Novelty Journals

ISSN 2394-7330

International Journal of Novel Research in Healthcare and Nursing
Vol. 12, Issue 2, pp: (87-92), Month: May - August 2025, Available at: www.noveltyjournals.com

# Application of Stereophonic 3D real-time sound and speech processing to conductive hearing loss: A Case Report

Mitsiou Nikolaos[1], Mevouliotis Ioannis[2], Vaitsis Nikolaos[3]

[1] Speech Therapist, Greece

[2] Audio Engineer, Greece

[3] Medical Doctor, Greece

**DOI: https://doi.org/10.5281/zenodo.15668568**

**Published Date: 15-June-2025**

*Abstract:* **Background: Stereophonic 3D sound processing offers new rehabilitative strategies for conductive hearing loss (CHL) by simulating natural acoustic environments, enhancing spatial awareness and speech understanding. These technologies mimic sound wave interactions with the head and ears, potentially easing challenges faced by those with CHL. However, their clinical application remains limited, as research has primarily targeted sensorineural hearing loss and cochlear implants. There is a pressing need to assess their effectiveness for conductive impairments in real-world settings. This case report seeks to evaluate the use of advanced sound processing techniques in clinical practice, focusing on functional outcomes and user experiences. Methods: This report presented a boy, aged 3.5 years, with conductive hearing loss (mild to moderate) in both ears, due to secretory otitis media (fluid in the middle ear). Through speech therapy sessions with application of combined use of bone conduction headphones and stereo three-dimensional sound & speech processing in real time, there was a significantly accelerating child's linguistic and social development, offering them an auditory experience as close as possible to normal hearing. Conclusions: The combined use of Bone Conduction Headphones and Real-Time Stereo 3D Sound & Speech Processing can create a rich, spatially oriented, auditory environment that: a) Restores auditory accessibility to children with conductive hearing loss, b) Accelerates phonological development, c) Cultivates spatial hearing and attention skills, and d) Creates a positive learning cycle.**

*Keywords:* **Real-Time Stereo Three-Dimensional Sound, Speech Therapy, Case Report, Greece.**

## 1. INTRODUCTION

Conductive hearing loss (CHL) is characterized by an impairment in the transmission of sound waves through the outer or middle ear, resulting in diminished auditory input despite normal inner ear function (1). This type of hearing loss can arise from a variety of etiologies, including otitis media, ossicular chain discontinuity, otosclerosis, and congenital malformations (2). The clinical implications of CHL are profound, affecting speech and language development, academic achievement, and social interactions, especially when left unaddressed during critical developmental periods (3). Traditional management strategies for CHL include medical interventions such as antibiotics or surgery, and the use of conventional hearing aids. However, these solutions may not always be feasible or sufficient, particularly in cases where anatomical anomalies or patient preferences limit their effectiveness (4). Consequently, there has been increasing interest in advanced auditory prostheses and signal processing technologies that can bypass or compensate for peripheral deficits, providing clearer and more natural sound perception.

Recent technological advancements have introduced sophisticated sound processing algorithms capable of enhancing auditory signals in real time. Among these, stereophonic 3D sound processing has gained attention for its potential to replicate spatial hearing cues, thereby improving sound localization and speech understanding in complex acoustic environments (5). Unlike traditional monaural or simple binaural systems, three-dimensional (3D) sound processing utilizes complex algorithms to simulate the natural spatial distribution of sound sources, offering users a more immersive and accurate auditory experience. In parallel, speech processing technologies have evolved to optimize speech clarity, reduce background noise, and enhance signal-to-noise ratios, which are critical for individuals with hearing impairments (6). The integration of these technologies into real-time systems allows for dynamic adaptation to environmental acoustics and user needs, thus providing personalized auditory rehabilitation solutions.

While the application of stereophonic 3D sound processing has been extensively explored in cochlear implant users and individuals with sensorineural hearing loss, there is a paucity of research focusing on its utility in conductive hearing loss. The majority of existing studies emphasize the benefits of such systems in complex listening environments, including speech-in-noise perception and spatial awareness. However, their potential in enhancing auditory perception for individuals with conductive deficits remains under-investigated (7).

This case report aims to fill this gap by exploring the application of stereophonic 3D real-time sound and speech processing technology in a patient with CHL. The integration of advanced signal processing algorithms offers a promising avenue for improving auditory experiences beyond conventional amplification, especially in cases where traditional hearing aids are limited or not suitable. By presenting a detailed account of the patient's clinical profile, intervention methods, and outcomes, this report seeks to contribute to the growing body of evidence supporting innovative auditory rehabilitation strategies for conductive hearing impairments.

The significance of this investigation lies in its potential to expand the therapeutic toolkit available to speech-language pathologists and audiologists, emphasizing the importance of personalized and technologically advanced solutions. Moreover, understanding how such systems influence speech perception and communication abilities in individuals with CHL can inform future research and clinical practice, ultimately enhancing quality of life for this population.

## 2. CASE REPORT

The case studied concerns a 3.5-year-old boy with conductive hearing loss (mild to moderate) in both ears, due to secretory otitis media (fluid in the middle ear), with a slight delay in expressive speech, difficulty in distinguishing phonemes, and poor phonological awareness. The case was treated at a Private Speech Therapy Center in Polygyros, Halkidiki (Greece).

The use of stereoscopic three-dimensional sound and speech processing in real time had the following goals: a) Acoustic discrimination of nearby phonemes (/π/ – /μ/, /κ/ – /τ/), b) Focusing on the sound source through directionality, c) Production of words with targeted phonemes, d) Self-monitoring of the voice through feedback, and e) Improvement of attention and perception of spoken language. The equipment and media used in the sessions were: a) Bone conduction headphones, b) Behringer XR12 audio console + Tablet with Mixing Station, c) Stereo headset microphone for clear voice input, and d) Stereo processing with controlled directivity, amplitude and pitch.

During the sessions, the following procedures were applied:

1. Welcome – Equipment checks (5’)
    a. Adjusting the therapist’s voice to the “center”
    b. Test of auditory directionality with words/sounds
2. Auditory directionality (5’)
    a. Voice comes from right/left – the child indicates the direction
3. Auditory phoneme discrimination (10’)
    a. Minimal pairs of words in different “positions” in the sound
    b. Audiovisual stimuli with images
4. Word production (5’)
    a. Repetitions with feedback: the child hears himself processed (with “air”, clarity and delay)
5. Farewell – Repetitive activity (5’)
    a. Sounds from different “positions” for farewell

ISSN 2394-7330

International Journal of Novel Research in Healthcare and Nursing
Vol. 12, Issue 2, pp: (87-92), Month: May - August 2025, Available at: www.noveltyjournals.com

The recommended pitch and width boost settings were:

1. Stereo Width
   a. Width: +30% to +50%
   b. Balance: Center (0)
2. Stereo Panning
   a. L ↔ R toggle for attention activation
3. EQ (treble – clarity)
   a. Low Cut: 80–100 Hz
   b. Low-Mid: –2 dB @ 250 Hz
   c. Presence Boost: +2 to +4 dB @ 2.5–4.5 kHz
4. Compression
   a. Threshold: –20 dB
   b. Ratio: 2:1
   c. Attack: 10 ms / Release: 80–100 ms
   d. Make-up Gain: +3 dB
5. Reverb (optional)
   a. Type: Small Room
   b. Mix: 15%–20%
   c. Decay Time: 0.8–1.2 sec

The benefits of the session were the focus and clarity of the voice in the spatial auditory space, the enhancement of speech discrimination and comprehension, the improvement of participation, attention and phonological awareness, and the facilitation of auditory memory and self-monitoring. Table 1 describes the evolution of speech therapy intervention with 3D Sound.

**Table 1. Evolution of speech therapy intervention with 3D Sound**

| | Development Goals | Examples of activities | Technical Settings | Progress Indicators |
|---|---|---|---|---|
| *Acoustic Accessibility and Focus* | - Phoneme Perception<br>- Sound Directionality<br>- Activation of Auditory Attention | - Locating sound in space<br>- Repeating a word<br>- Audio games with sounds | - EQ +4dB (2–4 kHz)<br>- Stereo panning (directionality) 30–45°<br>- Light compression<br>- Bone conduction headphones | - Points to the source<br>- Repeats sounds<br>- Distinguishes phonemes in positions |
| *Production and Self-Monitoring* | - Production of targeted phonemes<br>- Attention to his voice<br>- Auditory self-correction | - Voice delay<br>- "Say-listen-correct"<br>- Compound words of 2 syllables | - Delay 150–200 ms<br>- Panning (directionality) with motion<br>- Wet mix 40–50% (child's voice)<br>- Parallel acoustic feedback | - Notices and corrects mistakes<br>- Produces words clearly<br>- Shows active listening |
| *Social Interaction and Suggestions* | - Use of phrases with two or three words<br>- Verbal initiative<br>- Interaction with faces | - Questions/Answers<br>- Roles (instructions – reactions)<br>- Vocal "friends' game" | - Stereo simulation (2 sources)<br>- Delay 80–120 ms<br>- Reverb 10% (child's voice)<br>- Boost EQ reduction for naturalness | - Uses sentences<br>- Responds to questions<br>- Recognizes and approaches "others" |

Novelty Journals

ISSN 2394-7330

International Journal of Novel Research in Healthcare and Nursing
Vol. 12, Issue 2, pp: (87-92), Month: May - August 2025, Available at: www.noveltyjournals.com

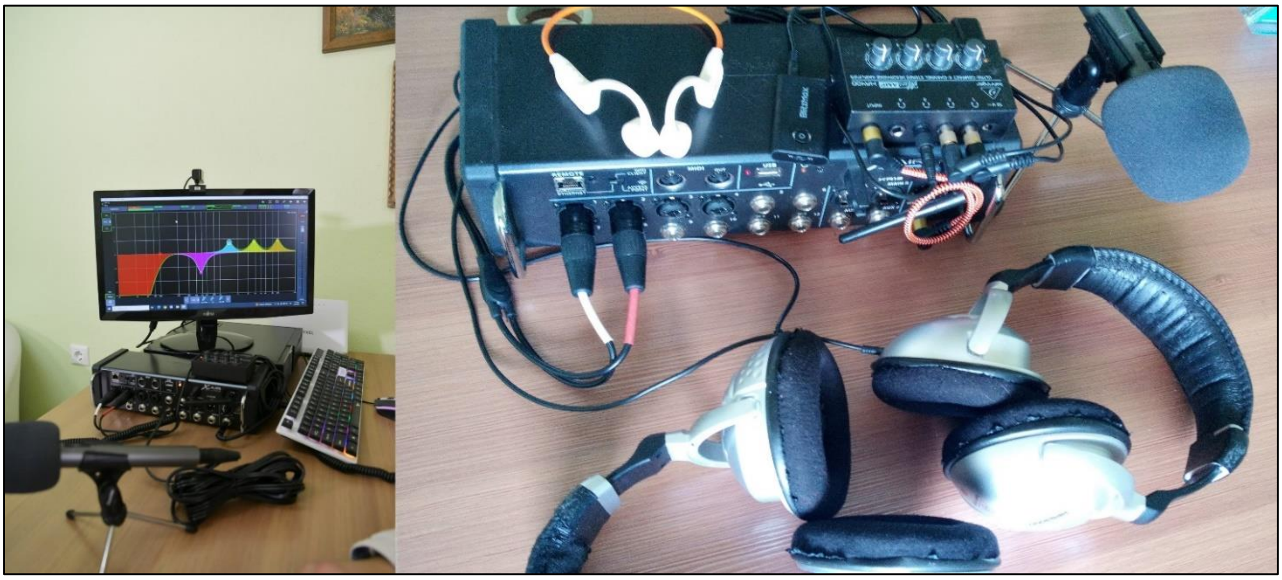

**Figure 1. 3D Stereo processing equipment**

## 3. DISCUSSION

Stereo width plays a curious role in therapy, particularly in speech training. Using spatial audio processing, therapists create immersive soundscapes that boost phonetic drills and help with speech recognition, often leading to unexpected improvements. By tweaking stereo width, sound can be sent to specific spots, so clients —quite often— learn to notice and tell apart subtle differences. Some clinics even mix in assistive listening devices that render sound naturally, making sessions longer and more comfortable, and in a way, reinforcing sound scenes with a fidelity that really supports learning. Generally speaking, these methods back up what's been bubbling up from recent voice signal analysis workshops (8).

Real-time 3D stereo sound paired with smart speech processing is shaking up speech therapy in surprising ways. It turns out that mixing ideas from cognitive science, acoustics, and tech isn't just academic chatter but a call for a blended, multidisciplinary take on how sound can reshape therapy (9). In most cases, these emerging tools hint at a shift toward therapies that are both quick on the trigger and driven by live data, making the process more engaging overall. Plus, those experimental images —especially ones showcasing sound localization techniques— give a nod to the core ideas behind these fresh, innovative practices.

Speech therapy today is taking an unexpected turn; emerging tech is quietly stepping in to reshape how treatments work. For instance, digital signal processing —specific devides for sound engineering that breaks down and analyzes sounds in real time— often delivers immediate feedback and paves the way for interventions tailored to the individual. Immersive audio tools can also create a three-dimensional sound space that makes sessions feel surprisingly interactive and engaging (10). Realistic avatar tech, meanwhile, has been embraced in ways that sometimes ease the familiar anxieties of traditional sessions by letting patients connect with virtual therapists (11). Generally speaking, these innovations don't just boost engagement—they're linked to better social and cognitive benefits, particularly helping those with autism spectrum disorder. All in all, the blend of technology and therapy hints at a future where communicative skills truly blossom and overall well-being gets a much-needed uplift.

Stereo width is catching attention as a fresh twist in speech therapy, one that could really shake up how we treat communication disorders. Instead of the usual methods, crafting a fuller, richer auditory scene seems to pull patients right into the process, often boosting both speech clarity and the way sounds are picked up. This idea gets even more weight when you consider our aging population —many of whom, in most cases, deal with chronic illnesses and hurdles that muffle clear communication. Also, current tech tools like those found in telerehabilitation make it easier, oddly enough, for patients to keep up with care even when they're not in a traditional clinic setting (12). And, as auditory tech continues to morph in unexpected ways, letting stereo width join the mix might just flip therapeutic practices on their head by offering a custom-fit approach that meets the varied needs of folks looking to improve their ability to communicate.

International Journal of Novel Research in Healthcare and Nursing
Vol. 12, Issue 2, pp: (87-92), Month: May - August 2025, Available at: www.noveltyjournals.com

Stereo width in speech therapy brings some interesting benefits and even hints at what tomorrow might hold. Therapists mix in wider soundscapes that help clients —especially those wrestling with hearing or speech challenges— get a clearer sense of where sounds are coming from and how they're processed. Research, in most cases, shows that when stereo width is tweaked, clients often mention they pick up on subtle speech cues more easily and can better separate speech from background noise. There's also a big chance for new ideas down the road; as tech continues to move forward, experts might roll out creative training programs that use stereo width to zero in on specific speech issues. Overall, evolving work in audio processing really underlines the value of these techniques, suggesting that their role in shaping more effective speech therapy interventions is only just taking off (13).

The emergence of stereophonic 3D real-time sound and speech processing presents remarkable possibilities for rehabilitative interventions in conductive hearing loss (CHL). In contrast to conventional devices, these systems are designed to replicate the natural acoustic environment, thereby offering users spatial information that enhances localization and comprehension of speech. By mimicking the intricate interactions of sound waves with the head and ears, these technologies have the potential to mitigate the deficits associated with conductive impairments. However, despite these encouraging advancements, the use of stereophonic 3D processing in clinical environments for individuals with CHL is still limited, as the majority of research has concentrated on sensorineural hearing loss or cochlear implantation. There is an increasing necessity to investigate its effectiveness specifically in relation to conductive impairments, particularly in practical situations. This case report seeks to add to this developing area by assessing the application of such sophisticated sound processing methods in a clinical context, with an emphasis on functional outcomes and user experiences.

Considering the possible advantages of stereophonic 3D sound processing in improving spatial hearing and speech perception, this case report offers a chance to explore its practical use in a patient with conductive hearing loss (CHL). The case centres on a patient experiencing unilateral conductive hearing loss who was equipped with an innovative 3D sound processing device as part of a tailored auditory rehabilitation program. The goals include evaluating enhancements in sound localization, comprehension of speech in noisy environments, and overall communication skills. By documenting this case, the research intends to shed light on the viability, advantages, and constraints of utilizing advanced 3D sound processing technologies in the treatment of CHL. Furthermore, it aims to guide future research initiatives and clinical methodologies, highlighting the significance of customized auditory rehabilitation approaches that utilize technological advancements.

## REFERENCES

[1] Porcar-Gozalbo N, López-Zamora M, Valles-González B, Cano-Villagrasa A. Impact of Hearing Loss Type on Linguistic Development in Children: A Cross-Sectional Study. Audiology Research. 2024 Dec;14(6):1014–27.

[2] Nittrouer S, Lowenstein JH. Early otitis media puts children at risk for later auditory and language deficits. International Journal of Pediatric Otorhinolaryngology. 2024 Jan 1;176:111801.

[3] Borre ED, Kaalund K, Frisco N, Zhang G, Ayer A, Kelly-Hedrick M, et al. The impact of hearing loss and its treatment on health-related quality of life utility: a systematic review with meta-analysis. J Gen Intern Med. 2023 Feb;38(2):456–79.

[4] Rajan D, Cureoglu S, Adams ME, Monsanto R. Otosclerosis and the evolution of stapes surgery: A historical and otopathological study. Laryngoscope Investig Otolaryngol. 2024 Dec;9(6):e70045.

[5] Litovsky R. Development of the auditory system. Handb Clin Neurol. 2015;129:55–72.

[6] Kates JM. Digital Hearing Aids by James M. Kates. 1 edition. Plural Publishing; 2008.

[7] Ausili S. Spatial hearing with electrical stimulation. [Netherlands]: Radboud University; 2019.

[8] Sunder K, Jianjun He, Ee Leng Tan, Woon-Seng Gan. Natural Sound Rendering for Headphones: Integration of signal processing techniques. IEEE Signal Process Mag. 2015 Mar;32(2):100–13.

[9] Geronazzo M, Serafin S. Sonic interactions in virtual environments [Internet]. Springer; 2022 [cited 2025 Mar 16]. Available from: http://hdl.handle.net/10044/1/97246

International Journal of Novel Research in Healthcare and Nursing
Vol. 12, Issue 2, pp: (87-92), Month: May - August 2025, Available at: www.noveltyjournals.com

[10] Tardón LJ, Barbancho I, Barbancho AM, Peinado A, Serafin S, Avanzini F. 16th Sound and Music Computing Conference SMC 2019 (28–31 May 2019, Malaga, Spain). Applied Sciences. 2019 Jan;9(12):2492.

[11] Seymour M, Riemer K, Kay J. Actors, Avatars and Agents: Potentials and Implications of Natural Face Technology for the Creation of Realistic Visual Presence. Journal of the Association for Information Systems [Internet]. 2018 Oct 31;19(10). Available from: https://aisel.aisnet.org/jais/vol19/iss10/4

[12] Pallarés Q. Comparison study of the lower-limb joint kinematics between an optical system of movement capture and a depth camera [Internet] [Bachelor's Thesis]. [Spain]: Universitat Politècnica de Catalunya; 2022. Available from: https://core.ac.uk/download/559250969.pdf

[13] Hartcher-O'Brien J, Buchholz M. Investigating the buildup of precedence effect using reflection masking. In Acoustical Society of America through the American Institute of Physics; 2006 [cited 2025 Mar 16]. p. 3083. Available from: https://asa.scitation.org/doi/10.1121/1.4787437