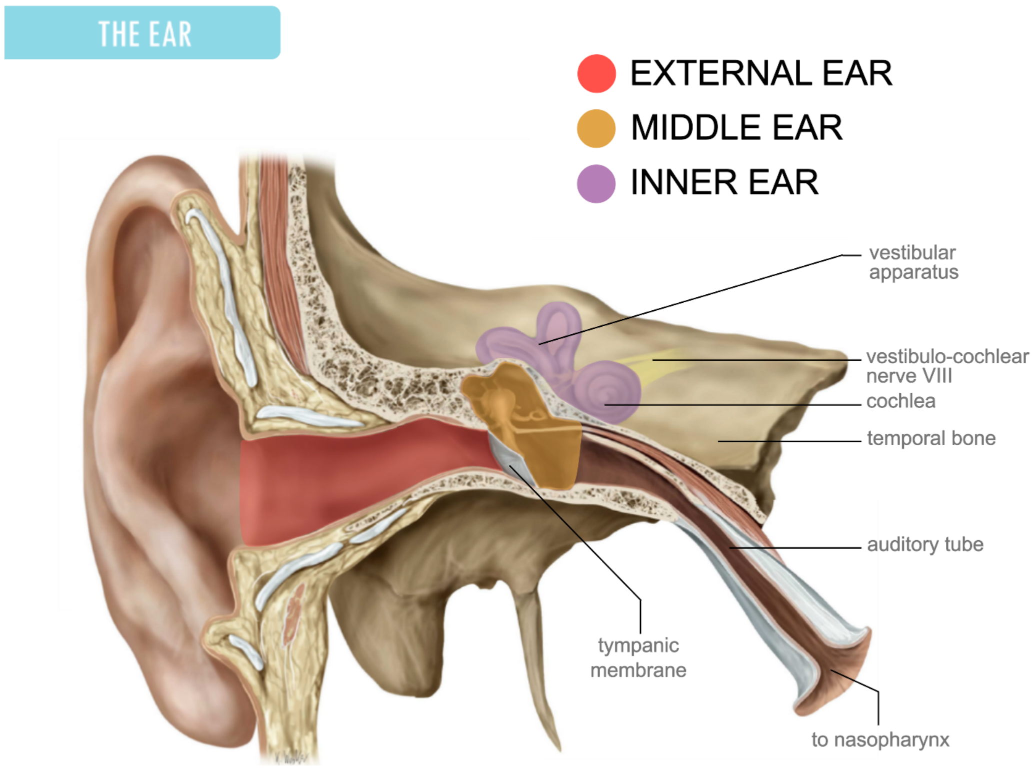
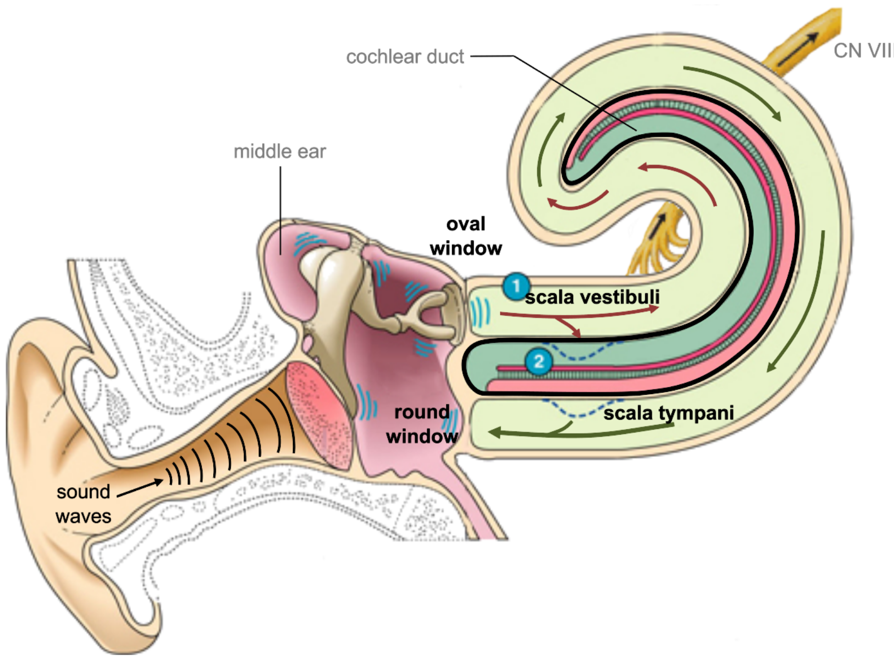
General knowledge of hearing losses

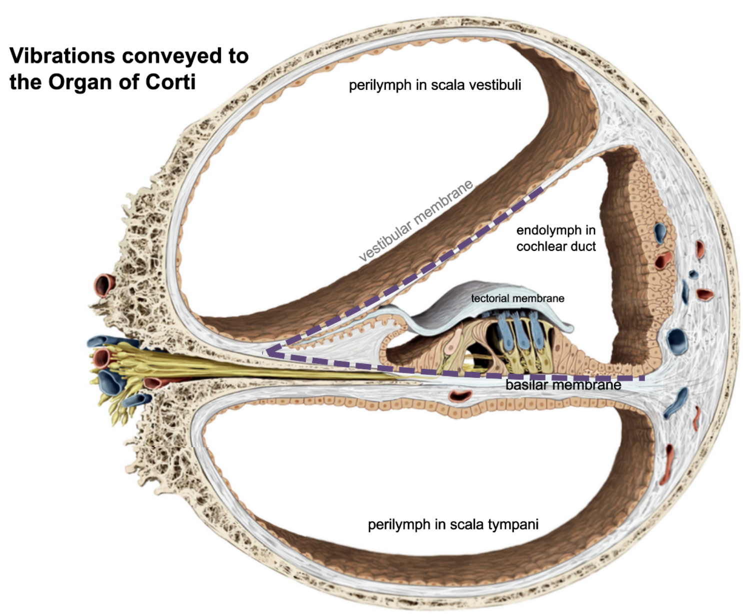
Ear Anatomy

Anatomically, the ear has the following three structures as shown in the picture below [1].





The above diagram illustrates how sound is conducted through human ears [1]. The mechanical sound waves would hit the tympanic membrane, whose vibration would be further amplified by the ossicles. Then the stapes would hit the oval window, passing the vibration into the cochlear. The hair cells in the cochlear are mechanoreceptors that can convert the mechanical vibrations into the release of neurotransmitters, which were converted into electrical signals and sent to the human brain.



The hair cells have different lengths, and the ones with longer lengths are responsible for capturing low-frequency sounds. The hair cells are aligned in such a way that the ones closer to the oval window are shorter, hence capturing high pitch sounds. If the ear is exposed to a high-noise environment, the hair cells closer to the oval window are more likely to be damaged as compared to the ones farther away. Consequently, people who always expose themself to high noise and the elderly are prone to lose the sensation of the high-pitched sound [2].

Hearing Loss

Hearing loss is a common symptom as people age. Almost half the people in the United States older than age 65 have some degree of hearing loss [3].

There are three main categories for hearing loss:

1. Conductive (involves outer or middle ear)
2. Sensorineural (involves inner ear)
3. Mixed (combination of the two)

Conductive hearing loss might involve excessive earwax buildup, rupture of the tympanic membrane, ear infection, abnormal bone growths or tumours. Damage to the inner ear would most likely lead to sensorineural hearing loss. Aging and exposure to loud noise are factors that might damage the hair cells or nerve cells in the cochlea that send electrical signals to the brain. When these hairs or nerve cells are impaired, electrical signals aren't transmitted as efficiently, and hearing loss occurs [3].

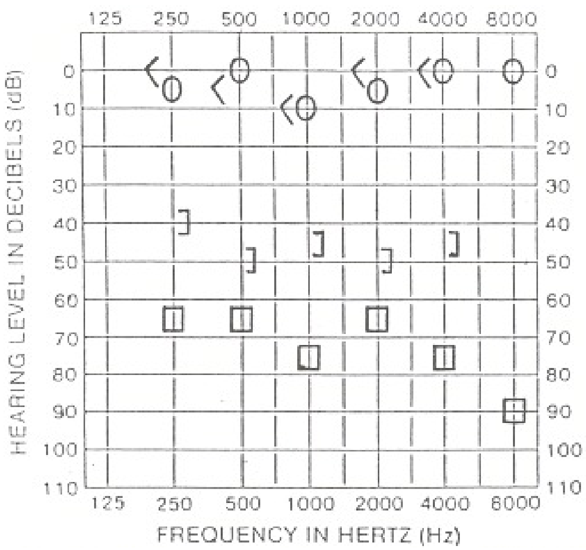
Understanding of existing practices

Clinical Audiometry Tests

Clinical audiometry aims to test the functions of the hearing mechanism, including tests of both mechanical and neural sound transmission, and speech recognition ability.

Single frequencies, also known as pure tones are used to test both air and bone conduction. These and speech testing are done with an audiometer. The audiometer is an electric instrument consisting of a single frequency generator, a bone conduction oscillator for measuring cochlear function, and an attenuator for different loudness. There are some other tests including impedance audiometry, which measures the mobility and air pressure of the middle ear system and middle ear reflexes, and auditory brainstem response (ABR), which measures neural transmission time from the cochlea through the brainstem.

To elaborate on the **pure tone audiometric air conduction testing**, the patient would be sitting in a sound-proof room and be given a pair of headphones. A series of tones with varying loudness and frequencies would be given to the patient. When the patients acknowledged the sound signal, the patient would raise their left or right hands corresponding to the left and right ears. The clinician would measure in decibels (dB) at which this tone is perceived 50% of the time. This measurement is called the threshold. The testing procedure is repeated at specific frequencies from 250 to 8000 Hz for each ear, and the thresholds are recorded on an audiogram as shown in the figure below. Bone conduction testing is done by placing an oscillator on the mastoid process and measuring the threshold at the same frequencies. Masking noise is often used to prevent the nontest ear from participating in the test [4].



Legend: < Right ear, bone conduction; ○ Right ear, air conduction;] Left ear. bone conduction; □ Left ear, air conduction.

This figure shows the audiometry results. The zero level on the audiogram is an arbitrary sound pressure level indicating the ideal normal hearing level. It can be seen that the right ear shows thresholds that are within normal limits for air and bone conduction. The left ear shows a mixed hearing loss. The air conduction thresholds show an additional loss as compared to bone conduction. The bone conduction hearing loss is indicative of sensorineural loss and the difference between air and bone conduction signifies a conductive hearing loss, also known as an air-bone gap.

Moving on to **speech testing**, which is the measurement of a patient's ability to hear and understand speech. The speech reception threshold (SRT) is the lowest decibel level at which a patient can correctly repeat 50% of test words. The speech threshold should be within the 10 dB range of the pure tone average at frequencies of 500, 1000, and 2000 Hz. The speech discrimination score is obtained using phonetically balanced, one-syllable words. The test can also introduce different levels of background noises to simulate the Words-in-Noise Test. If the test sounds are loud enough, Speech discrimination scores are often good in patients with purely conductive hearing losses [4].

Electrodes are placed on the patient's vertex, earlobes, and forehead for **auditory brainstem response** (ABR) audiometry. A sound stimulation such as clicks is delivered through earphones, and a computer sums the responses voltage potentials for the first 10 msec after sound stimulation. A display of five characteristic waves is generated at predictable latencies acquired from the patient's response. The responses should be repeatable for an accurate evaluation [4].

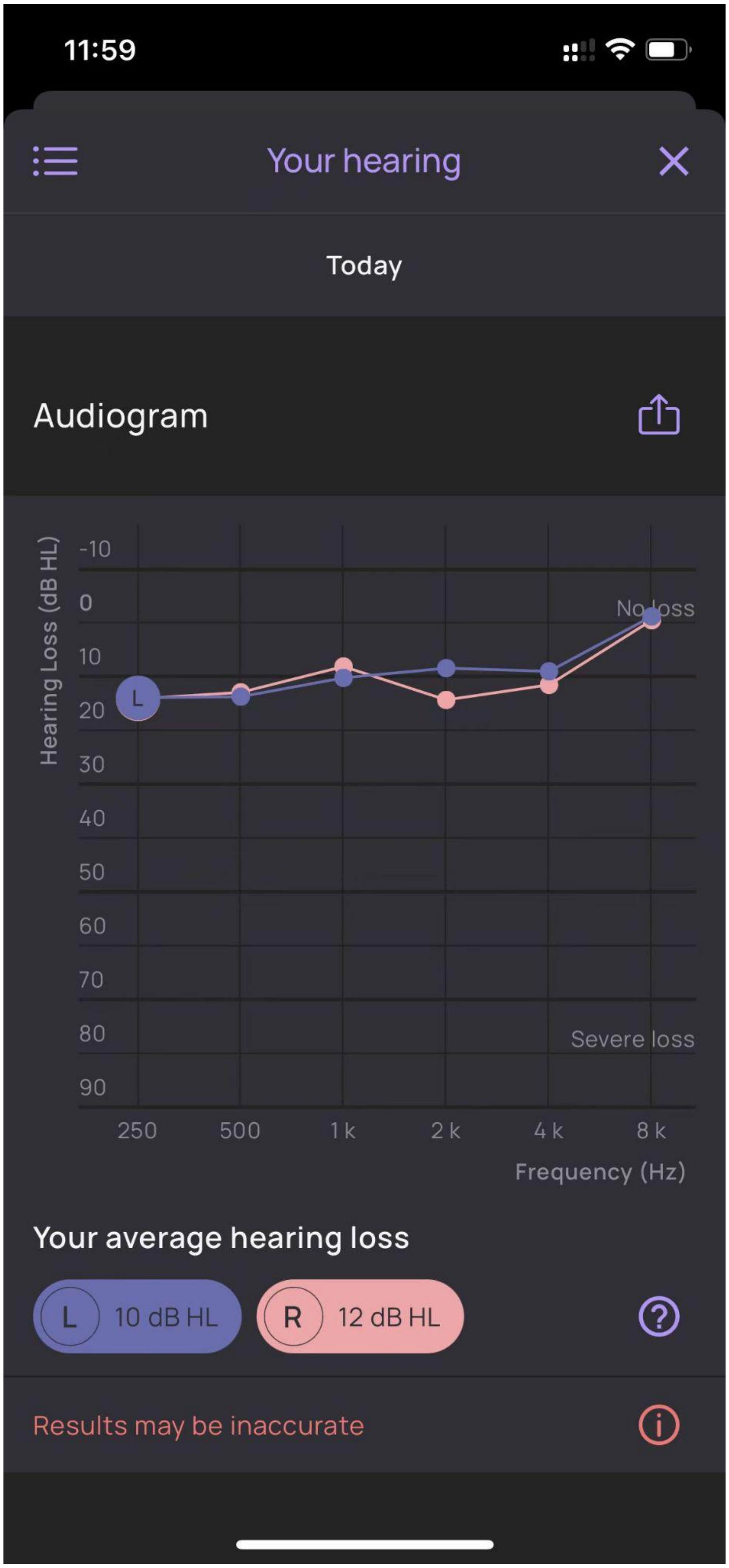
Mobile Audiometry

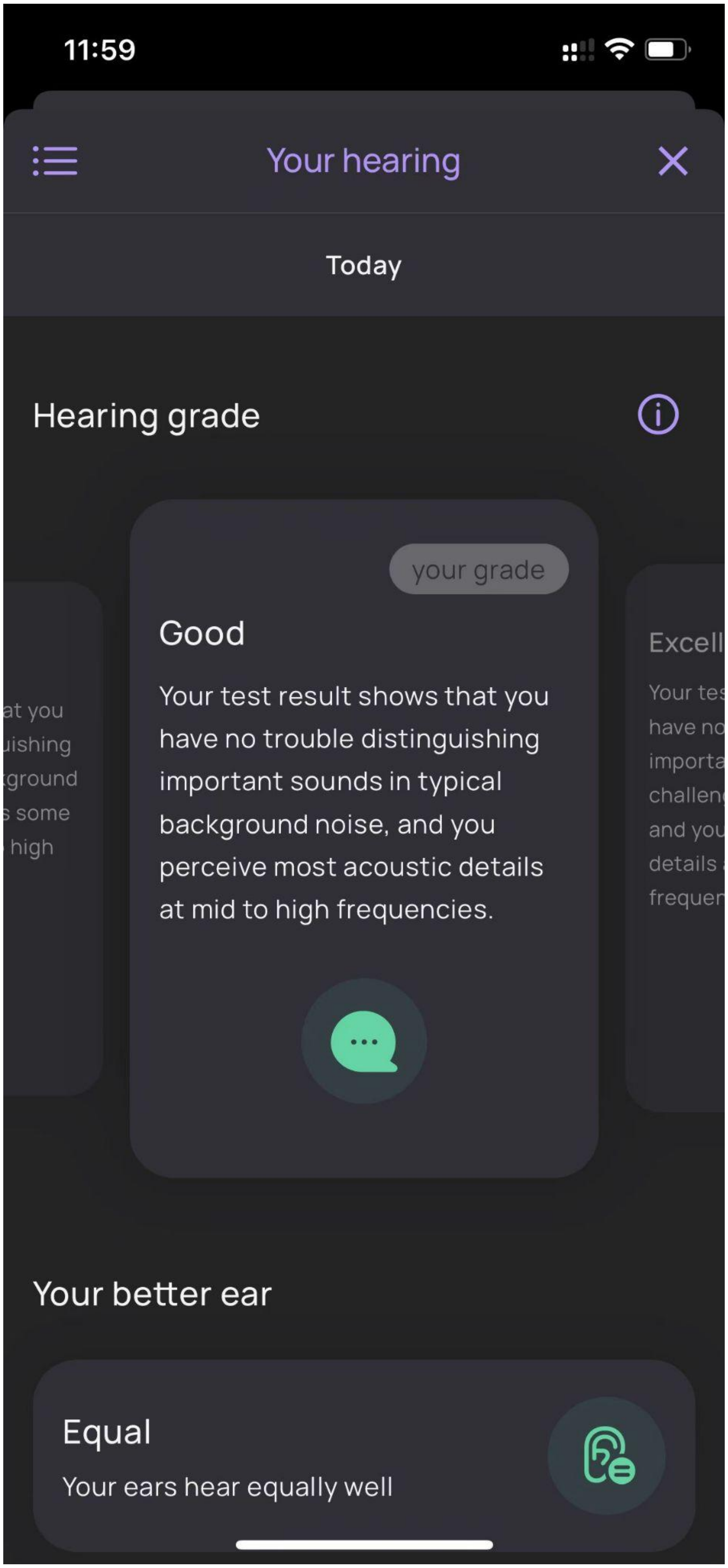
Various studies have been conducted to evaluate the accuracy of mobile-based audiometry in identifying hearing loss. It has been proven that mobile audiometric applications can correctly estimate pure tone thresholds and screen for moderate hearing loss. Thanks to the technological advancement in noise cancellation headphones, the addition of noise reduction strategies provide a portable and effective solution for hearing assessments in various settings outside quiet clinics. However, formal audiometry is still required when abnormalities are identified in audiometric screening.

IOS

Mimi Hearing Test (Also available on IOS)
https://apps.apple.com/ca/app/mimi-hearing-test/id932496645

This is a very popular IOS app that provides two hearing tests. Before and during the test, the app would use the microphone to monitor the surrendering noise level. If the environment is too noisy, the hearing test would be interrupted. The app would also recommend users to apply Do Not Disturb mode to disable all notifications that might interrupt the test. The app recommends using calibrated earphones like Airpods Pro for testing and warns user about using uncalibrated headphones might lead to inaccurate results. The first test sends out pure tone sounds at varying amplitude and frequencies. The test would start with high frequency sounds. At each frequency, the amplitude of the sound would gradually increase until the user presses the button and then start to decrease the volume. The user needs to press the button when hearing the sound, and hold the button until the sound disappears. The second test would utilize similar methods, however, the app would ask user to choose a background noise at a comfortable level. In the end, the app would provide an audiogram and a feedback as shown in the pictures below. The test can take up to 5 minutes to finish.


11:59
Your hearing
Today
Audiogram
Hearing Loss (dB HL)
-10
0
10
20
30
40
50
60
70
80
90
No loss
Severe loss
L
250
500
1 k
2 k
4 k
8 k
Frequency (Hz)
Your average hearing loss
L 10 dB HL
R 12 dB HL
Results may be inaccurate



11:59
Your hearing
Today
Hearing grade
your grade
Good
Your test result shows that you have no trouble distinguishing important sounds in typical background noise, and you perceive most acoustic details at mid to high frequencies.
Your better ear
Equal
Your ears hear equally well

Hearing Test & Ear Age Test

https://apps.apple.com/ca/app/hearing-test-ear-age-test/id1067630100

This app is not as popular as Mimi. It has two tests --- hearing test and ear age test. The hearing test is similar to Mimi, however, it only asks the user to click the button once hearing the sound. It does not require the user to hold and release the button. The ear age test gives frequencies in the increment of 1000 Hz starting at 8000 Hz. It gives the user two buttons to click --- can hear, cannot hear. If the user chooses cannot hear, the test would terminate and returns the ear age. Otherwise, the app would keep giving sound signals at 1000 Hz higher.

Android

Hearing Test

https://play.google.com/store/apps/details?id=mobile.eaudiologia&hl=en_CA&gl=US

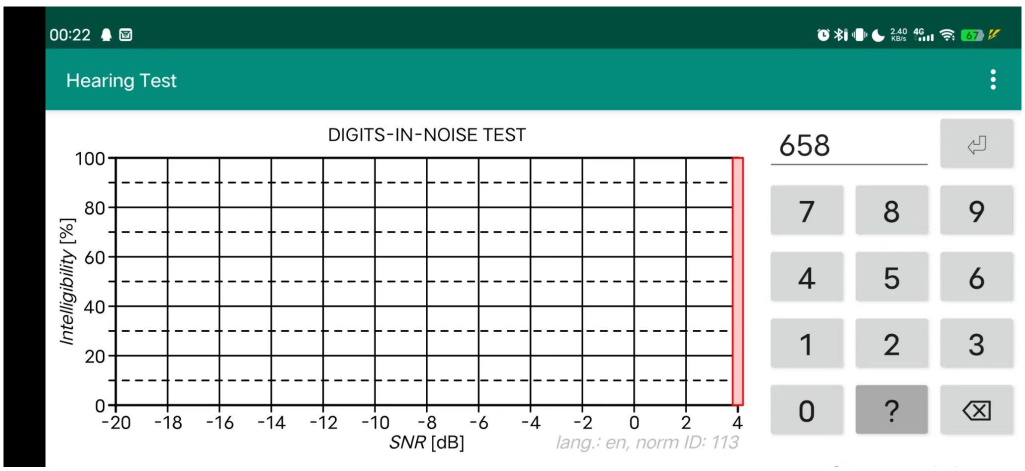


Figure: speech recognition

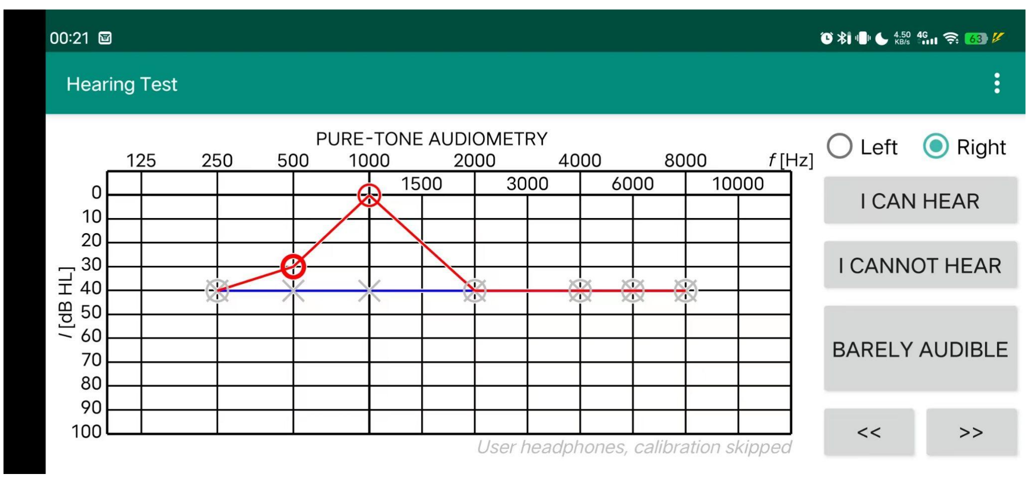


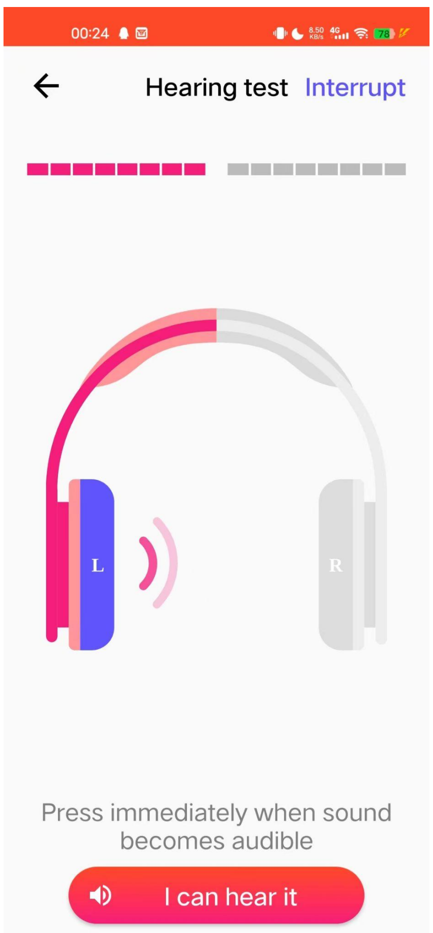
Figure: single frequency audio tests

This is the most popular hearing test app on Android. The app has two tests similar to Mimi ---- speech recognition and single frequency tests. However, the tests are distinctly different. The single frequency sound tests provide users with a chart outlining the sound amplitude in decibels and also the different sound frequencies. The users can move the sound level around and draw the audiogram by themselves. For the second test, the app would say english numbers and ask the user to choose the corresponding numbers under different noise levels.

Hearing test, Audiogram

https://play.google.com/store/apps/details?id=com.it4you.dectone.gui.hearingtest&hl=en_CA&gl=US

This app only offers one test, which asks the user to press the button if the sounds can be heard. The test can be finished in 10 seconds. The overall quality is crude as compared to the other apps. A result would be given based on how many times the user clicks the button to acknowledge hearing the sounds.



Summary

The report attempted to test all popular applications on both Android and IOS. The common tests across those applications involve the tests for speech recognition under noisy backgrounds as well as recognizing single frequency sounds at varying amplitudes and frequencies. The only major audiometry testing app to be found on both platforms is Mimi Hearing Test, which I believe is built with more sophistication and more consideration for user bias. I also like the idea to have the users test their hearing abilities in the Android app. A combination of a user-reported audiogram and a reaction-generated audiogram could be utilized to generate a more accurate result.

Reference

1. G. J. Tortora, B. H. Derrickson, B. Burkett, and G. Peoples, *Principles of anatomy and physiology*. Milton, QLD: John Wiley and Sons Australia, Ltd, 2022.
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3. "Hearing loss," *Mayo Clinic*, 16-Apr-2021. [Online]. Available: https://www.mayoclinic.org/diseases-conditions/hearing-loss/symptoms-causes/syc-20373072. [Accessed: 24-Jul-2022].
4. H. K. Walker, W. D. Hall, and J. W. Hurst, *Clinical methods: The history, physical, and Laboratory Examinations*. Boston: Butterworths, 1990.
5. J. Saliba, M. Al-Reefi, J. S. Carriere, N. Verma, C. Provencal, and J. M. Rappaport, "Accuracy of mobile-based audiometry in the evaluation of hearing loss in quiet and noisy environments," *Otolaryngology–Head and Neck Surgery*, vol. 156, no. 4, pp. 706–711, 2016.