

# Analyzing the Use of Sounds in FPS games and its Impact for Hearing Impaired Users

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**Figure 1:** *Half Life 2 (a), XIII (b) and Call of Duty: Modern Warfare 2 (c) - Screenshot for each game analyzed illustrating a visual redundancy for information conveyed through sound.*

## Abstract

Although very popular, most FPS games are disliked by the Brazilian deaf community due to some difficulties faced, mainly with fast reactions that the player must have to proceed with the missions. FPS game's designers use sound strategies to convey information to the player, and if the game does not provide some kind of visual redundancy, deaf or hard of hearing players encounter a bad game experience. Continuing a previous research, we performed a semiotic inspection in three games of the genre aforementioned (Half-Life 2, Modern Warfare 2, XIII). This paper corroborates the previously identified strategies that are used to provide information to players via audio and analyze how the lack of this information can impact a player who cannot hear, by identifying the redundancies provided by each of the three games.

**Keywords::** first-person shooter games, accessibility, deaf, human-computer interaction, semiotic inspection method

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## 1 Introduction

Digital games have gained a major role in the entertainment market. An explanation for this popularity could be that games provide something that other forms of entertainment, such as books, music, and movies, cannot provide: interaction. As the popularity of games increases, making games accessible becomes more important. Still, little research has been conducted in this area [Yuan et al. 2010; Coutinho et al. 2011a].

Game accessibility is the ability to play a game even under functional limitations, or disabilities [IGDA 2004]. It is a social matter to ensure the inclusion of all kind of people at leisure, including digital one, because every player should be able to dispose of digital games as an entertainment option, in spite of their physical conditions [Bierre et al. 2005].

In terms of audio accessibility, interacting with games often requires the use of elements as audio components, which may not be perceived by those who have hearing difficulties. If the sound elements are not represented in other ways, like visual redundancies, the player with hearing impairment may miss important parts of the interaction, which may cause frustration and even a breakdown in the gameplay, preventing the player's advance through the game.

In our previous research [Coutinho et al. 2011b], an electronic questionnaire was applied to people with some degree of hearing

loss investigating game accessibility matters. One of the findings from the study was that games of the FPS genre were the most disliked among the respondents. FPS games very frequently make extensive use of sound in order to create a convincing game atmosphere and captivate players [Huiberts 2010; Droumeva 2010]. For those reasons, the FPS genre was chosen as the target for our inspection. This research also analyzed how audio had been used for communication in the game Half-Life 2 and what was the impact in game experience in case that information was not received.

In this study, we present the results of the analysis of sound use done for Half-Life 2 and other two games of the First-Person Shooter (FPS) genre - Call of Duty: Modern Warfare 2 and XIII.

The analysis of the three games was conducted systematically through the use of the Semiotic Inspection Method [de Souza et al. 2006; de Souza et al. 2010]. Each game was inspected in order to identify which characteristics of the audio were being used to convey information and how those characteristics were employed to communicate relevant information to players. The identified characteristics of the sounds were grouped into classes and the way those classes were used to communicate were grouped into strategies of communication. Another outcome of the inspections is a description of how the communication strategies were used in each game and their impact for hearing impaired users. In order to evaluate the impact for hearing impaired users we analyzed what was being conveyed through that strategy, what visual redundancy was available for that information and what was the impact of not having access to sound.

In this paper, our main focus is to present how the communication strategies were used throughout the analyzed FPS games, and the visual redundancies chosen for them in different contexts. This analysis provides insights regarding the use of audio in the design of new games, as well as their impact for players with hearing impairments. These insights can be useful for the design of new games and also for the evaluation of existing ones.

Our previous work is extended in this paper since we identify that the audio strategies to convey information found in one FPS game were also found in two others of the same genre, which may indicate a way to support designers of games in their projects and evaluations.

Next section presents related works that analyze games focusing in deaf player's experience and interaction. In Section 3 is presented which FPS games were chosen for analysis, and the motivation for such. Section 4 brings the methodology and a brief explanation about the classes and strategies identified on the games. In Section 5, the strategies of sound usage are linked with the classes used by designers to transmit information and with the redundancies encountered in each game for those, and in Section 6 we dis-

cuss the results. In the last section, we present the conclusions and possibilities for future work.

## 2 Related Work

In spite of the huge development we are experiencing in the field of digital games, there are still many barriers for people with disabilities. This is an important issue that have not been fully explored in the literature.

[Yuan et al. 2010] makes a survey on the current state-of-the-art in research and practice in the accessibility of video games and points out relevant areas for future research. Through analysis of a number of player interactions with games from different genres, a general game interaction model was defined by them. This interaction model consists of three distinct steps that players perform when playing games : (1) receive stimuli (2) determine response and (3) provide input. This model can be used for identifying how a disability, like hearing loss, affects a player's ability to play games. Players with hearing loss may be unable to receive stimuli from the game. In this research many games were surveyed for strategies that improve accessibility with focus on games for hearing impaired players. Though many games support subtitles, audio cues such as the sound of footsteps, may indicate important events to a player and are absent in many games. The overall strategies identified by the authors are to replace audio with text, may it be subtitles or closed caption, and to replace audio cues with non-text, such as visual cues, a sound radar or signing.

The proceedings [Torrente et al. 2009] of the first ACM International Workshop on Multimedia Technologies for Distance Learning shows that multimedia content in general and educational games in particular, present accessibility challenges that must be addressed to maintain the learning inclusivity. For it, it is necessary to develop new accessible multimedia technologies that guarantee that the learning experience is motivating and engaging to all students. The authors show different strategies that were used in the development of their system. One of these strategies is a game engine architecture in which the output system is always redundant. For example all audio tracks have images and texts representing them.

## 3 Inspected Games

The focus of our research was the impact of the use of audio in FPS games for hearing impaired users. Thus, in order to select the games to be inspected we took into consideration whether they offered audio, as well as other representations, such as closed captions or visual redundancies, that would allow hearing impaired users to play the game. It is interesting to note that although the games offered some alternative representation for sound, none of them mentioned in their announcing material accessibility for hearing impaired users.

Three FPS games for personal computers were selected:

- Half Life 2 (Figure 1a): The game was awarded “Game of the Year” by 39 publications in 2004 and had sold more than 6.5 million copies by 2008. It was also very well received by deaf community players because of its use of closed captions.
- Call of Duty: Modern Warfare 2 (Figure 1c): the game is similar in style to Half Life. However, being more recent, it makes use of different audio processing techniques that make sounds more realistic (i.e. the use of Doppler effect). Thus, this game allowed us to analyze what would be the impact of not having access to these new effects.
- XIII (Figure 1b): The game is based on comic books and uses onomatopoeia and speech bubbles as visual redundancy for the audio. Furthermore, it would allow for the comparison with the different strategy used in Half-Life 2. The game's onomatopoeias (Figure 2) are redundancy for some sounds, contributing for accessibility for deaf or hard of hearing players. It was interesting to compare the visual redundancy of au-

dio communication between onomatopoeias and closed captions (HL2).

In order to facilitate the understanding of the characteristics of the games discussed in the analysis, we present briefly each games plot. Half-Life 2 is set in a fictional future Earth where the planet's resources are been harvested by alien invaders. The player takes the role of Gordon Freeman, a scientist who helps the resistance and tries to free humans from the alien oppression. His main weapon is the gravity-gun, a gun that levitates objects and is key to solving some of the game's puzzles. The whole game is split into 10 chapters. The first three chapters were evaluated: “Point Intersection”, “A Red Letter Day” and “Route Kanal”, focusing in communication through audio. Its cover box does not relate closed captions with accessibility for hearing impairments.

The second game inspected was Call of Duty - Modern Warfare 2. It is a game with a plot set in a universe in which a terrorist group carries out several actions in order to start an armed conflict between the U.S. and Russia. This story is told through the first person perspective of five different characters. All characters get involved in some kind of armed conflict, and therefore the player assumes their roles and should participate in battles. The game is divided into three acts, each of which contains six chapters. All chapters of the first act of the game were evaluated: “SSDD”, “Team Player”, “Cliffhanger”, “The Russian”, “Takedown” and “Wolverines!”.

The game XIII, third and last, is about an agent who wakes up with no memory at a beach, and is slowly gathering information that may refer to his past, stating his true identity. This agent has a sixth sense that alerts the player about the position of enemies, thus facilitating the player's defense. The first two scenarios of the game were evaluated: “The Beach” and “The Military Base”.



Figure 2: XIII - Onomatopoeia of an explosion.

## 4 Methodology

Semiotics Engineering is a theory of Human-Computer Interaction that perceives the phenomena of interactions between users and software as a form of communication from the software designers to users through the software interface [de Souza 2005].

According to the theory, that communication is achieved through the codification and decodification of information in interface signs. Upon contact with the interface, users receive the information conveyed through the signs and grasp the software designer's underlying intentions.

The Semiotic Inspection Method (SIM) is an inspection method based on Semiotics Engineering [de Souza et al. 2006; de Souza et al. 2010] that lets evaluators assess the quality of the communication achieved by software interfaces. During the inspection, different types of signs are identified in the interface and later analyzed in order to reconstruct the software designer's intentions such as to whom the system is targeted, what its goal is and how to interact with it. Besides, the inspectors also analyze how that information is being presented to users and identify potential problems that users may have to interact with the system.

As our objective lied on analyzing the communication through sounds in FPS games, mostly the audio signs were analyzed, but also some other types of signs that presented the same information conveyed by sound in an alternative way.

- What information does the sign transmit?
- What are the goals of this information?
- There are redundancies for this information?
- What is the relevance of this information?

These issues are guides to the identification of classes, strategies, and for the analysis of the impact and the lack of any of them.

The identified signs were, then, grouped into *classes*, indicating what characteristics of the audio had been used to communicate different types of information. From the same analysis, we also identified how those characteristics (classes) were used to communicate information to players from the standpoint of the game designer's intentions and these results were grouped into *strategies of communication*.

The lack of each class for the player experience was also evaluated (analyzing possible redundancies that may minimize these impacts). Thus, it can be noticed the impact for deaf players (or partially deaf).

Below, we present all the classes and strategies identified during the inspections of the three games:

- *Sound volume* The sound volume can be used to hint the player how far his character in the game is from the source of the sound emission.
- *Sound distribution* If the player has a stereo speaker set in his computer, the game can send different audio channels for each speaker, thus simulating the direction between the game character and sound source.
- *Timbre* It is the characteristic of the sound that allows the player to distinguish between two sound notes in the same frequency but produced by different sound sources. This distinction is used by the player to identify different characters in a dialogue, the sound of weapons of an enemy, etc.
- *Timing* It represents the time at which a sound is emitted by a source. This is important because the time at which a sound is emitted to the player may indicate a change in a state of the game.
- *Speech* Is the content found in the dialogues of the game, being the player's character one of the interlocutors or not. This content may be essential to the player because it is widely used in developing the plot and in explaining new missions.
- *Tempo* It is the speed at which the same sound is played by the same source. The pace which is executed this sound can tell the player how much time is left before the occurrence of a new event in the game, or the frequency at which an event is repeating itself.
- *Music* The music played during the game can be used to inform the player what is the context or a context change in the environment where he is.
- *Perceived frequency* Represents a change in the sound frequency due to a sound source that moves quickly from one direction to another in relation to the game character.

The classes represent the existent types of audio signs in FPS games. The strategies on the other hand, describe how the classes are used to convey information in the game.

Below is the list of the different strategies identified on the three FPS games:

- *Enabling sound and localization* This strategy provides the player with information about how far and in what direction a sound source is from him. The designer can use sound *volume* and *distribution* to provide this information.

- *Characterization of game elements* Provides the player with individual characteristics that allows him to distinguish one sound source from another. The designer can use *timbre* to provide this information.
- *Interaction feedback* Whenever an action is performed in the game a characteristic sound can be performed to inform the player that the action was completed successfully. The designer can use *timbre* to provide this information.
- *Communicating threat* To inform the player that a threat is near using sound is important because it is not guaranteed that the player have visual contact with the threats all the time. The designer can use all classes to provide this information.
- *Use of speech to transmit information* To develop the plot, inform the player their current status, new missions and any other information that can also be obtained through text that the developer wants. The designer can use *speech* to provide this information.
- *Raising emotions and sensations* To give the player information which might change his emotion towards what is happening in the game can greatly increase his immersion and satisfaction. The designer can use *music* to provide this information.
- *Inference of velocities of moving sound sources* This strategy is used to inform the player how fast the objects or other characters are moving around him. The designer can use sound *volume* and *tempo* to provide this information.

In the next section we present the main results obtained with the analysis. For each strategy we describe how it was used in the game, the visual redundant representations available and the potential impacts for the hearing impaired users.

## 5 Results

For each strategy we present the classes used by the three designers to achieve its purpose. A strategy as a designer intention, can be applied to a game with a combination of different classes of sound usage.

The game can also provide redundancy for the classes in each strategy and, depending on the redundancy, the lack of a class may or may not cause a loss to the gameplay and the game continuity. The redundancies identified in each game are listed for each strategy below.

### 5.1 Enabling sound localization

In all games, the more intense the *volume* of the sound emitted by another character or object in the game is, the closer its sound source. This feature is essential for the player to identify his position in relation to the various elements of the game.

They support Dolby Surround technology, i.e., if the player has the proper equipment, the sounds are emitted by the speakers to simulate a real environment ahead of the player. Therefore, the *distribution* of the sound emitted by the speakers provides a way for the player to infer the relative position between his character and the sound source.

Only in Call of Duty - Modern Warfare 2 if an object is moving at high speed, close to the player, it is possible to infer by *perceiving the frequency* of its sound, if this object is approaching or receding, and how close it is. A missile is an example of object in the game that emits a characteristic sound that suggests change of frequency.

#### Half Life 2

The localization of sound sources on the player's behalf is very important in Half-Life 2, as it enables the identification of incoming enemies and projectiles.

The game's closed captioning system does not depict localization information from the sounds, but only shows a text describing



the sound itself. This may lead to a worse game experience for players who cannot hear.

During dialogs, this fact also represents a drawback, as the game camera does not focus on the current interlocutor, rendering players with hearing impairments dependents on the subtle movement of the mouths of the characters to identify who is talking at each moment.

However, the information of the direction of a shot that hits the player is shown graphically (see Figure 3), near the character. This graphical representation allows deaf users to identify the source of the shot. It may also make it easier for any user to identify the source of the shot, than inferring it only by sound distribution in the speakers.



**Figure 3:** *HL2* - Redundancy for the direction of shot that hit the player. The red arrow on the right points the shot source's direction.

## Modern Warfare 2

Through the visual representation of an event, it is possible for the player to identify the distance at which he finds himself from one event, and if an high speed object is approaching or receding, without the perception of sound. But player may not know that an event is happening, losing important context. If the visual representation is obstructed by a wall or object, the sound becomes the only way for the user to perceive the event. In that case, the deaf user will not have access to the information being conveyed and will lose important aspects of the context of the game.

Whenever a character gets hit, besides the sound, there is an indication in the portion of the screen near the player's weapon, showing the direction of the originated shot. As the information is always displayed directly in the screen, this information is not easily missed by the player.

In any FPS game, one of the player's main goal is to keep his character alive. So, the visual redundancy for shots displayed by *Modern Warfare 2*, is an important characteristic for deaf players to achieve this objective. However, many other events such as an helicopter's flight behind the player do not have a visual redundancy to the sound sign and may not be perceived. Even though this loss may not directly cause the characters death it may delay the accomplishment of tasks putting a deaf player in disadvantage in the game, in relation to others.

## XIII

Most events that generate sounds, have associated onomatopoeias located where the sound sources are seen, with the size related with the noise intensity. They indicate the position of the source, as well as the volume and distribution provides this idea. Explosions, gunfire, steps through the wall (Figure 4), etc, have a graphical representation commonly noticed due the size and highlight of the onomatopoeia effect.

The player's character has a sixth sense that indicates the position of the enemy when he approaches, through a box that surrounds him. Very useful to achieve the goal to maintain the character alive.



**Figure 4:** *XIII* - With this onomatopoeia of steps - "tap" - the player can notice the presence of enemies (behind the wall) without the need of hearing their footsteps.

Several times in the game, it is possible to watch the trajectory of shots (the bullet trace is rendered), which allows the player to perceive the enemys approximate position (since the character may have moved after shooting).

The speeches in the game are always graphically represented as speech balloons, just like comic books. They point to the source of the speech, providing the same inference that speakers phone do, so the player can identify from which side is the origin of the speech.

By visual indication of a red arrow near the weapon, players can identify the origin (up, down, left or right) of a shot that decreased their health.

## 5.2 Characterization of game elements

The player must be able to distinguish easily the elements in the game and sound noises can be used for it. *Timbre* applies naturally to every sound effect in these three games and it refers to their uniqueness.

### Half Life 2

In *Half Life 2* the redundancy for this strategy is only the graphical representation of objects, enemies and surfaces, to recognize different game elements. Without the perception of sound, the player have to be alert to visualize everything around and distinguish every component or scene.

### Modern Warfare 2

The only redundancy identified to be present in *Modern Warfare 2* for this strategy is the pure visual representation of the element or event. Through direct observation of the visual representation of a particular element or event, it is possible for the player to classify what is in his sight. If the visual representation of the element or event is obstructed by a wall or object, the player will not notice the existence of the same.

## XIII

For that strategy, redundancies may not be clear enough to be substitutive of the sound. For example helicopter noise, the timbre of a voice, are not fully demonstrated through images. However, the sound of a voice is represented by a balloon, and this points to which character is speaking, characterizing each one, but it is like comic books: does not provide total immersion. The deaf player can not distinguish different types of weapons unless they are close enough to be recognized by its shape.

In some cases, like fire and explosions, the visual representation is able to convey all the information transmitted with the sound. The reason for this is the use of different onomatopoeias for different events. For instance, when an enemy is hit an onomatopoeia

for a scream is shown, or when the enemy is hit by shots, the onomatopoeia for the shots are shown next to him.

### 5.3 Communication of Threat

*Timing*, *music* and *speech* are used to communicate to the player the imminence of an event that may threatens him.

Sound alerts are shown in the games as sign of imminent threat, for instance when the pattern of the music changes to a more dramatic tune, it may indicate that something important is about to happen. Speeches also can directly indicate threat.

#### Half Life 2

One kind of enemy (a scanner robot) provides visual and audible signs that represents the imminence of an obfuscation: a little bulb starts to blink right before. This way, the player can react even when the sound is not perceived.

The other type of enemies may be perceived by a specific sound. They all have a graphical representation that allow their recognition, as well. However, in order to perceive the visual representation it must be in the characters line of sight, whereas the sound can be perceived even if the enemy is not visible to the character. Thus, not having access to the sound may put the player in disadvantage.

#### Modern Warfare 2

In this game, before an explosion of a grenade, a beep is heard by the player indicating that this event will occur. The same information is displayed on the *heads up display* (HUD), by an icon of a grenade, until the explosion occurs (see Figure 5).



**Figure 5:** MW2 - Redundancy in HUD (grenade picture in the middle) that represents an imminent grenade explosion.

During the game other characters may give the player warnings such as “get down”, informing the player that he should stoop to protect himself of an explosion for example. However, not all communication conveyed by sound is displayed textually in the screen to the player. Thus, in the absence of sound, the player may not receive all the threat alerts.

Music is used in the game to set the mood of the context. However, there is no redundancy for music. Even though the music is not critical for the achievement of game’s objective, the player may lose the immersion factor, which could have a negative impact on his experience with the game.

#### XIII

When enemies are “felt” by the characters 6th sense, there is a characteristic sound that alerts the player to an imminent threat. Visually, the characters 6th sense of the enemys presence is represented

by a box that surrounds the approaching enemy (Figure 6). In this case there is no loss for the player who cannot hear the alert sound.



**Figure 6:** XIII - Occurrence of the sixth sense: the enemy is located with a box.

When the enemy fires a gun, the sound of a shot is emitted, and it is also possible to watch the trajectory of the bullet (its trace is rendered).

As it is the case with the other games, there is no redundancy for the games music.

### 5.4 Interaction Feedback

In all three games, when characters interacts with objects within the game (weapons, munition, doors, etc) each action is related to a different *timbre* that distinguishes that action from the others. In some cases, even when the action takes place out of the sight of the players character it can be perceived through the timbre.

#### Half Life 2

Some actions executed by the player that have an audio sign associated to it also cause a closed caption description to appear on the screen, like when the player reloads his weapon by pressing the ‘R’ key. In the middle of a battle, knowing that the gun was effectively reloaded is crucial to continue the fight with advantage, and the closed caption helps that perception. Another redundancy is the animation of the gun itself, that mimics a real gun being reloaded.

Many events, such as the impact of a bullet in a tough surface, a movement of the enemy’s weapon, simulates very realistically the physics of the real world. These kinds of events have animations that allow the deaf user to notice that the event happened. A bullet in a tough surface makes a hole, the gun of the enemy makes a typical move when is about to be shot.

#### Modern Warfare 2

Some events have both an audible and visual feedback, so in some cases there is no significant loss to the player.

An example of redundancy is the grenade indicator in the HUD that, if there is a grenade about to explode in an environment close to the player, a soft beep will be heard by him, and at the same time an image indicating that there is a grenade in the region will be displayed in the screen. When noticing the icon in the screen, even without hearing the beep, the player can react to the event that is about to occur.

#### XIII

When the player interacts with the scenario, his actions emit sounds and the visual redundancy allow him to perceive them happening.

### 5.5 Use of speech to transmit information

The dialogue between the characters has several essential information for the player to continue the campaigns properly. The charac-

ters *speech* convey context information of the game, and even necessary information for completion of future phases. It also provides more immersion.

### Half Life 2

The dialogs in Half Life 2 are always closed captioned. The interlocutors also make gestures that help players to understand the context of the speech. A gesture can indicate the mood of an interlocutor, the content of the dialog, but must be recognized by the deaf player to be fully understood.

### Modern Warfare 2

In Modern Warfare 2, all content of spoken dialogue is displayed as text subtitles in the game interface, as well as the speaking character's name. There is no loss of information to the player in this case, but while a player is reading the dialogue, another important information may be missed. Furthermore, since hearing impaired people often may have difficulties in reading text they may be more vulnerable to losing other aspects of the game while reading.

### XIII

Whenever a character speaks, a speech balloon is shown with the dialogue content. Even when player's character and speaker are not in the same environment, the speech balloon appears in a spotlight image that localizes the source. Once again no information is lost, the only problem may be in the time needed for hearing impaired users to read the text.

## 5.6 Raising emotions and sensations

As in movies, *music* in the game is used to inform players about the environment around them, as well as increase player's emotions and sensations and provide them with a better experience.

### Half Life 2

Characters in the game have also facial expression with good quality (due to a powerful graphics engine). By interpreting these expressions, the player can feel the emotions of these characters (see Figure 7). This could be an interesting feature to deaf players, since sign languages make use of facial expressions to convey information.



**Figure 7:** HL2 - The same character has a relief expression (in the left image) and a worried expression (right).

### Modern Warfare 2 and XIII

These games do not offer any other representation for the mood conveyed by the music. Once again, although it is not important in achieving the games goal, it may have an impact on users experience.

## 5.7 Inference of velocities of moving sound sources

The change of frequency in which a particular sound is executed, can help the player to infer the speed at which the emitter of the

sound is moving. As an example, the characters movement generates the sound of steps with a time interval between them, if the character starts to run, the interval between the sound decreases, giving the impression of increased speed (*tempo*).

### Half Life 2

The deaf player can interpret the variance of objects or characters speed by sound and by the animations provided by designers. One example is the distinct animations for a character walking and running, accordingly the sounds of both events.

### Modern Warfare 2

In this game, the player can infer the velocity of an object, through the change of its sound frequency. If the object is in the character's line of sight, its movement or some other visual representation will also convey the objects velocity. For instance, when a missile is launched, the smoke trace created by its movement also gives the idea of velocity, while the space between each smoke ring is bigger when the speed is faster, and smaller otherwise.

### XIII

This strategy was not used by designers in XIII.

## 6 Discussion

The analysis described in this paper illustrate how the classes and strategies proposed in [Coutinho et al. 2011b; dos Santos Coutinho 2012] can be used to analyze the use of audio signs in FPS games, as well as the alternative representations made available for each of them. Thus, they can be considered an epistemic tool to be used in evaluating the accessibility of FPS games.

The next tables show which classes were used in each of the three games, Table 1, and which classes were used to implement each strategy in each game, Table 2.

**Table 1:** A comparison of which classes of sound features were identified on the inspections of each of the three games: Half-Life 2, Call of Duty: Modern Warfare 2 and XIII. A tick (✓) indicates that a class was identified in a game, whereas a dash (-) indicates it was absent in that game or was not identified in the inspection.

#	Class	HL2	MW2	XIII
1	Sound volume	✓	✓	✓
2	Sound distribution	✓	✓	✓
3	Timbre	✓	✓	✓
4	Timing	✓	✓	✓
5	Speech	✓	✓	✓
6	Tempo	✓	✓	-
7	Music	✓	✓	✓
8	Perceived frequency	-	✓	-

After analyzing the strategies of sound signs used in each game, we can say that the use of sound signs is often similar in all three of them. This could be an indication that some classes of sound signs are more appropriate than others to achieve specific communicative goals.

Although the use of sound to convey information has many similarities, different approaches to providing an alternative ways of representing that same information were used. For instance, whereas in Half-Life 2 in some situations a light transmitted the same information as a bip, in Modern Warfare 2 a graphical sign was shown on the screen to indicate a ticking grenade, and in XIII onomatopoeias were used to represent sounds. The analysis made it clear that having a visual representation of a sound is not always enough, since it may not convey the same information as the sound, or even if it does, it may only be available in more limited contexts (e.g. if the object emitting the sound is in the characters line of sight).

**Table 2:** A comparison of which strategies of sound usage that were identified on the inspections of the three games: *Half-Life 2*, *Call of Duty: Modern Warfare 2* and *XIII* and the the classes #s used in each strategy.

#	Strategy	HL2	MW2	XIII
1	Enabling sound localization	1, 2	1, 2, 8	1, 2
2	Characterization of game elements	3	3	3
3	Communication of threat	1-4, 6, 7	1-8	1-4, 7
4	Interaction feedback	3	3	3
5	Use of speech to transmit information	5	5	5
6	Raising emotions and sensations	7	7	7
7	Inference of velocities of moving sound sources	1, 6	1, 6, 8	-

## 7 Conclusion

The sound classes and strategies were used in this paper to evaluate the use of sound signs in FPS games and their accessibility for hearing impaired users. The fact that they were useful in the analysis of three different FPS games suggest that they could be used to support game designers in the project or evaluation of games. Our focus was accessibility, but notice that by making sure that the game is accessible to the deaf could also benefit other users who do not have access to sound due to a technological problem (e.g. sound speakers not working) or social contingency (e.g. playing in a public space).

The description of how the three games used the strategies and alternative representations can also be useful for game designers to reflect about their own choices. However, one aspect to be considered is that the alternative solutions proposed should also be in line with the game context as a whole. For instance, the onomatopoeias allowed the designer to transmit information being conveyed by sound, even in contexts in which the sound source was not visible to the character (see Figure 4). However, the onomatopoeias may only make sense in games that explore the comic book metaphor, and not in others.

The analysis also showed that not all audio signs necessarily have the same relevance in the gameplay. The signs that convey information that are relevant for players to keep their characters alive or achieve the games goal need to have alternative representations, if the game is to be accessible. Otherwise, those who do not have access to audio signs will be in disadvantage in playing the game. However, other audio signs may go without an alternative visual sign without impacting the players performance. Such is the case of signs that aim at providing users with a feeling of immersion. This does not mean that they are not important, since they may have a great impact in the users experience and satisfaction with the game.

The next steps in this research involve the use of the classes and strategies proposed in analyzing other FPS games in order to collect more data and consolidate the set proposed. Also, it would be interesting to use them to evaluate the use of audio signs in other types of games, such as RTSs (Real-Time Strategy) games, adventure games and others.

A broad use of these strategies to evaluate games could also generate data that could point to patterns of use of audio signs in specific types of games, as well as alternative representations that are able to convey the same information. The identification of such patterns could lead to the proposal of a guide to create games that are accessible to hearing impaired users.

The contribution to accessibility in games is relevant, since currently there are so few works that focus on the topic, specially regarding accessibility for hearing impaired users [Yuan et al. 2010; Coutinho et al. 2011a]. Also, as technology becomes cheaper the use of sound could become more broadly used in other types of systems, and the lessons learned in the game domain could be useful to support accessibility in other domains as well.

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