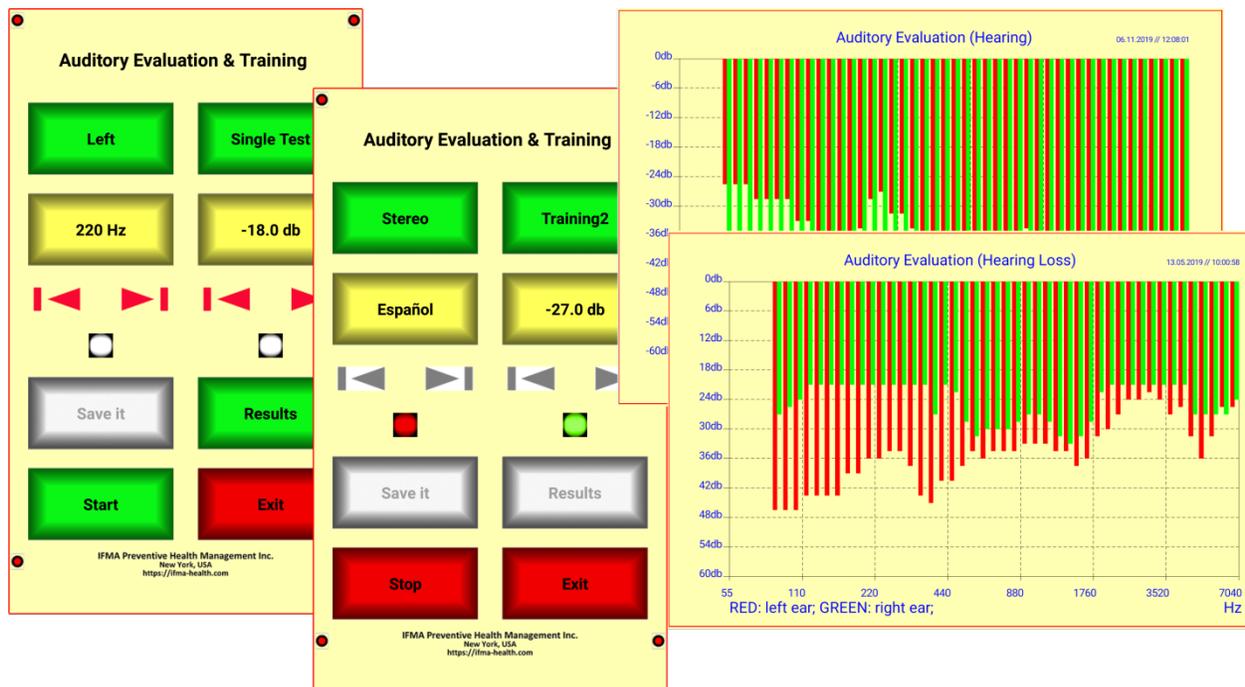




Hearing Loss & Auditory Training

Self-assessment auditory evaluation combined with personalized, hearing-loss specific auditory training

Documentation & Manual (Android)



When Do You Need this «App»

Hearing Loss

Hearing loss is a common medical condition among older adults with a prevalence of >50% in people aged 60 years or older [1]. It causes the sufferers to lose the ability to efficiently communicate with family, peer group, and work place. It leads to chronic stress and is associated with significant psychological and medical co-morbidity, such as social isolation, cognitive decline, and depression [2].

Etiology

Hearing loss is a complex, etiologically diverse medical condition where multiple genetic and environmental factors are involved. Environmental factors include noise exposure, ototoxin exposure, infections, smoking, and comorbidities like hypertension or diabetes. Critically important for speech intelligibility are frequencies affected by hearing loss in the range between 55 Hz and 7,040 Hz (7 octaves).

Hearing Aids

Patients typically report improved quality of life with use of hearing aids but commonly complain that they cannot understand speech, especially in the presence of background noise. Despite usage of directional-microphones and noise-reduction strategies, everyday communication through hearing aids has still really frustrating limits at present.

What You Can Do About It

For adults with hearing loss, specific auditory training can facilitate communication in noisy situations as it almost always improves speech intelligibility [3]. Also, auditory training on a regular basis counteracts feelings of helplessness and cognitive decline very efficiently – getting involved and doing something about it is the most important step to successfully cope with hearing loss.

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- [2] Hsu WT, Hsu CC, Wen MH, Lin HC, Tsai HT, Su P, Sun CT, Lin CL, Hsu CY, Chang KH, Hsu YC: Increased risk of depression in patients with acquired sensory hearing loss: A 12-year follow-up study. *Medicine (Baltimore)*. 2016; 95(44): e5312
- [3] Humes LE, Skinner KG, Kinney DL, Rogers SE, Main AK, Quigley TM: Clinical Effectiveness of an At-Home Auditory Training Program: A Randomized Controlled Trial. *Ear Hear*. 2019; 40(5):1043-1060

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Hearing-Loss Specific Auditory Training

The application program «AudEval App» provides (1) a high-resolution auditory evaluation that can be carried out in the home environment and covers 56 frequencies in the range between 55-7,040 Hz; and (2) individually organized, hearing-loss specific training sessions that help to improve auditory thresholds and speech intelligibility (supported languages: English, French, German, and Spanish).

Single Tests

Single Tests determine the users' hearing threshold for a given frequency (tone) for either the left ear, the right ear, or both ears together. Single Tests present the tone of the chosen frequency several times while successively adjusting loudness. The procedure starts with the user-defined initial loudness (e.g., -25.5 dB) and reduces loudness in steps of -1.5 dB until the user is unable to detect any sound.

Full Tests

Full Tests determine the users' hearing thresholds for 56 frequencies in the range between 55-7,040 Hz (7 octaves; 8 tones per octave), beginning with the left ear and, upon completion, continuing with the right ear. For each single frequency, loudness is successively increased in steps of +1.5 dB (starting with user-defined minimum) until the user acknowledges the tone's audibility. The outcome is displayed as bar charts "hearing loss as a function of frequency".

Training 1: Working on auditory thresholds

Training 1 loops through 56 frequencies between 55-7,040 Hz (7 octaves; 8 tones per octave); the tone duration is 8 seconds with pre-specified loudness and for the selected ear(s). **Please note**: any auditory training will show the desired effect only if the training sessions are repeated on a regular basis (e.g., twice per day for 15 minutes).

Training 2: Working on speech intelligibility

Training 2 presents a standard text with background noise at a pre-specified loudness and for the selected ear(s). Focus is laid on speech intelligibility: Users begin with a comfortable loudness and concentrate themselves on understanding each single word. Subsequently, users may reduce loudness and repeat the training twice a day for 15 minutes, noting down training time and intensities. Available languages are English, French, German, and Spanish.

Installation Instructions

The «AudEval» App is installed through Google Playstore. The App creates a folder «AuditoryEvaluation» and will set the playback loudness to a fixed value, therefore requiring the respective permissions.

Headphones

The «AudEval» App combined with personalized auditory training requires headphones as a prerequisite, preferably with a linear frequency response from 10 Hz to 20 kHz. Over-ear headphones (closed ear design) are better than in-ear solutions.

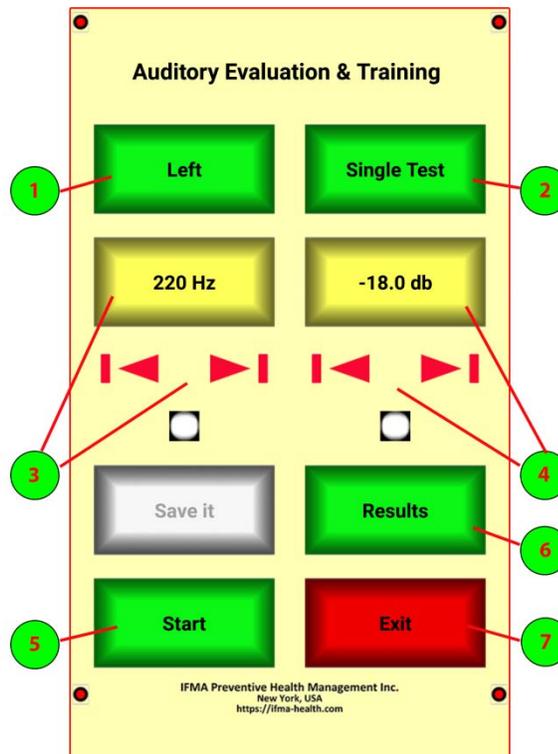
Turn off all sound enhancing features of your smartphone: bass boost and the like!

Hearing loss measured through relative quantities

Throughout the entire application, hearing loss is measured in terms of relative quantities [dB] – there is no need for calibrated absolute values.

Main Screen

Upon start of the «App», the main screen is presented through which users interact with the program by selecting options and by starting the auditory evaluation / training sessions. Some buttons let users chose between several options by consecutive clicks.



1 Selects Ear <Left | Right | Stereo>: selects ear(s) to be evaluated/trained.

2 Selects Test / Training : <Single Test | Full Test | Training1 | Training2>

Single Test evaluates one single frequency [selected by buttons 3] at a given loudness [selected by buttons 4], and for the ear(s) selected by button 1. [Buttons 3, 4: left arrow “◀” decrease and right arrow “▶” increase].

Full Test evaluates all frequencies 55 - 7,040 Hz (7 octaves; 8 tones per octave) beginning with the left ear and continuing with the right ear. For each frequency, loudness is successively increased in steps of +1.5 dB, beginning with the user-definable starting point, until users acknowledge the tone’s audibility.

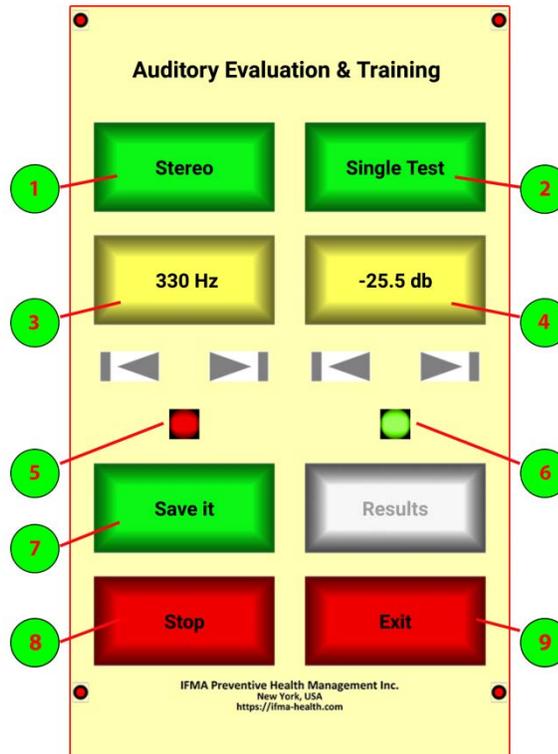
Training 1 works on auditory thresholds, while Training 2 aims at word intelligibility.

5 **Start**: starts evaluation/training, interrupted by <Stop> button (activated on <Start>).

6 **Results**: summarizes the outcome by means of bar charts.

7 **Exit**: terminates the application program.

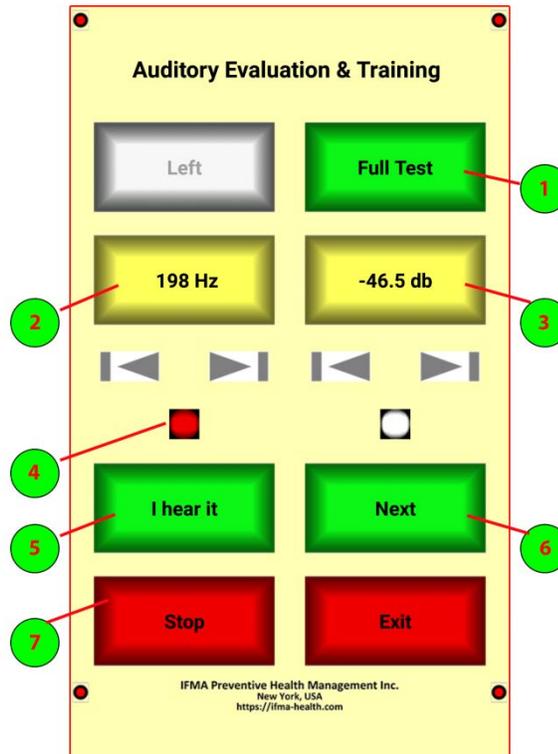
Single Tests: Loss-Specific Frequencies



Single Tests determine the users' hearing threshold for a given frequency (tone) for either the left ear, the right ear, or both ears together. Single Tests present the tone of the chosen frequency several times while successively adjusting loudness. The procedure starts with the user-defined initial loudness (e.g., **-25.5 dB**) and reduces loudness in steps of **-1.5 dB** until the user is unable to detect any sound.

- 1 **Select Ear:** selects "left ear", "right ear", or "both ears (stereo)" for test.
- 2 **Select Test/Training:** Single Test.
- 3 **Frequency:** displays current frequency [Hz] under test (tonal pitch).
- 4 **Intensity:** displays current loudness [dB] under test.
- 5 **LED (left ear):** displays current activity on left ear (on: tone; off: no tone).
- 6 **LED (right ear):** displays current activity on right ear (on: tone; off: no tone).
- 7 **Save it:** once the user's hearing threshold is detected for a given frequency [displayed on button 3] and its threshold loudness [displayed on button 4], the respective value can be saved as "result" for inclusion into bar chart diagrams.
- 8 **Stop:** users can always interrupt an active test by pressing the <Stop> button.
- 9 **Exit:** terminates the application program.

Full Tests: Frequency Range 55 - 7,040 Hz

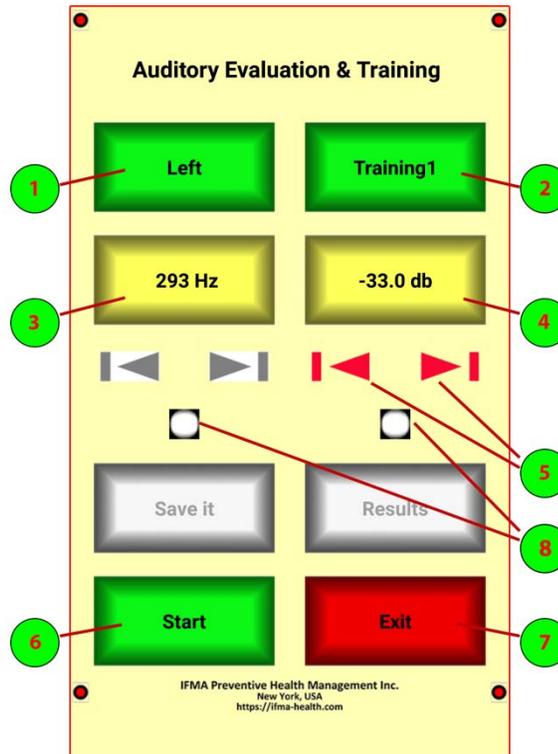


Full Tests determine the users' hearing thresholds for 56 frequencies in the range between 55-7,040 Hz (7 octaves; 8 tones per octave), beginning with the left ear and finishing with the right ear. For each single frequency, loudness is successively increased in steps of **+1.5 dB** (starting with user-defined minimum) until the user acknowledges the tone's audibility. The outcome is displayed in form of bar charts.

- 1 **Select Test/Training:** Full Test.
- 2 **Frequency:** displays current frequency [Hz] under test (tonal pitch).
- 3 **Intensity:** displays current loudness [dB] under test.
- 4 **LED (left ear):** displays current activity on left ear (on: tone; off: no tone).
- 5 **I hear it:** users press this button as soon as they hear the test tone. Subsequently, the test tone of the next higher frequency is presented.
- 6 **Next:** users press this button if they do NOT hear the test tone within the first few seconds. No response within 8 seconds is treated as <Next>.
- 7 **Stop:** users can always interrupt an active test by pressing the <Stop> button.

A full test typically takes 5 minutes, yet may take up to 10 minutes depending on the users' response times.

Training 1: Working on Auditory Thresholds

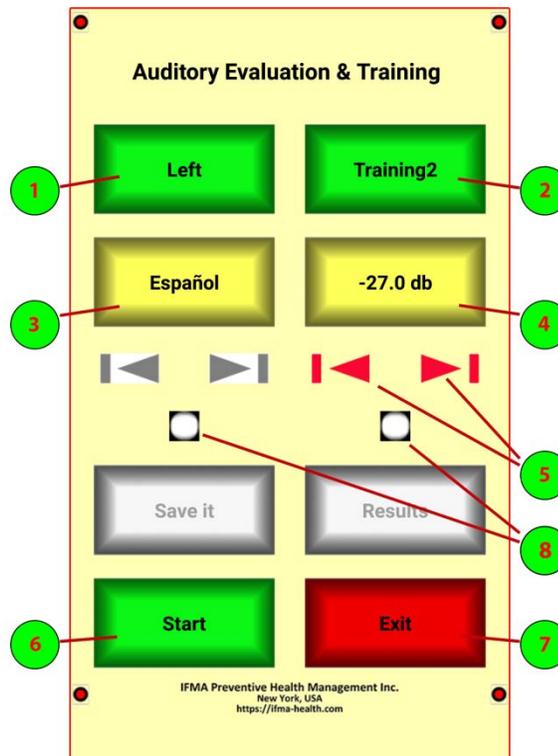


Training 1 loops through 56 frequencies between 55 - 7,040 Hz (7 octaves; 8 tones per octave); each tone is presented for 8 seconds with the pre-specified loudness [selected by button **5**] and for the ear(s) selected by button **1**.

- 1** **Select Ear:** selects “left ear”, “right ear”, or “both ears (stereo)” for training.
- 2** **Select Test/Training:** Training 1.
- 3** **Frequency:** displays current frequency [Hz] under training (tonal pitch).
- 4** **Intensity:** displays current loudness [dB] under training, selected by button **5**: left arrow “◀” decreases and right arrow “▶” increases loudness.
- 6** **Start:** starts Training 1; can be interrupted by <Stop> button (visible on <Start>).
- 7** **Exit:** terminates the application program.
- 8** **LEDs:** display current activity on left and right ear.

Please note: Any auditory training will show the desired effect only if the training sessions are repeated on a regular basis (e.g., twice per day for 15 minutes).

Training 2: Working on Speech Intelligibility

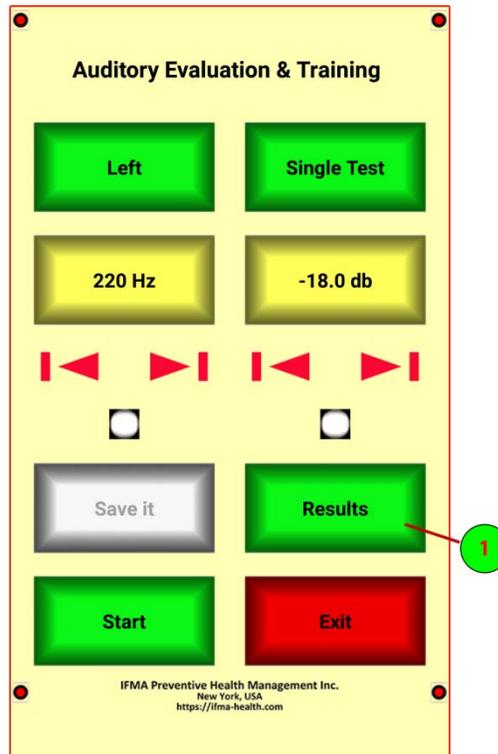


Training 2 presents a standard text with background noise for 60 seconds at the pre-specified loudness [selected by button 5] and for ear(s) selected by button 1. Focus is laid on speech intelligibility: Users should begin with a comfortable loudness and concentrate themselves on understanding each single word. Subsequently, users should reduce loudness and repeat the training on a regular basis (e.g. twice a day for 15 minutes), noting down the training time and the intensities used.

- 1 **Select Ear:** selects “left ear”, “right ear”, or “both ears (stereo)” for training.
- 2 **Select Test/Training:** Training 2.
- 3 **Select Language <English | Français | Deutsch | Español>:** users can chose between 4 different languages: English, French, German, or Spanish.
- 4 **Intensity:** displays current loudness [dB] used for training [selected by button 5].
- 5 **Select Intensity:** selects the loudness [dB] to be used in the “Speech Intelligibility” training: left arrow “◀” decreases and right arrow “▶” increases loudness.

Please Note: Any auditory training will show the desired effect only if the training sessions are repeated on a regular basis (e.g., twice per day for 15 minutes).

Results: Hearing Loss from 55 to 7,040 Hz



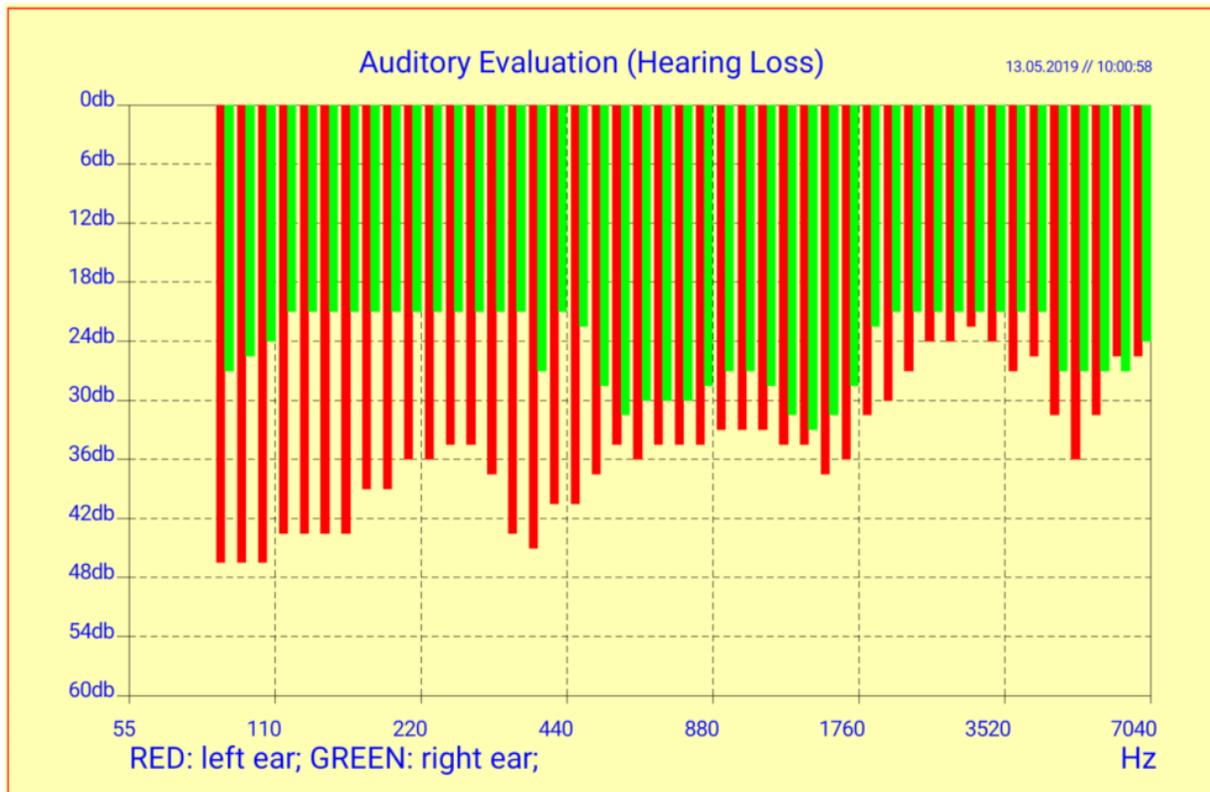
- 1 **Results:** once hearing thresholds have been determined through “Single Tests” or “Full Tests”, the evaluation outcome should be reviewed by pressing this button. All outcomes can be stored, along with date and time, in folder «AuditoryEvaluation». In particular, the results of all evaluations can easily be printed for documentation purposes (e.g., through cloud printing).

Results of “Hearing Loss” evaluations are displayed in form of bar charts as a function of frequency (hearing loss [dB] × frequency [Hz]) over the frequency range 55 - 7,040 Hz [7 octaves: 55-110Hz, 110-220Hz, 220-440Hz, 440-880Hz, 880-1760Hz, 1760-3529Hz, and 3520-7040Hz; 8 tones per octave].

Frequency [Hz] is plotted along the horizontal axis and hearing loss [dB] along the vertical axis with red bars denoting the left ear and green bars the right ear. A loss of up to 20 dB is regarded as “normal” and does not require specific action. Left-right differences are common. It is worth noting, however, that “hearing loss” exhibits distinct between-subject differences – each sufferer has his/her own pattern of affected frequencies. In consequence, a personalized, hearing-loss specific auditory training is often the only way to improve word intelligibility (to some extent) as hearing aids have still really frustrating limits in this respect.

Hearing Loss Characteristics

The hearing loss characteristics below show significant left (red) - right (green) differences with highly significant losses on the left ear over the entire frequency range. Of particular relevance regarding speech intelligibility are the pronounced losses between 300 - 600 Hz, while the losses around 110 Hz are less relevant in this context. None of the hearing aids currently on the market supports characteristics like this but rather, sufficient support is only found for losses at frequencies above 500 Hz.



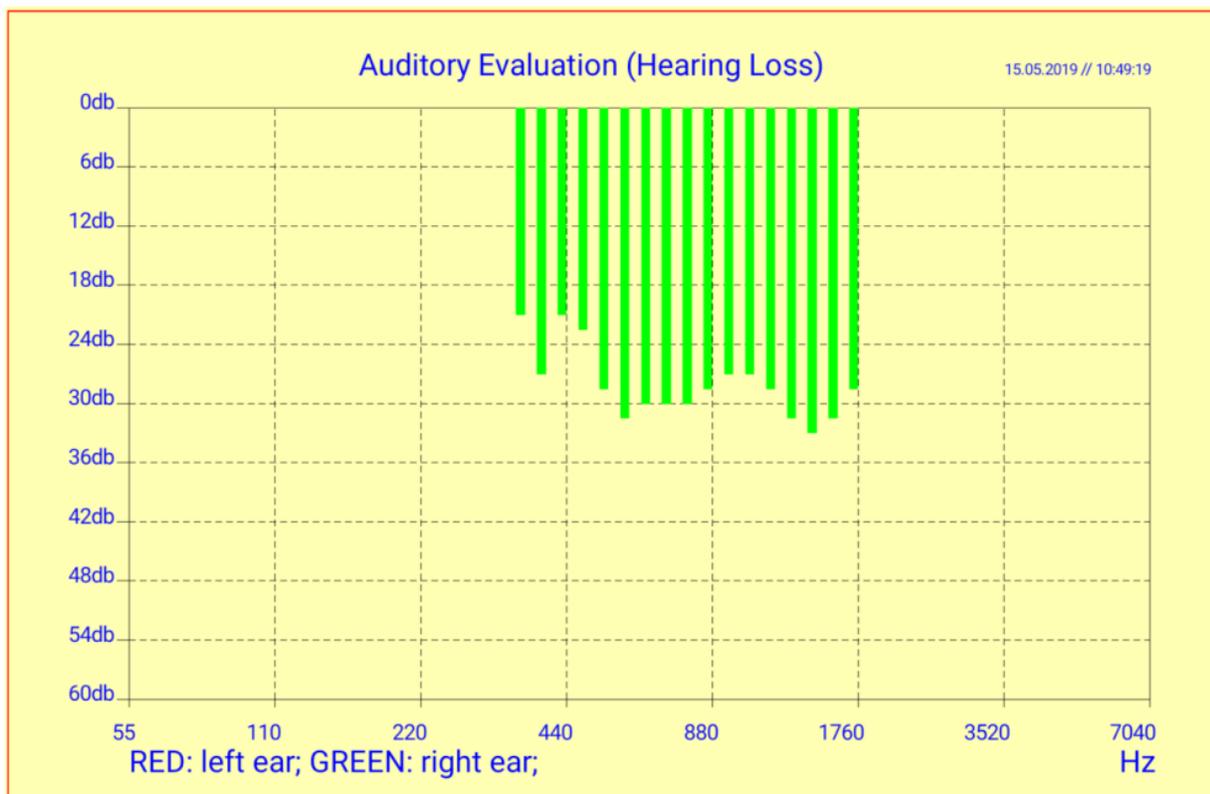
Results are stored in folder «AuditoryEvaluation» in the universal *.png format, along with date and time, so that the training progress can easily be monitored. For example, test outcomes can be printed out systematically for documentation purposes through cloud printing. Indeed, users should keep track of how and when training sessions were successfully completed.

Results: Hearing-Loss Specific Tests

Once hearing loss has been carefully evaluated (we recommended several “Full Tests” in the morning and the evening), “Single Tests” come into play (in addition to Training 1 and Training 2). Single tests allow users to specifically target the frequencies with the largest deficiencies, that is, to concentrate efforts on hearing-loss specific auditory training sessions. In fact, in a considerable number of cases sufferers show distinct losses in a small, individually very specific frequency interval while most other frequencies respond fairly well.

Hearing-loss specific auditory training (as provided by “Single Tests”) might improve the situation in these cases and users should give it a chance (with some patience).

In the example below, hearing-loss specific auditory training was carried out for a user’s right ear (right ear: green bars) and the frequency interval 330 Hz to 1584 Hz. This kind of training takes just a few minutes and is intended to complement “Training 1”.

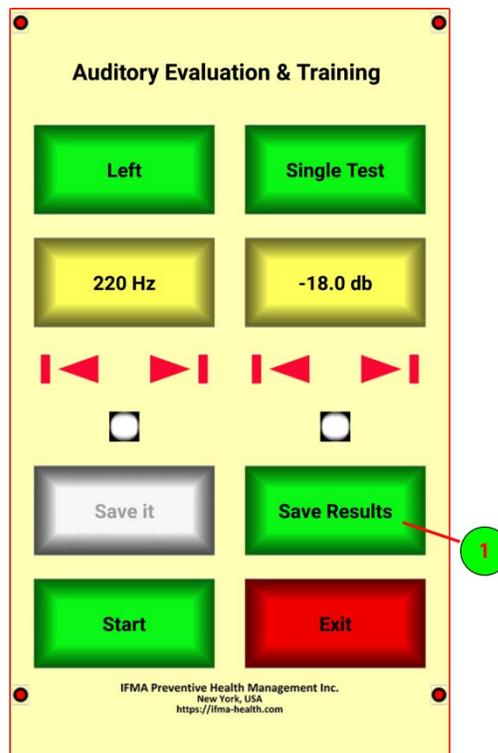


Needless to say: users should keep track of their training sessions, analyze results, and set ambitious goals.

Results: Development over Time

For adults with hearing loss, specific auditory training sessions can facilitate communication in noisy situations as they almost always improve speech intelligibility. Critically important here is the training at regular and sufficiently dense intervals. When each word/syllable of the training text is clearly understood, users should try to reduce the loudness in the speech intelligibility training by **-1.5dB**: set ambitious goals and learn what is achievable!

Besides improving speech intelligibility, auditory training sessions on a regular basis counteract feelings of helplessness and cognitive decline efficiently – getting involved and doing something about it is the most important step to successfully cope with hearing loss.



- 1 **Save Results:** stores results in folder «AuditoryEvaluation» in the universal *.png format, along with date and time, so that the training progress can easily be monitored. For example, test outcomes can be printed out systematically for documentation purposes through cloud printing. Indeed, users should keep track of how and when training sessions were successfully completed.

Please Note: Any auditory training will show the desired effect only if the training sessions are repeated on a regular basis (e.g., twice per day for 15 minutes).

Philanthropy

We plan a representative scientific study of the characteristics of hearing loss in the general population and would very much appreciate if users could send us their hearing loss charts by email. Thus, we will be able to rely on a much broader basis of empirical data when developing new training approaches.

Advancements in this field are primarily made possible by data contributions of users like you:

Thank You.

Data Privacy: All information collected within the scope of this scientific project is processed in a strictly anonymous way and used only for the purpose of this project using statistical (epidemiological) analyses. Specifically, data are stored in such a way in our databank that the identity of the users who contributed the data cannot be revealed under all circumstances.

Wish List to Hearing Aids Manufacturers

We have tested high-end devices of several major manufacturers. Firstly, none of these devices covered the lower frequency range 88 - 660 Hz at a sufficiently dense **tonal** resolution, thus cutting off an estimated 35% of people from effective help. Secondly, none of these devices came with an accompanying smartphone «**App**» that lets users adjust the device's frequency response according to individual requirements. Finally, adjustment procedures provided by professionals in hearing aid centers turned out to be inefficient and tediously time-consuming. Typically, numerous sessions were required for individually optimized solutions. The vast majority of customers would have done this optimization much better and more efficiently at home – if they have had the respective smartphone «**App**». Here is our wish list to hearing aids manufacturers:

- (1) Hearing aids should have an evenly spaced **tonal** resolution over 7 octaves [e.g., 55-7,040Hz] with 8 **tones** per octave; the amplification of each tone should be individually adjustable.
- (2) Higher-valued hearing aids should be sold with an accompanying smartphone «**App**» that allows users to individually adjust the amplification of the evenly spaced **tones** (equalizer with at least 4 bands per octave).

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