An empirical survey of satisfaction with audio accessibility in video games for those with hearing loss

Maximilian Curtis*, Sandy J.J. Gould, and Daniel J. Finnegan

School of Computer Science and Informatics, Cardiff University

November 2025

Abstract

Previous work has explored d/Deaf and Hard of Hearing Gamers' (DHG) experience, focusing on best practices for captioning, and information representation with visual cues to enhance the DHG experience. In this paper, we present the results of an online survey (N=100) using Qualtrics involving participants who self-identified as having hearing loss to explore their satisfaction of audio accessibility in games. Our results showcase players resorting to makeshift solutions, such as avoiding certain games and entire genres due to the lack of audio accessibility. Overall, our participants articulates a clear need for more options and customisability. Comparing these experiences against current guidelines, we identify significant gaps in guideline adoption. Based on our findings, we propose design opportunities to further audio accessibility in these areas.

1 Introduction

Over 465 million people worldwide are considered d/Deaf or Hard of Hearing Chadha et al. (2021). Within the United Kingdom, this is approximately 12 million people, one person out of every six. d/Deafness presents in a wide range of ways, with each being unique to a person. Each person's experience is highly unique and so there is not a single 'one size fits all' perspective that works. Those who identify with hearing loss are referred to under the umbrella term "Hard of Hearing" or d/Deaf (DHH) Zahnert (2011). Though these terms are not prescriptive, and are often based on self-identifiers, they provide us with a taxonomy for describing the the community at large and the variance in hearing loss in d/DHH people.

*Maximilian Curtis. Email: hedgesm@cardiff.ac.uk 0009-0002-7388-9210

Audio plays a crucial role in the immersive experience of modern video games, often providing emotional depth and a form of direct game-play feedback to the player. From the spoken element of dialogue, to the ambience of background sounds, audio serves a major role in enhancing the game-play experience Guillen et al. (2021); Rogers et al. (2019). With so much information given to players through the medium of audio, having hearing loss can massively impact the feeling and understanding of a video game. The inability to discern spoken content, understand contextual game-play cues, or engage with audio-based mechanics can impede DHH players' experiences.

Playing games is often a social experience, yet DHH people may be excluded due to inadequate accommodations or insufficient options of communication channels an audio dominated context. This can result in barriers that isolate DHH people from gameplay experiences that others enjoy. These barriers are compounded the lack of standardisation and regulation that other parts of the entertainment industry benefit from Powers et al. (2015). For example, although there are different guidelines, such as the Game Accessibility Guidelines (GAGs) GAG ([n. d.]), these are described as the best practices for developers to follow and are not enforced Westin et al. (2018). Porter et al. state that "initiatives need to come from the top down." and that "they will only be optimally effective when the audience they specifically address are the stakeholders and executives with the authority to drive change" Porter and Kientz (2013).

2 Related work

Subtitles–a common audio accessibility options within audiovisual media–are a written transcription presented on screen in synchrony with the spoken content. Captions are often more beneficial , and are becoming more commonplace. Due to them providing a more comprehensive understanding of their audio environment, with non-spoken noise being presented, often crucial to the understanding of events unfolding on screen.

Some games aim to provide the player with more context to the verbal captions. This can be especially helpful in scenarios where characters are talking off-screen, or there are too many characters to be able to easily identify the speaker. Yet even with captions providing information like the name of the speaker and environmental sounds; information like the tonality, volume, direction, language, accent and pronunciation of the speech can be lost to DHH viewers. For example, environmental sounds and background music may provide important information to the player like the emotion of the speaker, how well the player character can hear or understand the speaker, or even which person is currently speaking Schuller et al. (2013).

Furthermore, audio is typically used to indicate feedback to the player when they perform an action, or signal in-game information through an audio user interface (AUI). For example, clues to solve a puzzle like signalling a door has been unlocked. Standard practice for presentation of subtitles and captions follows non-interactive audiovisual content, white text with no background at

the bottom centre of the screen. People require various fonts, sizes and colours to gain the best experience from this content Al Amin et al. (2021); Butler (2019, 2020); Berke et al. (2019). For this, video games such as Halo: the Master Chief Collection Industries (2014) can provide various options. These customisation options pertain to the visibility of the text background, the font, the size of the text and the colour of the text.

For "Hard of Hearing" people, there are more options available to help alleviate potential issues. The three part sound system is common, and allows the player distinct volume control over; dialogue, the spoken content within the game; SFX, diegetic non-speech sounds; ambience/Music, the overall soundscape presented to the player. Some games allow players to change the type of audio from surround sound (5.1 or 7.1), to mono, or allowing the player to isolate individual sounds. A good modern example of this is within "Forza Horizon 5" games (2023), where not only is there an SFX option, but specific options for your opponents' car volume, tire volume, and crash impact volume. The music provides more detail, allowing for distinction for volume when the player is in the menu or in a race, meaning that when the player needs to focus, they don't need to change the volume setting every time they change game-states.

Brook Brook (2017) provides a list of potential ways that certain sounds can be represented as visual cues, particularly focusing on how UI elements are related to their sound categorisation. They use the IEZA categorisation to identify what sectors of game audio are covered by Non-diegetic, Diegetic, spatial, and meta UI visual cues. Though the needs of the game and thus their visual cues can change and vary based on genre Haddad and Strand (2019). This gives an example in "Final Fantasy 14" Enix (2010) and it's application of on screen audio visualiser to show a waveform representation of all audio coming through the game at any one time. This example helps present the 'loudness' of various sounds to the player but provides little way of distinguishing what those sounds represent.

Haptic feedback can also be used as an alternative modality. It is a physical way of providing information to the player. This is most often done through vibration packs within a game controller. This is often used shooter games, vibrating the controller to emulate the feeling of recoil for immersive purposes. This can be used for directional information and accessibility, and has been proven to be very effective Salazar et al. (2016); Tappeiner et al. (2009). While haptic feedback is most commonly associated with vibration, its applications vary. Force feedback, where the level of force required to press a button or move a joystick can vary and change, has existed within video games for over 25 years Ouhyoung et al. (1995). Research in haptics often focuses on those with vision loss Walia et al. (2020), showing that it can work well as an alternative modality for those with varying accessibility needs.

Oftentimes games provide communication through a voice chat, acting as a real-time way of exchanging information supporting rapid decision making and fast gameplay . This is particularly prevalent in competitive, cooperative and team based game genres . As stated by the game accessibility guidelines, having a text chat is a simple alternative for d/Deaf players, allowing players to

instead type out messages to each other. Though this does little to aid them in situations where efficiency and speed of communication is important, for which player use voice chat, a simultaneous communication method. Research Wadley et al. (2014) shows that voice is used by most players, even with access to other options. This is due in part to the aforementioned inefficiencies of text chat in gameplay. An example of this is when using text chats and typing out a message, interacting with the game takes precedence and can stops players from finishing and sending those messages Lee et al. (2025), leaving the intended information unsent. The lack of simultaneous communication in text chats means that there is a large communication gap for players that use text based communication **?** in comparison to voice chat. This communication gap goes both ways. Without voice to text, Deaf players are unable to receive communication from their teammates, and with text chat they are unable to send messages with the same efficacy. Visual communication systems have been designed to alleviate some of these problems. The most common visual communication systems are the radial dial and "ping" system. This allows players to pick a set message from a circular dial and place that message somewhere in the game space for other players to see. Wuertz et al. Wuertz et al. (2017) shows that players find this type of communication more useful in various context based scenarios, such as pointing to certain area's of the map to warn other players. One empirical study Leavitt et al. (2016) shows that the usage of these systems can correlate with an improved team cohesion and performance. However, this modality suffers from a lack of expression and detail, only allowing players to choose simple set messages such as 'Danger here', or 'Move to here'.

3 Method

To understand the persistence of existing issues, and the prevalence and impact of audio accessibility upon the d/DHH community, we sampled 100 d/Deaf and Hard of Hearing people about their gaming experiences.

3.1 Participants

The participant population was sourced from the online research participant platform Prolific [1]. The platform's built-in inclusion criteria was used to advertise to relevant participants. These criteria were as follows; Being in the UK; Being over the age of 18; self-identifying as d/Deaf or Hard of Hearing; having played more than 3 hours of video games per week. We used a random sampling method of 100 participants. A short description of the research and the Participant Information Sheet (PIS) were provided beforehand. Each participant read the PIS detailing the studies' research questions and gave their consent before accessing the survey. All participants completed the same survey, with questions and responses in the same order. All participants were compensated

[1] `https://www.prolific.com/`

through Prolific with £5 (˜£30/hr, ˜$39/hr USD) [2].

We were motivated to understand the issues with audio accessibility rather than making a comparison of categories of deafness. To this end, we limited our inclusion criteria for hearing loss as purely self-identifying, to allow people from all sides of the d/DHH community within the United Kingdom to arise. DHH experiences are known to vary across populations and countries (Woll, 1998; Bat-Chava, 2000). With this in mind, we wanted to avoid making naive comparisons across geographical and cultural populations. Table 1 provides a breakdown of the extent of participants' hearing loss. [3]

Table 1: Percentage of participants who identify with different types of hearing loss. Participants were given a list to choose from. No participants selected the 'other' option.

Identified as:	**%**	**Level of Hearing Loss**	**%**
Hard of Hearing	47	Mild (21dB - 40dB)	43
Tinnitus	29	Moderately (41dB - 70dB)	23
Hearing	12	Severe (71dB - 90dB)	5
Partially Deaf	8	Profound (90dB+)	0
Deafened throughout life (Post-Lingual)	1	No Hearing Loss	6
Deaf from birth (Pre-Lingual)	1	Unknown	20
Prefer not to say	2	Prefer not to say	3

3.2 Materials & Procedure

We conducted a survey using the Qualtrics System[4]. A full copy of the survey is provided in the supplementary materials to this paper.

Our survey consisted of 21 questions: 5 questions sampled demographic data e.g., age, hearing loss; 4 questions focused on hardware and software while playing games; 3 questions asked about types of gaming experiences e.g., genre and multiplayer; the final 9 questions were about players' satisfaction and gameplay experience overall: 3 for satisfaction of accessibility, 3 for satisfaction of communication options, and 3 open-ended questions asking about a positive and a negative experience, and how they would improve. Regarding satisfaction and overall experience, participants were asked to answer Likert scale questions for 6 different audio accessibility options. These were: Subtitles, Visual cues, Audio Visualisations, directional visualisations, haptic feedback, customisable sound settings. We drew upon the Game Accessibility Guidelines (GAGs) to determine these 6 options. To accommodate open responses, we provided an "other" option for each of these questions for cases where participants often used an

[2] Average Completion time was 00:09:54 [9 Minutes 54 Seconds]

[3] Only 2 participants stated they identified as 'hearing' and reported 'No hearing loss'. This may be due, in part, to some with milder hearing loss attributed to age not identifying with deafness but acknowledging their disability by partaking.

[4] `https://www.qualtrics.com/`

accessibility option when playing that was not listed in the GAGs. Participants were also asked to answer likert scale questions for 5 communication options: In game text messenger, In game voice chat, External text messenger, external voice chat, in game visial communication systems.

3.3 Analytic approach

For the open-ended questions, a qualitative approach was deemed appropriate to obtain the depth of understanding from participant answers while remaining grounded in the general context of play in contemporary video games, and the personal context of their individual factors. We conducted a reflexive thematic analysis following the Braun and Clarke (Braun and Clarke, 2021) methodology with a primary coder. We followed a deductive approach, allowing for current understandings of audio accessibility and game genres to group transcripts and codes together for further coding. To this end, the deductive approach is also guided by the social model for disability, as well as previous understandings of d/Deafness, and audio accessibility. An advisory coder was used to acknowledge the subjective interpretation of the coding within this style of thematic analysis.

Data was pre-transcribed by participants, but was cleaned of any identifiable information. A pre-derived codebook was used based off of known key points surrounding audio accessibility and deafness. A top down approach was followed, filing codes into the codebook, adding new codes where the codebook did not suit. Initial stages captured semantic meanings with latter re-coding focused on latent meanings. This was extremely iterative, with cycles repeating after deliberation of new codes. These were then clustered into specific codings, and was scrutinised on a secondary 're-coding' with an advisory coder. Codes were combined and examined to show overlapped meaning and derive themes, which were then reviewed. This was done to identify any incongruent themes. Extracts within the data were chosen as they were deigned to be illustrative of the theme or analytically relevant. Following RTA, our synthesis and contextualisation of data occurred throughout, and so discussion and reporting of results occur within a singular section.

4 Results & Discussion

4.1 Quantitative

This section reports the contextual participant data collected, as well as the reports on their satisfaction of audio accessibility and communication from the Likert questions. This data is used to provide a context to individualistic responses reported in the latter qualitative results section, and to provide an over-arching context to the narrative provided in the later discussion section.

4.1.1 Gaming Experiences

We collected information pertaining to the players' gaming experiences. This included the hardware used, video game genres and types of video game experiences they play. This data is shown in Tables 2, 3. These tables show the totals for this data, as participants could select as many options that applied to them. The table 4, shows a single choice on whether players participate in online gaming environments, and whether they participate in these environments alone, or communicated with others in them.

4.1.2 Audio Accessibility

This subsection details the results of the likert questions pertaining to; satisfaction, participant usage, and perceived implementation of audio accessibility options. The figure 2 shows users self reported usage rates of associated audio accessibility options, allowing us to identify which current options are in use more often by members of the community. The Figure 1 shows users reported satisfaction scores with their associated Audio Accessibility option, showing their overall views on that option in contemporary gaming. The final figure 3 shows users self-reported implementation rates of these options in games, i.e. how often these options are available to them to play in games, whether they use them or not.

As shown in Figure 2, the most commonly used audio accessibility option was subtitles, with 29% of participants using it "always" and 83% using it more than half the time they play. These results are reflected in participants' self-reported satisfaction with different tools. For subtitles, 91% of participants found them to be satisfying and 35% found them extremely satisfying. The two audio accessibility options, Visual Cues and Customised sound settings, both had a similar usage rate, with approximately 60% of participants using them half the time or more. The variations between them come from slightly more participants using them "Often" or "Always". When comparing how often Visual cues and Customised sound settings options are observed by participants to be implemented in games, customised settings are perceived to be implemented "always", much more than visual cues (23%).

The final three settings' usage in order of most use were: Directional Visualisations (55%), Audio Visualisations (48%) and Haptic Feedback (45%). While haptic feedback had the lowest overall usage rate, 12% of this is attributed to it being reported as not available in games, the highest of any option. Haptic feedback also has the highest "always" usage rate of these three options at 15% compared to 7% (Audio Visualisation) and 8% (Directional Visualisations): when asked how often people see the options implemented, with 49% of people saying haptic feedback is available in less than half of games they play. However, when we investigated the satisfaction of these options, a larger portion stated that it was "extremely satisfying" though haptic feedback had the lowest overall positive satisfaction ratings of any option. Haptic Feedback also had 43% of participants being neither satisfied nor dissatisfied with the option, being by

far higher than any other option on the list.

4.1.3 Communication

This subsection details the results of the likert questions pertaining to; satisfaction, participant usage, and perceived implementation of communication options. Within our dataset, we had 3 potential options for people to identify the types of multiplayer experiences they participated in, as shown in table 4. 60 participants reported that they played multiplayer games and choose to communicate while playing, while 35 choose to not communicate while playing. As 35 players stated they choose not to communicate while playing games, we have split the data into separate figures. Satisfaction of communication options is shown in figures 4 for players who choose to communicate, and figure 5 for those that don't. Similarly, figures 7 and 9 show usage and implementation respectively for those that communicate, and figures 8 and 10 show usage and perceived implementation for those that don't.

When comparing how often the perceived implementation of various options, we could see that the most implemented communication option was non-verbal in game communications with 73% saying it was available over have of the time. This was followed by in game text messengers (68%) and in game voice chat (58%). Both external options were reported as more often being not available (External Text Messenger 62%, External Voice chat 53%). Our reported usage of these communication systems shows that more than half our participants who choose to communicate use In game non-verbal (63%), external voice chat (55%), In game voice chat (53%), in game text chat (50%) more than half the time. External text messenger were reported to being used far less. 40% of those who state they do not communicate in multiplayer gaming experiences, state that they do use in-game text messengers more than half the time they play. Similarly, over half of them stated that they used built in communication tools within the games (51%). This same group shows a heavy disuse of in game voice chat with 3% using it more than half the time they play (51% Never use). This is also shown in the external systems with 52% never using external text messengers and 60% never using external voice chat software.

When asked about their satisfaction of these systems, those who choose to communicate report high satisfaction with almost all systems. Positive satisfaction scores were; 70% in game voice chat, 67% In game Text Messenger, 67% In game non-verbal, 60% External Voice chat, 53% external text messenger. Those who choose not to communicate were overall more undecided on all options, with less extremely satisfied in all options. Though the only systems with significantly more negative were External text messengers (29% negative), and in game text messengers (31% negative).

4.2 Qualitative

This subsection presents the qualitative findings from the open ended questions regarding the participants good and bad experiences with audio accessibility

in recent video games. To contextualise these results, we present the following definitions for optionality – the ability to have sophisticated control over a set of options –, and customisability – the ability to manipulate elements of a game. These terms are crucial in understanding the two major ways in which participants presented their opinions throughout these results. Optionality is often seen through alternative system implementations such as utilising different, or multiple, modalities for presented gameplay information. This term is used to encapsulate players feelings about the types of options available to them when participating in the gameplay experience, and the lack thereof. Customisability is used to describe players feelings about how the systems within the game can be adapted and moulded to fit their specific needs. We found that the information given by participants were framed in these two ways with the participants' needs referring to more options or the ability to customise current options appearing across all major themes.

Our analysis revealed four distinct themes. We identified the first theme as **current solutions and personal workarounds**. When asked for games that were accessible and why, participants responded accordingly, with many stating that the games themselves are not accessible to them without external tools. The second theme identified was the ongoing prevalence of issues surrounding **text based audio accessibility**. We identified the ongoing need for more subtitles, and for them to be implemented without translation issues. With the interactive nature of many games, the need for more detail and context based captions was prevalent. The third theme identified was **audio mix and sound settings**. The presentation of audio was oft deemed inaccessible as a basis. The "Audio Mix" was frequently mentioned when referring to the volume, balance and other controls within their sound. This has led to needing more distinct and granular control over the different parts of the audio. Finally, We found that a large marker for bad audio accessibility in video games was the usage of **audio as a necessary mechanic** that cannot be participated in otherwise through alternative modalities. We defined audio as a necessary mechanic as any situation in which the primary focus of gameplay is auditory based, and in which the lack of audio would place one at a disadvantage.

4.2.1 Current solutions and personal workarounds

It encapsulates how participants feel about the current over level of access to games, how their needs are met, and when they aren't, what they can do about it. Participants showed a range of viewpoints with some stating that most games met expectations, with the few that didn't, there were tools that helped to mitigate issues. While others had to complete more complicated tasks in order to access their games, or face not being able to access them at all.

No games are accessible We started the open-ended questions positively, asking for good experiences in games. However, even when asked about positive experiences with audio accessibility, some respondents responded in a negative

light. Stating that they have yet to have any good experiences with audio accessibility

> *"Theres never actually been a game that i'm satisfied with"* (P43)

Similarly, P95 simply stated:

> *"There is none"* (P95)

Participants showed their feeling that no game provides a good level of accessibility. Displaying the negative outlook that some d/DHH people have towards the industry and their implementation, or lack thereof, of audio accessibility.

This negative outlook may be due to the issues, still not being addressed, even in highly funded AAA gaming experiences. A wide variety of games were mentioned, with some participants mentioning smaller 'indie' games with a smaller budget, and others mentioning games with a much higher budget and larger team. These games included; 'Call of Duty', Apex Legends, 'World of Warcraft', 'Minecraft', 'Grand Theft Auto', among others. Participants showed a strong distaste that games with such a high status had low, bad or no audio accessibility options.

What games are playable When players are faced with the issue of having no way to properly interact with the games they want to, they can feel locked into a tough situation. Making the choice between playing a game that they know will not be as enjoyable for them, or not play it at all. This situation can lead to some going to quite drastic measures, like not playing any games that do not meet their needs.

> *"...so now I avoid these types of games"* (P63)

> *"Some indie games do not have sound options, and that makes me more prone to uninstalling them"* (P17)

When considering the social implications of gaming and its pervasiveness in contemporary culture, this can have an effect on d/DHH players.

This was most commonly presented as shooter games with 'Fortnite' and 'Call of Duty' both being mentioned across multiple accounts. Games that fit into competitive or team-based competitive games best fit the descriptions of games that didnt fit players needs. [5] However, this choice limits them to the games that have the options they require, which in the currently inaccessible gaming space may reduce the amount of games available to them by a significant degree, depending on their needs.

Similarly, players would more often choose to play games in which their accessibility needs are met, avoiding other types of games.

> *"The option to raise or lower the volume and to change the settings, at least its present in every game I play regularly".* (P49)

> *"I think the games i play are well designed"* (P46)

[5] These games and their audio based mechanics are more strongly defined in the theme (audio as a Necessary Mechanic).

Sound Off Other participants stated that if the sound was not of a high enough quality or did not have accessible features, then they would often play video games without any sound on at all. The example given by one of our participants is the MOBA (Multiplayer Online Battle Arena) "DOTA", a game in which, described by the participant, the audio cues are less important than for other games. It can be more enjoyable for players in these experiences as they know, even if they cannot participate in the auditory experience for that game, that it is not a requirement to their gameplay experience.

> *"I don't need to be able to hear to play the game"*
>
> *"I played Dota and audio is fine for me there because u can play even with music on its not that needed to win"*

This is pursued to a higher degree with some participants who described that they do this for almost every game, no matter how important the audio is within that experience.

> *"most games I play I have to admit I turn the sound off"* (P97)

Though players do this even when they knew it would provide them with a worse gaming experience. It is their only way to participate in the ever-rising gaming culture, play with their friends, or enjoy the games that they wish to play.

> *"Can be played without audio but you still wont get the full gaming feeling"*

The challenges that some face can be combatted by using a specific type of hardware, such as headphones, allowed them to have an accessible experience. This workaround was specifically mentioned to help focus on spatial and directional audio situations, such as in "fortnite".

> *"My headset is very good so it usually alleviates any problems I might have"* (P29)
>
> *"I like sometimes plugging in a headset gives me a better idea where the enemy is"* (P21)

Though this can be a solution, it is not one without its faults, as using particular hardware can help address the issue but may not be possible for a variety of reasons. Needing additional hardware can mean higher costs, longer and more complicated set-up and, on occasion, the hardware just may not be compatible with that game or system. These additional downsides to these simple workarounds to participate can dissuade some players, pushing them towards other workarounds, such as avoiding the games they wish to play as mentioned before. Further to this, some people's personal circumstances also mean that simple workarounds like headphones are not preferable to them.

> *"I don't prefer wearing headphones when gaming at home as a father"* (P88)

For those that still want to play the games they enjoy, yet cannot due to poor accessibility and the simpler workarounds being unavailable, they must look elsewhere for their accessibility needs. For some to play the games they want, they outsource their accessibility to third party systems.

> *"None of the games I have played have knocked it out of the park without me having to use 3rd party software" (P68)*

These systems vary but can include automatic subtitling systems such as live captioning by Windows [6], or audio visualisers. An example used was a sound amplifier/booster;

> *"I use a external sound application which helps makes specific noises louder for my needs to catch sounds like footsteps"* (P86)

These systems come with their own faults and issues with their implementation. One of the largest downsides to these third party systems is that within some games and genres, such as various competitve games, their use is outright not allowed and the use of them can result in players being banned from playing.

These two subthemes aim to show the continued prevalence of such a strong issue that excludes players to such an extent that they do not play those games at all. Within the context of the other themes shown in this work, there are a great many solvable issues present in the realm of audio accessibility. With many players stating that they would entirely avoid a game if it didnt have subtitles available to them, the simple issue is to provide for these issues.

These arent issues that are only present in small games with tight budgets and low development time. Though some indie developed games were mentioned, like '911 dispatcher', a great many contemporary AAA games were also mentioned. Games like 'The last of us 2', 'Grand Theft Auto V', 'Halo Infinite', are multi-million dollar ventures. The lack of basic access to be known and implemented across these games is . Even eSports and competitive focused games, that draw in millions per year , have these issues, like 'Counter Strike, Fortnite, Call of Duty','Overwatch'. Though these games have a strong competitive theme to them, they also aim to bring in as many players into their competitive scene as they can.

4.2.2 Text based Audio Accessibility

One system that has been in use across audiovisual media for decades is subtitles, and video games are no exception . Subtitles have been called for by the d/Deaf community as bare minimum access for many years . Subtitles in standard audiovisual content are now more often mandated, such as with OFCOM for the UK and the European Accessibility Act (EAA) for Europe, [7]. As of the timing

[6] `https://www.microsoft.com/en-us/windows/tips/live-captions?msockid=0c3335843ebd634d153b27d13f9a6219`

[7] This update to the European Accessibility Act, came into effect after the current survey's data collection and analysis

of writing, the EEA does not specifically mention traditional video games, and only affects standard audiovisual content.

However, a large portion of our participants [n=33] mentioned issues pertaining to subtitles, captions, and text based options. With other participants [n=10], mentioning captions in relation to specific games that meet their expectations when other games do not provide captions.

> *"[s]ubtitles are not available at all and I could not understand dialogue"* (P78)

Having the ability to turn on subtitles is often seen as the bare minimum access option. Yet as we can see here, a huge portion of people still find that they are not available to them across all games they want to play. The fix here, as plainly stated, is

> *"for every game to have subtitles"* (P99)

Visibility We found a host of issues brought up within text based accessibility that are often present across all forms of media. These focused on the visibility and obscuration of captions, i.e. how easy they are to see, to read, and how much of the screen they cover (and the impacts upon that). These issues have been well documented across various other pieces of research (**?**), particularly in the standard Television and movies domain (**?**). These same issues are heavily present in the video game media format, and the effects they have upon the games played. Out of our 100 participants, 14 participants directly mentioned bad subtitling practices in relation to their visibility. All discussed how scaling of text on screen, in relation to font size, scaling, placement, and line length, very negatively impacted their experience.

> *"Wolfenstein II has the worst subtitles of any game I have ever played.. too small, bad contrast too long sentences"* (P3)

Some games try to present captions as a diegetic part of the gameplay, creating a font or stylised caption that fits the games world as compared to those that provide a more readable and directly usable font.

> *"they put a "glow" affect on the letters to make them look computerized"* (P87) *"dyslexic font made it easier to read and engage"* (P66)

These are often used as an aesthetic choice, prompting for looks and style over usability. These types of captions are not inherently bad, and may improve the experience of many players, bringing them more into the games world with its diegesis. However, having this as the default option, with no standardised alternative does not provide the accessibility required by captions. Captions are first and foremost, an accessibility practice, and by default should provide the most usable experience for players.

Accuracy Another focus point of subtitles implementation is to ensure they are correct. Providing inaccurate subtitles can be just as inaccessible to DHH players as not providing any subtitles at all. Across standard audiovisual media, those who use subtitles often prefer them to be verbatim (**??**). This is echoed by our participants:

> *"Subtitles that match are great - I hate when a word has been shortened"* (P14)

Game developers may believe that using a cheaper system like machine translated subtitles are the easy answer to this issue. However, unless these are checked over to be entirely correct then they can reduce player enjoyment, and are not suitable replacements to hand-created subtitles. With P89 stating that games captions were hard to understand because the captions:

> *"were made with a translator"* (P89)

The uniqueness of gaming Our participants showed interest in more contextual information being provided in their captions. Due to the interactive nature of video games, the necessity of various audio cues to gameplay, and non-main character speech shows their required proclivity for inclusion in captions. New research de Lacerda Pataca et al. (2023, 2024) is emerging showing that emotional expression can, and should, be shown within captions. Though shown in only a TV and movie context in research so far, games will also heavily benefit from presenting tonal, emotional, and other vocal context based information. This helps d/Deaf players remain immersed in the emotional connections to their games.

In addition, with new genres, ways to interact, and different gameplay elements coming in year by year, we must consistently review how our current understanding of text based accessibility in relation to gaming. With a focus of current legislation, research, and guidelines focusing on non-interactive media (e.g. the BBC captioning guidelines), we must identify how these are affected by the nuances of gaming.

Though it can be argued that preferences will remain similar to standard audiovisual media (**?**), some research argues that there may be larger differences in preferences in certain gaming situations (**?**).

Overall Text Based Comparing our results to the Game accessibility guidelines, many basic issues still persist. These include; quality and translation issues of captions, visibility of text, and the physical lack of caption availability. The issues presented by our participants show that even the GAG basic guidelines are not being met in a satisfactory way for our participants. Subtitles are not being provided at all, let alone for "important speech" or "supplementary speech". When it comes to providing captions for "significant background sound", "indication of who is speaking", and "presentation of subtitles/captions

to be customised". While research surrounding best captioning practices continue to improve, and accessibility guidelines are brought up to date on modernistic ideals, these are not thoroughly implemented within games. The 'state of the art' may take years to implement but the data presented within this paper show that even the basic issues, those that are more simple and standard to implement, are not being followed. This may be due to lack of legislation surrounding the enforcement of these guidelines. In traditional audio-visual media in the UK, captioning guidelines are enforced by OFCOM, with heavy penalties and fines for those that do not comply. It may be that the gaming industry requires such heavy handed enforcement to ensure best accessibility practices are met en masse.

4.2.3 Audio mix and sound settings

Modern video games typically have three major volume settings: Dialogue, Ambience/Music, SFX (Sound Effects). This is stated as the standard within the Game Accessibility Guidelines. We purport that this does not provide enough granularity, especially in the modern gaming sphere as stated by P6 and P9

> *"it came out in 2021, only 3 sound options is crazy"* (P6)

> *"There is no option for footsteps volume or more complex audio settings"* (P9)

One readily deployable fix for this option may be to introduce optionality to players.

> *"A better way to change the sound volume per category"* (P52)

Other participants followed the idea of manual configuration of sounds into its deepest forms, asking for some form of sound effect isolation. The use of sound effect isolation would allow players distinct control over the volume of certain specific sounds. The ability to isolate sounds, can be largely beneficial to those who need assistance with hearing a single important sound. This can be useful for games where there are a few gameplay relevant sounds that players may want at a much higher volume than their standard sounds.

Variations of Audio Mix Issues Not only is the lack of options perceived as the major concern for DHH players, but the implementation and segmentation of sound into these settings. Issues within audio mixes appeared in a few different ways;

- games where the same volume setting will be louder or quieter in different areas.

> *"the volume is either really loud or really quiet depending on where you are or what you are doing so you are constantly having to change the settings."* (P36)

- Games where multiple sound items on the same setting are not correctly equalised

> *"you have to hear the footsteps but the audio track of the shots is the same and the sound is too loud but if you turn it down you don't hear the footsteps"* (P23)

- Games where gameplay focused sounds are drowned out by unrelated sounds

> *"[. . .] couldn't really hear the voices but heard the music and sound effects causing me some issues"* (P72)

- Games where many noises overlap and vie for the players attention

> *"It feels like there's too much noise everywhere in the game and it's not mixed properly"* (P60)

Competitive Gaming As many competitive FPS games rely on hearing very specific sounds, this issue was exemplified and therefore mentioned by a large portion of our participants [n=] This could be due to these games having a strong reliance on certain sounds, and the preservation of higher quality audio mixes is more relevant.

Within competitive games that have a team-based element, this issue is present within the communicative aspect. Participants stated that audio settings for communication was often much less granular. This made it hard to equalise the volume of voice chat audio of other players.

An example brought up by multiple participants was the competitive team-based FPS 'Overwatch'. Like in other competitive team based FPS games, passing information quickly to teammates is an important part of the game, making voice chats quite hectic:

> *"overwatch – everyone yelling over each other"* (P66)

Due to this environment, some participants found that it can be hard to equalise the volume of voice chat with the game itself

> *"I find it hard to balance built in voice chat with the multiple sound effects of the game"* (P19)

Participants identified that granularity and customisability of each player was integral to creating an accessible audio environment here. Having both overall control of the volumes and a manual individual control over each player was beneficial to curating an easier voice chat communication experience.

We also noticed participants state that in addition to mono sound options, it would be useful to be able to adjust the balance of audio so that one channel is louder than the other:

> *"[T]here is no way to adjust the sound intensity between headphones to determine which one should play louder. if you increase the sound level, the whole thing increases"* (P22)

(P22). These settings can be used primarily by those with unilateral hearing loss, as their hearing in one ear may be significantly reduced while the other is of a good level. Without a balance option, these players have to either not hear on one side or have the volume too loud for the other side.

One potential solution to the audio mixing problem was to implement a "[l]istening distance" (P89) setting option. This would allow players to set a preferred distance so sounds within that distance are louder and more well-defined to the player, allowing for easier acquisition of information. For example, if a player is very close to a non-player character who is talking to them, then the ocean sounds in the distance would be much further reduced to make it easier to hear.

Overall Audio Mix Our results underscore the importance of more optionality and customisability within sound settings. The current standard of 'Speech, effect and background' has been shown to not be satisfactory by our participants. While modern games are meeting this current standard, players do not find this an acceptable experience. Therefore more detailed audio options must be implemented in games. When designing and categorising audio into settings, it is important for developers to build audio groupings in a way that can be understood by players. Game developers should create audio groupings by the use and importance of the sounds. This will allow players with reduced hearing to increase the volume of gameplay relevant sounds to more easily interact with the games systems. Game developers should allow the player to adjust volume of overall groupings of sounds, while also allowing them to adjust smaller, more specific sub-groups and, in some cases, individual isolated sounds.

Future research in this area could explore the effects of having a contextualised sound settings menu. While it is common practice currently to provide an example of the sound item whose volume is being changed, this provides little to no contextualisation of how loud that sound is in comparison to the other sounds and the game overall. This could be implemented as an in-context preview: an auralization that the player can run that will play a 5-10 second clip of the game exemplifying all the different sounds in an example of their context in game and thus their volumes in relation to each other. This will help players reduce wasted time of opening their settings, changing volume, testing in game for a few minutes, then re-opening and repeating; as well as having to go through this and change settings when entering a new zone or gamespace.

4.2.4 Audio as a necessary mechanic: Modalities of representation

A recurring theme across many responses was the treatment of audio as a necessary game mechanic. In many titles and genres, crucial gameplay information

is communicated primarily, or exclusively, through sound. When no alternative cues are offered, this puts d/DHH players at a fundamental disadvantage, especially when these audio focused mechanics are integral to the gameplay experience. This issue was most strongly associated with the 'FPS (First Person Shooter)' Genre and 'MOBA (Multiplayer Online Battle Arena)' and other competitive based genres, where players said that the ability to play the game well and compete on a comparative level to others, you must be using audio.

> *"In multiplayer games and my hearing loss getting worse I feel that the advantage is to hearing players."* (P55)

The general call to action from our participants was in the form of visual modalities,

> *"More visual prompts would be helpful in many games"* (P70)

(P70) Though by far the most mentioned, this is not the only alternative modality to make these audio based mechanics usable for d/DHH players. Game developers should also heed the contextual use of these mechanics in their games to ensure alternative modalities are balanced and competitive to use.

Issues of Audio reliance Some of the participants who mentioned that audio is a necessary mechanic felt that this situation was most challenging due to the information provided in audio being critical to gameplay with no alternative way of identifying that information.

Our participants commented on the specific application of spatial audio being used to direct the player, which while not exclusive to the team based competitive gaming genre, is often a mainstay in their gameplay. The main example of this being used is to allow players to identify where enemy players are at any given time by hearing the distance (through volume), and direction of their footsteps, gunshots or other sounds.

This is a mechanic that many d/Deaf players cannot interact with, and with this audio mechanic being so ingrained into the core gameplay, therefore are unable to compete to the same level **??**, by definition they are disadvantaged by the game itself.

In these competitive FPS scenarios, it is important to be able to quickly identify where the enemy players are and react based on the audio cues enemies make. Without these audio cues, players were unable to identify the direction of the sounds and so would be caught off guard:

> *"most of the time the enemies came running from our backs and it was imperceptible to hear their footsteps"* (P71)

How can Modalities assist Though the information presented through audio based mechanics is often necessary within games, this does not mean that it is the only possible way of presenting that information.

Visual based modalities were the most requested option in relation to this issue among players.

> *"proper visual cues or alternative signals"* (P95) *"audio cues displayed on screen"* (P85) *"visual cues for audio cues for bosses also directional cues for directional audio cues"* (P68)

The quality of these visualisations should also be focused on, with the level of detail of knowledge passed through them being equitable to their auditory comparisons. These audio cues, within the FPS genre for example, are used to determine the 'what and where' of any given sound.

> *"Moments in the games [sic] you can hear people walking around on surfaces that have no text cues to identify. This is often a feature of the game with [sic] being able to walk slow and fast to make different noise levels and or equipping different types of shoes to soften sounds"* (P55)

Even with basic implementations of directional audio cues, these will present only some of the necessarity information granted by their audio counterparts

One game that was reported to be well equipped in this scenario was Fortnite Games (2017). This was due to its radial dial visualisation that reported the sound, what the sound was, the direction, as well as the volume (shown through the size of the cue) to indicate distance.

> *"fortnite-like visualization of where the shots and steps come from"* (P20)

These style of cues have been shown to be helpful in these gaming situations **?**Haddad and Strand (2019).

Without these alternative modalities, DHH players will always be at a disadvantage, especially within the competitive scene. Although there were worries about how implementing these kinds of settings could affect the game balance.

> *"it would be easy for people with normal hearing to abuse these settings to take advantage of this."* (P90)

Previous research shows that while it helps bridge the disadvantage for d/DHH players, it does not detract from the hearing player experience **???**.

The pervasiveness of this issue specifically within this genre is well documented and understood by d/DHH communities

> *"I have to say that these [directional audio] are problems that are found in FPS games in general and in particular in online competitive ones."* (P90)

Though it is not the only game genre where **Audio as a necessary mechanic** exists. Our participants also identified many other genres where the effects of this are just as severe.

These ideas also go into the MOBA genre, a heavily researched area .

> *"you need to hear the sounds of the champions sometimes to help you in the game"* (P7)

There are often benefits of hearing the voicelines of different characters in the game. When they cast different abilities, they will say a specific line just before or during the initial stages of using the ability. Reacting to the voiceline can give a player an extra few moments to defend, move or counteract the ability. The inability to hear this voiceline, therefore means players lose out on those potential few extra moments and thus are at a marked disadvantage.

Though we will not identify every genre and every game mechanic that use audio as necessary mechanics, it is a present marker in a wide variety of game experiences. Though most pervasive within those genres as detailed, this is an issue that persists into gaming as a whole. The last decade has shown an increasing importance of spatial audio within games and VR experiences Broderick et al. (2018). This is exacerbated by the rise in esports in games leading to more publicity of these genres and a higher playerbase. These games demand higher situational awareness, and quick reflexes based on audio cues pushing the spatial audio to even further importance.

Our study builds upon the current understanding of player needs in visual cues by showcasing how prevalent these issues still ares. Our results show the frustration these players experience from not being able to compete in these games.

Our results showed that not only was there an imbalance in the lack of directional information but also a lack of contextual information. Game developers should ensure that when presenting information in a visual format, that they account for all gameplay relevant parts of the audio information they are translating. This study shows that there needs to be an equitable experience for those using visual cues to those who do not. For game balance preservation, information presented must be equitable in all circumstances. For a hearing player, a sound not only identifies what the noise is, but where it is coming from, and contextual information pertaining to that sound. The simple footstep sound can provide information on what character is being played, how fast they are running, in what direction, on what surface, etc; whereas a directional arrow only shows a 'sound' and a direction.

Communication Another mechanic that is often necessary and based on audio is the voice chat feature. Again, this feature is mostly found within competitive team-based games, such as FPS' like Call of Duty and CS:GO but is found within other competitive games like MOBA 'League of Legends' and even non-competitive, social games like 'Grand Theft Auto Five'. The use of voice chat in competitive scenarios is often chosen as quick communication is often needed to pass information along to team-mates. The inability to partake in this feature greatly disadvantages players, leading to frustration and even social isolation.

> *"Most teams use microphones to communicate but I find it very difficult with too much noise from too many people, so I now avoid these type of games!"* (P63)

Those that choose to keep playing these games are then faced with the difficult proposition; Try and use voice chat, or use a text chat that is slower and often more cumbersome.

> *"the texting option in game is not user friendly should almost have an external keyboard"* (P21)

Contemporary games have explored the use of optionality in communication, providing more ways to share information past voice and text.

> *"you have an option to do a voice chat with people in your team. And different type of pings in-game and a built in text chat"* (P41)

Participants stated they felt more satisfied if they could choose how they could communicate with other players rather than being forced to use a single system that was implemented.

Bringing an overlap to text and voice chat is a difficult prospect. Having a voice to text option built-in for players may provide some alleviation. Current third party systems, like the Microsoft Live Captioning system, are focused on the receiving parties side of communication, and thus do not make affordances about how many people are talking, and who is saying what. This can create an amalgamation of sentences spoken at the same time, that is hard to parse for the reader. If games were to instead use speech to text on the speakers side, it can more easily differentiate speaker identities. Similarly, on the senders side of communication, many hearing players exclusively use voice chat, meaning that they may not see text chats from their DHH teammates. Providing a text to speech option may help alleviate this issue in some cases, alerting hearing players of their d/Deaf counterparts messages.

In relation to non-verbal communication, like emotes and pings, research Leavitt et al. (2016) shows the benefits of these tools for the standard player experience. Further research should investigate how these tools can be implemented in such a way that provides an equitable communication experience as a replacement for vocal communication.

5 Conclusion

Audio accessibility has been a recognised concern within the gaming sphere for years, yet our survey indicates that many of the problems thought to be solved remain unmet in today's titles. Basic features like: high quality, customisable captions; fine grained audio categorisation; reliable communication tools, are still too often absent, incomplete, or of low quality. Although industry guidelines exist, they provide a generalised discussion point focused approach. Their voluntary nature and lack of enforcement mean compliance and acceptance is inconsistent at best. Our participants repeatedly encountered issues that have been long documented, and should be far better in the modern day. We also described more novel frustrations, showing the importance of audio in contemporary gaming, such as communication where non-verbal communication and

its affects on gameplay remains under-researched. This issue is relevant now more than ever with the team based competitive shooter game genre gaining a larger playerbase and competitive scene over recent years. Our findings reveal that, for the players of the games, audio accessibility has not kept pace with the technical possibilities, research, or potential design space.

Modern games have made huge jumps forward in providing good audio accessibility. However, there is still a lack of optionality and customisation within these features. The lack of options available to participants shows the need for adoption of new innovative ideas. Our participants identified the lack of control over these options as heavily detrimental to their experience. We should understand the variance in deafness and cater to that variance by providing users more control over systems in games.

Game developers should work to not only include accessible options, but ensure they are built-in borne accessible designs. Similarly, platform holders, such as Xbox, Sony and Steam, should explore mechanisms for incentivising, and potentially mandating, accessibility compliance. Only by treating these old issues as urgent design priorities, rather than optional extras, can we ensure that video games become a truly equitable experience. Without stronger industry regulation and enforcement mechanics, basic audio accessibility will continue to stagnate, depriving DHH players of the gaming experiences so many take for granted.

6 Acknowledgements

We would like to thank the participants for providing their personal experiences and partaking in this research survey. We thank the School of Computer Science and Informatics at Cardiff University for funding this research.

References

A. Al Amin, A. Glasser, R. Kushalnagar, C. Vogler, and M. Huenerfauth. 2021. Preferences of deaf or hard of hearing users for live-tv caption appearance. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 12769 LNCS (2021), 189–201. https://doi.org/10.1007/978-3-030-78095-1_15 ISBN: 9783030780944.

Yael Bat-Chava. 2000. Diversity of Deaf Identities. *American Annals of the Deaf* 145, 5 (Dec. 2000), 420–428. https://doi.org/10.1353/aad.2012.0176

Larwan Berke, Khaled Albusays, Matthew Seita, and Matt Huenerfauth. 2019. Preferred Appearance of Captions Generated by Automatic Speech Recognition for Deaf and Hard-of-Hearing Viewers. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA*

'19). Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3290607.3312921

Virginia Braun and Victoria Clarke. 2021. One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology* 18, 3 (July 2021), 328–352. https://doi.org/10.1080/14780887.2020.1769238 Publisher: Routledge _eprint: https://doi.org/10.1080/14780887.2020.1769238.

James Broderick, Jim Duggan, and Sam Redfern. 2018. The Importance of Spatial Audio in Modern Games and Virtual Environments. In *2018 IEEE Games, Entertainment, Media Conference (GEM)*. 1–9. https://doi.org/10.1109/GEM.2018.8516445

Luke Brook. 2017. *A sound idea: An investigation into accessible video game design for the deaf and hard of hearing*. Ph. D. Dissertation.

J. Butler. 2019. Perspectives of deaf and hard of hearing viewers of captions. *American Annals of the Deaf* 163, 5 (2019), 534–553. https://doi.org/10.1353/aad.2019.0002

J. Butler. 2020. The Visual Experience of Accessing Captioned Television and Digital Videos. *Television and New Media* 21, 7 (2020), 679–696. https://doi.org/10.1177/1527476418824805

Shelly Chadha, Kaloyan Kamenov, and Alarcos Cieza. 2021. The world report on hearing, 2021. *Bulletin of the World Health Organization* 99, 4 (April 2021), 242–242A. https://doi.org/10.2471/BLT.21.285643

Caluã de Lacerda Pataca, Saad Hassan, Nathan Tinker, Roshan Lalintha Peiris, and Matt Huenerfauth. 2024. Caption Royale: Exploring the Design Space of Affective Captions from the Perspective of Deaf and Hard-of-Hearing Individuals. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24)*. Association for Computing Machinery, New York, NY, USA, 1–17. https://doi.org/10.1145/3613904.3642258

Caluã de Lacerda Pataca, Matthew Watkins, Roshan Peiris, Sooyeon Lee, and Matt Huenerfauth. 2023. Visualization of Speech Prosody and Emotion in Captions: Accessibility for Deaf and Hard-of-Hearing Users. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3544548.3581511

Square Enix. 2010. *Final Fantasy XIV*.

GAG. [n. d.]. Game accessibility guidelines | A straightforward reference for inclusive game design. https://gameaccessibilityguidelines.com/

Epic Games. 2017. *Fortnite*.

Playground games. 2023. *Forza Horizon 5*.

Georgina Guillen, Henrietta Jylhä, and Lobna Hassan. 2021. The Role Sound Plays in Games: A Thematic Literature Study on Immersion, Inclusivity and Accessibility in Game Sound Research. In *Proceedings of the 24th International Academic Mindtrek Conference (Academic Mindtrek '21)*. Association for Computing Machinery, New York, NY, USA, 12–20. https://doi.org/10.1145/3464327.3464365

David Haddad and Casper Strand. 2019. *Visual Substitutes for Audio Cues - Providing situational awareness for players with auditory disabilities*. Malmö universitet/Teknik och samhälle. https://urn.kb.se/resolve?urn=urn:nbn:se:mau:diva-20123

343 Industries. 2014. *Halo: the Master Chief Collection*.

Alex Leavitt, Brian C. Keegan, and Joshua Clark. 2016. Ping to Win? Non-Verbal Communication and Team Performance in Competitive Online Multiplayer Games. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. Association for Computing Machinery, New York, NY, USA, 4337–4350. https://doi.org/10.1145/2858036.2858132

Juhoon Lee, Seoyoung Kim, Yeon Su Park, Juho Kim, Jeong-woo Jang, and Joseph Seering. 2025. Less Talk, More Trust: Understanding Players' In-game Assessment of Communication Processes in League of Legends. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–17. https://doi.org/10.1145/3706598.3714226

Ming Ouhyoung, Jiann-Rong Wu, Wu-Nan Tsai, Tzong-Jer Yang, and Chung-Hsi Huang. 1995. A Force Feedback Joystick and Its Use in PC Video Games. In *Proceedings of International Conference on Consumer Electronics*. 326–. https://doi.org/10.1109/ICCE.1995.518008

John R. Porter and Julie A. Kientz. 2013. An empirical study of issues and barriers to mainstream video game accessibility. In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, Bellevue Washington, 1–8. https://doi.org/10.1145/2513383.2513444

George Powers, Vinh Nguyen, and Lex Frieden. 2015. Video Game Accessibility: A Legal Approach. *Disability Studies Quarterly* 35, 1 (Feb. 2015). https://doi.org/10.18061/dsq.v35i1.4513 Number: 1.

Katja Rogers, Matthias Jörg, and Michael Weber. 2019. Effects of Background Music on Risk-Taking and General Player Experience. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '19)*. Association for Computing Machinery, New York, NY, USA, 213–224. https://doi.org/10.1145/3311350.3347158

Jose Salazar, Yasuhisa Hirata, and Kazuhiro Kosuge. 2016. Motion guidance using Haptic Feedback based on vibrotactile illusions. In *2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 4685–4691. https://doi.org/10.1109/IROS.2016.7759689 ISSN: 2153-0866.

Björn Schuller, Stefan Steidl, Anton Batliner, Felix Burkhardt, Laurence Devillers, Christian Müller, and Shrikanth Narayanan. 2013. Paralinguistics in speech and language—State-of-the-art and the challenge. *Computer Speech & Language* 27, 1 (Jan. 2013), 4–39. https://doi.org/10.1016/j.csl.2012.02.005

Hanns W. Tappeiner, Roberta L. Klatzky, Bert Unger, and Ralph Hollis. 2009. Good vibrations: Asymmetric vibrations for directional haptic cues. In *World Haptics 2009 - Third Joint EuroHaptics conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*. 285–289. https://doi.org/10.1109/WHC.2009.4810863

Greg Wadley, Marcus Carter, and Martin Gibbs. 2014. Voice in Virtual Worlds: The Design, Use, and Influence of Voice Chat in Online Play. *Human–Computer Interaction* 30, 3-4 (2014), 336. https://doi.org/10.1080/07370024.2014.987346

Angel Walia, Prakhar Goel, Varnika Kairon, and Mayank Jain. 2020. HapTech: Exploring Haptics in Gaming for the Visually Impaired. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–6. https://doi.org/10.1145/3334480.3381655

Thomas Westin, JaEun Jemma Ku, Jérôme Dupire, and Ian Hamilton. 2018. Game Accessibility Guidelines and WCAG 2.0 – A Gap Analysis. In *Computers Helping People with Special Needs*, Klaus Miesenberger and Georgios Kouroupetroglou (Eds.). Vol. 10896. Springer International Publishing, Cham, 270–279. https://doi.org/10.1007/978-3-319-94277-3_43 Series Title: Lecture Notes in Computer Science.

Bencie Woll. 1998. Cultural and Language Diversity and the Deaf Experience. *International Journal of Bilingualism* 2, 1 (March 1998), 104–105. https://doi.org/10.1177/136700699800200107 Publisher: SAGE Publications Ltd.

Jason Wuertz, Scott Bateman, and Anthony Tang. 2017. Why Players use Pings and Annotations in Dota 2. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, Denver Colorado USA, 1978–2018. https://doi.org/10.1145/3025453.3025967

Thomas Zahnert. 2011. The Differential Diagnosis of Hearing Loss. *Deutsches Ärzteblatt International* 108, 25 (June 2011), 433–444. https://doi.org/10.3238/arztebl.2011.0433

7 supplementary material

Table 2: Hardware used by participants for playing video games

Hardware Used					
Platform	**n**	**Audio Outputs**	**n**	**Audio Config**	**n**
PC	73	Headphones	81	Stereo	78
Mobile Phone	58	Built-In Speaker	51	Surround Sound	33
Nintendo Console	43	Earbuds	26	3D Audio	18
Playstation Console	41	Home Theatre System	18	Mono	15
Laptop	34	None	1	Other	1
Xbox Console	22			Unknown	5
Tablet	16				
VR	12				
Other	3				

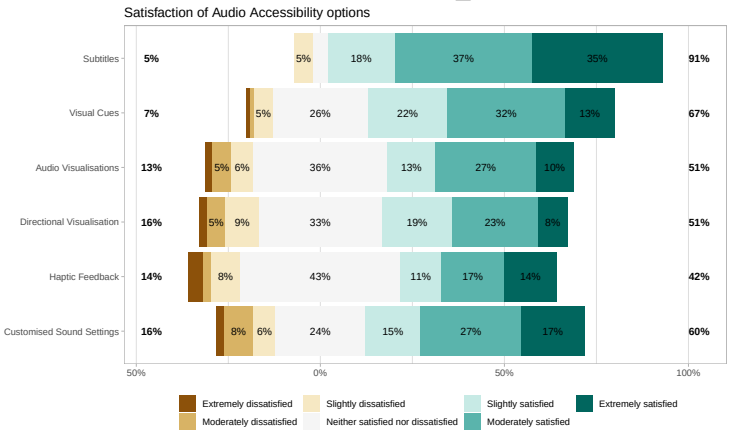
Table 3: Participants' experiences of different kinds of gaming experiences and genres

Gaming Experiences	**n**	**Genres Played**	**n**
Single Player	97	Action	86
Casual Multiplayer	75	Shooter	83
Competitive Multiplayer	61	Role Playing Game	79
Massively Multiplayer Online (MMO)	61	Adventure	79
Online Party Games	57	Racing + Sports	70
Team Based Competitive Multiplayer	49	Fighting	53
Couch Coop	44		
Local Party Games	32		
Esports / Tournaments	13		
Other	1		

Table 4: Participants' experiences of multiplayer games

Multiplayer Communication	**n**
I play multiplayer games and communicate while playing	60
I don't Communicate but do play Multiplayer games	35
I do not play Multiplayer	5

Figure 1: Participant Satisfaction with Audio Accessibility Options



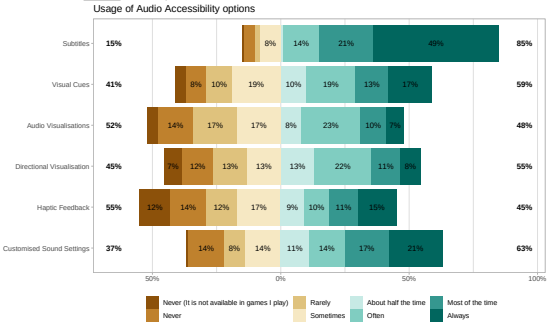
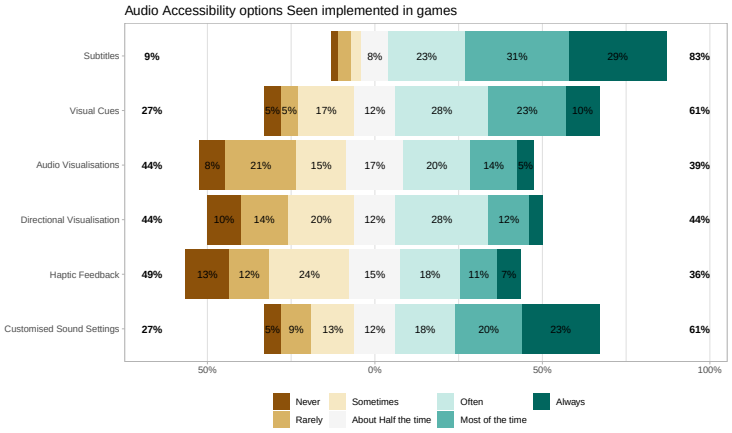


Figure 2: Participant Usage of Audio Accessibility Options

Figure 3: Perceived Audio Accessibility Implementation



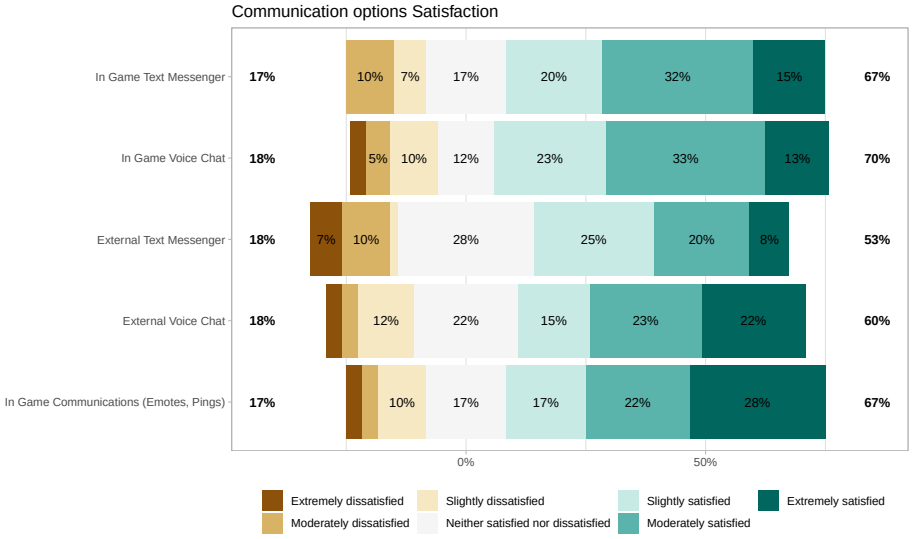


Figure 4: (Does Communicate)

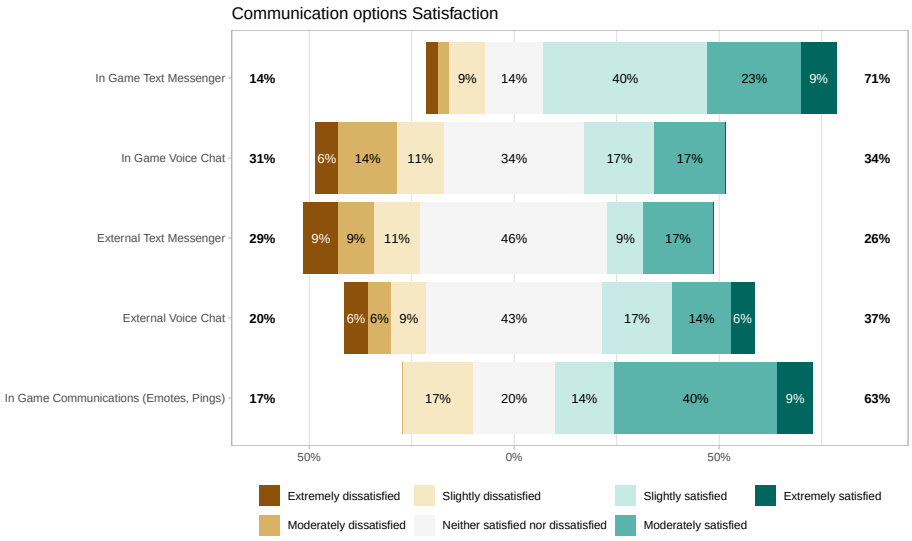


Figure 5: (Does Not Communicate)

Figure 6: Participant Satisfaction with Communication Options

Figure 7: Participant Usage of Communication Options (Does Communicate)

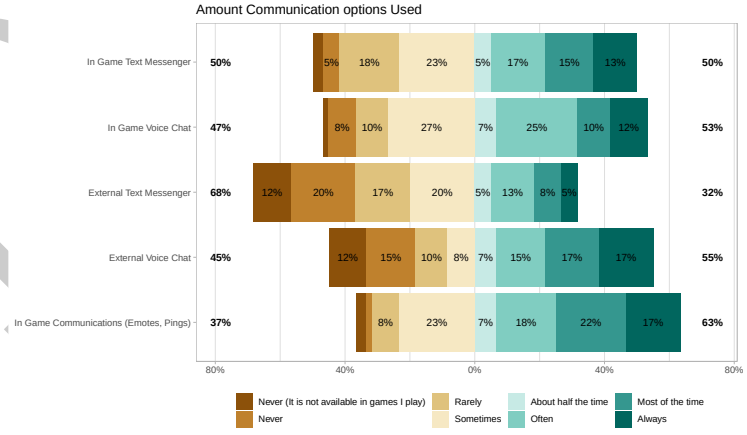


Figure 8: Participant Usage of Communication Options (Does Not Communicate)

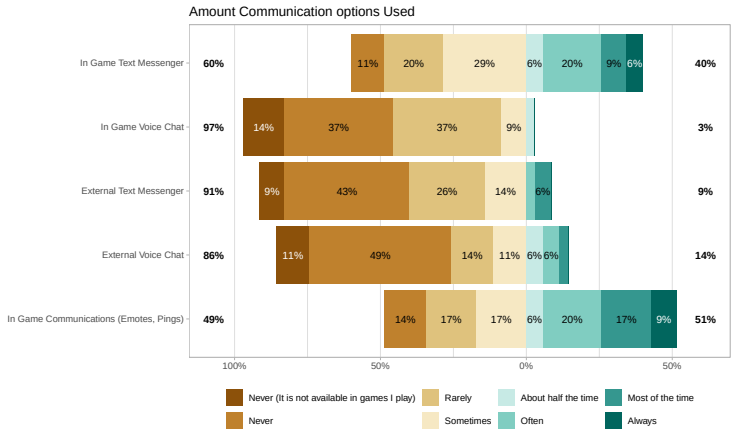


Figure 9: Perceived Communication options Implementation (Does Communicate)

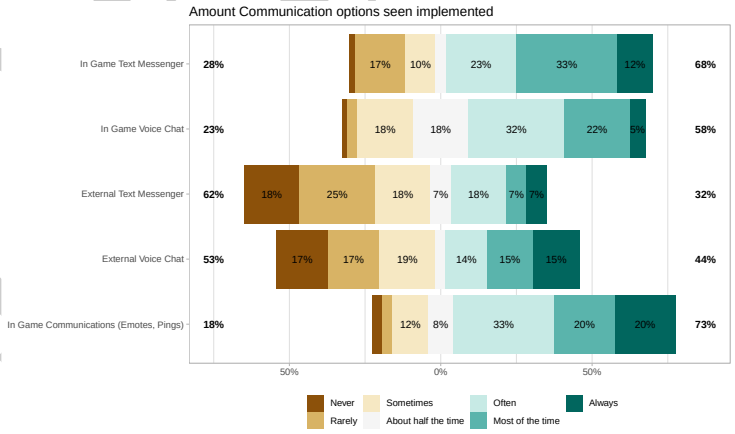


Figure 10: Perceived Communication options Implementation (Does Not Communicate)