Investigation of using directional haptic feedback for localizing sounds in a gaming context

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INTRODUCTION

Many deaf and Hard of Hearing (HH) people can struggle with localizing where sounds are coming from, and the information conveyed in the sound may be inaccessible. This can limit the experience in playing video games and put the player at a disadvantage. An ominous sound cue in a horror game or footsteps of enemies in multiplayer games are some examples vital to be able to localize. In the context of video games, the issue also extends to people with hearing but who may be impaired in other ways, e.g., required to play without sound output. Making the issue not only relevant for deaf and HH people. Designs that map sound directions to visual cues such as arrows have been implemented in many mainstream games previously and the information about sounds may be conveyed with captions.

Research has described that it is possible for people to translate directional haptic feedback to an external location based on where on the body the stimulation occurs (Jones & Sarter, 2008; Visell, 2009). Many previous works have used haptic feedback to create spatial awareness, e.g., for astronauts (Bernard et al., 2017) and aircraft pilots (Cheung & Bouak, 2009) to orient themselves. As waypoint navigation cues for pedestrians (Erp et al., 2005), in vehicle driving navigation (Nukarinen et al., 2015) and many other applications. However, as a recent literature review (Fletcher, 2021) states, sound-localization through haptic feedback has been little studied.

Haptic feedback has been used in game controllers for many years, more as a novelty than as an interface for conveying information. Providing directional haptic feedback in these handheld controllers seem unsuccessful (Granados, 2021). Haptic feedback through a vest has been shown to enhance the player immersion and overall quality of experience for gaming (Eid et al., 2014). In the context of driving, it is suggested that haptic cues can produce faster reaction times, and may have a lower cognitive load, than visual cues (Nukarinen et al., 2015). People with HH have expressed that haptic vests help them perceive and localize sound (Granados, 2021), but there seems to be a research gap around whether, or how much, a haptic vest could substitute hearing for sound localization.

Thus, the problem is that it has not been ascertained if directional haptic feedback could substitute the auditory sensory system in localizing sounds. In a video gaming context, solving the problem could create accessible and equitable gaming experiences for people unable to hear audio cues. This study will investigate the following research question:

RQ: How well can directional haptic feedback, through a haptic vest, perform in localizing sound cues compared to the auditory sensory system, in a 3D first-person shooter game, in terms of player performance and player experience?

The question is constructed with the PICO framework (Patient/Problem/Population, Intervention, Comparison/Control, Outcome(s)), with components in the question being:

P: localizing enemy sound cues
I: directional haptic feedback
C: auditory sensory system
O: equal player performance and player experience

1 THEORY & SIMILAR WORK

1.1 Accessibility

One motivation for this study is to help increase accessibility in video games. The study defines accessibility as "*the extent to which products, systems, services, environments and facilities are able to be used by a population with the widest range of characteristics and capabilities (e.g. physical, cognitive, financial, social and cultural, etc.), to achieve a specified goal in a specified context.*" (Persson et al., 2015, section 7.3). Furthermore, the study follows the biopsychosocial model of disability that describes disability from biological, individual and social aspects and how they impose limitations on an individual (Barnes, 2011). The International Classification of Functioning (ICF) by the World Health Organization (WHO) is a framework for discussing health and disability through the biopsychosocial model (WHO, 2002).

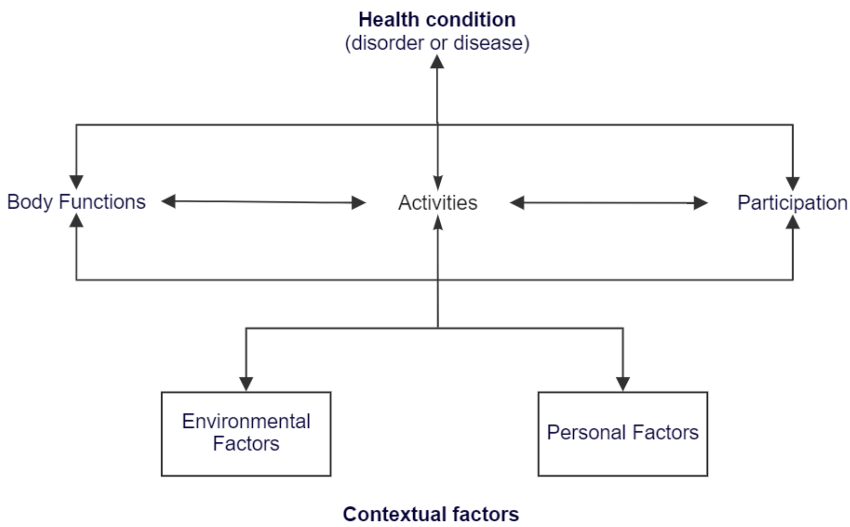

Figure 1 *The components of WHO's ICF (WHO, 2002).*

As Figure 1 shows, disability is viewed as the outcome of interactions between health conditions in the top and contextual factors in the bottom. In the center is activities, the execution of tasks by an individual, which is affected by all the surrounding components. The interactions can both be negative or positive. In the context of this study, the activity would be to play a video game and be exposed to sound cues. Example of inhibiting components could be the absence of audio speakers (environmental factor), damage to the inner-ear (body function) or hereditary hearing loss (disorder).

The study follows a 'design for all' approach, aimed at creating accessibility for the widest population possible. Adhering to the United Nations Convention on the Rights for People with

Disabilities, obligating its states to "*promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity*" (UN, 2006, Article 1). Countries around the world are working more towards ratifying this declaration. In 2000, the Swedish government set a goal of making Sweden accessible to all by 2010 (Regeringen och Regeringskansliet, 2000). Swedish legislation also has a law that prohibits discrimination in any form or situation (Riksdagsförvaltningen, 2008). In 2019 the European Union adopted the European Accessibility Act aimed to make products and services more accessible (EU, 2019). Ratified by the Swedish government in 2021 in "Tillgänglighetsdirektivet" which includes video games, set to apply to products and services on the market by 28 June 2025 (Regeringen och Regeringskansliet, 2021).

1.2 Localizing sounds through haptics

In a doctoral thesis, Granados (2021) examined the impact of directional haptic feedback, through a gamepad controller in a 3D FPS game, for locating where enemies appeared. Granados conducted an experiment, comparing four cue conditions using different directional cues: visual, haptic, both and none. Participants without hearing impairments (n = 39) played all cue conditions in either a no-audio or audio condition. Participants with Hard of Hearing (HH) (n = 4) played all conditions in no-audio. There were no differences in the participants' performance across the cue conditions and visual cues were shown redundant, not affecting the performance. But the small number of participants with HH makes these results unreliable. Furthermore, Granados also performed a pilot user research interview with deaf and HH people (n = 8). The interview indicated that the participants experienced exclusion from games that heavily relied on the players' ability to identify and localize sounds. A few of these participants had used haptic vests to feel sounds and one participant said that it helped them a lot to locate sounds.

Jain et al. (2021) has begun investigating sound accessibility in the context of Virtual Reality, providing a taxonomy and design space for developing visual and haptic substitutes of Virtual Reality sounds. The authors developed two early haptic prototypes and conducted a preliminary evaluation. The first prototype was a haptic torso-belt and the other an app for a smartwatch, controlling its vibrations. The belt is meant to convey several sound characteristics and direction while the smartwatch only gave directional feedback by vibrating twice for sounds locating to the right and once when locating to the left. However, the evaluations did not give any results regarding localization of sounds.

2 METHOD

2.1 Data collection & analysis

The research strategy will be that of experiment. Conducting a within-subjects experiment design with three conditions, being sounds conveyed through solely (1) directional audio, (2) directional haptic and (3) nothing (no audio & no haptic). The participants will be playing a set number of rounds of a first-person shooter game such as Counter Strike. A game where sound localization is vital in combating the opponents. Data representing player performance will be collected as kills, deaths, and lost/won rounds. Struggles to localize the enemies should tend to lead to more deaths and losses. Self-reported data on the participants experience will also be collected via interviews. The data would thus be both quantitative and qualitative. The quantitative data lends itself to statistical analysis and the qualitative data to a thematic analysis.

2.2 Material

Haptic vest was chosen for its apparently increasing availability on the market. Two examples based on vibrotactile stimulation include Woojer at 3500 SEK (https://www.woojer.com) and BHaptics at 3000/5000 SEK (https://www.bhaptics.com). However, more research should be done on the suitability and requirements on the technology for this study. These systems may not be simply ‘plug and play’, conveying sound locations in a suitable manner. Can specific sounds be re-mapped in these systems?

More research would also have to be done to understand what sound cues should be mapped to haptic feedback and how they should be represented as haptics. Also, whether the game proposed can be used with these on the shelf vests. Another simple game would maybe have to be developed, or a vest constructed so that desired mappings could be done. A starting point for requirements on the vest and how sounds should be mapped could be (Jain et al., 2021; Jones & Sarter, 2008; Visell, 2009).

2.3 Population/target group

As the study follows a design for all approach, the population should be as varied as possible. However, as the intention is to compare hearing and haptic the participants need to be able to perceive stimuli in these sensory modalities. Furthermore, as the stimuli will be presented through a video game it is important that the participants have a similar amount of experience with this media to minimize extraneous variables affecting the experiment.

2.4 Ethics

Even though the study has a design for all approach, the study intends to help increase accessibility for people with Hard of Hearing (HH). Not including these representative users in the experiment may be regarded as unethical (Sears & Hanson, 2011). A possible solution would be to have two user groups in the described experiment, one extra group with HH and deaf people only partaking in condition 2 and 3.

3 RESULTS & IMPLICATION

The expected outcomes are that the player performance for the haptic condition 2 will be close to equal to the audio condition 1 and that the participants are positive to the experience of localizing sounds through haptic feedback, answering the RQ. These findings would not be conclusive enough to say that directional haptic feedback can substitute the auditory system in localizing sound in every possible situation, but it would help pave the way for future research.

The findings could have implications in several areas both real-world and virtual. If the expected outcomes are shown in the study, more people would be included in games that rely on sound localization and provide an equitable experience. Similarly in real world applications, this could increase the safety for the deaf and HH in their everyday life. Being able to localize a car horn, emergency siren, etc. People in environments where everyone’s hearing is impaired could be helped localizing certain sounds, e.g., airport ground staff, driving cars or motorcycles, workers in loud construction sites, etc.

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