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Visualized sound effect icons for improved multimedia accessibility: A pilot study

Karen Collins *, Peter J. Taillon [1]

Canadian Centre of Arts and Technology, University of Waterloo, 200 University Ave., W. Waterloo, ON, Canada N2L 3G1

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ABSTRACT

Sound effects are often used to communicate important information in multimedia such as video games. For instance, they may tell the player that a character has just snuck up on them, is firing at them, or is about to paddle over a waterfall. Nevertheless, there are times when playing sound may be inappropriate, may be inaudible, may become fatiguing and/or may be inaccessible for hard of hearing and deaf users. Therefore, an alternative to sound that can relay the same information would be beneficial to many users. The majority of studies into alternative presentations of sound for these purposes have focused on dialogue at the expense of music and sound effects. The paper introduces a pilot study of "SoundSign", a prototype symbolic representation of sound effects for multimedia, using an innovative icon and compass that indicates direction, sound cue and proximity. Users who have disabled the sound, are hearing-impaired or are otherwise unable to hear sound will still get the information needed. A description of SoundSign and the results of a usability test are presented.

1. Introduction

Accessibility in user interfaces has been the subject of much work in interaction design, but research and technology in video game accessibility has lagged behind [1]. As others have pointed out [2], however, in addition to serious games and educational games that serve a direct function (learning, rehabilitation and so on), games play an important role in social play, and the creation of accessible games can ensure social inclusivity and reduce feelings of isolation or difference amongst those with impairments. The International Game Developers Association Game Accessibility Special Interest Group (IGDA GA-SIG) was formed in 2004 as an attempt to raise awareness about accessibility issues with games, and outlined a definition of video game accessibility as "the ability to play a game even when functioning under limiting conditions. Limiting conditions can be functional limitations, or disabilities—such as blindness, deafness, or mobility limitations".[2] Despite the efforts of the IGDA GA-SIG, however, accessibility has been a low priority within the game industry, with large companies such as Ubisoft only recently (in 2008) even including basic options such as subtitles in their games [3]. In part due to limited time and financial resources for "extras" like accessibility, but also in part due to a lack of awareness, the games industry has yet to make a serious commitment to making games more accessible. Nevertheless, when one takes into account the amount of people with some form of disability (approximately 23% of the US population if one defines disability broadly) [4], as well as the fact that many users may use accessible options without having a disability (one study suggests 32% of users who use built-in accessibility options on computers) [2], there is clearly a need for more accessible options in games.

Game accessibility research has focused primarily on creating games that are accessible for the blind, cognitively or mobility-disabled. Miller et al. [5], Sánchez et al. [6] and Friberg and Gärdenfors [7], for instance, discuss games for the blind (a popular area of research), and more recently this concept has advanced to games that attempt to be accessible to all [8]. There has been very little research into making games more accessible to the hearing-impaired, although other areas of hearing-impaired accessibility permeate the human–computer interaction literature [9–11].

One particular point of note regarding accessible gaming is that the focus has been on *functional usability*—that is, the physical ability to play a game—rather than user *enjoyment* or *experience* of a game. Games are, by their very nature, created for the purpose of enjoyment and fun. Part of this fun and enjoyment certainly is attributed to usability, but the enjoyment of a video game goes beyond merely being able to physically play a game (usability). The difficulty of a game (thereby its frustration levels) can be greatly increased by a lack of access to some of the information being output by the game. Sepchat et al. [12] make a distinction between *interaction problems* (problems in information perception from the game and problems in transmitting commands to the game) and what they term *level problems* in which the game difficulty level is too high, there are problems understanding the game

* Corresponding author. Tel.: +1 519 888 4567x38326; fax: +1 519 725 0651.
E-mail addresses: collinsk@uwaterloo.ca (K. Collins), ptaillon@uwaterloo.ca (P.J. Taillon).
[1] Tel.: +1 613 520 2600x1861.
[2] The IGDA GA-SIG offers a timeline of accessibility in games, and demonstrates that many of the ideas are not new, but are just now gaining acceptance and interest.

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play, game speed and so on. These types of level problems do not mean that the game is unplayable, but rather that the game is less enjoyable for the disabled/impaired player. The IGDA white paper on accessibility describes the problem in terms of user satisfaction: gamers play games for entertainment, "not to experience a sense of frustration. Unfortunately, once a player gets shot for the tenth time because they can't hear the footsteps of someone coming up behind them, they are not likely to be entertained" [4]. It can also be argued that, from an economic standpoint, the frustrated user is unlikely to recommend the game to others.

1.1. Hearing-impaired game accessibility

When it comes to hearing-impaired gaming, the focus of accessibility has been on dialogue at the expense of music and sound effects. At best, in most media music is represented in captions by a title and/or musical note to indicate that music is playing (and there have been attempts to include colour to display emotion [9]), but in many games, music is used to indicate rhetorical, emotional and affective information to the player. One particularly ignored accessibility issue with video games is sound effects. Sound effects add information to the narrative, foreshadow events and actions, hint at off-screen action, serve as symbols or leitmotifs for characters and locations, create a sense of time and place, provide proximity and location cues of adversaries, and most importantly, can warn the player to take a particular action [13]. In many cases, playing without the sound effects in a game leads the player into peril. For example, in many stealth games (a sub-genre of first-person shooters), sound effects inform the players of nearby enemies, and also cue enemies to the player's whereabouts. The more noise the player makes, the more likely they are to be tracked by an enemy.

One study into the role of sound in games [14] tested the reaction of gamers to games with and without sound. The responses of the participants indicate the importance of sound in games: "The first thing I notice is that my time of reaction has increased by ten..."; "I didn't always notice things happening." These quotes hint at several important factors: most importantly, sound enables shorter learning curves and guides a player through a game. Other research into the physiological responses to games has shown that physiological arousal is significantly increased by audio [15,22]. In a document for mobile phone game developers, Nokia [16] points out, "From a cognitive point of view, the auditory channel is an excellent way to relay information and give feedback to the player. While the background music can be used to enhance the emotions and mood of the game, a specific sound effect can be used to *communicate meaningful game information*" (our emphasis).

Websites such as Deafgamer.com rate games with letter grades according to hearing-impaired accessibility. *Hitman: Blood Money* (Eidos 2006) for instance received a "C" with the comments, "There is no gauge to show you visually how much noise [agent] 47 is making. Non-essential conversations and comments from NPC's [non-playing characters] are not subtitled... There are also no captions". In addition to the hearing-impaired, of course, there are other times when an alternative to sound cues is needed. Nokia's same guide, for instance, warns, "the game should be playable without the sounds. Allow silent starting of games. If intro music is implemented, there must be a way to switch it off. Prompt for sound settings at the start of the game..." [16]. Indeed, most mobile games need to provide some alternative, as the assumption is that these devices are often played in a public space and therefore the player is either using headphones or playing with sound off. Other games may be played in shared social spaces also, such as in the home. Another reason players may want to turn sound off is the concept of listener fatigue. When playing a game for a lengthy amount of time, hearing many sounds can get tiring, and therefore the player may want periods of silence. There is, therefore, a clear need for some form of alternative way to represent sound effect information in another modality.

This paper presents a pilot study of a prototype method of displaying audio information for when sound is unable to be heard or turned off in a game. We first present previous approaches to the problem, followed by a description of the methods of our own approach. We follow this with a usability pilot study with objective and subjective feedback, and a discussion of our results.

2. Previous approaches

2.1. Text-based approaches

While many games are still released without captioning, there are an increasing number of games that include some form of closed or open-captions (text and/or emoticons) for some auditory information.[3] For example, colour coding of captioned text has been used sometimes to distinguish between speakers, and some games show a speaker portrait of the speaking character next to the caption. Animated speaker portraits or avatars can also increase readability by showing facial expressions to add context (e.g. *Freedom Force vs. The Third Reich*, VU 2005). *Action captions,* originating from comic books, have been used very rarely to represent sound effects on screen using onomatopoeic text ("bang!" "pow"). *Speech balloons,* similar to those found in comic books, for example, help to tell the user which character is speaking, or where a sound source is emanating from (e.g. *Mario and Luigi: Partners in Time*, Nintendo 2006). Speech balloons can also be used to indicate events that have been typically used to represent sound effects, such as in *Legend of Zelda: Phantom Compass* (Nintendo 2006), in which a balloon is used in conjunction with a sound change to indicate approaching enemy. This *Zelda* game, for Nintendo DS (a portable device), is highly effective in integrating speech balloons so that the user can play the game with the sound off and still be cued to important changes. *Sound balloons*, like speech balloons, can also indicate sound effects, where descriptions of sounds can be provided in text with an indication showing location of sound, although these are rarely found [17].

There are several difficulties with text, however, most notably the speed with which text must be read. Games occur in real-time in high speed and the player needs to be able to read very quickly in order to take in all the information required, as well as react to that information. Language barriers are common, in that even where games are localized (translated for another market), there are generally only a limited number of languages that games are translated into—and some players play in a second language, which means reading speeds vary. Third, there are, as intimated above, problems of interpreting speaker, location and emotion in text captions.[4] Finally, of course, the use of text captions assumes that all users can read, whereas many children play video games before they can read (or at least, read at the level/speed required).

2.2. Non text-based approaches

Alternatives to text do exist. It is possible, for instance, to use the sub-woofer to convey some information through the vibrations that occur with loud bass sounds, and controller vibrations to provide some haptic feedback, although other than a message that there is "some kind of sound occurring", the communication is limited. Videos of animated sign language could be implemented in

[3] Closed captions are encoded in a media stream and require a decoder to display. Open captions are "hard coded" into the screen, so there is no way to switch them on or off.

[4] A new TV enhanced captioning standard, CEA-708, allows for alternative fonts, colours, caption positioning and other options related to text-based enhancements.

games, although they have yet to be. However, these have the difficulty of distracting the player for long periods from on-screen action, along with localization difficulties (there are many regional variations of sign language), and are more expensive to implement. Likewise, picture-in-picture or split-screen video clips (such as in *XIII: The Game,* Ubisoft 2003) that show details of auditory information that may be happening off-screen are too distracting and require considerable extra programming.

Other visual information used to indicate what is traditionally communicated through sound have limitations—a threat metre to show the danger levels for instance is useful but provides only very limited information. Sound visualizations—images or animations to represent sound events—have been used in some games for a select few sounds. *The Sims 2* (EA 2006) for instance has "sound waves" that emanate from ringing telephones or other sound emitters. Some attempts have been made to combine approaches, such as that of Lee et al. [9], which comes closest to the idea proposed here, but these approaches are complicated and relate only to film/television. Moreover, the focus of these is still text-based, although instrument icons have been used to represent the fact that music is playing. A further difficulty in representing audible sound is with the concept of acousmatic sound. Acousmatic sound, defined by music composer Pierre Schaeffer as sound without seeing the originating cause, was refined by theorist Michel Chion to refer to off-screen sound in film [18]. For example, there may be a sound off-screen, alongside a pathway that a character is walking, that is meant to draw attention towards an item or object. No existing system is in place to indicate these sounds to the player when the sound is turned off.

In summary, there are many limitations in the available approaches, which has meant that there has been very little adoption of any attempt to make games more accessible to the hearing-impaired. Moreover, there are as yet no standards for these visualizations, they are used sporadically in very few games, and require considerable extra programming effort (and therefore cost).

3. An approach to improve iconic sound effects: SoundSign

Based on the difficulties encountered with existing systems, we created a new sound imaging system called SoundSign with the premise that the system:

- is symbolic (not reliant on language), is easy to learn, and intuitive to use;
- is hardware and software independent and integrates easily into existing audio software or game engines and web technology;
- is icon or font-based, scalable and able to be rendered in black and white as well as colour;
- adapts to future change or game-specific needs (potential options include: motional cues using colour, blinking for immediate actions required, and user-generated fonts to suit styles of game—kids/cute, aggressive/militant, regular, sleek/modern, old, etc.);
- could use sound metadata or sound information retrieval techniques to indicate when symbols are necessary (either text-based metadata or actual reading of sound file);
- displays in a succinct, accurate manner positional information of sound events and proximity information.

The result was a compass-like format with a visual icon, as shown in Fig. 1.

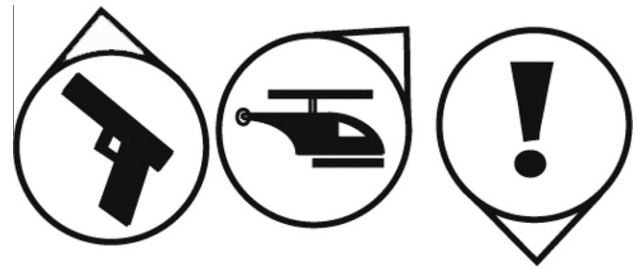

Fig. 1. Example sound icons set in compass: gunshot, overhead vehicle, generic "warning".

The first step was to decide which sound effects required a sound icon, since some sound effects are more important than others, and having too many sound icons would distract from the purpose of the system (to indicate sound cue information). We used quantitative and qualitative methods to study game sound from hundreds of games by playing games with the sound on and off and recording which sounds were most missed. Our qualitative methods included interviewing sound designers for games as to what they felt the most important sounds were in games. We also had three students play 50 games and list the most important sounds after 15 min of each gameplay. Finally, we collected and compiled the sound asset lists from 13 popular games from sound designers and audio programmers working in the game industry.

We settled on a list of 26 of the most important commonly used sound effects found in a variety of genres, using 26 as a number to map the icons to a letter of the alphabet so that the icons could be created as a font for easy implementation. These were:

> alarm/siren sounds, generic 'bad'/warning sound, check weapon, door bell/knock, electricity/machine, footsteps, gunfire, human noise, fire, indiscernible talking/'walla', explosion, glass breaking, timer, generic noise, overhead vehicle, projectile launch, equipment on/off, radio/CB, scream/cry, telephone, underwater sonar, vehicle sounds, water sounds, non-human being sounds, hailing/calling, and a generic 'good' sound.

Each letter of the alphabet represents an icon inscribed in a circle (Fig. 2). This font is not designed to be fixed in style, but rather should be flexible in that the stylistic elements can be adjusted to suit the game, while preserving the semantics of the font. The icons for the prototype game were selected based on existing font widgets. Each icon has a corresponding alphanumeric key, so that implementation by a sound designer can be made with minimal effort. These icons sit on a layer above the background compass, a rotational pointer which indicates direction of the sound. Sounds occurring above or below the virtual character were indicated

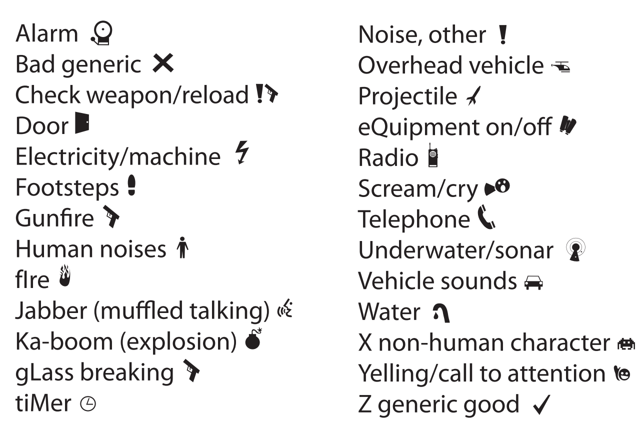

Fig. 2. The 26 most common sounds mapped onto alphabetical keys.

Fig. 3. Screenshot showing two opacity gunshots and a reload occurring in *Assault Cube.*

using a short straight horizontal line on top or bottom of the compass point.

The SoundSign compass is turned on or off by the player at the game's option screen, and when turned on is stationary, positioned in the lower right hand of the screen. This way, players can become accustomed to looking in one spot for their audio information, and the particular position in this case would not occlude game display information. In games that already use this position for game display information, the SoundSign may have to take another position.

For 2D games and media (typically platform or casual games that take place in a 2-dimensional space), the compass can act like a clock face, with 12 rotational settings and four opacity settings based on the sound's proximity and direction to the player. The compass graphic sits in one position which gets rotated according to (x,y)-coordinates (and, typically, stereo positioning of sound). Proximity is calculated from (x,y)-coordinate of the player and the sound, with four proximity settings that alter the opacity of the compass (50%, 75% and 100%, with 0% representing no important sound present) (Fig. 3). A short demo video and a downloadable game file can be found here: http://www.gamessound.com/ss.htm.

4. Experimental framework

4.1. Prototype basis

A prototype of SoundSign was developed based on the game *Assault Cube*, a Linux-based open-source first-person shooter.[5] We selected a first-person shooter since not only are they highly popular (the third highest selling genre of video games), but, based on our research leading up to the design of SoundSign, we found that sound in first-person shooters is particularly critical in keeping the player's character alive (in particular, knowing when and where gunshots are occurring). A recent study of user interfaces in first-person shooters ranked that visual information regarding ammunition, radar and health were all highly important, and in particular that many players prefer having a visual rather than audio warning if critical levels are being reached (for instance, only 19% of players preferring an audio warning over a flashing indicator for health meters) [19].

[5] http://assault.cubers.net/.

4.2. Prototype implementation

The prototype for this experiment required embedding code directly into the target platform source code. The original source code was written in C++ and linked to the OpenGL graphics libraries. The prototype was developed and tested under Linux (Ubuntu 8.10) using the GNU Project gcc compiler version 4.3.3.

During execution, the game program maintains in real-time a 2-dimensional grid-map data structure, locating all the players (entities) in the environment. Relative distance information is readily computed as the entities navigate through the environment, and this is crucial given proximity is an important factor in game-play. The map provides both (x,y)-coordinate information for the sound sources, and a relative sound level, depending on the distance from the player. Code that read and redisplayed the sound direction and distance was inserted into the main game engine and the audio driver, and when action on the screen was updated, the appropriate icon could be displayed along with direction and level information. A small queue was implemented to facilitate the simultaneous display of several icons in the event that more than one sound was heard. Each icon had a timer instantiated with it, so that after 3 s, a given icon would disappear. A maximum of three simultaneous sound events was displayed (three icons) at any one time. In this case, when there were more than three simultaneous sounds, the three closest to the player were shown. Typically, sounds are assigned priority codes in games and these priority codes can be used to select which sounds should be displayed.

4.3. Measuring usability: hearing-abled gamers

We undertook a usability test of our prototype SoundSign with the following questions in mind:

- Do users utilize the tool (i.e. respond to events indicated by tool) when the sound is turned off or kept on?
- How much do users utilize the tool when sound is off, and when sound is on?
- Did users find the tool useful?
- How well did the users understand the icons, having been given no instructions?
- Was the tool too much of a distraction for the user?

The effectiveness of the user interface for such a system is best measured in both subjective and objective ways, by recording reaction of the participants. Only attempting raw statistical measurement, for example monitoring if game scores improve over time, is difficult to formulate and the results would lack relevance. As such, we chose to use think-aloud protocols as well as structured interviews to measure subjective response, and eye tracking to measure objectively. Most participants, however, had difficulty with think-aloud while playing what for all of them was a new game (and a game that had much simultaneous action) that required considerable attention, and abandoned think-aloud during their play despite encouragement. As such, post-game interviews enabled us to identify areas of difficulty as well as success while the participants reflected on gameplay.

The objective testing (eye tracking) enabled us to record data on the use of the SoundSign during game play. As indicated by other research [20], eye tracking can be useful for usability testing when conventional usability methods (click analysis, questionnaires, interviews, think-aloud) cannot provide enough data. It is particularly useful in determining where the user focuses visual attention. An additional benefit, of course, is that it can expose response bias.

The test participants consisted of 10 hearing-abled students at the University of Waterloo, recruited through on-campus signs announcing a study of video game sound. Approximately half of the participants were regular gamers, and half considered themselves to be casual gamers. With the exception of one participant who classified himself as an expert gamer, however, there was no significant difference in response to SoundSign between casual and regular gamers. The expert gamer (participant 4) reported that he did use SoundSign during gameplay, and his eye tracking results supported this statement.

Participants were tested by a research assistant, and were given no instructions with regard to what was being tested, and so were not focused on any area of the game. This lack of instruction also enabled us to test how intuitive the SoundSign system would be to new users. As one of our primary goals was to create a simple system that would be easy to learn, it was important that the system not require any instructions. Participants were brought into the lab and played *Assault Cube* with both the sound and SoundSign on for 10 min. Sound was then turned off, and players continued to play for an additional 10 min.

4.4. Measuring usability: hearing-impaired gamers

An email was sent to the IGDA-GA-SIG list-serv, and a posting about the project were made on the *Game Accessibility Forum* in September 2009 (subsequently removed). These postings were for the purpose of soliciting feedback on SoundSign. Seven gamers responded to the query by email, and three hearing-impaired gamers (self-defined) later agreed to run an experiment on themselves and self-report by email. An experiment was designed whereby the player would play the game for 10 min with SoundSign turned off, followed by 10 min with SoundSign turned on. Gamers were asked to respond to the following questions:

(1) Did the SoundSign system convey information that you were unaware of previously (when SoundSign was turned off)?
(2) Do you feel that you were able to more effectively play the game with SoundSign?
(3) How do you find SoundSign compared to other systems that provide the same information through other formats (e.g. closed captions)?
(4) Do you have any other comments that you'd like to add?

All three gamers agreed that it was easier to play with SoundSign turned on, and that the system conveyed additional information, notably the direction of gunshots. Whereas previously the information was primarily conveyed with merely a flash of the screen and a trail being left behind the bullet, with SoundSign, the participants reported that they could more quickly identify the direction of bullets. All three gamers reported that SoundSign was preferred to other formats of presenting sound information. While these responses suggest that SoundSign is effective for hearing-impaired gamers, we suspect that the participants may have been trying to please us by responding positively.

More telling, however, was the open-response question 4 in which respondents could add comments of their own. One participant noted, "I noticed a big difference when it was on the screen. I could tell not just when they were shooting, but also when they were re-loading" (an exclamation mark beside the gun was used for the reloading sound). "I felt like [sic] I could play faster, more confidently" said another participant. Finally, one participant elaborated quite extensively: "I think that the system is good because with text it takes too long to read, and by [the time you've read it] you've been shot three times. I think the icons are nice and simple. I'm not sure that I like them in that [on-screen] location, though, because in some games other inventory might be in that location. It might be good if the player can move the icons around the screen to where they want".

We agreed with this participant that if SoundSign could be repositioned by the player that it may be more effective for some players. Nevertheless, for this pilot study we wanted to use an eye-tracker for more objective measures, and leaving SoundSign in one position was more efficient and more accurate for analyzing the data.

5. Usability experiment results: hearing-abled gamers

5.1. Subjective feedback

Participants were asked if they found SoundSign useful when sound turned off, asked if they relied on it for sonic information during play, and whether they found it difficult to follow the icons while playing the game at the same time. They were also given a chance to raise questions or ideas about SoundSign. No participants reported being too distracted by the system, although one student thought that their attention was somewhat divided: "When I'm looking at the screen, there's a lot of things to look at, so my attention was divided" (participant 1). About half of the participants, however, reported that they didn't even notice the SoundSign system when the sound was on: "When the sound was on, I didn't really notice the icon system. I just listened to the sound" (participant 5).

A few participants reported some minor difficulty having not been given any instructions, although most found it very intuitive: "It was pretty intuitive. It worked well. When it said something was behind me, there was something behind me" (participant 5). The most positive responses to the system occurred when the sound was turned off, with most participants saying that they came to rely on the iconic system for information previously obtained through sound: "I had to look at the (SoundSign) to see where the opponent was shooting me from. To me the (SoundSign) became like a health meter or ammo indicator... they became like that. They were important to me" (participant 1). When asked to compare the system with being able to hear sound, a range of responses occurred, mostly positive about the system: "I think (SoundSign) was a reasonable alternative to the sound. It did pretty much the same thing as the sound" (participant 5).

In particular, coming back to our earlier point about accessibility and enjoyability, players commented on how difficult and less enjoyable playing the game was without sound. Many participants were surprised at the significant drop in their skill level and mentioned that the game wasn't as fun when the sound was turned off. And, while they appreciated the alternative to sound, some felt it didn't capture the emotional, visceral qualities of playing with sound. One particularly interesting finding, however, was that many experienced players felt that the SoundSign system increased their ability to play the game: that is, by having simultaneous visual and sonic information, their reaction times were faster and shooting was more accurate. Future tests to explore the accuracy of this perception will need to be undertaken.

5.2. Objective feedback

The participants were all eye-tracked during game play, using a monocular system by Applied Science Laboratories (ASL), in which the participants had to sit with their head in a chin rest mounted in front of them on a desk in front of the computer monitor playing the game. The sample rate was 60 Hz. The SoundSign system was fixed in the bottom right-hand corner of the screen, which became our area of interest (AoI). The number of fixations within the AOI was recorded, along with the gaze % (proportion of overall time) spent in the area of interest.

The gaze % (proportion of time on area of interest) mean was an increase of 3% of the total time spent playing looking in the direction of SoundSign when sound was turned off, suggesting that participants used the system significantly more when sound was off. Although this may seem a small percentage, when one considers that this area had little interest other than the SoundSign system, the extra 18 s of overall gameplay spent looking at that part of the screen would have been significant, given that a gaze takes only a fraction of a second. Out of the recorded participants, 7 out of 10 had longer fixations on that area of interest with the sound off, and an average gaze duration (cumulative duration playing time as a percentage of the overall time playing) of 7.85% was spent looking in the area of interest.[6] The number of fixations within the area of interest also showed a marked increase in use when the sound was turned off. The average increase in 40 fixations (accounting for saccades) when sound was turned off, to a total of 97 fixations in that area.

6. Discussion

There were several limitations to our study, including the realism of play; notably, the fact that players rarely play a game without moving their heads. There was also a slight lag in the game's graphics due to the eye tracker's recording (a limitation of the eye tracking technology used). The limited number of user tests provided useful anecdotal data but will need further testing for reliable statistical data. Another test, where users have no SoundSign icons during the first part of play with sound on would also be useful, as would a more objective test on hearing-impaired gamers. Another experiment would be to conduct the test with alternating the order of play (without sound followed by with sound) and tracking eye movement. One reason for not selecting hearing-impaired gamers at this stage was that it is difficult to gather think-aloud responses during gameplay with participants who use sign language, since their hands are tied up with game controls [21]. Likewise, we could not test differences in sound on versus sound off scenarios. Of particular interest would be the impact of compensation, where it might manifest that hearing-impaired players react differently in an objective experimental scenario when using SoundSign.

We do not yet have significant data on how SoundSign compares to other existing (largely textual) modes of representation discussed in Section 2 above, but we anticipate that not only will game players find an iconic system much more easy to learn and use, but developers will also be able to implement such a system with reduced development time required. Additional research into the multimodal interaction of sound and image—and the player's perception of increased ability to play with both sound and visual cues should also be undertaken—as this is an interesting way to test the user's cognitive load during play and how these are impacted by redundancy.

Despite the limitations of our pilot study, there was a clear suggestion that further work in this area would be very useful in terms of creating an accessible system for hearing-impaired gamers. Both objective and subjective data suggests that a visual iconic system that is intuitive and provides simple and fast information regarding proximity, sound effects and direction are useful in video games when the sound is disabled. Some players spent significantly longer times gazing at our SoundSign system when audio cues were removed from gameplay. Without audio cues in regards to enemy direction and proximity, for instance, players can be at a significant disadvantage without sound. Of particular note is that the findings suggest that sound effects play a significant role in game play (at least in this type of game). Sound is often an afterthought when it comes to game design, and yet the reliance on sound is clearly indicated by the usefulness of SoundSign.

7. Conclusions and future work

This paper illustrates the value of a visual alternative to sound effects for video games, and highlights the need for more work in this area. Participants found that an alternative to sound effects was necessary for this particular genre (first-person shooter), in which important game information is relayed through sound effects. While this particular game is playable without sound effects, many users found the game more enjoyable and more playable with the SoundSign system on when sound was turned off.

A second prototype with a variety of potential revisions is in development, including the use of colour differentiation and 3-dimensionality of the SoundSign for surround-sound games. We will also allow the user to select placement of SoundSign on the screen and test a variety of types of games. Another version of this prototype is a heads-up display version, a transparent display that allows the player to play the game without moving gaze away. This eliminates the usefulness of eye tracking, but other testing methods will be employed. In particular, we would like to test the player's skill level and ability to play a game that is dependent on sound. We are currently constructing a game for this purpose.

A long-range milestone is to design a general-purpose module that would integrate into existing game audio engines (e.g. Audiokinetic's Wwise or Firelight Technologies' Fmod). This would maintain the SoundSign functionality, without the requirement for specific game-dependent coding. A final stage would be to integrate into and test the technology in non-game applications that might make use of alternate representations of sound, including PDAs and other handheld devices.

Further iterations could include, for instance, an indicator of player-generated sounds. In stealth games where the amount of noise that the player makes can cause the player to be recognized by enemies, the player needs to be aware of how loud their movement is. A different type of indicator could be developed to show these sounds, since directionality is not typically a factor in player-generated sounds. In addition, we will further explore the usability of our particular chosen icons, and adjust these based on our findings, and explore further design options for particular genres based on a human–computer interaction approach to icon design e.g. [23].

We have demonstrated a clear need for more research in the area of audio accessibility in games. Not only do we not have the data to compare usefulness across different systems, but there have been limited attempts to develop alternatives to sound for hearing-impaired gamers. While audio's impact on the player's psychophysical response has been the subject of some recent study [14,15], its impact on playability remains a largely unexplored area of gaming technology.

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[6] Some of this percentage of gaze in this area of interest can also be attributed to the fact that there may have been enemies in that particular AOI, so the % of gaze in the area of interest may not be entirely attributed to SoundSign. It is not possible, however, to separate the reasons for the gaze. Longer testing times with further numbers of participants may help us to clarify the results.

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