

# Using Augmented Reality for Gamified Auditory Training and Evaluating Auditory Processing

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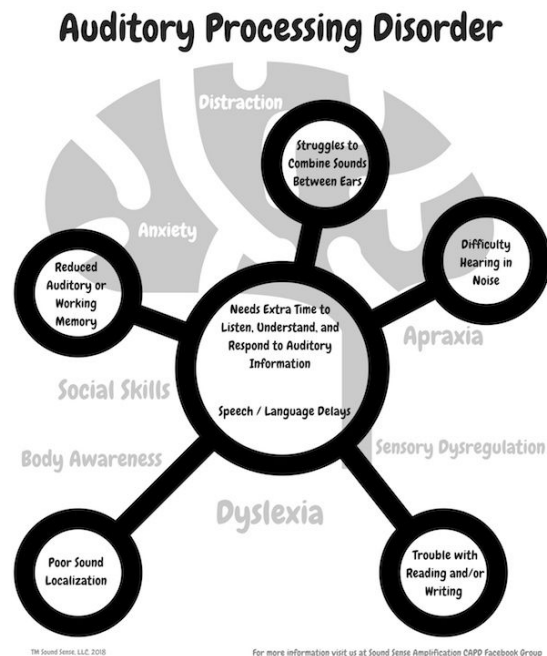


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# Research Background- Hearing Impairment

- **Global Prevalence of Hearing Disabilities:** Approximately 20% of the global population is affected by hearing disabilities, a trend that is on the rise (WHO, 2021).
- **Consequences of Hearing Impairment:**
  - Leads to diminished spatial awareness and localizing sounds, complicating navigation and social interactions.(Dai et al. 2018)
  - Most well known risk factor for dementia (Livington et. al 2020)
  - Socially isolating and a key factor in deterioration of quality of life (Carlsson et. al 2015)
- **Diagnosis and Treatment Challenges:**
  - The multifaceted causes of hearing impairment complicate diagnosis and treatment, necessitating comprehensive and personalized rehabilitation strategies



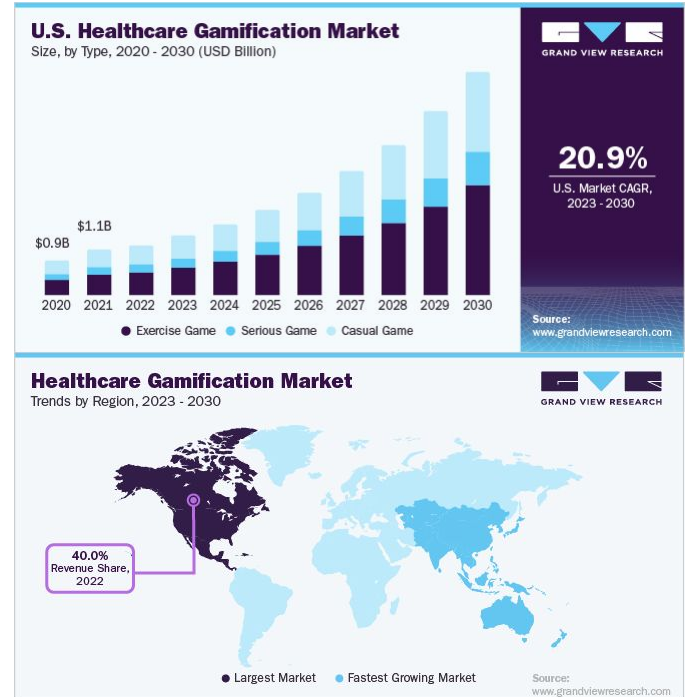
## Research Background- Auditory Training

- **Hearing Aid and Cochlear Implant Limitations:**
  - Struggle to fully mimic natural hearing, especially in noisy environments.
- **Proven Benefits of Auditory Training:**
  - Enhances speech perception and spatial hearing abilities, including users of hearing aids and cochlear implants.
  - Research shows long-term improvements in understanding speech in noise and sound localization.(Henshaw et al 2013)
- **Digital Therapeutics (DTx):** Advancements in digital technology has introduced a rise to DTx (evidence-based, software-driven interventions delivered on digital platforms)
  - Effective and accessible healthcare solutions (Dang et al. 2020).



# Research Background- Gamification of Healthcare

- Overall Benefits of Gamification
  - Enhances patient engagement and adherence to treatment plans (Seixas et al., 2021).
  - Makes managing health conditions more interactive and motivating
  - Improves understanding and involvement in one's own health management.
- Medication Adherence
  - Reduces the risk of treatment failure due to missed medication (Tran et al., 2021).



## Research Background- Gamification of Training and Rehabilitation

- **Gamification Trend in Auditory Training**
  - Engages a broad population in effective auditory training using gamified applications (Xiang et al., 2023).
    - Particularly effective for children, making rehabilitation processes more enjoyable and less intimidating (Moore et al., 2021).
  - “AT programs are often game like and should not be tedious for the patients to ensure their compliance.” (Stropahl et al. 2020)
  - Applications focus on auditory cognition abilities
    - Speech in Noise, auditory working memory, similarly pronounced words



Lingoany, 2020

<https://play.google.com/store/apps/details?id=com.LingoAny.listenplay>

## Research Background - DTx Examples



*Amplify (First FDA approved Hearing Loss DTx, 2020, Amptify)*



*EndeavorRX (FDA approved DTx for ADHD, 2020, Akili Interactive)*

Digital Therapeutics need to be **clinically validated** and **prescribed** by medical professionals



# Research Background- Limitations and Proposed Solution

## Limitations of Existing Auditory Training Applications

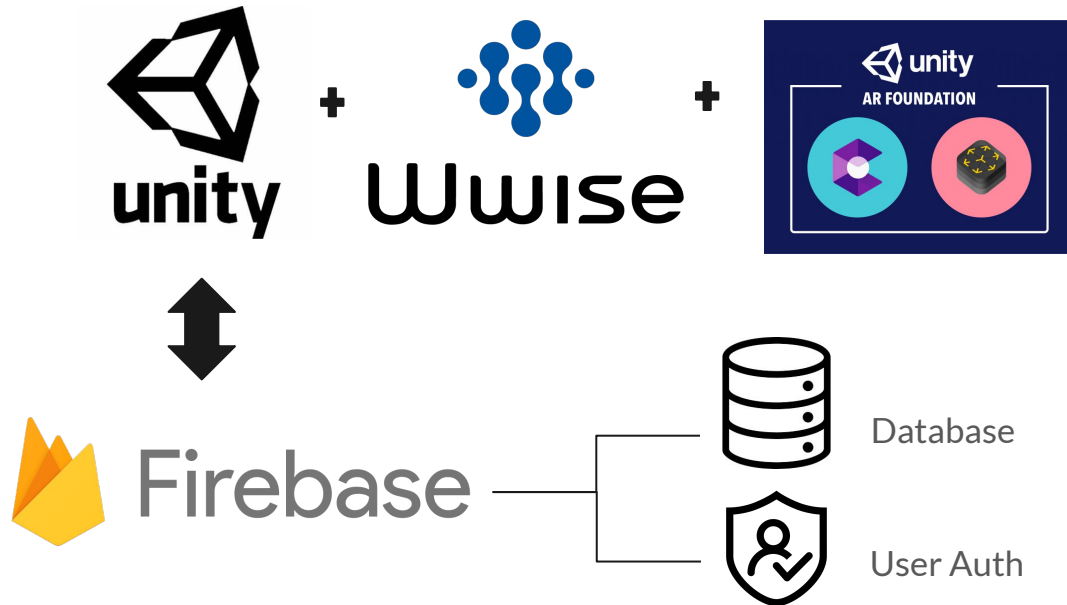
- Absence of **spatial audio** which is crucial to replicate the complexity of the real world
- Most mobile auditory training applications lack clinical validation or longitudinal studies
- Training applications lack integration with other **rehabilitative** treatments

## Proposed Solution

- Incorporate spatial audio to provide a more realistic and more effective training experience through AR.
- Enabling '**in-situ**' training in real environments to improve skill transfer.

# Technical Implementation

- Hardware Use: Apple iPhone 14 Pro and AirPods Pro 2
  - Why: Make use of iPhone's LiDAR sensor for environment awareness and AirPods Pro 2 API to get access to the earphone orientation
    - Achieve 6DoF Audio
- Software Used: Unity Game Engine and AR Foundation (Apple ARKit and Google ARCore), Audiokinetic Wwise, and Google's Firebase



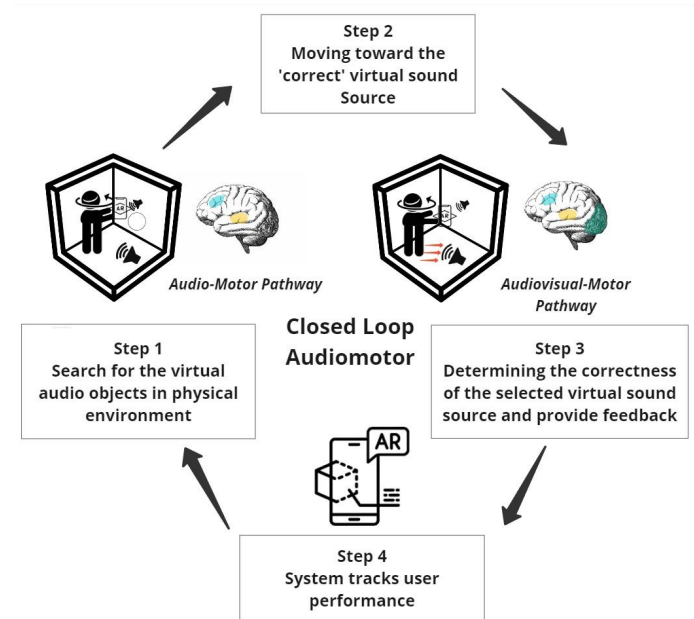
# Game Concept

- Mobile Augmented Reality (AR) Based Game to provide accessible in-situ training
- Game Theme: Spirit Restaurant Management
  - Concept: Users run a restaurant for spirits, to narratively prime the user to interact with invisible, yet virtually existing objects
- Balance between motivation and auditory training principles
- Multi-sensory training paradigm
  - Closed Loop audiomotor pathway
    - Auditory stimuli responding in realtime to motor actions



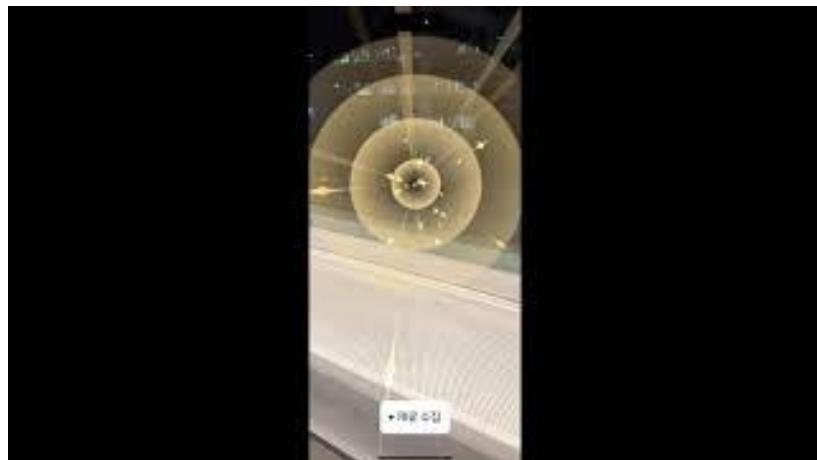
# Multi-Sensory Training Paradigm

- **Closed-Loop Feedback:** Integrating motor actions with sensory feedback in real-time to create a responsive training environment.
- **Continuous Interaction:** Shifting from discrete trials to continuous gameplay, enhancing engagement and learning.
- **AR and Full-Body Movement:** Utilizing AR to extend training into full-body movements, making tasks mimic real-life scenarios more closely.



# Game Demo - Speech in Noise Module

- **Module Overview**
  - **Objective:** Improve speech in noise perception and sound localization through
  - **Task:** Identify the correct word from two competing auditory stimuli and noise
- **Gameplay Mechanics**
  - Identify correct ingredients placed in the player's environment through audio cues to acquire objects.
  - Provide visual cues when close to the ingredients.
  - Words are masked by continuous background noise.
- **Example Level**
  - Make 김밥 - First Step(김 vs 침) Second Step(밥 vs 감) Third Step(햄 vs 뱀)

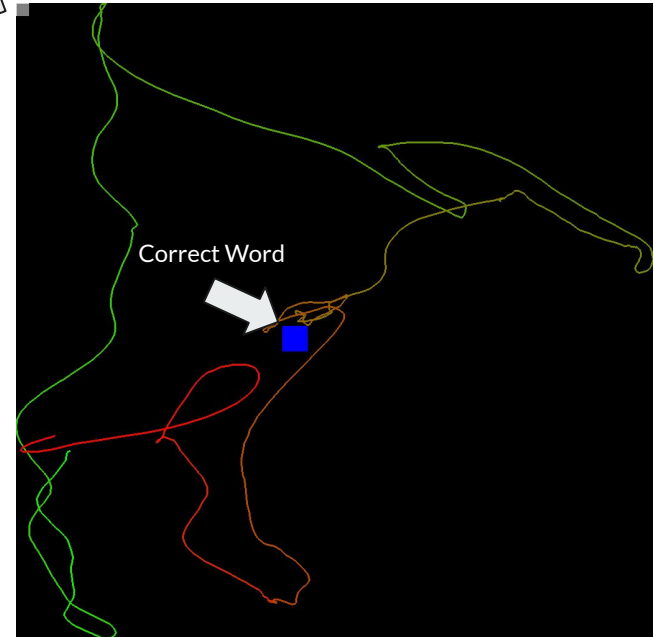


# Diagnostics Available - Navigational Data Generation

Incorrect Word

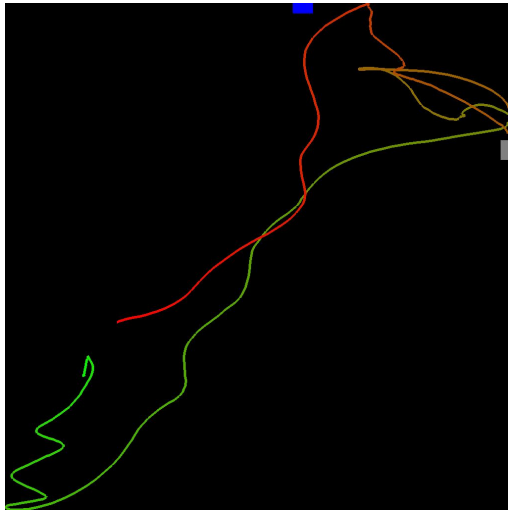


- **Navigational Data Generation Process**
  - Collect positional and auditory response data during gameplay of each session
    - Paths are drawn from green to red to represent the time passed
  - Visualize the navigation data using advanced visualization techniques.
  - Can combine multiple navigational datasets to create a heatmap
- **Importance in Diagnosis**
  - Navigational data provide a clear, visual representation of auditory processing abilities.

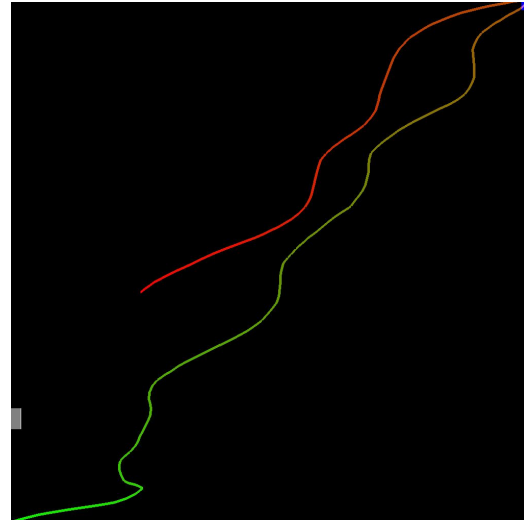




## Navigational Data - Comparison of Single Side Deafness and Normal Hearing



Single Side Deafness (25, F)



Normal Hearing (25, M)

# Game Demo - Sound Localization Module

- **Module Overview**
  - **Objective:** Enhance sound localization and selective auditory attention skills.
  - **Task:** Protect oneself from approaching transparent spirits (theme: warding off troublesome customers).
- **Gameplay Mechanics**
  - As spirits get closer to the player, their sounds become louder and more opaque.
  - Players create barriers to block and destroy the spirits.
  - Players must differentiate between good and bad spirits.
- **User Interaction**
  - Strategically move and position to track and avoid the movements of the spirits.
  - Use auditory cues to create barriers at the right time and location.



# Diagnostics Available - User Analytics

- Making use of Unity Analytics and Firebase we can acquire user performance metrics and demographic information
- **Player Frequency**
  - When players play, how often they play
- **Player Engagement**
  - How long players play, what module or scene they spend the most time on
- **Time for Task Completion and Difficulty**
  - How long did it take for task completion, what words were difficult, what was the volume of the background noise and target noise
    - Observe player skill growth
- **Player Progression**
  - Where players are facing difficulty
  - What stage or step can they not complete



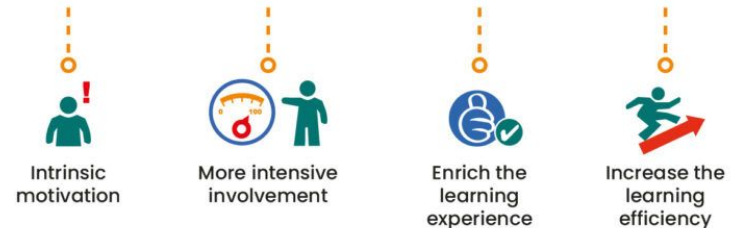
Example Unity Analytics

# Expected Results

- **Enhancement of Auditory Processing Skills**
  - Improvement in sound localization and selective auditory attention abilities.
- **Increased User Engagement and Motivation**
  - Interactive and immersive game design encourages consistent practice.
- **Enhanced Skill Transfer Through In-Situ Training**
  - Training in an AR environment enables practical application of learned skills in daily life.
- **Accessible Rehabilitation**
  - Utilization of mobile devices makes the game accessible and user-friendly for a wider range of individuals, including those with hearing impairments.



## GAMIFICATION





# Future Work for Application

- **Incorporation of Standard Hearing Evaluation**
  - Integrate routine hearing tests for users before starting modules to provide a diagnostic tool for medical professionals and motivate users to show their hearing abilities are improving
- **Expanding Visualization and Data Gathering**
  - Further develop the current visualization of navigational data to account for user environment
  - Expand upon the data gathering from user performance metrics
- **Enhanced User Engagement**
  - Develop more content aimed at boosting player retention and sustaining engagement.
  - Create adaptive difficulty system based on user performance metrics currently being gathered
- **Advancements in AR Capability**
  - Focus on further enhancing AR capabilities for more accurate estimation of the user's environmental acoustics and provide more realistic auditory experience.

**Thank you for your attention**

