Car Cabin Sound Personalization (CCSP)

Alango Technologies Whitepaper
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1. The Story of Missed Sound

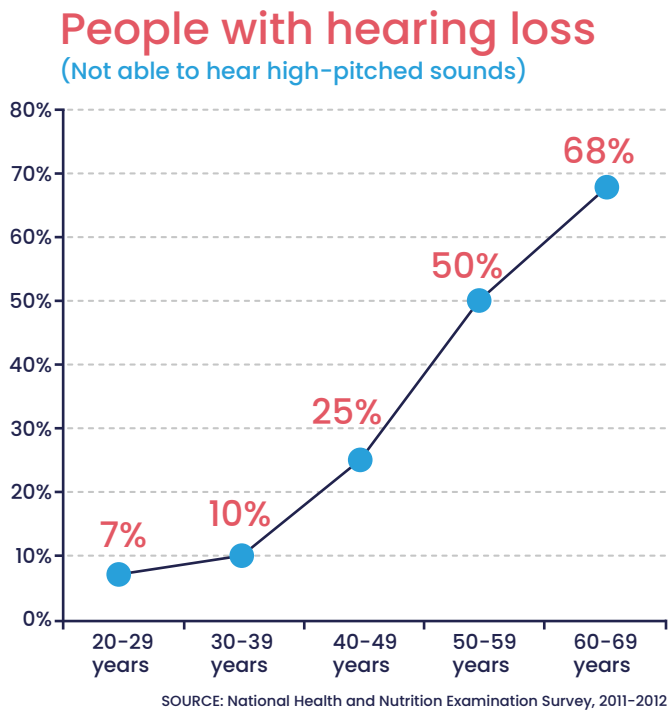
In March 2025, Alango Technologies exhibited at the annual Global Audio Summit (GAS) in Shanghai, organized by the China Audio Industry Association. Over the past 3 years, GAS has become a major event that brings together the academic world and the industry that develops technologies and products related to sound. After showing a demo on sound personalization, we were invited by one of the biggest car manufacturers in China to do a demonstration in a real car. The next day, we brought our demo DSP board, connected it to the car's audio system via a Bluetooth transmitter and let our hosts experience the system, including a 5-minute listening test. During the test, one of the young engineers in his 30s realized that he had significant hearing loss at high frequencies, which he attributed to listening to loud music through headphones. When he experienced the sound in the car tailored to his impaired hearing, his reaction was, “WOW, I didn't realize how much I was missing”. We hope that future cars will enable him and others to discover and regain the sound they are missing.

2. Why Car Cabin Sound Personalization

Car manufacturers invest a lot of time and millions of dollars in perfecting and tuning sound systems for cars to find the best compromise between size and cost constraints. Tuning is usually done by experts with “golden ears” who can detect subtle nuances to achieve the fine balance between bass, midrange and treble. Unfortunately, this perfect balance is only fits people with healthy hearing. The perception of sound dynamics for people with hearing loss is different. They are less sensitive or even deaf to sound nuances, especially at low levels, and therefore miss out on the benefits of a perfect sound system. Millions of dollars and days of comprehensive fitting work by experts become pointless. The users cannot appreciate it. Is it possible to pre-process the sound played through the car sound system to restore the missing sound details for people with hearing loss? Not completely, but something can be done with Car Cabin Sound Personalization technology.

3. The World of Hearing-Impaired Drivers

According to the World Health Organization, 1.5 billion or 1 in 7 people over the age of 18 on earth have some degree of hearing loss and therefore cannot hear the full spectrum of sound. The figure below shows that the situation worsens with age.



Half of people in their 50s and two-thirds of people in their 60s have some degree of hearing loss. When these people drive, they cannot fully enjoy even the best in-car sound system unless their hearing loss is compensated. But does this create a need for sound personalization in the car system itself? Aren't all these hearing-impaired drivers already satisfied hearing aid users? When we promote sound personalization, are we addressing a genuine need, or are we offering a solution to an audience that may already feel adequately served?

3.1 Hearing Loss and Hearing Aids

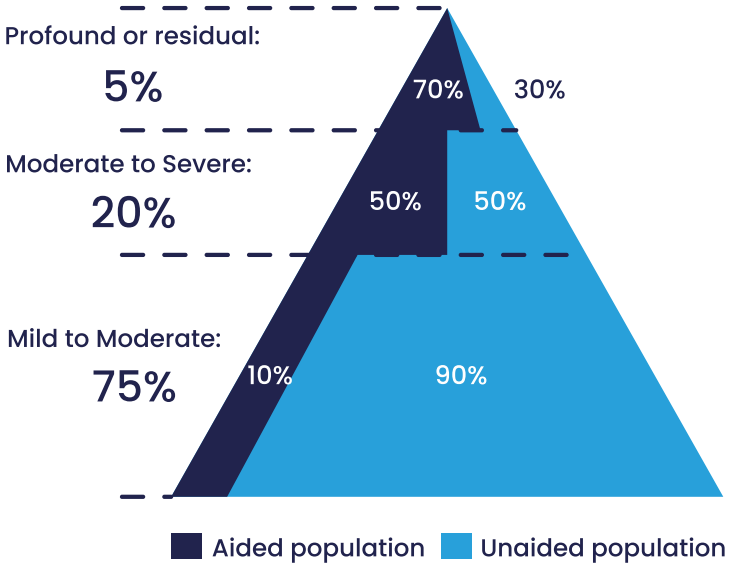
Let's take a look at the statistics on the degree of hearing loss and hearing aid users in the figure below. The total area of the pyramid is 1.5 billion people.

The bottom 75% or 1.1 billion people have only mild to moderate hearing loss, most often in high frequency regions above 6000Hz. These people manage quite well without hearing aids in almost all situations. They therefore do not

have enough motivation to spend money or “waste” their time to use a product that gives them limited benefit but requires careful handling and makes them look handicapped. The result is that 90%, or one billion people with mild to moderate hearing loss, do not use any type of hearing amplifiers. This one billion people miss the full audio, most of them are not even aware of that.

The middle 20% is still a large number of 300 million. These people really need hearing rehabilitation, but only half of them use it. We have 150 million people who can barely enjoy music, even if they turn up the volume to a level that is unbearable for others. Many of us know people like that.

The upper part is relatively small and can only be helped with very powerful hearing aids or cochlear implants. We cannot say that sound personalization can be useful for them.



In total, there are more than 1.1 billion people worldwide with a hearing loss who are unable to fully enjoy car sound systems. We assume that many of these people are drivers.

3.2 The Limitations of Hearing Aids for Audio

Let us assume that two miracles have happened:

1. All people who buy a car are given a hearing aid as a gift
2. All people who get a hearing aid use it.

Does this solve the problem of experiencing the best audio quality in the car?

it does not. Hearing aids are not high-quality audio devices. Their tiny balanced armature speakers are not capable of reproducing sounds below 400 Hz and above 6000 Hz. They cannot produce sound that can match the frequency range of even a moderately good car sound system. People with mild to moderate hearing loss cannot benefit from hearing aids as a replacement for car sound personalization technology.

4. PersonaSound™ Technology for Cars

Alango has been working on the development of hearing and listening enhancement technologies for 10 years. Recently, Alango has adapted its PersonaSound™ technology, developed for hearing enhancement in hearing aids, headphones and TWS earbuds, for sound personalization in the car. PersonaSound incorporates all the necessary, fully customizable technologies with various options to improve sound for people with hearing loss.

4.1 Hearing Compensation Principles

To compensate for hearing loss, PersonaSound uses the principles of multiband Wide Dynamic Range Compression (WDRC), which is the principle used in most hearing aids today. The input signal is first divided into frequency sub-bands, known in audiology as “channels”. Individual compression schemes optimized for a specific hearing loss are then applied before the sub-bands are combined into a full-band output signal. A simple, non-formulaic explanation of the consequences of sensorineural hearing loss and its compensation by WDRC can be found in the white paper “Digital Signal Processing for Over-the-Counter Hearing Aids”.

For best results with WDRC-based hearing compensation, processing settings must match the user's hearing loss at different frequencies. This loss is measured by the quietest tones a person can hear across specific frequencies. The thresholds are expressed relative to the levels of a young person with normal hearing. This means that if a person's hearing threshold at a certain frequency is 40 dB, that person can only hear sounds that are 40 dB louder than a young person with normal hearing can detect at that frequency.

4.2 Hearing Assessment and Tuning Procedures

In audiology, the hearing thresholds for a set of frequencies are referred to as an "audiogram". The thresholds (audiograms) can be measured by a hearing care professional, determined during an explicit self-test of the user, or inferred non-directly from the user's actions that indicate a preference for a sound enhancement corresponding to one audiogram over another when listening to audio content. Alango supports 5 methods to personalize a car sound system.

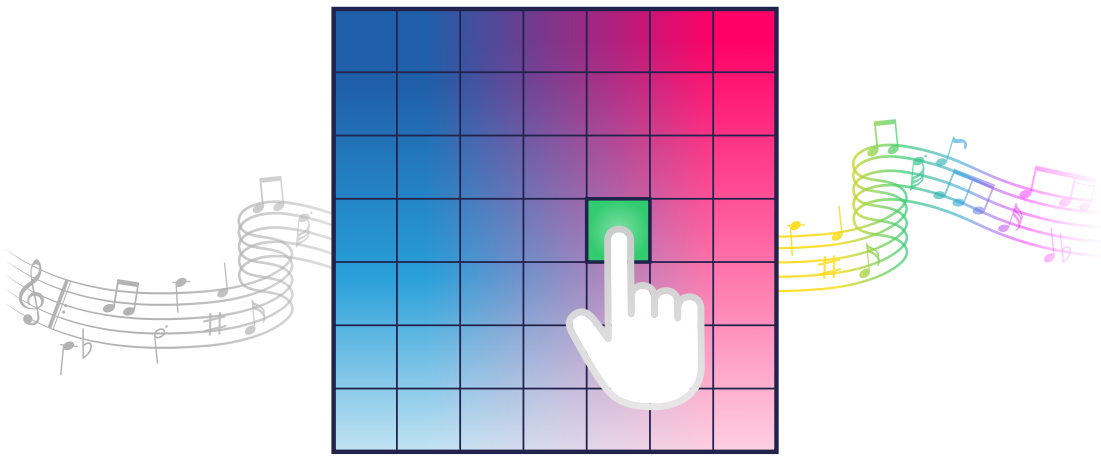
4.2.1 Preset Based

This is the simplest type of tuning, where the user can choose between a small number of audiograms. The figure below shows an example where users simply enter their age (group) and the average audiogram for the selected age is used.

This method isn't limited to age selection—other criteria can be used too. A two-step approach is also possible: first, the user enters their age; then, real-time sound adjustment is applied, optimized for that age group, as described by the Best Sound Point approach below.

4.2.2 Best Sound Point

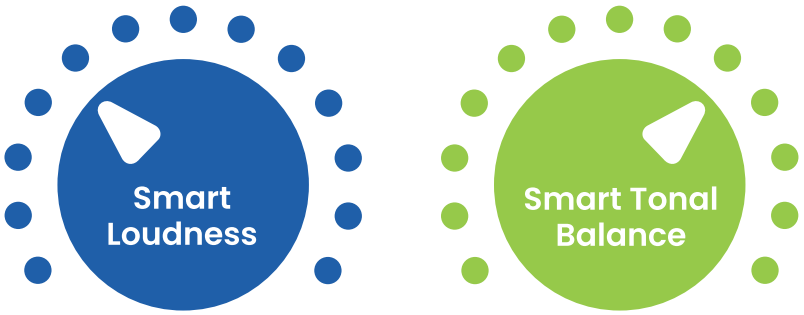
Best Sound Point (BSP) Tuning is a patent-pending method developed by Alango that allows quick, easy and intuitive selection from a large number of presets that the user can choose from in under 5 minutes. The figure below illustrates the principle with a 7x7 grid.



The user navigates through a grid of cells while listening to speech or music. Pressing a specific cell activates one of the profiles from a set of predefined profiles, each profile corresponding to a specific hearing loss. The profiles are arranged to simplify tuning. For example, the vertical position represents the average hearing loss across all frequencies, while the horizontal position defines the difference in thresholds between the low and high frequencies. Moving upwards increases the loudness of low-level signals, while moving left or right changes the balance of amplification between the low and high frequencies, making it easier to reach the Best Sound Point.

4.2.3 Smart Loudness and Smart Tone control

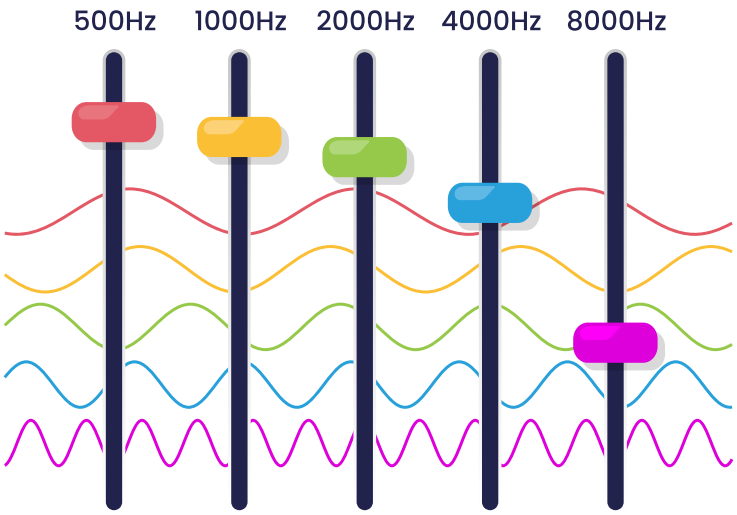
In this mode, users adjust the sound they hear with just two controls such as virtual knobs shown in the figure below.



The Smart Loudness control adjusts the average hearing threshold (the average audiogram level), where an increase in the threshold corresponds to a higher amplification and a higher perceived loudness of low volume signals. The Smart Tonal Balance control does not change the average audiogram level, but its slope, which changes the amplification balance between low and high frequencies.

4.2.4 Hearing Self-Test

In the hearing self-test users listen to wobbling tones of different frequencies one after the other. Users adjust the loudness to find their hearing thresholds—the quietest sounds they can still hear.



After the test is completed for all frequencies, a special procedure developed by Alango is activated to transfer the results of the test to the corresponding parameters of the Wide Dynamic Range Compressor. The parameters are different for audio playback and voice communication. Audio playback requires less compression and longer release times to better preserve the dynamics of the music.

4.2.5 Explicit Audiogram Input

Users can explicitly enter the audiogram they received during a hearing test performed by a hearing care professional. As with the hearing self-test, the audiogram parameters are converted into parameters of the Wide Dynamic Range Compressor.

4.3 Personalized Audio Enhancement by Audio Enhancement Software Package

The Alango Audio Enhancement Package (AEP) is a suite of audio processing technologies, including Wide Dynamic Range Compressor. The package receives its parameters via the initialization procedure or during active playback, modifying processing on the fly and allowing fine-tuning of audio enhancement on the fly via the sliders/buttons or the Best Sound Point interfaces. The package provides channel-synchronized stereo or multi-channel processing to maintain the tonal balance of each audio channel.

In addition to the Multiband Wide Dynamic Range Compressor, the AEP package includes other blocks to help users with hearing loss achieve better sound experience in mobile environments.

Spectral Compander, a sub-block of SonicVibrance technology, reduces the instantaneous spectral dynamic range, which improves the perception of weak spectral components. Spectral Compander compensates to a certain extent for what is known in audiology as “spectral smearing”, i.e. the reduced ability to distinguish between adjacent sound frequencies.

Adaptive Volume and Equalization compensates for the masking effect of ambient noise by selective dynamic amplification of frequencies according to the short-term noise spectrum.

VoiceFirst technology reduces the background noise in movies and TV shows that often prevents the hearing impaired from understanding the main dialog.

All of the above blocks are parameterized and can be considered as part of the personalization of a car sound system. A detailed description and sound examples of these hearing assistance technologies integrated into the Audio Enhancement Package can be found here.

5. Conclusion

Personalizing in-car sound systems to compensate for individual hearing loss is an important technology that significantly improves the in-car listening experience for people with hearing loss. Most cars are still occupied and driven by a single person, for whom personalization of sound can be beneficial. For two people of similar age with typical hearing loss for their age, the compromise can be found. For multiple occupants, there are sound zoning technologies that rely on speakers being integrated into active headrests. Then the sound optimization in the car can be truly personal for each occupant.

Let’s make every ride sound better — for YOU!