a separate information piece to convey something more complex (McGookin & Brewster, 2004). In games, earcons are commonly musical and are created from motifs derived from musical properties (e.g., rhythm, timbre, pitch, register, and dynamics). The *Left 4 Dead* series (Valve, 2008) is a good example of earcons in games. A low, rumbling stringed motif accurately reflects the grotesque vomit-projecting character of the ‘Boomer’, while a few high register, nimble notes on the piano represent the agile and screeching ‘Hunter’. Such motifs play whenever the player is in close proximity to these enemy characters and—while they provide the player with little actionable information when first heard—once the connection between the earcon and the character is established, the player can use the sounds to support their in-game strategy.

When it comes to games, the interface has been a growing area of research interest. However, the role of sound is often neglected in studies of the interface (Fagerholt & Lorentzon, 2009; Johnson & Wiles, 2003; Jørgensen, 2012; Skalski, Lange, & Tamborini, 2006). We cannot do justice to the work that has been done in the space we have here, but for overviews, we recommend Gaver (1986), Brewster, Wright, and Edwards (1993), and Kramer (1993). Likewise, the use of auditory indicators in other forms of interfaces and situational awareness design has been a growing area of interest (e.g., Endsley, 2001; Endsley & Jones, 2016). Nevertheless, the bulk of this research is concerned with designing for interfaces and awareness, and in this research paper we are concerned with evaluating and understanding the current choices of sounds used, rather than specifically *designing for* these game situations. Moreover, this is not a comparison of real-world examples of interface sounds with game-world examples: while that may make for an interesting study, it is outside the scope of our current research.

Two Studies to Understand the Role of Specific Game Sounds

We can infer from previous literature on the informational role of sound in non-game interfaces that—at least in some instances—sounds in games are critical to the understanding of the gameplay environment. However, the extent to which specific sounds play a role in the actual enjoyment or player experience within that game remains to be determined. Thus, we present two studies to tease out the role that health sounds have on player experience and enjoyment of games. Study 1 examines the presence versus absence of health interface sounds and Study 2 focuses on the use of abstract versus non-abstract sounds.

Both studies took place at the University of Ontario Institute of Technology, which was set up to approximate a typical video game playing environment, primarily for the purpose of limiting artifacts associated with nervousness or discomfort for the collection of physiological data. Participants were seated at a desk with a PC workstation that had all files required to run the game. They were also provided with a pair of professional studio headphones (AKG K240 Studio) and a Microsoft Xbox 360 controller for input. Both studies were run in random sequence. An experimenter was present in the room at all times, positioned behind a cubicle wall, separating themselves from the 'playtesting' area. Participants were welcomed to the lab and briefed on the experimental process. After signing a consent form, each participant filled out a short demographic survey regarding their gameplay habits. Individual differences in procedure and methods are discussed separately below. All studies complied with the research ethics guidelines provided at the University of Ontario Institute of Technology.

Study 1: Investigating Presence and Absence of Health-Related Interface Sounds

For Study 1, our goal was to determine the impact of the presence or absence of health-related sounds on gameplay experience. It follows prior sound-on/sound-off studies (Dixon et al., 2014; Nacke et al., 2010; Wharton & Collins, 2011), but shifts the focus to health-related sounds, because we consider this the most important audio feedback in games.

Methodology. Custom game testing was conducted by way of a customized first person shooter (FPS) game, developed in the *Unity3D* (Unity Technologies) engine, together with a small team of undergraduate programming assistants. The engine facilitated a suite of logging processes by which various game metrics could be recorded. The game supports typical FPS interactions, such as running, jumping, and shooting enemies. Archetypal design elements were also used, including health pickups, exploding barrels, and alternative enemy types.

The game consisted of a single level, the goal of which was to collect six cupcakes that were scattered throughout the game world. In the event that the player runs out of health, they are returned to the beginning of the level and all of their progress is reset. The anticipated average completion time was 10-15 minutes. Difficulty was relatively high, both to ensure that the full range of health-related sounds would be auditioned during gameplay, and to support the functionality of these sounds as critical gameplay feedback. Other sounds were incorporated into the game environment, including sound relative to the player/enemy weapons, enemy character sounds, objective signifiers, and an ambience background track that played throughout the game.

Player-character health sounds had four auditory features: 1. character damage sounds (grunting noises that occur when the player receives damage from an enemy or the environment), 2. health pickup sounds (confirming health pickups), 3. a low-health alert (a continuous beeping), and 4. a death scream (when player health drops to zero). Graphical features that cued health-related feedback included a visual health meter (0-100) and blood-spatter screen overlays that appear when the player sustains injury. For this study, two iterations of the game were developed, one with all health-related sounds present throughout gameplay (S) and one with all health-related sounds removed (NS).

Protocol. Prior to playing the test games, experimenters ensured participants were comfortable with the controls and gameplay. To confirm this level of comfort, participants first completed a 60-second trial of related gameplay. Repeated measures (within-participants) testing was adopted and each participant played both S and NS experimental conditions (the order of which was counter-balanced between participants to account for order/learning effects). Gameplay was restricted to 10 minutes but would be less if the game were completed before that time. Participants A total of 24 participants (14 male, 10 female), all university student volunteers, contributed to this experiment. Prior gameplay experience rated high (7-point Likert scale, 7 is highly experienced, M = 6.08, SD = 1.06) as did prior FPS experience (M = 5.04, SD = 1.65); however, the range of stated hours spent playing games per week varied significantly (between 0-35 hours, M = 16.25, SD = 9.94, only one participant stated that they currently played zero hours). Participants were not expressly screened for hearing disabilities; however, none reported being unable to hear any of the sounds in the game, including those that were added or removed as part of the experimental condition. No participants reported being trained as musicians or sound designers, and therefore all were treated as casual listeners.

Materials and data collection. With regards to objective data acquisition, facial electromyography (EMG) and skin conductance (SC) level were selected to provide quantitative measures of affective valence and arousal (based on similar setups described in other studies (Nacke & Grimshaw, 2011; Nacke et al., 2010). We used a NeXus-10 MKII (Mindmedia BV) physiological recording system with BioTrace+ software. SC sensors were attached with Velcro straps to the proximal phalanges of participants' ring and pinky fingers (right hand). EMG sensors were attached with adhesive tape on the corrugator supercilii (above they eyebrow) and the zygomaticus major (cheek) muscle locations to measure facial muscle activity. A grounding sensor was also attached behind the right ear of the participant. Prior to testing, a five-minute baseline measurement was taken as the participant relaxed and focused on a neutral image. The sample rate was 2048 SPS. We followed standard procedures from the physiological game evaluation literature (Mandryk & Nacke, 2016; Nacke, 2015).

We also collected high frequency game metrics (up to 50 units of data per metric per second) during the play sessions. Based on these metrics, we gathered information about the total time spent playing the game, the player's position and movements, as well as how much health players had remaining and how many objectives they had collected. These metrics allowed us to determine exactly where and when a player was taking damage, and let us track their movements in relation to highly damaging hits. The total number of deaths and whether a player successfully completed the game was also recorded, to reveal if the presence of informative health sounds had any impact on players' overall successes or failures in the game.

Following completion of each game session, participants completed a set of survey questions. We chose the PANAS (Positive and Negative Affect Schedule) (Watson, Clark, & Tellegen, 1988), PENS (Player Experience of Need Satisfaction) (Ryan, Rigby, & Przybylski, 2006), and IMI (Intrinsic Motivation Inventory) (McAuley, Duncan, & Tammen, 1989) survey scales for evaluation, because they had previously been asserted to give the broadest view of player experience without risking survey fatigue. Thus, we wanted to comprehend the basic levels of positive and negative affect of the participants, as well as deeper insights into how their need satisfaction and intrinsic motivations changed. During gameplay, we screen-capture recorded players' in-game behaviour and, following completion of both game types, participants were subjected to a brief exit interview, which was recorded (audio only) for later analysis.

Limitations of the study. There are several possible validity limitations of our study approach: First, it is possible that internal validity was limited, because of the non-dynamic nature of the game as well as the within-participants design of the study. Since the game and the location of its enemies and objectives did not change from one play session to another (aside from the addition or removal of health-related audio), it is possible that minor learning effects came into play. The size of the game level itself was not expansive, and players would have had the opportunity to learn the locations of the objectives and threatening areas. This would allow them to develop dominant strategies over the course of their first playthrough and use that information in the second. Despite this, our condition order was counterbalanced across the sample population, so the majority of these effects should be mitigated.

Results

All measures that satisfied parametric assumptions were evaluated using a paired-samples t-test, while those that violated parametric assumptions were evaluated using a Wilcoxon signed-ranks test (unless noted otherwise).

Physiological data. Of the physiological measures collected, the data from the SC sensors satisfied parametric assumptions, while both channels of EMG collected did not. No significant physiological effects of participants could be measured in Study 1 (with both parametric and non-parametric tests), ($p > .05$). Despite physiological measures being useful in identifying a greater amount of issues within games than traditional methods alone (Miller, Parecki, & Douglas, 2007; Nacke, 2015; Nacke, Wehbe, Stahlke, & Noguiera, 2016), this corroborates previous results by Nacke et al. (2010) which showed no physiological effects on players as a result of sound.

On average, participants experienced similarly moderate levels of arousal throughout play between both game conditions (e.g., sound: MS = 53.62%, SDS = 22.16% and no-sound: MNS = 50.46%, SDNS = 26.72%). Likewise, both corrugator and zygomatic activity was comparable between groups. SC data was normalized and the data showed the arousal level of participants varied greatly during play session (likely because of intense gameplay bursts and lull periods of less engagement, where no enemies were present). The lack of statistical significance in physiological data replicates results obtained by Nacke et al. (2010).

It stands to reason that over the 10-minute sessions we ran, a relatively small amount of time is actually spent experiencing health-changing events. We noticed some players may have involuntarily tensed up their facial muscles during intense moments of gameplay. This was not necessarily in relation to a change in their health, which could also have caused some inconsistencies in the physiological recording. In the future, it would be helpful to design an experiment, in which the researchers have more control over when and how these health-related events occur, rather than leave it up to the chance of them emerging in gameplay.

Game metrics. When examining the gameplay data, we were mainly interested in the number of successes that occurred and the failures that participants had throughout their play session. A failure was characterized by a player's health reaching zero and them having to start over. A success occurred when a player collected all 6 objectives within the 10-minute time limit. When playing without health-related sounds, the number of failures a participant experienced ranged from zero to six (MNS = 1.91, SDNS = 1.53), compared to a range of zero to five when playing with sounds (MS = 1.54, SDS = 1.53). A total of nine participants (38%) successfully completed the game with health sounds turned off, and ten (42%) had success with them on. Five of these (21%) participants completed both conditions successfully before running out of time. These results suggest a small improvement when playing with the sound on. However, none of the differences were significant.

Questionnaire data. For the PANAS questionnaire, the data for positive affect satisfied parametric assumptions while the data for negative affect did not. None of the survey results were significantly different between study conditions. For positive affect, results showed that participants had similar average levels of positive affect, both when playing without health related sounds (MNS = 30.79, SDNS = 8.98) and when playing with health related sounds (MS = 31.08, SDS = 7.26). Likewise, there were similar levels of negative affect when playing without health feedback sounds (MNS = 15.12, SDNS = 1.18) and with health feedback sounds (MS = 16, SDS = 7.20). On average, participants experienced higher levels of positive affect than negative affect.

All subscales for the IMI satisfied parametric assumptions, except for the pressure/tension scale. Players reported similar levels of interest and enjoyment when playing without (MNS = 2.58, SDNS = 0.92) and with (MS = 2.74, SDS = 0.90) health related sounds. Likewise, the perceived competence of our participants was comparable between no-sound (MNS = 3.32, SDNS = 1.30) and sound (MS = 3.28, SDS = 1.08) types. Participant effort was also similar no-sound (MNS = 3.51, SDNS = 0.99) and sound (MS = 3.43, SDS = 1.14). Finally, pressure and tension felt by participants were similar when playing without health related sounds (MNS = 2.21, SDNS = 0.95) and with them (MS = 2.30, SDS = 1.06). Remembering that the maximum possible score of any of these subscales is five, it is possible to ascertain that participants experienced moderate levels of interest or enjoyment, as well as pressure and tension. Furthermore, they felt that they performed above average in terms of their competence at the game and had to exert a moderate to high level of effort to achieve this.

Of the PENS results, the subscales of Competence, Relatedness, and Intuitive Controls were normally distributed, whereas Autonomy and Presence were not. However, they were also not significantly different between experimental conditions. In terms of perceived player competence, participants felt that they performed reasonably well without auditory health feedback (MNS = 3.36, SDNS = 0.98) as well as with it (MS = 3.46, SDS = 0.88). Similarly, players did not feel much relatedness in either the No-Sound (MNS = 1.85, SDNS = 0.74) or Sound (MS = 1.94, SDS = 0.71) conditions. The controls for the game were perceived as intuitive, no matter whether health sounds were absent (MNS = 3.99, SDNS = 0.60) or present (MS = 3.93, SDS = 0.61). Players also felt almost no difference in presence between playing without health sounds (MNS = 2.05, SDNS = 0.88) or with them (MS = 2.11, SDS = 0.78). As with the IMI, the maximum score in any of these subscales is five. Unsurprisingly, the slightly above average scores for perceived player competence match the results from the IMI. Participants also felt that the controls for the game were intuitive. Despite this, they also felt that the game world was not relatable, and they did not feel present in it, although they did feel moderately autonomous. We also asked three general additional questions: When asked how fun the game was, participants did not find the game with health related sounds (MS = 2.96, SDS = 1.08) much more fun than without (MNS = 2.79, SDNS = 1.14). Likewise, dying in the game bothered them nearly equally when playing without sounds (MNS = 2.63, SDNS = 1.50) and with (MS = 2.50, SDS = 1.50). From all of the above dependent measures, the only statistically significant difference found was in awareness of health (Wilcoxon Signed-Ranks test, see Figure 1). Players reported that they were significantly more aware of their health when playing with informative health sounds (MS = 4.13, SDS = 0.99) than without (MNS = 3.50, SDNS = 1.29); $z = -2.470$, $p = 0.014$, $r = -0.504$.

Interview results. Interviewing participants at the end of the experiment provided valuable qualitative information. What is presented here represents some qualitative evidence for our argument, but more detailed interview results can be found in Robb (2015). When asked if they could tell the difference between the play sessions, 16 participants (67%) identified at least some of the sound differences, with six (25%) correctly identifying all changes. Many participants (54%) felt that neither session was more difficult than the other, but seven (29%) felt that the game was more difficult without the presence of health-related sounds, and the remaining four (17%) felt that having those sounds actually made the game feel more difficult. All participants commented on the importance of audio cues in games, citing reasons from informative feedback to increasing immersion and simply sound as a reward mechanism.

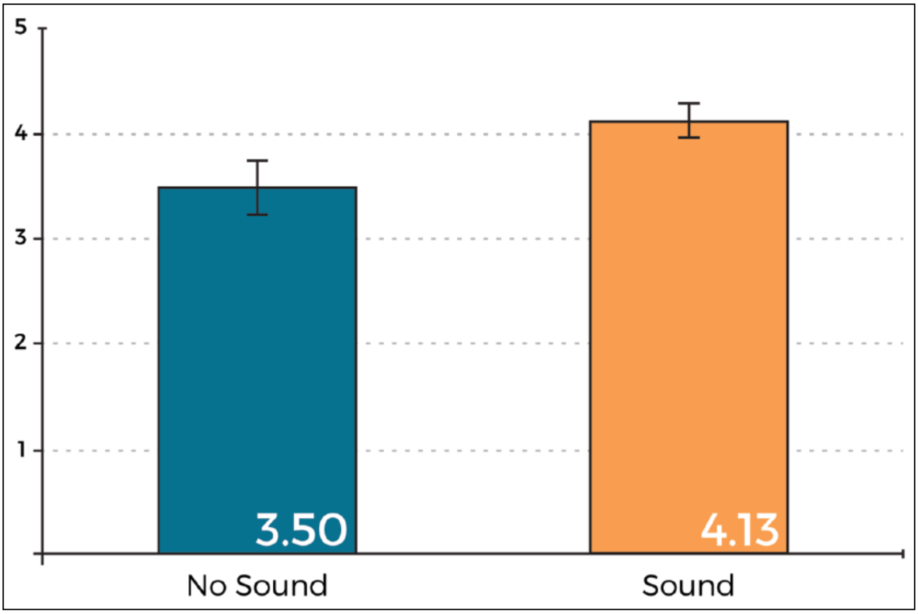

Figure 1. Health awareness rating in sound and no sound conditions.

One finding was that participants were interested in changing the sound used itself, with most people interested in altering the frequency of the alert sound based on the level of health. Sixteen (67%) were in favour of the idea and 13 (54%) thought that the frequency should increase as health lowers. Two (8%) thought that the frequency should decrease as health decreases. The final person (4%) elaborated that the frequency should increase if the abstract beeping sound is used, but decrease if the sound is more realistic (e.g., heartbeat). A further six (25%) had no opinion or mentioned it being context dependent. Only two (8%) thought frequency should not be dynamic.

The fact that participants are almost evenly split about what kind of sound they would want to hear speaks to a need for further examination. Many participants simply mentioned alert noises that they were familiar with or that the type of games they usually played implemented. Additionally, some participants mentioned they did not have an outright preference, but "proper" sounds to use were dependent on the game context.

When asked how the change in sound made them feel, participants had many things to say, although five (21%) mentioned that not having any sound for health feedback was frustrating. Less than half (42%) of participants did not mention audio at all when asked how they judged whether they were near death in a game, mostly citing visual cues such as character-hit flashes and health bars. Reasons that participants cited when asked if and why audio health cues were important include things like needing to focus on the gameplay and not on the health bar, and learning how much damage you can take before needing to get health pickups. In terms of what kinds of sounds the participants would like to hear to denote a low level of health, nine (38%) mentioned that they would prefer some sort of realistic sound, such as heavy breathing or a heartbeat sound. On the other hand, another nine (38%) said they would prefer a more abstract kind of sound (not unlike the beeping used in the next experiment). The remaining six (25%) either had no preference or said that it would depend on the context of the game. When asked about changing the volume of a health alert sound based on a player's level of health, ten (42%) disagreed, saying it would be a bad idea. Another nine (38%) thought that increasing volume at lower levels of health could be helpful, while the remaining five (21%) said it would depend on the game context.

Study 1's interviews contradicted the questionnaires and physiological measures: First—although those who were explicitly frustrated about the lack of health audio were in the minority—they all felt passionately about the issue:

> "It's so frustrating; I actually make my brother sit in the room with him telling me where things are attacking me and if my health is low." (P12, describing other games without health cues).

Even those that did not explicitly mention being frustrated were at least disappointed with the lack of feedback:

> "I realized that I had become reliant on the low health sound." (P24)

> "I wasn't quite understanding why I wasn't getting the warning that my health was low." (P23)

These comments clearly speak to the need for some sort of audio-based feedback for critical gameplay cues like player health. However, some comments from participants raised questions about the different experiences with and preferences for abstract and realistic health sounds. Thus, we conducted another study comparing those two health-sound modalities.

Study 2: Investigating Abstract and Everyday Health and Situational Game Sounds

As discussed in the previous study, there were some differing player preferences when it comes to the types of auditory warnings that they are provided within games. The two most common types could be divided into 'abstract' and 'realistic' sounds, approximating the notion of earcons and auditory icons found in existing auditory interface work, where realistic sounds have a basis in real-world, bioacoustic environments (e.g., breathing, heartbeats, corollaries to auditory icons discussed in the introduction), and abstract sounds are created artificially through electronic or other synthesis methods (corollaries to earcons) (alternate naming conventions might be "abstract" and "everyday" sounds (Macaulay & Crerar, 1998) or "other known" and "other unknown" (McGregor, Leplatre, Crerar, & Benyon, 2006). Study 2 sought to determine the effectiveness of each of these types of sounds for performing tasks within games, and to explore the experiential differences between the two types of sounds. Situational awareness and perception of character health were measured. These were chosen because of the frequency with which players of commercial shooter games need to perform these tasks and because they are aligned with Study 1.

The creation of the two designed sounds was based on a series of surveys of current practice in game sound design, followed by interviews with five game sound designers regarding their choices and practice (outlined in Robb, 2015). It was found that a division existed between a choice that interface sounds should be a part of the diegesis of the game world (realistic/environmental) or separate from the game world (abstract). The notion of diegesis in games is well-studied (e.g., Jørgensen, 2007, 2010; Kromand, 2008; Wolf, 1997) and although no consensus exists on how we should divide or delineate between game-world and extra- (or para- or non-) game world, a consensus does exist that the notion of diegesis is disrupted by games. An on-screen interface may exist "only" in the game world (such as in a heads-up display that the player-character may be seeing the interface on their helmet screen), or it may be an overlay that has no direct role to the diegesis. The visual interface design has been much studied, and clearly influences player experience. However, the auditory aspect of the interface has not been studied to any significant extent, and it remains to be seen if the auditory aspect of interfaces plays a similar role. Moreover, we do not know if interface sounds should be diegetic or non-diegetic (to use broad terms: in other words, environmental or abstract).

Methodology. As discussed above, no significant physiological effects were observed in the previous experiment. Despite physiological measures being useful in identifying a greater amount of issues within games than traditional methods alone (Nacke & Grimshaw, 2011), we made the decision to exclude physiological measures from Study 2. Game performance data was once again logged. Two separate game-based tasks were developed, using the game framework of Study 1. Each version was centred around a basic task of impending death and situational awareness. Both versions were stripped of gameplay and focused on the task related to reacting to the sound. The player character is placed in a dark room, only able to see a short distance in front of them. A player can only change the direction the character is facing and interact using a single button.

Participants. A total of 30 people (14 female) participated in the experiment, ranging in age from 18 to 34 years (M = 23.73, SD = 3.80). Effort was taken to recruit both participants that were experienced video game players as well as those that were novices or new to the medium (on a 7-point Likert scale on which 1 is inexperienced and 7 is experienced, M = 4.80, SD = 1.90), with players spending between 0 and 84 hours per week playing games (M = 10.02, SD = 17.18). On average, all participants had moderate experience with FPS games (M = 4.17, SD = 2.31). To ensure that participants would provide usable data for the study, an optional demographic question was included asking participants if they had any impairments to their hearing. Only one participant answered 'yes', with one other preferring not to give an answer. Both of these participants were able to complete all tasks related to the experiment without difficulty and as such their data was not discarded.

Experiment design and protocol. It was important that the experience of each type of audio was recorded for each participant, so a within-participants design was used. The experiment itself was run in two phases: completing the situational awareness task (2A), and then completing the impending death task (2B). The player experience was evaluated for changes in the type of audio; that is, abstract audio or realistic audio, for each task. Each phase was counterbalanced to account for any possible learning effects. All participants completed the situational awareness phase before completing the impending death phase, but experimental conditions within each phase were counterbalanced. The sounds used for each phase were different, because of the difference in nature of the tasks, and it is unlikely that there were any learning effects from Study 2A that could have affected Study 2B. The abstract sound consisted of two square-wave notes played rapidly (total duration of 95ms with reverb tail), approximately 1200Hz followed by 1000Hz.

Participants were instructed to play each task until it was completed, and each condition was followed by a Self-Assessment Manikin (SAM) (Bradley, 1994) to gauge affective states of players (replacing our other measures). Furthermore, after each phase of the experiment, a short interview was recorded with participants to obtain a deeper understanding of their feelings towards each type of sound and their player experience in general.

Study 2A: Situational Awareness

In the situational awareness task, a participant heard a sound coming from one of four random locations surrounding them, and had to locate the source of the sound as quickly and accurately as possible. The sound looped until the player pressed the button to confirm where they think it was located, then another sound began to play after a brief period of silence. Each possible sound source played twice, for a total of eight sounds to locate. A timer was featured at the top of the screen, showing participants the number of seconds that have elapsed since the sound began. The sounds that were chosen were a beeping tone (abstract) and footsteps (realistic). In investigating the pattern of situational awareness-based audio, the beeping noise was unexpected and not tied to a definitive source within the game world. However, the footstep sounds were comparatively more suited to the environment, and made sense within the context of the world, even if their source was not visible. No other feedback was provided to participants. Study 2A was explained and the first condition of the first experimental phase was completed. Participants were then instructed to fill out the SAM to indicate affective states. The second condition was completed subsequently, followed by another SAM questionnaire. Upon completion of the first phase, a short interview was recorded with the participant. Then, participants commenced Study 2B described below. During Study 2A, the game collects two main data points: 1. Time to Target:

The time it takes a participant to locate the source of the sound. The time is recorded as the number of seconds from when the sound began emitting until the confirmation button is pressed. 2. Accuracy: The angle between the participant's targeting crosshair and the centre of the sound source, in degrees. It is possible to calculate a percentage that is representative of how accurate a participant's location guess is, because the minimum angle is 0 (crosshairs are positioned exactly on the sound source) and the maximum is 180 (crosshairs are positioned exactly opposite from the sound source).

The position of the player-character and the direction facing is stored, along with the computer's system time and the total time elapsed since the game was started. These data points are not directly related to the experiment and are only necessary in the event that there is a need to verify primary data.

Study 2B: Impending Death Task

In the impending death task, the player character takes a randomized amount of damage at an irregular interval. The participant was asked to press the button when they felt that they had 25% of their health remaining. When the player took damage, there was a brief red flash, accompanied by a grunting sound. After the first hit occurs, an abstract or realistic sound played intermittently, increasing in frequency for every 15% of health that is lost. Once a participant pressed the button to indicate that they felt they were near 25% health, a bar appears, showing the exact level of health. In the event that a participant allowed their health to fall to zero, the game exited automatically and the trial was considered a failure. In the abstract sound condition, the health warning noise was a simple warning beep, as used in Study 1, whereas the sound used for the realistic condition was a beating heart.

In Study 2B, only one main piece of data was collected, the amount of health remaining: The amount of health that the participant's character has remaining as of the time that they press the confirmation button. This number was between 0 (no health remaining; a failed attempt) and 100 (the maximum level of health). As in phase 1, additional positional, directional, and time data was gathered, but was not used for in-depth analysis. The qualitative data from the interviews in the previous studies was helpful and, thus, we continued to use interviews in this study, too. In addition to measuring the performance of the tasks, the players provided an assessment of their mental state and answered semi-structured interview questions regarding their reactions to each relevant sound.

Study 2B was conducted in a similar way to the first. The task was explained to participants, and the first condition was administered. Once again, a SAM questionnaire was filled out. The final experimental condition was then completed, and a final SAM was collected. The SAM was scored using a 9-point Likert scale (focusing on arousal, valence, dominance). On the valence subscale, a lower score indicates a more positive valence while a higher score indicates negative valence. Finally, the interview for Study 2B was recorded. Participants were interviewed with questions regarding their preference of the two sounds, as well as to evaluate how well they thought that they performed each task. Then participants were debriefed from the study.

Study 2A: Situational Awareness Results

As with the analysis of study 1, distribution of data determined the employment of parametric (t-test) or non-parametric (Wilcoxon Signed-Ranks) testing, while our analysis also accounted for repeated measures. None of the survey results in the situational awareness phase were normally distributed (i.e., parametric). Participants experienced similar levels of pleasure when playing with abstract ($M_a = 3.93$, $SD_a = 1.60$) and realistic ($M_r = 4.07$, $SD_r = 1.62$) sounds. Likewise, there was little difference observed between the levels of dominance reported across abstract ($M_a = 4.90$, $SD_a = 1.56$) and realistic ($M_r = 5.10$, $SD_r = 1.81$) conditions. Participants appeared to experience slightly higher levels of arousal when playing with abstract sound ($M_a = 5.50$, $SD_a = 1.83$) than with realistic sound ($M_r = 5.10$, $SD_r = 1.85$), but this difference was not significant ($p > .05$).

The performance indicators during Study 2A were the speed at which a participant was able to locate a sound, as well as the accuracy of their guess. Time was measured in seconds, and the accuracy was measured as the angle between the direction the character was facing, and a vector drawn from the player's position to the source of the sound. This angle was then converted into a percentage value, assuming 0% accuracy at an angle of 180 degrees (i.e., the player is facing the direction exactly opposite the sound) and 100% accuracy at an angle of 0 degrees (i.e., the player is facing the source of the sound exactly). The data for time was normally distributed, while both measures of accuracy were not. Participants were highly accurate in both the abstract (M_a = 19.60 [89.11%], SD_a = 32.52[18.07]) and realistic (M_r = 20.09 [88.84%], SD_r = 18.94[10.52]) conditions. Likewise, the average times taken to confirm the location of a sound were similar regardless of whether the located sound was abstract (M_a = 8.39s, SD_a = 3.99) or realistic (M_r = 8.45s, SD_r = 4.50).

Although in many cases the differences are not large, when looking at the results across all participants, fourteen (47%) people completed the realistic task more quickly, while sixteen (53%) were able to complete the abstract task more quickly. For accuracy, ten (33%) participants were better at locating realistic sounds compared to abstract sounds, while twenty (67%) performed better when listening for abstract sounds.

When asked which of the two sounds they preferred, twenty-one (70%) participants liked the realistic footstep sound better. However, when asked which sound they felt was more useful, fourteen (47%) participants felt that the abstract alert sound was better suited to the task. Another fourteen (47%) felt that the footsteps were more useful, with the remaining two (7%) claiming that both types of sounds had their useful aspects, and that neither was more suited to the task than the other.

Most participants (73%) felt that they could accurately identify the source of the sound, while another five (17%) were unsure, with three (10%) feeling that they could not find the sounds at all. Players were more confident in their ability to find their targets quickly, with twenty-five (83%) claiming that they had no trouble doing so. Another two (7%) were less sure of themselves, with the remaining three (10%) reporting that they had difficulty completing the task in a reasonable amount of time. Participants were also asked if they had any additional comments regarding either sound. Most did not have anything helpful or informative to say, although several mentioned that the footsteps (realistic) sounded more natural to them. A few participants (10%) remarked that the sound of the footsteps was creepy and made them anxious. Some others remarked on different properties of the sounds, with one claiming that the footsteps sounded as if they were moving around the room and were thus harder to locate. Another participant claimed that it was more difficult to tell if the footsteps were in front of, or behind the character than when listening to the abstract beeping. Little was said about the abstract noise, with one participant describing it as a negative noise, like an alarm. It is worth noting that no participants had anything objectively negative to say about either type of sound, regardless of their preference or past gaming experiences.

Study 2B: Health Awareness Results

In the health perception phase of the experiment, only the results for the pleasure scale of the SAM satisfied parametric assumptions. There was, however, no significant difference between the pleasure reported by participants as a result of abstract ($M_a = 4.43$, $SD_a = 1.91$) or realistic ($M_r = 4.23$, $SD_r = 1.94$) feedback audio. There was also no noticeable difference between the reported arousal when playing with abstract ($M_a = 4.67$, $SD_a = 1.52$) or realistic ($M_r = 4.37$, $SD_r = 1.33$) sound. Finally, participants experienced similar feelings of dominance whether the sound was abstract ($M_a = 4.63$, $SD_a = 1.27$) or not ($M_r = 5.03$, $SD_r = 1.38$). See Figures 2 and 3.

The performance indicators for the health perception task were the amount of health that the character had remaining, as well as the absolute difference between that value and the target value of 25. Figure 2 shows the differences between both performance indicators. Neither of the metrics were normally distributed. Wilcoxon signed-rank testing revealed that participants within the abstract feedback group presented significantly lower health estimates ($M_a = 55.57$, $SD_a = 24.56$) when compared to the 'realistic' feedback group ($M_r = 41.00$, $SD_r = 18.14$), $z = -3.018$, $p = .003$, $r = -.551$. It furthermore followed as expected, that the absolute distance from the target health was much higher in the abstract condition ($M_a = 31.50$, $SD_a = 23.31$) than that in the realistic condition ($M_r = 17.60$, $SD_r = 16.53$), $z = -2.791$, $p = .005$, $r = -.510$. When examining which experimental conditions were the most successful for each participant, it was found that nineteen (63%) players had the most accurate estimate of their health when listening to the heartbeat sound. There was a single participant (3%) that managed to have the exact same distance from the target health in both conditions, while the remaining ten (33%) experienced greater success with the beeping alert.

Similar to our protocol in Study 2A, participants were first asked about their preferred sound. Most (73%) preferred the realistic heartbeat sound, while five (17%) preferred the abstract beeping. The remaining three (10%) participants had no clear preference for sound type. Interestingly, when asked which sound type was more useful for estimating remaining health, only eighteen (60%) felt the realistic feedback was better suited to the task. Another nine (30%) felt the beeping sound was a better indicator. Three (10%) had no preference.

Responses were mixed considering the accurate determination of character health remaining. Only twelve (40%) participants felt they were able to estimate how much

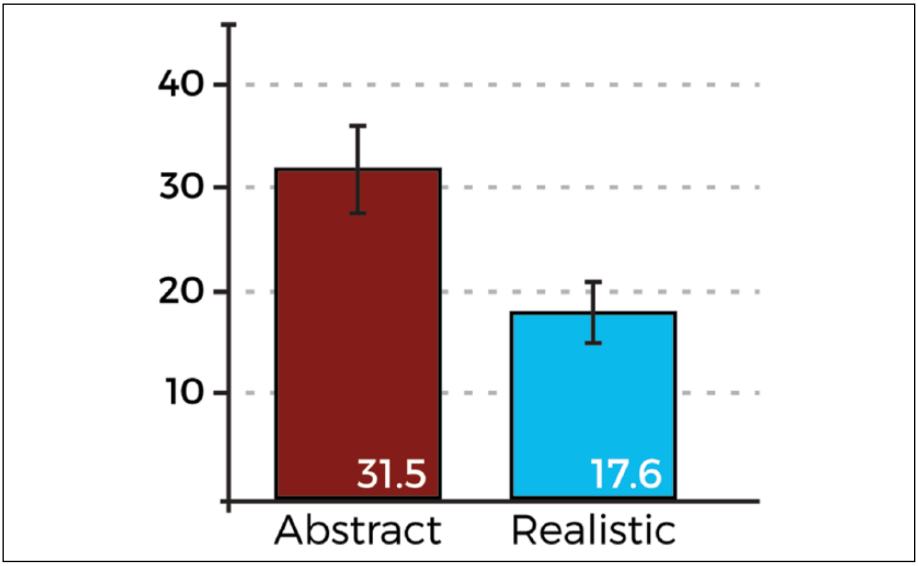

Figure 2. Absolute distance from target health.

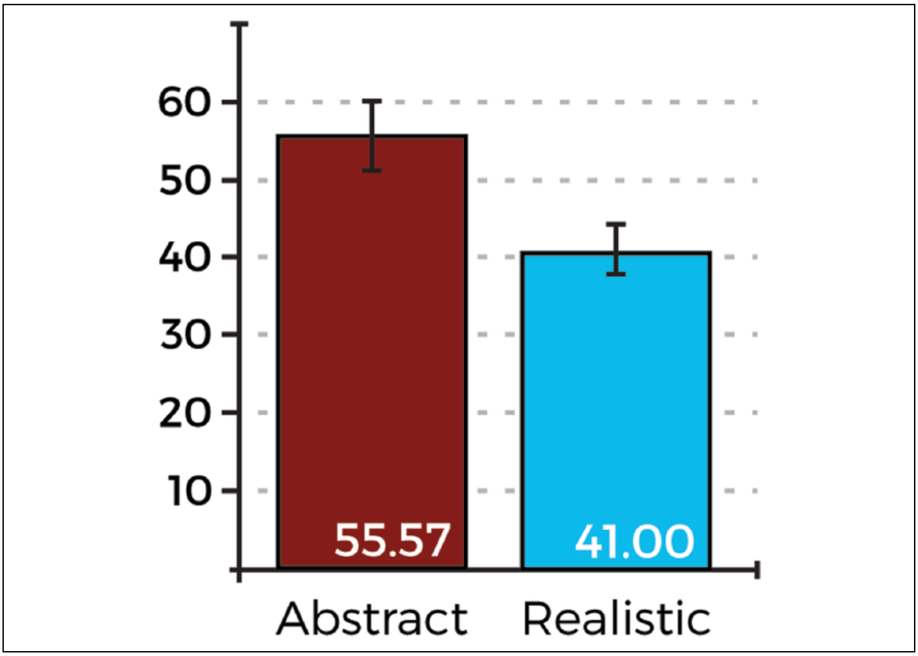

Figure 3. Health level estimates.

health they had remaining, while ten (33%) had no idea. The remaining eight (27%) expressed having a vague idea of what their health status was, but had little confidence in their assumptions. Much like phase 1, many participants mentioned in some way that the realistic sound was more natural for the situation. Some reported being familiar with it as a measure of health, while others simply mentioned that it made the exercise feel more urgent or more personal. Furthermore, two participants explicitly stated that the heartbeat made the task more immersive. With regards to the abstract beeping notification, two participants felt that it was out of place, while another claimed that it made them feel anxious. A single participant even mentioned that the beeping annoyed them. Finally, one other participant mentioned that performing the task using only sounds was strange and unnatural, citing that games often provide a health bar to consult for a more accurate reading of health.

Discussion

The null result of physiological and questionnaire measures in Study 1 contradicts the results found in Dixon et al. (2014), a study of sound on and off in gambling games. There could be several reasons for the difference here, including the genre distinctions, the redundancy of sounds selected here (that is, all sounds had a visual corollary on-screen), or the purpose of the sounds involved (reward versus information/warning). However, while the study here corroborates non-significant physiological results from prior studies (Nacke et al., 2010), the second study, which had a more controlled design omitted physiological measures from the assessment, but interestingly showed no significant differences in the SAM either. It might be the case that sound cues are perceived in games more subtly than we currently imagine and that and impact assessment remains difficult. Further research is also needed to explore how the function and genre impact sound's role in games.

The interview results in Study 1 suggest that players are consciously aware of the role that sound plays in some games, and they are aware of a reliance on sound, despite the redundant role of sound in the game tested. This suggests that in games with a high cognitive load like first-person shooter (FPS) games, sonic feedback could be more valuable to players than heads-up displays or other visual feedback. Players reported feeling more aware of their character's level of health in the play session where the auditory feedback was present. Many participants mention having to pay attention to multiple things at once in a fast-paced game environment. For example:

> "I don't look much at the health bars because I'm trying to focus on the game." (P4)

Many participants criticized the constant beeping sound used in the experimental game, referring to it as annoying and redundant after some time. If a player has a low level of health for a long period of time, that may be because they are unable to reach some means of restoring health, not necessarily that they are unaware or otherwise have forgotten about their status. The sound becomes a source of acoustic frustration rather than information. However, it is likely that most game designers would want some acoustic frustration in times of high stress, such as impending death, to add to the excitement of the game. It remains to be seen if having some kind of "off switch" on the sound would reduce the excitement or enjoyment of the game. Of those participants that gave numerical and non-context dependent answers to the question of how low a player's health should be before an alert noise is played, responses averaged to 26.17% of the total health. From this, we can conclude that most players of fast-moving first-person shooter games would feel comfortable receiving a low-health warning when they have around 1/4 of their health remaining. This would give them ample time to correct any rash actions they are performing and seek out a safe place with a method of restoring their health before their character dies.

The lack of statistical significance for any of the quantitative measures in Study 2A is surprising, although promising for designers who have a preference for one type of sound over the other. It is worth noting that this split between preference for abstract or realistic sounds is not simply in relation to what kinds of sounds players like to hear, but also what kinds of sounds players feel are useful, at least for understanding events happening around them in the game world.

Although 67% of participants performed better at locating abstract sounds, the difference in accuracy was still small. As both, the beeping sound and the footsteps, were heard for similar amounts of time, this slight advantage may be related to previous experiences with notification-like sounds. It warrants further study. With regards to the SAM, the lack of significance could be explained because of the short time involved in completing experimental tasks. Emotional responses need time and involvement to form (Nacke & Grimshaw, 2011). Many participants completed the task within five minutes, which may not have been a long enough exposure to the sounds to evoke a distinct change in emotion. It is possible that with a longer experimental session, or perhaps meaningful gameplay consequences to task successes or failures, a reaction could be observed.

Many participants felt confident in their ability to complete tasks successfully regardless of their actual ability. This may be a side effect of a lack of game feedback to tell players if they were performing well. For example, one participant (P19) felt confident in their ability to locate where the sounds were coming from. She cited having "mom ears" as the main perceived success factor, but in reality she averaged 55.64% accuracy when listening for the beeping sound and 57.41% accuracy when listening for the footsteps sound.

Many participants struggled with the health perception task. Some felt the instructions were not clear enough or did not understand that the feedback noise would increase in frequency. This may have resulted in some participants ending their first trial prior to having a low level of health simply because of a perception that the noise, especially the abstract beep, must mean something bad. This gives an interesting outlook into the amount of urgency that players associate with these kinds of sounds. Although they performed poorly at the task, the beeping may convey a greater sense of danger to players than the heartbeat. This could possibly be a previously learned response, as participants may have a natural association with such beeps in the form of alerts or alarms. As the average level of health for abstract feedback was 55.57%, it can be deduced that an abstract tone repeating every three seconds (the frequency for 50-65% health used in Study 2B) is enough to communicate to a player that they are near death. When listening to the heartbeat, the players waited on average until the next set of intervals, feeling that they had low health at 41% or one heartbeat every two seconds.

Despite the split preference of sound type in the situational awareness task, in the health perception task, a clear majority (73%) preferred the realistic sound option. Some participants stated that realistic sounds were better suited to player-centric events. Participants found that heartbeat noise is more readily associated with health, so it is easier to understand the information that the sound tells you. Many interviewees claimed that the realistic variants of each task felt more immersive. That immersion was evident for the two participants that referred to the footstep sounds in Study 2A as "creepy."

Summary and Conclusions

Based on the results obtained in this experiment, we can make five design recommendations for informative user interface audio in FPS games:

1. **Provide players with a clear auditory indication that they are being damaged.** This may seem obvious, but some participants mentioned that some games did not offer any auditory feedback related to their health. It may not even be necessary to provide an alert sound; as with earcons, the background music or other ambient audio could be altered to give the player a hint that something within the game state has changed (Ng & Nesbitt, 2013). Although players may have difficulty understanding the meaning right away, they can plan more effectively for upcoming danger. It may even prevent some artificial difficulty caused by a player's ignorance of their character's status.
2. **Alert players of impending death at about 25% health.** Without any clues to the usefulness of this threshold, participant interviews suggested that the preferred level for signalling low health is around one quarter of full health. Until some usability studies have been run to determine a more concrete number, we recommend that the alerts be triggered within this window. It gives the player enough time to react before getting into a certain-death scenario, but not so early as to cause unnecessary panic or annoyance.
3. **Try to offload visual information to audio cues.** Some participants mentioned that auditory feedback allowed them to focus on gameplay. By identifying information that can be conveyed with sound, it may be possible to increase a player's satisfaction and allow them to remain in Flow and reduce on-screen graphic clutter. By giving the players the ability to learn to listen for and react to these cues, we give them more opportunities to improve their game mastery. However, visual information should be provided as an option, particularly for hearing-impaired players.
4. **Involve members of the sound team in early design sessions.** The context, aesthetics, and design of a game determine a sound designer's effectiveness.

By having even a single member of the sound team attend design and concept meetings, it could become easier for a game company to design better sounds that fit within a game's context. This echoes Lord's (2004) view that an important part of player experience is to design sound and music to affect aesthetics, feedback, and rewards for players.

5. **Offer players a relatively safe environment to learn the meanings of abstract audio cues.** Sometimes players had difficulty understanding what sound element they were listening for. In this study, the abruptness of introduction to the sound was done intentionally to obtain a raw, unbiased idea of how players perceived each type of sound. However, in a commercial game, players may get frustrated if they do not understand what sound feedback is trying to communicate to them. Designers need to ensure that a player is exposed to these sounds (similar to exposing them to game mechanics) in context and in such a manner that they have enough time to process and learn what the sound means.

Moving forward, it would be worthwhile to evaluate abstract and realistic audio cues for other player-centric interface or other game events in addition to sound design patterns as proposed by Ng and Nesbitt (2013). Many of the areas this study has touched, need to be more thoroughly examined. First, it would be useful to do a more in-depth analysis to determine if there are indeed any physiological reactions related to the presence or absence of different categories of audio. By breaking the gameplay down into only the events that we are interested in, it would be easier to pinpoint if those events or cues affected a player's physiological signals in any way. Looking at small frames of time would assist in preventing any subconscious muscle movements from muddling the data on a larger scale. In this study, there was no change in game difficulty to account for differing levels of gaming experience of participants. This may be worth exploring in the future to gain more specific insights about how each skill level experiences and uses auditory informative feedback. More advanced players are more likely to have surround sound systems and sound positioning in the stereo field could play a role in player responses (Goodwin, 2009).

Further research could help us validate and expand upon this study. We suggest a future study where sound does not play a redundant role by being accompanied by visuals on-screen to assess the importance of the sounds in the absence of visuals. Finally, the notion of abstract and realistic audio in games should be examined in closer detail. Sound in games is challenged by the need for constant repetition and therefore requires variation. Variation in sound is made through real-time digital signal processing (DSP: e.g., frequency variation) or recording multiple samples and randomizing them. But in cases where the meaning of a sound must be learned by the player, we have to question how much variation can be applied to a sound before it loses that meaning. Furthermore, we should investigate how many repetitions it takes before a sound's meaning is learned.

This paper presented two studies into health-related sounds in games. The first study examined the impact of the presence of these sounds accompanied by visual feedback on the player experience, and obtained essentially a null result. The second study compared abstract with realistic sound effects in representing health and situational awareness were more effective or more preferable to players. Although no significant effects were discovered for the situational awareness phase, participants were better at estimating their character's health when listening to a realistic sonic indicator. Furthermore, when interviewed, the majority of participants claimed that the realistic sounds provided a more immersive experience. As a caveat, these results are currently only applicable to FPS games, and we must verify these findings in other video game genres. The results of the studies show that providing redundant auditory feedback for key gameplay events is preferred by players and may assist in their enjoyment of gameplay. The results suggest that when designing interface audio for feedback directly related to the player's character, it is prudent to favour realistic sounds. The reasoning for this preference is two-fold: Not only did players have an easier time estimating their level of health, but they also reported that the heartbeat sound made the experience more immersive. Perhaps contextually-appropriate sounds are more realistic than abstract, iconic interface sounds in realistic games, but the appropriateness of this recommendation is likely dependent on the genre. Further research may tease out the preferences and influences on player enjoyment and experience.

It was determined here—however obvious it may have seemed—that the presence of health-related audio is beneficial to players, allowing them a better understanding of their health status throughout a game session. However, the degree of this importance is still in question, as a clear indicator for the preference of including auditory indicators has not been shown. A preferred threshold for receiving low-health warnings was discovered, but even this was not significant enough to make bold statements about the importance of these sounds to the player. Further work on interface sounds in games is clearly warranted to determine if their presence or absence, or their particular design style, influence player experiences. Our most important contribution in this paper is some audio design guidelines that may help game developers create more effective in-game sounds.

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Tom Garner's initial PhD and postdoctoral research at the University of Aalborg focussed upon modelling of auditory perception in a virtual context and understanding the affective potential of sound. He is currently working as a Research Fellow at the University of Portsmouth, researching: the historical developments and future potential of sound within virtual reality; auditory perception frameworks as a means of enhancing intelligent agents; and the effects of sound upon anxiety within virtual reality exposure therapy.

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Karen Collins is Canada Research Chair in Interactive Audio at the Games Institute, University of Waterloo. Her work focuses primarily on sound and music in games and explores how new technologies impact our audio experience. This research has included studies of sound on smart tables (horizontal computers), mobile phones, video games, and how sound is used in slot machines to manipulate players. She has published four books on game audio; Game Sound (MIT Press 2008), From Pac-Man to Pop Music (Ashgate 2008), Playing With Sound (MIT Press 2013) and the Oxford Handbook of Interactive Audio. She has recently finished a documentary film and book project on game audio history called Beep.

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Lennart E. Nacke is the Director of the HCI Games Group and an Associate Professor for Human-Computer Interaction and Game Design at the University of Waterloo. He is known for his pioneering research on physiological evaluation and interaction in video games as well as his ground-breaking gamification research. Dr. Nacke has chaired the CHI PLAY 2014 and Gamification 2013 conferences, and is currently the chair of the CHI PLAY steering committee. He has served on the steering committee of the International Game Developers Association (IGDA) Games User Research (GUR) Special Interest Group (SIG) in the past. He is also currently editing a textbook on Games User Research.

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