The information presented in this whitepaper applies to products manufactured by GN that are comparable with equivalent technology as ReSound. For further information, see reference list.

Sound quality comparison of Auracast and teleloop systems in a real-world environment

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Abstract

As the first hearing aid manufacturer to implement Bluetooth® LE Audio with Auracast™ in our products, ReSound is uniquely positioned to offer opportunities for comparing audio quality for sound transmitted via teleloop versus the new Bluetooth technology. This study compares sound quality and user preference between Auracast and traditional teleloop (hearing loop) systems in a realistic environment. Participants with and without hearing loss listened to audio samples via both systems without knowing which type they were listening to. Results showed strong and consistent preferences and ratings for Auracast across all participants. Qualitative comments described Auracast as fuller, richer, and clearer, while the teleloop was characterized as metallic, flat, and thin. Auracast seems capable of meeting audio quality needs broadly rather than being limited to users with specific needs. It may therefore support more rapid, widespread adoption than teleloop systems to the benefit of all consumers of streamed audio.

Assistive listening devices and systems supplement hearing aid use by offering better signal-to-noise-ratios (SNRs) for desired sounds that hearing aids don't adequately provide access to. This is often the case in public spaces such as theaters, places of worship, ticket counters, taxis, and more. Assistive listening technologies have developed alongside hearing aid technology through the past century, with telecoils being the first of their kind in the late 1930s.[1] Perhaps because of their long service in assistive listening technology, telecoils and the teleloop systems that provide the signals telecoils pick up are often spoken of as being old or outdated technology. This is like saying that phones are outdated; the pronouncement does not take into consideration that there have been many advances in the technology through the years. Advances in materials and design have allowed greatly reduced size and superior performance of telecoils compared to the early versions. Telecoils have long been integrated with the hearing aid amplifier, improving SNR and offering programmability. And amplified telecoils show much improved immunity to electromagnetic interference compared to their predecessors which greatly improves sound quality. They are very effective in picking up a good fidelity signal from teleloop systems as well as hearing aid compatible phones and delivering it to the hearing aid amplifier. They offer great benefit to hearing users in doing so.

Today, assistive listening technologies fall into three types: teleloop, infrared, and Radio Frequency (RF). Of these, only the teleloop has until now provided an effective, simple and non-proprietary solution that delivers the desired sound directly to any hearing aid user's telecoil-equipped hearing aids. This appears poised to change in the coming years.
Bluetooth®, a digital wireless RF-based technology, has been the primary standard for transmission of audio and visual content in consumer electronics for more than 20 years. Although it was expected that Bluetooth would make its way into hearing aids as well, heavy power consumption meant that the technology was not that well-suited. Proprietary RF streaming technologies have proliferated in hearing aid systems and in mobile devices. As a result, a hearing aid with RF wireless technology probably supports at least 3 different proprietary wireless communication protocols including one that is hearing aid brand specific and two that are specific to mobile device operating systems. This has created a confusing landscape of direct connectivity to hearing aids that lacks the simplicity and universal compatibility that makes teleloop systems and telecoils so attractive.

In 2022, the Bluetooth SIG (Special Interest Group) released Bluetooth Low Energy (LE) Audio with Auracast. In addition to better sound quality and lower latency compared to classic Bluetooth, this new version promises to deliver a similar user experience as the teleloop to all users of the technology. That is, a wireless audio streaming solution that is simple, high quality, and non-proprietary. Why is this significant? Previously, users of hearing aids and users of consumer electronics received audio via technologies specific to each user group. Teleloops and other hearing aid compatible technologies were for hearing aid users while classic Bluetooth was mainly for users of consumer devices. Bluetooth LE Audio with Auracast is for everyone. It is an example of universal design in accessibility to streamed audio. Universal design focuses on the design being usable by all

people, regardless of ability. It accommodates all people rather than being a custom design for people with special needs. And if everyone is accommodated, that can mean that the technology becomes more widely adopted so that it is available for more people in many more environments.

Key facts on teleloops and Auracast

Teleloop systems are also known as hearing loops, induction loops, and telecoil/T-coil systems. Combined with telecoils in hearing aids, the technology enables people with hearing loss to hear sounds more clearly. A microphone picks up sound and sends it into a loop of wire installed around a room or into a smaller portable loop placed close to the hearing aid user. The wire creates a magnetic signal across the area inside the loop and its nearby surroundings, and this magnetic signal is picked up directly by telecoils in the hearing aids. Teleloop technology provides a single analogue mono audio stream with a typical frequency range of at least 100 Hz to 5kHz, as required by the relevant IEC standard.[2] It is common practice in hearing aid design to high-pass filter the telecoil response such that the low-frequency cut-off is around 300 Hz. The purpose of this filtering is to minimize a drawback of telecoils and teleloop systems, namely hum or other interfering noises that typically are picked up. The frequency response is nevertheless suitable for speech transmission, which is the intended use of teleloop applications.[3]

Auracast is a rapidly emerging audio streaming alternative or supplement to wireless audio via teleloop. It is a broadcast technology built on Bluetooth LE Audio which uses Low Complexity Communication Codec (LC3).[4] With this technology, a single transmitter, known as an Auracast broadcaster, sends one or more audio streams that nearby compatible receiving devices such as phones, earbuds, and hearing aids can discover and join without having to pair with the transmitter. The type of audio signal transmitted through Auracast systems is digital stereo and can operate at 16 kHz or with a 24 kHz sample rate. It has a typical frequency range of 50 Hz – 11 kHz.

Table 1 presents an overview of attributes of wireless technologies that could be used to deliver audio to hearing aids (adapted from Bruce et al [5]). Bluetooth LE with Auracast provides many advantages compared to the other technologies. Two additional advantages that often are mentioned compared to teleloops are that users are not limited to being within a specific area that is looped and that it doesn't require professional installation. While it is true that the position of the user is important in using a teleloop, there is also a limit on the reach of any of the other technologies, so it is not known how extensive the relative advantages will be. Another unknown is what the installation of Auracast transmitters will require for optimum performance in any given environment. Unlike teleloops, there are as yet no standards covering this.

Rationale for study

Because Bluetooth LE Audio with Auracast is still new, there is little research on how it is experienced by users, including those with hearing loss who use hearing aids as well as those without hearing loss. For Bluetooth LE Audio with Auracast to qualify as universal design, the experience for listeners with and without hearing loss should be similar. One critical aspect of the user experience for audio streaming is the quality of the audio. Furthermore, the experience should be at least as good if not better for hearing aid users compared to teleloops, which have stood as the gold standard for many years.

As the first hearing aid manufacturer to implement Bluetooth LE Audio with Auracast in our products, ReSound is uniquely positioned to offer opportunities for comparing audio quality for sound transmitted via teleloop versus the new Bluetooth technology. In an unpublished study from National Acoustic Laboratories, ReSound Nexia™ hearing aids and the ReSound TV-Streamer+ were used to accomplish exactly this.

	Teleloop/ telecoils	Bluetooth classic	Proprietary RF	Bluetooth LE/ Auracast
Delay in audio stream	√	X	√	√
Power consumption in hearing aid	√	X	√	√
Stereo	X	√	√	√
Broadcast ability	√	X	√	√
Multiple streams	X	X	X	√
Privacy/security	X	√	√	√
Spillover of signal	X	√	√	√
Non-proprietary	√	√	X	√

Table 1. Attributes of different wireless technologies that can deliver audio to hearing aids.
A checkmark indicates that the technology offers an advantage while an X designates a disadvantage.

A sound source was coupled to both a TV-Streamer+ and a teleloop system. Sound scenes including speech in quiet, speech in noise and music were transmitted by each system and picked up by either the hearing aids' telecoils or Bluetooth radios. The hearing aids were mounted on a manikin head and recordings were made of each condition. An open online test was made available to anyone who chose to participate, and listeners were instructed to listen to the sound samples with headphones. Forty-nine people completed the assessment. They rated sound quality using a MUSHRA[6] methodology. Overall, results strongly supported that Auracast transmission via the TV-Streamer+ provided better sound quality than the teleloop and telecoil. Regarding the three sound scenes, similar sound quality advantages were noted for speech in noise and music, while results for speech in quiet were mixed. The investigators hypothesized that sound quality differences might be even more marked in more realistic conditions.

In this first study of its kind, we wished to investigate the sound quality of Auracast versus teleloop with participants listening to the two technologies through hearing aids fitted to their individual hearing loss in a realistic listening situation. In addition, we included people with normal hearing to get an impression of how well Auracast can be expected to fulfill the promise of universal design in access to streamed sound. The study evaluates sound quality, subjective speech perception, and preference with Auracast and teleloop technology in people with hearing loss as well as in people with normal hearing.

Methods

Participants

A total of 36 individuals participated in the study: 18 with mild-to-moderate sensorineural hearing loss (13 males, 5 females) and 18 with normal hearing (14 males, 4 females). The participants with hearing loss had a median age of 75 years (interquartile range 17 - 80 years) and were all experienced hearing aid users, with a median of 12 years of hearing aid experience (interquartile range: 6 - 19 years). All used premium Receiver-in-the-Ear (RIE) hearing aids from various hearing aid brands. The participants with normal hearing had hearing thresholds within normal limits and claimed no hearing loss. Their median age was 45 years (interquartile range: 36 - 49 years).

Hearing aids and fitting

The test participants were fitted with a pair of ReSound Vivia™ RIE hearing aids (VI962) as this model includes telecoil. The hearing aids were fitted with medium power receivers and power domes. Power domes were chosen to ensure maximum bandwidth from both Auracast and teleloop for better comparison.

Test conditions

Participants were asked to evaluate sound quality, subjective speech perception, and their overall preference between the Auracast and teleloop systems. They were asked to rate sound quality on a scale from 1 (worst) to 10 (best) for each technology while listening to five different speech and music samples. They then rated their speech perception using the same scale while listening to two speech samples. Finally, participants listened to the sound samples again and indicated which technology they preferred. During all listening tasks, acoustic input through the hearing aid microphones was deactivated.

Test setup and material

The test was conducted in a meeting room at GN's facilities to simulate a realistic use scenario in a real-world environment and to ensure proper installation and calibration of both technologies. The meeting room has capacity for 16 people, and the setup is illustrated in Figure 1. The meeting room had an Auracast streamer (Auri™ by Ampetronic)[7] and a teleloop (C7-1 Perimeter loop driver by Ampetronic) installed. All sound samples were played from a laptop and fed into both systems through an external sound card (Fireface UCX II by RME).

The Auracast streamer was placed inside the meeting room and has, according to the manufacturer specifications, a transmission range up to 100 meters in all directions. The teleloop cable was installed around the perimeter of the room and was commissioned and passed all verification tests. No other teleloop systems that could interfere with the test were present nearby.

The Auracast and teleloop systems were calibrated relative to each other to ensure similar loudness. To do so, a 1 kHz tone from the PC was streamed to hearing aids mounted on a manikin with integrated ear simulators (HATS by Brüel & Kjær). The output of one of the hearing aids was measured with both systems. The sound card output levels for each technology were adjusted until the same SPL was observed.

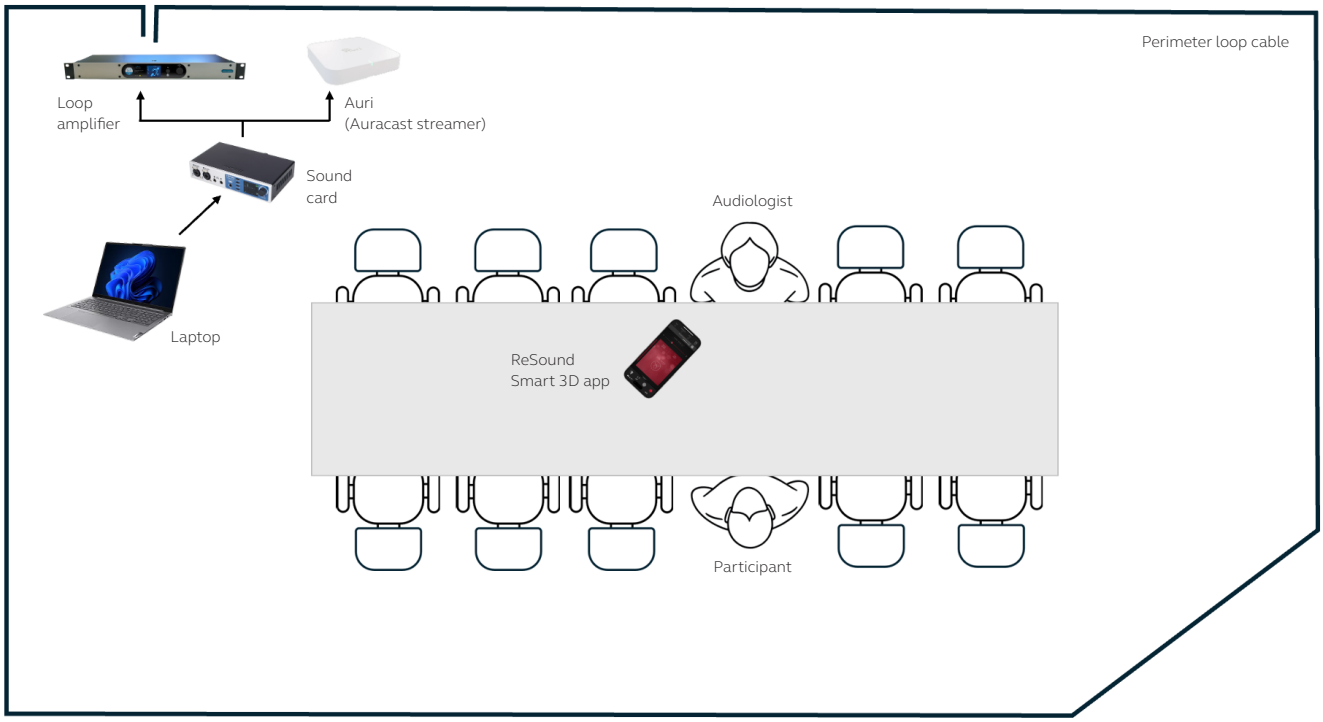

Figure 1. Illustration of test setup and placement of both test participant and audiologist during the test.

The test participants listened to 5 different sound stimuli that each lasted up to 30 seconds:

0. Familiarization: Instrumental music - Tarek Yamani – “Oysterly”
1. Male Speech: Podcast “Hvordan ved vi det” - “Havets Skjulte klimahelte”
2. Female Speech: Podcast “Du Kender typen” – “Johanne Kohlmetz”
3. Instrumental Music: Jherek Bischoff – “Tarrel in His Studio”
4. Music with female singer: Shit & Chalou – “To”
5. Music with male singer: Mario Rui Silva – “Kazum-zum-zum”

The speech samples were chosen with clear voices and pleasant rhythms to minimize listening fatigue and support cognitive analysis. The female voice has a clear, moderately high pitch and the male voice a clear, moderately low pitch. Music samples were picked for vocal clarity, absence of artistic effects, a wide frequency range, and a pleasant rhythm to aid concentration. The instrumental track’s slow tempo helps participants focus on the sound quality and sound texture of individual instruments. The presentation of sound stimuli was counterbalanced across samples (1 to 5) and presentation modes (Auracast/teleloop). The audiologist used the ReSound Smart 3D™ app to change between Auracast and teleloop technology during the test. The test participant did not know which technology was active at any given time (single-blinded methodology).

Frequency response measurement

In terms of sound quality, a possible advantage of Auracast streaming over teleloop is the wider bandwidth available to the user. As a baseline for the test, and for technical verification purposes, the frequency response of the same hearing aid unit with both streaming systems was measured on the HATS manikin with a logarithmic swept sine signal. The hearing aid was fitted with 15 dB flat insertion gain.

Statistical analysis

Given that Auracast was expected to be preferred over teleloop, one-sided tests were applied. To determine whether Auracast was significantly preferred over tele-loop, one sample t-test was used over the proportion of trials in which Auracast was chosen. When assessing each condition separately, a binomial test was used instead. Paired samples t-test was used for sound quality and subjective speech perception comparisons, and this was both to compare the overall rating of Auracast versus teleloop, and to evaluate each system separately for each conditon. Additionally, independent samples t-test was used to evaluate whether participants with normal hearing thres-holds rated differently than people with hearing loss.

Results and discussion

Frequency response

As shown in Figure 2, Auracast maintains a strong low-frequency response even at 100 Hz, whereas the teleloop signal exhibits a significant roll-off which begins around 300 Hz, in line with expectations due to the high-pass filter to avoid interfering noise. Already at 200 Hz there is a gap larger than 10 dB between the systems, and up to 40 dB at 100 Hz.

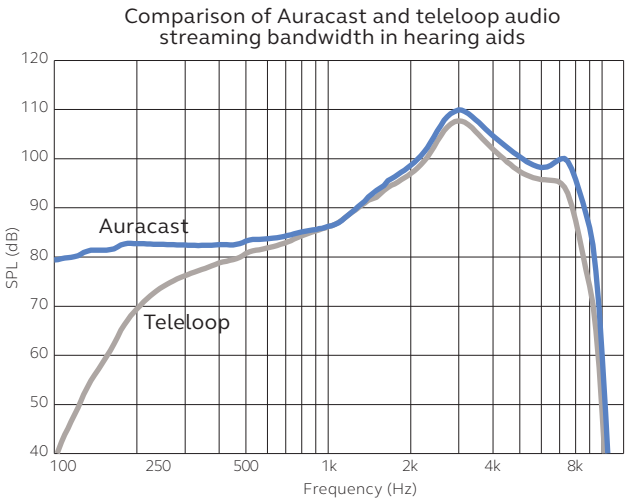

Figure 2. Auracast and teleloop frequency response measured in a manikin with a tone sweep.

Preference results

The participants with hearing loss were asked to choose which system, Auracast or teleloop, they would prefer to listen to if they should listen for an hour or longer. Participants did not know which technology they were listening to at any given time. There was a preference for Auracast 76% of the time and for teleloop 24% of the time; the difference in preference is statistically significant (p = .010).

The preference for Auracast over teleloop is consistent across sound samples and is illustrated together with the overall preference in Figure 3. For male speech, 72% prefer Auracast versus 28% for teleloop (p = .048). For female speech, 67% prefer Auracast and 33% teleloop (p = .119). Auracast is most strongly preferred for instrumental music and for music with a male singer: 83% versus 17% in both cases (p = .004). For music with a female singer, 72% favor Auracast compared with 28% favoring teleloop (p = .048). The preference for Auracast over teleloop is significant in all conditions except for female speech.

The preferences for Auracast over teleloop were unequivocal among the participants with normal hearing. The overall preference was 99% for Auracast and 1% for teleloop including all ratings for all sound samples (p < .001). This direction of the preference ratings is consistent with the preferences observed in participants with hearing loss; however, the preference for Auracast is significantly stronger amongst the participants with normal hearing than for those with hearing loss (p = .005).

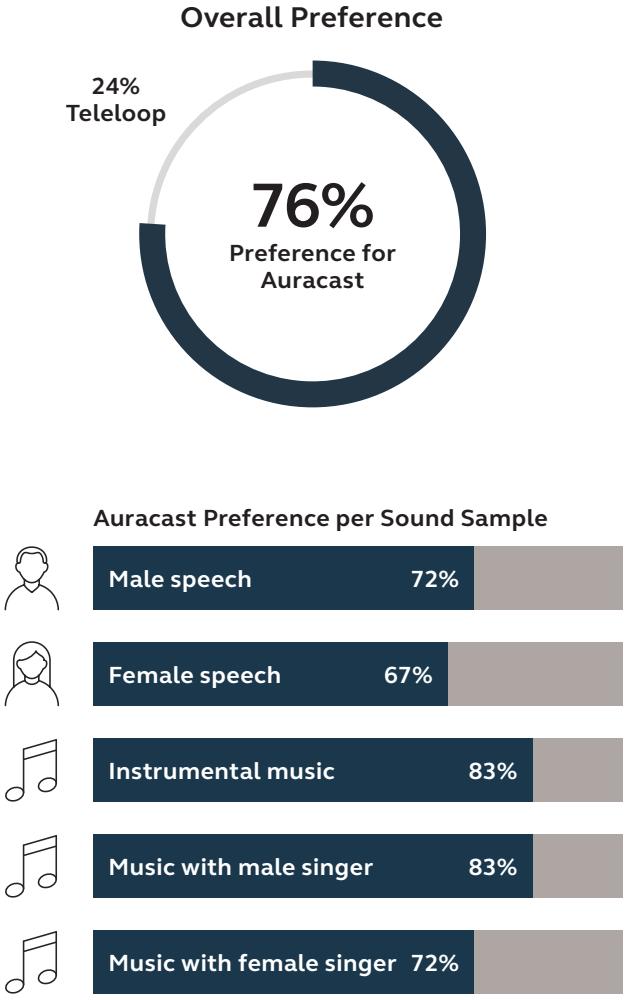

Figure 3. The overall preference for Auracast versus teleloop for all participants with hearing loss and for all sound samples combined (top) as well as the percentages of participants who preferred each sound sample (bottom).

Sound quality results

Participants were also asked to rate the sound quality of the Auracast and teleloop technologies, still being blinded to the technologies, while listening to the 5 different sound samples. They were asked to rate the sound quality using a rating scale from 1 being the worst sound quality to 10 being the best sound quality.

The participants with hearing loss rated sound quality better with Auracast than with teleloop consistently across the sound samples. Figure 4 shows the mean sound quality ratings per sound sample and for the overall result. The overall result shows that the rating is significantly better for Auracast with a mean rating of 7.9 while the mean rating with teleloop is 5.9 (p = .006).

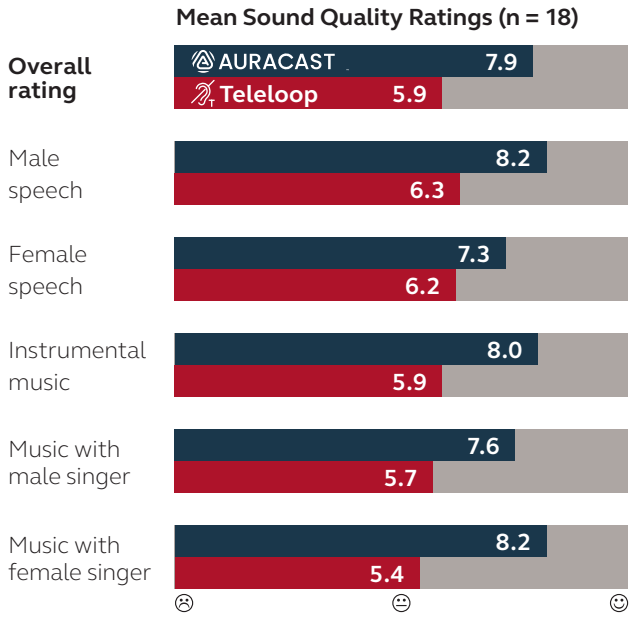

Figure 4. Test participants with hearing loss' mean overall as well as per sound sample sound quality rating for Auracast and teleloop.

The mean sound quality ratings for Auracast versus teleloop are: male speech 8.2 versus 6.3 ($p = .011$); female speech 7.3 versus 6.2 ($p = .054$); instrumental music 8.0 versus 5.9 ($p = .014$); music with a male singer 7.6 versus 5.7 ($p = .021$); and music with a female singer 8.2 versus 5.4 ($p < .001$). Except for female speech ($p = .054$), all differences favoring Auracast are statistically significant.

The mean overall sound quality rating by the participants with normal hearing was 8.1 for Auracast and 4.4 for teleloop (1 = worst, 10 = best), a significant difference ($p < .001$). By sound sample, mean ratings are: male speech 8.3 versus 4.8 ($p < .001$); female speech 8.4 versus 4.7 ($p < .001$); instrumental music 8.4 versus 4.0 ($p < .001$); music with a male singer 7.9 versus 4.1 ($p < .001$); and music with a female singer 7.7 versus 4.2 ($p < .001$). The higher ratings given to Auracast are found significant in all scenarios. Again, the direction of these results is consistent with those from participants with hearing loss, but the participants with normal hearing rated teleloop significantly lower than the participants with hearing loss did ($p = .006$).

Speech perception results

The test participants were also asked to rate speech perception with Auracast and teleloop technology when listening to male and female speech and while still being blinded to the technologies. They were asked to rate speech perception on a 1–10-point scale with 1 being the worst speech perception and 10 being the best speech perception.

The mean speech perception rating with Auracast and teleloop for male- and female speech combined and separately is shown in Figure 5. The overall mean speech perception rating for male and female speech combined is 8.3 for Auracast and 6.6 for teleloop ($p = .014$). For male speech the means are 8.3 and 6.8 ($p = .030$), and for female speech 8.2 and 6.4 ($p = .010$). All differences favoring Auracast are statistically significant.

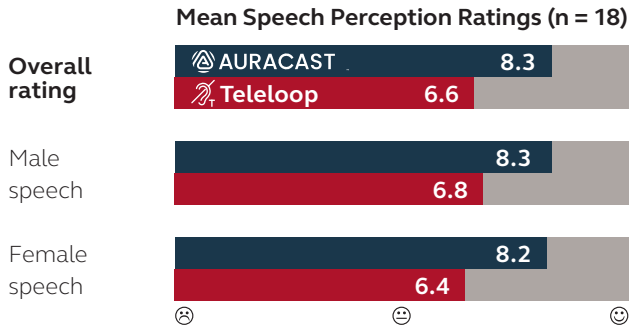

Figure 5. Test participants with hearing loss' mean overall as well as per sound sample speech perception ratings for Auracast and teleloop.

The overall mean speech perception rating amongst participants with normal hearing is 8.8 for Auracast versus 7.3 for teleloop ($p < .001$). For male speech the means are 8.7 and 7.3 ($p < .001$), and for female speech 8.8 and 7.3 ($p = .001$). All differences favoring Auracast are statistically significant and are consistent with the results observed in participants with hearing loss.

Differences in measured speech understanding would not be expected in this test setup. Because this task involved a subjective rating of how well they were following the speech, it may have been influenced by lower listening effort in the Auracast condition or other unknown factors.

Participant feedback on preferences

Participants with hearing loss explained why they rated and preferred each technology. Some used technical terms (e.g., stereo vs. mono; bass and treble), while others relied on analogies or comparisons to familiar devices (e.g., "like an old radio"). Figure 6 presents a word cloud of these comments; more frequently used words appear larger. Overall, most participants found Auracast clearer and more pleasant than the teleloop. Those familiar with audio terminology described Auracast as stereo, fuller, and richer in bass and treble. By contrast, the teleloop was repeatedly described as metallic, flat, and thin, often likened to an old radio, and was said to lack the qualities that made Auracast preferable. More technical participants specifically noted that the teleloop sounded mono and lacked bass and treble.

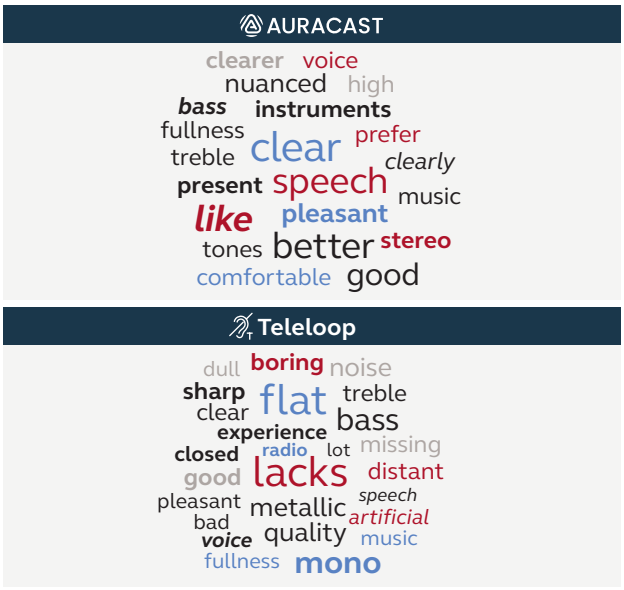

Figure 6. Word cloud of participant comments for Auracast and teleloop. Larger words indicate higher frequency.

Conclusions

- All participants demonstrate a significant preference for Auracast streaming over teleloop.
- Auracast sound quality is rated significantly better than teleloop sound quality by all participants.
- All participants reported significantly better speech perception with Auracast over teleloop.
- Compared to those with hearing loss, the participants with normal hearing showed significantly stronger preferences and higher sound quality ratings for Auracast vis-à-vis teleloop.
- The similarity in results for the participants with hearing loss and with normal hearing suggest that Auracast technology can serve the audio quality needs of all users. These results speak to faster and wider proliferation of Auracast compared to teleloop systems

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