Haptic system as an accessibility mechanic for hard of hearing and deaf people on video games

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Abstract. *This paper introduces a new haptic wearable system designed for hard-of-hearing or deaf individuals. The system's primary objective is to create an immersive, engaging, and distinctive experience within video game contexts, by incorporating a haptic feedback interface with vibration motors. The system modular approach allows it to be applied in diverse contexts beyond gaming without needing structure changes, as it has a high-level graphic interface, able to create and edit effects regardless of its use.*
The obtained results are very promising to increase the immersion level of deaf people in games and other environments.

1. Introduction

Haptic effects are defined by effects related to the sense of touch; the skin absorbs the effect, and the individual can imply its meaning from it. There are several haptic effects, such as vibration, heat, and force [Danieau et al. 2012]. These effects are used in electronic applications: for decades, mobile devices have used the vibration effect to alert, reassure selections, and notify events in the device. Besides it is also used in video game controllers. Currently, there are features such as a vibration intensity scale to notify the user of different game options and events and haptic feedback, an improvement towards a more immersive experience [Charity 2021].

This work is focused on wearable vibration haptic systems: systems that cover a part of the body, usually the torso and arms, and have many vibration motors scattered across the surface to expand the possible vibration patterns and increase the quantity and quality of the transmitted data for the user, to improve the user experience. This study explores how a haptic system can be an accessibility feature for hard-of-hearing and deaf people, applying it to transmit sound cues as tactile cues.

This work was heavily inspired by research about game accessibility using haptics. Mainly, Granados [Granados 2021], Corrêa *et al.* [Corrêa et al. 2012] and Ho-Ching *et al.* [Ho-Ching et al. 2003] explored the boundaries between how accessibility focused on deaf people is currently done, using mostly haptic and visual cues. They also explored how to categorize sound cues and comprehend their importance to the context, bringing insights and methods to this research.

2. Proposed system

Under specific circumstances, the game activates haptic effects triggers and sends requests to the server, which handles and processes them and sends serial data to the wearable device. This one receives it and redirects it to the vibration motor drivers by Pulse Width Modulation (PWM). Each driver transmits it to the motors, which vibrate proportionally. The player perceives it through the skin, interprets it in the game context, and takes action.

To achieve this course of action, the planned system can be divided into three steps: a wearable interface with serial requests support, an editor interface for creation and edition for haptic effects, and a game implementation for validation.

2.1. Wearable interface

The wearable interface must manage the motors, fit people with different body types, and be easy to assemble and disassemble. The interface receives the input from an external source, a server, and manages it. This application requires low processing but must have several IO ports. The ESP-32 microcontroller [Systems 2023] was chosen for this function.

The control system was based on [Alexandre 2021], which created a driver to amplify the input by PWM and created a scale of motor vibration that can be distinguished when applied to human skin, using the motor 1027 [Vybronics 2023]. For the implementation, some modifications were done to decrease costs and components amount.

It was decided to use 12 motors: six for the torso and three for each arm. A printed circuit board was built for the wearable interface with the control system. The board is fastened on the body and, to avoid direct contact with the skin and ensure security, a 3D-printed case was made. To attach the system to the user, the board and the motors are connected to elastics fastened with velcro. Its measures allow the prototype to fit people with different body sizes. It also can be easily assembled and disassembled.

The firmware was developed for the ESP32 to allow communication between an external resource, the computer, and the wearable. It was defined as eight initial intensity levels, from $0V$ to $3.3V$. The program was developed in C language. There were tests in this stage to ensure the wearable interface quality, the motor application with different intensities, and the best arm and torso module positioning.

2.2. Editor interface

For high-level control of the haptic interface, an editor was developed. The editor can create and retrieve data and has a simple interface that can be manipulated for people without any technical background. To achieve these goals, a two-part model was planned with a server and a graphic user interface (GUI), using React [Walke 2013], JavaScript, and Flask [Ronacher 2010], Python.

The server uses serial communication to transmit data to the firmware, and it is also responsible for handling requests from the GUI or the game. The transmitted data can be both from saved sequences as generated ones, it depends on the user or the game.

The GUI is compounded by three pages. The first one, the homepage, Figure 1, includes functions to test the modules. The second, the editor, Figure 1, is the main feature, allowing the creation of haptic sequences through time, besides the control of the database. The last one, the library, Figure 1, lists and executes all the saved sequences.

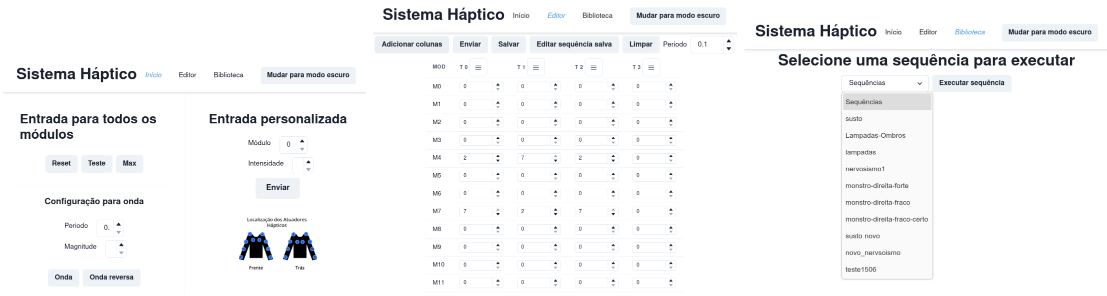

Figure 1. Pages

2.3. Game implementation

The chosen game to showcase the haptic system is based on an indie kind of game called *The Backrooms*, which is an escape-horror game: the player is constantly provoked by sound cues and must escape from a monster in a maze. In this implementation, the monster can only be located by haptic signals.

The planned implementation is a version with four sound mechanics converted into haptic: the flickering lights, the player's wheezing, the monster's sound, and the jump scare. Unity (C# language) was chosen to implement this game. The implementation included a small office-themed maze with the lights constantly blinking and a dark environment. A first-person character controller from Unity implemented the player, with basic mechanics such as walking and running. The game's goal is to find the exit of the maze. A brighter room portrays the exit portal.

It was decided that the monster is invisible because it was hard to choose any monster visually compatible with the game theme. If the monster was invisible, this problem did not exist and the only way to define its location could be by the haptic effects, enriching the user experience and making from this mechanic fundamental to the game, thus the game would be a haptic-visual experience.

The effects were created with deaf volunteers from the university deaf community. Every session to create effects or test the game was conducted in the local sign language. The routine was to explain the effect trigger and its sound through visual analogies, propose an initial sequence, test and change properties of the sequence as frequency, motors used, and intensity levels until the result achieves the objective of the effect, and thus save the sequence in the library.

3. Obtained Results

The results can be divided into wearable interfaces and their reception, creating and adding haptic effects to the game and players' reception.

3.1. Wearable Interface

Figures 2 show a user with the device. The device is based on a set of three pairs of bracelets and a pair of suspenders, crossed in the back and fixed on the belt. In Figure 2, it is possible to see how the straps are positioned with the belt fastened by inward velcro. The crossed straps improve stability and it creates a central space to fix the case with the driver without needing other tools to be placed. All wires extend from the case.

Figure 2. User with the wearable device assembled, front and back view

The system was tested with 12 people, four of whom are hard-of-hearing/deaf. They received the product well, with some complaints about the rough velcro and some size adjustments that were necessary. The users usually could distinguish three levels, compatible with [Alexandre 2021] results. It was observed there were better locations around the same length of the arms and it depends on the player's position and the arms' arrangement. This effect was only observed during the tests phase, but previous research point out different sensibility according to arms arrangement [Murray et al. 1995].

3.2. Creating haptic sequences and adding to the game

The first effect to be created was the flickering lights. The chosen motors were the shoulders ones because they are facing up. The effect lasts about one second, and each motor turns on alternately. They are triggered when the player is under a light.

The next effect was the anxiety feeling. It uses the motors in the arms. The effect applies short pulses for one second in both arms synchronously, similar to the heartbeat. They are triggered every ten seconds, which decreases with each interaction by one, down to four seconds, this behavior creates an uneasy emotion in the user.

The third was the monster effect, including the monster's distance and direction from the player. Six motors were used: the upper arm duo, the back duo, and the chest duo to represent four directions, forward, backward, right, and left. When the monster is distant, the signal is short, weak, and lasts to repeat, and when it is close, the signal is longer, stronger, and repeats itself faster. There are variations to imply the monster's location. The three dynamic properties are redundant to improve the gameplay: if the player does not notice one, the other properties can still represent the information. But if the monster is too close, the signal repeats itself too quickly and it is easier to find the monster. To avoid it, a minimum distance was determined to receive the monster effects. The player does not receive any signal if they are too close and must remember the last monster signal to avoid it until the distance is superior to the range. It makes the game harder and more engaging because the player knows if they get closer enough, they won't be able to identify where the monster is, and the chances of being found by it increase.

These effects use motors that are not shared. Thus the player can connect between location and meaning, observing pattern or intensity only if necessary.

The final effect was the jump scare, it overlaps any other effect executing and it is the most important one. It is a three-step sequence, described by all motors in full, medium, and non-force sequentially. This effect happens when the player and the monster are close enough, and it's the only effect that uses the maximum power of the system. It is accompanied by the screen shook and, after it finished, all the lights were turned off.

The creation and implementation process was very rich and received feedback from all volunteers. The focus was to create easily recognized effects that could improve the experience. During this stage, it was observed the server always overwrites the last effect, turning off any motors used before. This approach made the game harder because the effects are constantly changing among the flickering lights, the anxiety, and the monster effect. In this scenario, the player must be more careful when wandering around.

The modular design of the system created simple methods to insert requests and substitute effects, features used many times to adjust to the opinions of the players. The volunteers were critics of the details to improve the experience and their opinion was the central part to provide a well-received game, as explained in the next section.

3.3. Players reception

After each implementation, some tests focused on checking usability and immersion were performed. The script case was to explain the plot (the player is trapped in the maze and must escape to avoid a monster), to explain each effect, its triggers, and specific actuators, and how the controls work, keyboard and mouse, then the game started.

Usually, the explanation was insufficient to clarify how the system works. As the haptic effects can constantly be changing, the users needed test rounds to learn how to deal with it and understand each effect and its trigger. However, after the test, they quickly comprehended the effects and played the game without problems. It was possible to transmit data about direction and meaning through the skin without any sound to help. The players easily associate each vibration source with its meaning. At the end of each test, no volunteer showed problems understanding the gameplay and the cues. It achieved a secondary goal to create, develop, and test a game based only on haptic and visual cues.

The general public response was positive. Every player was satisfied with their ability to gather and understand each effect, they were responsive to the environment and engaged with the game's purpose. Many players showed interest in playing the game with other maps or testing other game genres with the device.

In particular, the deaf volunteers emphasized how much they appreciated the experience of playing with more information than only visuals, and they were excited about future applications. They commonly showed characteristics such as stress, vigilant posture, and anxiety as planned. They were eager to enjoy.

4. Conclusion

This paper presented a new haptic interface to transmit information through vibration motors, focusing on hard-of-hearing and deaf users. Its structure provides an easy-to-assemble versatile wearable device with an editor able to create haptic events with a high-level graphic interface. The haptic system was able to inform the user and it was proven in a dynamic game setting, being able to transmit meaning. The players were able to quickly understand the haptic cues, and essential information to progress in the game.

As the proposed system is complete with its own hardware and software, it could also be applied in other contexts soon. The editor could be used to create haptic effects to express sound effects in other media types. In the future, the current actuators could be replaced with stronger ones, allowing a larger scale of intensities. Also, it could have more motors to provide more possibilities, including more sophisticated sequences.

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References

Alexandre, I. (2021). Acionamento de motores aplicados a interfaces táteis.

Charity, J. (2021). Video games' sensory revolution: How haptics reinvented the controller.

Corrêa, L. P. D., Coutinho, F. R., Prates, R. O., and Chaimowicz, L. (2012). Uso do mis para avaliar signos sonoros: quando um problema de comunicabilidade se torna um problema de acessibilidade. pages 47–56.

Danieau, F., Lécuyer, A., Guillotel, P., Fleureau, J., Mollet, N., and Christie, M. (2012). Enhancing audiovisual experience with haptic feedback: a survey on hav. *IEEE transactions on haptics*, 6(2):193–205.

Granados, J. A. (2021). *Level-up! Identifying ways to make video games more accessible for deaf and hard-of-hearing individuals*. PhD thesis, Wichita State University.

Ho-Ching, F. W.-l., Mankoff, J., and Landay, J. A. (2003). Can you see what i hear? the design and evaluation of a peripheral sound display for the deaf. pages 161–168.

Murray, W. M., Delp, S. L., and Buchanan, T. S. (1995). Variation of muscle moment arms with elbow and forearm position. *Journal of biomechanics*, 28(5):513–525.

Ronacher, A. (2010). Flask. https://flask.palletsprojects.com/en/2.3.x/. Last Accessed Jun. 22, 2023.

Systems, E. (2023). *ESP32 - Technical Reference Manual*. Shangai, China.

Vybronics (2023). *Coin Vibration Motor VC1027B001D Datasheet*. Vybronics. Last accessed 4 june 2023.

Walke, J. (2013). React. https://react.dev/. Last accessed Jun. 22, 2023.