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Simulation of any Two limitations of the Human Auditory System

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Abstract

The sense of hearing is frequently overshadowed by sight, yet its significance lies in the vast amount of information it provides through sound, which comprises fluctuations or vibrations in air pressure. These auditory cues, including pitch, frequency, etc., termed "sound parameters," are pivotal in understanding the limitations of human auditory perception. This paper presents findings from two experiments aimed at investigating these limitations. To simulate these constraints, the study employs overlapping rhythms and manipulations of sound parameters, implemented through HTML, CSS, and Javascript.

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Introduction

Human Auditory System

Together, the external ear, middle ear, inner ear, and auditory nerve make up the human auditory system, which processes sound. The eardrum vibrates in reaction to sound waves that are collected by the external ear and sent through the auditory canal. The cochlea in the inner ear receives these vibrations through the middle ear bones, and hair cells there transform them into electrical signals. After that, the auditory nerve sends these impulses to the brainstem and auditory cortex, where they are interpreted. People can sense and understand a large variety of sounds because of this anatomical channel, which facilitates contextual engagement, communication, and spatial awareness.

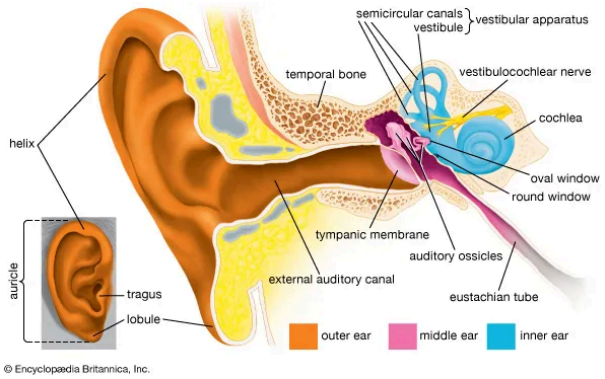


Figure 1: Human Auditory System

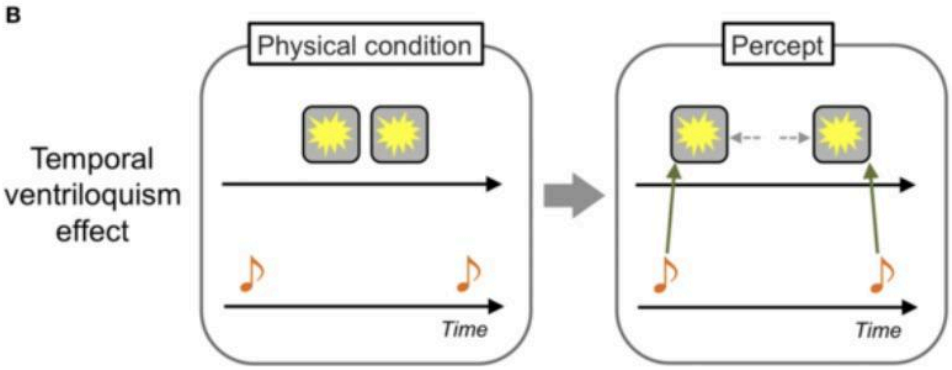
Limitations

The system's sensitivity to sound properties, such as pitch, frequency, amplitude, and duration, is constrained, even though these factors are essential for auditory perception. For example, the auditory system may have trouble differentiating between comparable frequencies or processing sounds with extremely high or low amplitudes. Furthermore, temporal conflict presents a problem since the auditory system has a limited capacity for processing fast changes in sound, which can make it difficult to discern between overlapping auditory stimuli or to perceive exact temporal sequences. This highlights the need for careful consideration in the design of auditory interfaces and systems, especially in contexts where precise timing and parameter differentiation are required. These limitations in sound parameter discrimination and temporal resolution can impact various aspects of auditory perception and communication.

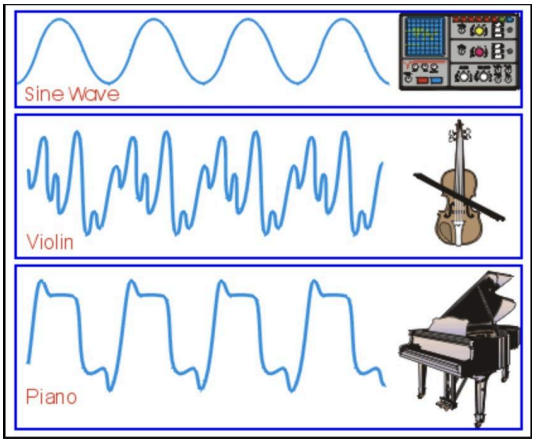
Introduction to the Simulation Implemented

The goal of the study is to investigate and model two basic limitations of the human auditory system: sound parameter limitations and temporal conflict.

Auditory temporal resolution plays a critical role in the everyday experience of listening to complex acoustic patterns[6] which occurs when the auditory system finds it difficult to interpret overlapping auditory stimuli. The project uses the method of playing two different sounds with overlapping rhythms to mimic this occurrence. The research intends to simulate a situation where the auditory system is challenged to effectively perceive and distinguish between several concurrent auditory inputs by providing users with these overlapping rhythms. This offers a firsthand understanding of the difficulties the auditory system has while processing intricate auditory situations, including conflicting sound sources or overlapping conversations.



The project not only focuses on time conflict but also sound parameter restrictions like pitch discrimination. Although the capacity to distinguish between various pitches is essential to auditory perception, the auditory system is inherently limited in this capacity. Users are given two auditory stimuli and asked to choose which of the two sounds has a higher pitch to replicate this constraint. The project attempts to illustrate the difficulties the auditory system faces in accurately hearing and differentiating between sounds based on their pitch, frequency, and other sound properties by putting users through this auditory discrimination task.



Approach to the Solution

The audio simulations are done using the **"Howler.js"**[3] library of JavaScript. With the help of the feature-rich and adaptable JavaScript audio library Howler.js, which allows us to create dynamic and captivating web applications with rich audio experiences. Play, pause, loop the audio, and load the audio are a few of the functions. The library offers consistent audio playback across various mobile platforms and devices because it is optimized for mobile devices.

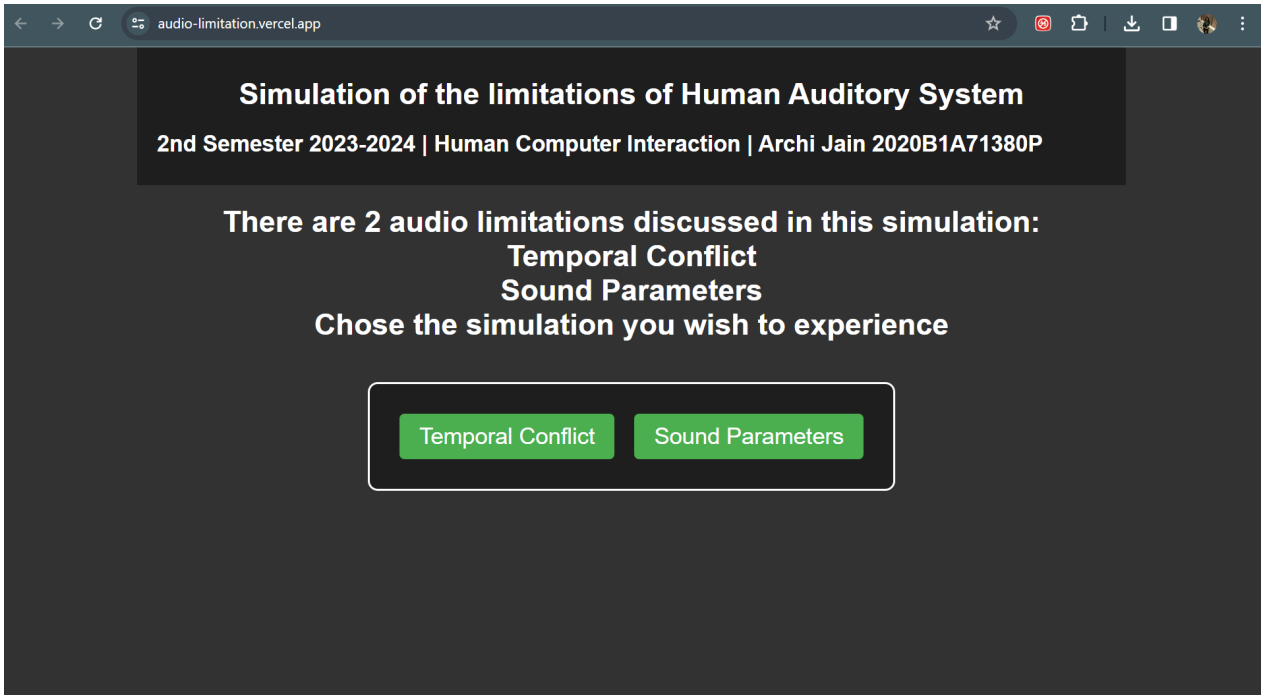
Using the **Web Audio API**,[4] we can manipulate sound parameters directly within the web application. This involved generating sounds with varying pitches, using oscillators and audio sources provided by the API. Additionally, several other effects can also be applied such as reverb and distortion to modify the characteristics of the audio signals. I created dynamic and interactive audio experiences for users, all within the browser environment. This allowed me to craft immersive auditory environments and engage users with rich sound interactions directly on the web platform.

For the design of the menu the following aspects may influence implementation:

1. System Sound Output
2. User's Auditory Capabilities
3. External Noise or Disturbance

Solution Design

The solution is implemented using HTML, CSS, and JavaScript, using the JavaScript library howler.js to create the menu. Deployment of the demonstration was done using Vercel.

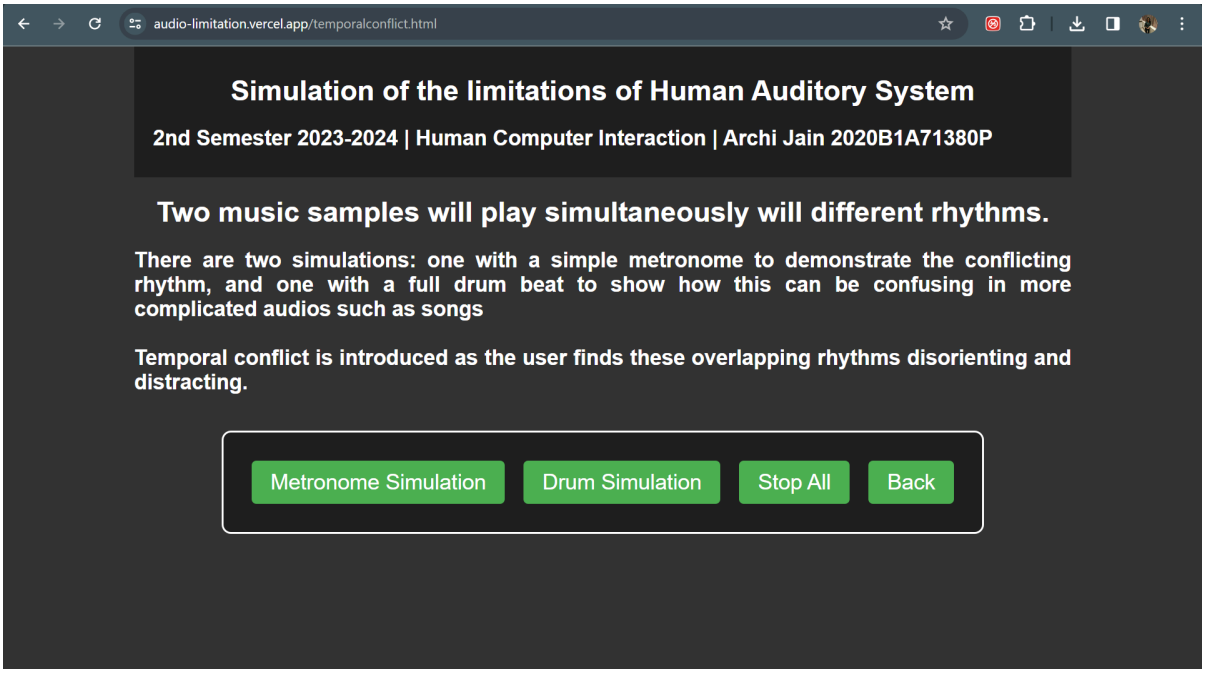


Temporal Conflict Simulation

Howler.js is used to manipulate audio samples to demonstrate how when 2 samples of confliction rhythms are played simultaneously, the auditory system perceives it as discordant and confusing.

This is done with two examples

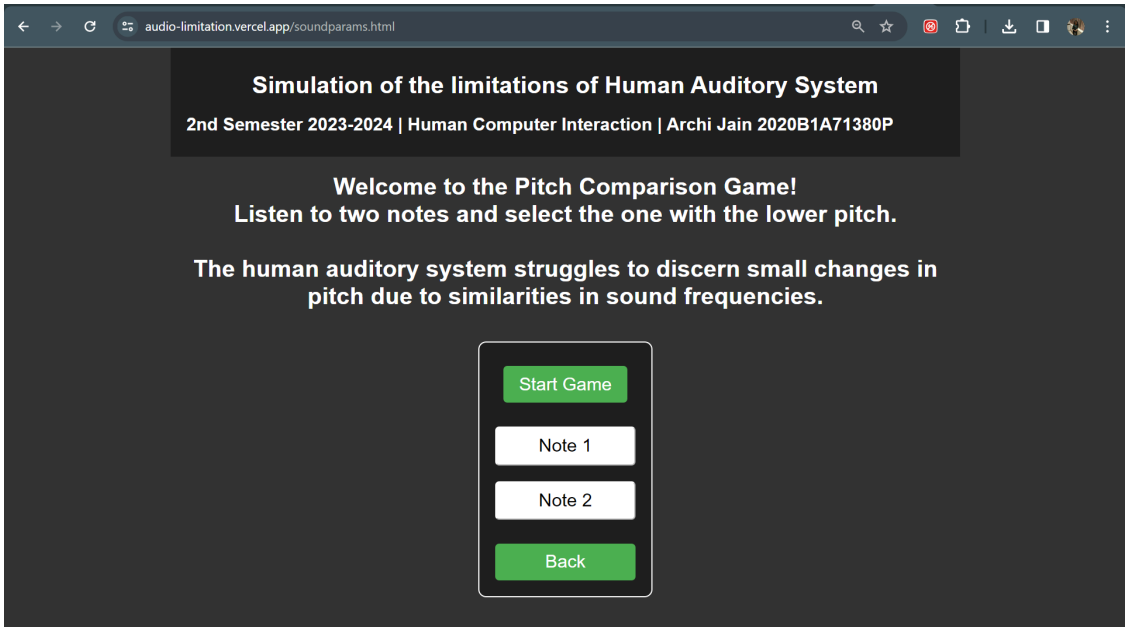
1. A simple metronome - a series of clicks in a consistent rhythm. Two samples are used - one in 4/4 time signature and the other in 3/4 time signature. These clashing rhythms cause a discordant overlap.
2. A sample drum beat - With one drum beat in 4/4 time and the other in 3/4 time, this example illustrates how with more complex audio samples, this problem is further exacerbated, and this effect can be felt even more with full songs.



Sound Parameter

Web Audio API is used to generate two sound samples at different pitches. The user is then asked to choose which one is of lower pitch. The two samples are close in pitch, and thus the user may struggle to differentiate between the two sounds.

The source code for the demonstration is hosted on a public GitHub repository located here.



Conclusion

This project offers an interactive investigation into the limitations and intricacies of the human hearing system. Users are given an immersive experience through web-based simulations and interactive tasks that improve their comprehension of auditory perception and the difficulties the auditory system faces in processing complicated auditory data. The research also emphasizes how crucial it is to take auditory limits into account when designing interactive systems such as cockpits, dashboards, etc., especially in situations where accurate auditory perception is necessary for efficient engagement and communication to avoid conflict in the user's brain hampering the reaction time and response to stimuli.

Important Links

Description	Link
Project Demo	https://audio-limitation.vercel.app/
GitHub Repository Link	https://github.com/archi916/audio-limitation

List of References

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6. "Temporal Resolution" https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2023.1148476/full