

AUDIOLOGY

Quantitative enhancement of speech in noise through a wireless equipped hearing aid

Miglioramento della percezione verbale attraverso apparecchi acustici dotati di sistema wireless

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SUMMARY

The development of new hearing aid technology can improve speech understanding in complex listening environments. The purpose of this study is to evaluate the benefit offered by the use of wireless technology applied to hearing aids. Participants were fit with binaural hearing instruments and underwent speech-in-noise tests. The signal was transmitted either by a speaker or wirelessly directly to the hearing aid. In our experience, hearing aids with wireless systems have an advantage in two particular conditions. The first can be achieved while listening wirelessly with microphones excluded (recommended when listening in noisy environments), while the second is in conditions of asymmetric listening; the wireless signal perception remains effective, but at the same time it allows the patient to receive environmental signals. Hearing aids equipped with wireless systems may be particularly useful when listening to people talking even in noisy environments and/or receiving other sound sources such as TV and landline or cell phones.

KEY WORDS: Sensorineural hearing loss • Hearing aids • Rehabilitation • Wireless technology

RIASSUNTO

Lo sviluppo di nuove tecnologie audioprotesiche potrebbe migliorare la comprensione del parlato in particolari condizioni di ascolto ambientale. Scopo di questo studio è stato valutare i benefici offerti dall'utilizzo della tecnologia wireless applicata agli apparecchi acustici. I partecipanti sono stati sottoposti a test di percezione verbale nel rumore dopo aver indossato apparecchi acustici binaurali. Il segnale è stato trasmesso sia da un altoparlante sia in modalità wireless direttamente all'apparecchio acustico. Nella nostra esperienza, gli apparecchi acustici con sistemi wireless risultano utili soprattutto in due situazioni. La prima è l'ascolto wireless a microfoni esclusi (particolarmente raccomandato in ambienti rumorosi), mentre la seconda è in condizioni di ascolto asimmetrico; la percezione del segnale via wireless rimane efficace, ma allo stesso tempo anche la percezione dei segnali ambientali rimane buona. Concludendo, gli apparecchi acustici dotati di sistemi wireless risultano particolarmente utili per una buona percezione verbale anche in ambiente rumoroso, e/o per la ricezione di altre sorgenti sonore come la TV o telefoni di rete fissa o cellulare.

PAROLE CHIAVE: Ipoacusia neurosensoriale • Apparecchi acustici • Riabilitazione • Tecnologia wireless

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Introduction

Sound is an integral part of our daily experience as it conveys relevant acoustic information that contributes to communication and mapping the environment where we live. Hearing impaired subjects, by means of amplification, may compensate only partially for the loss of acoustic information. In fact, hearing aid users are always searching for a kind of “auditory clearness”, either in situations in which communication is corrupted by ambient noise, or in situations in which verbal message comes from electronic devices such as television, computer and mobile phone. Several studies have already reported speech perception as the single most important aspect of hearing that attributes to hearing aid success¹⁻⁵.

The continuous search for solutions to improve hearing aid efficacy in listening to electroacoustic sources has led to the implementation of wireless technology in hearing instruments.

The purpose of this study is to evaluate the benefit offered by the use of wireless technology applied to hearing aids. In particular, we measured the aided reception threshold for speech stimuli as emitted by a loudspeaker within a room contaminated by a composite cocktail party and traffic noise. This acoustic condition is intended to simulate listening to a radio or TV in a noisy room full of people speaking together and with a window open on a busy road. Speech reception threshold (SRT) was thus compared in condition of free-field air-conducted speech,

and wireless-conducted signal. Changes in signal to noise ratio was the parameter that was evaluated.

Materials and methods

Subjects

A total of 9 subjects aged between 21 and 27 years were included in this study (3 males and 6 females). All participants had normal hearing (≤ 15 dB HL at 250, 500, 1000, 2000, 4000 Hz).

Hearing aid

For the time of experience, each subject was binaurally fitted with Gn-Resound Alera hearing aids using a standard soft earmold. The instruments were programmed for a linear gain of 16 dB, omnidirectional microphone and noise reduction system excluded. In addition, they were set up to operate in the following modalities: wireless off/on (P1, P2) and microphone on/off (mic+, mic-). It is notable that while in the wireless mode, the Alera may be programmed to operate either with mic- or mic+. With microphone excluded (mic-), only the wirelessly transmitted signals reach the subject's ear. With microphone open (mic+), wireless signals from the electroacoustic source and acoustic signals processed by the hearing aid mix together within the external ear canal.

Gn Resound uses a proprietary wireless technology operating in a frequency range of 2.4 GHz that allows communication between the hearing aids and other devices up to a distance of 7-10 m. The main feature of these devices is the ability to connect wirelessly to any electroacoustic source. The communication between the sound source and the hearing aid is operated through an interface-device ("Unite TV Streamer" for TV or an audio-system, or "Unite Phone Clip" for mobile phones). Using a remote control, the hearing aid user can manually choose among the available listening programme, enable or disable the wireless connection, or modify the volume (range 0-40 dB) of the wireless transmitted sounds. For the present experience, the volume control was fixed halfway, corresponding to 20 dB of extra-output.

Examination room

Subjects were examined in a sound-attenuated 3 × 4 m room, with a reverberation time of 0.4 sec. A noisy diffuse sound-field was obtained by using four loudspeakers horizontally arranged (placed at 0°, 90°, 180° and 270°, height 1.20 m) each at distance of 1 m around the subject. A fifth loudspeaker delivering the speech message was placed frontally.

A PC was programmed to play the sound files containing the stimuli, activate the loudspeakers via a MOTU board and control the sound levels. The fifth speaker, devoted to speech signal delivery, was also connected to the United

TV streamer; in this way, the speech message could also reach the hearing aids wirelessly.

Stimuli

Background noise consisting of cocktail party was delivered from the 0°, 90°, 180°, 270° speakers, with the addition of traffic noise on the 90° and 270° speakers. The overall background noise level as measured after balancing the single speaker output, and at the subjects' head position was kept at 55 dB SPL(A). Speech signal consisted of 13 lists, each of 20 Italian meaningful sentences (speech audiometry by GNResound Italia, 2000). The speech delivered from the fifth speaker at 0°, was calibrated as rms level with reference to the overall background noise level.

Measurements

Speech reception threshold (SRT), corresponding to 50% of correct responses, was recorded through a simple up-down 2 dB step adaptive procedure going on up to 7-8 reversals. Usually, each SRT measure needed 14-18 sentences. SRT was thus obtained in free field, in the following aided conditions:

1. both hearing aids in P1 and mic+ (reference condition);
2. both hearing aids in P2 and mic-;
3. both hearing aids P2 and mic+;
4. both hearing aids in P2, mic- in one ear and mic+ contralaterally.

The first condition was taken as a reference to evaluate the effect of wireless transmission compared to the usual condition. Moreover, while the first three conditions realize a symmetrical listening condition, the fourth realizes a condition of asymmetrical listening.

Results

The results corresponding to the SRT in noise are expressed in terms of s/n ratio. Recall that more negative values of s/n ratio indicate higher performance. To better appreciate the effect of listening through the different setting of the hearing aids, data from all the aided conditions were normalized with reference to those obtained in the unaided condition (unaided = 0 dB s/n).

Figure 1 reports the means and standard deviation values of the s/n ratio as obtained from the nine subjects across the tested conditions.

Listening with hearing aids in normal mode (Woff/M.on)

If compared to unaided condition, the performance worsens, since the SRT requires a higher signal (3.7 dB). This is due to the lack of the effect of the pinna and the location of the hearing aid's microphones at the head side: they directly collect the masking from the speakers at 90° and 270° at some expense of the speech signal coming from the speaker at 0° (Fig. 1).

Listening in wireless mode: Won/M.off

In this condition, the primary speech signal is directly transferred to the ear canal from the electroacoustic source; as microphones are off, the effect of masking noise within the ear canal should be consistently reduced, at least to the minor portion overpassing the earmold. The Won/M.off condition improves the s/n ratio by about 23 dB when compared to the unaided condition, or 27 dB if compared to the aided condition in normal mode (Woff/M.on) (Fig. 1).

Listening in wireless mode: W.on/M.on

In this “hybrid” condition, the hearing aid output contains both the wirelessly received speech signal, and the masking noise collected by the open microphones. The SRT requires a s/n of -4.5 dB, corresponding to a better performance of 7 dB compared to the normal mode condition (Woff/M.on), but a worsening of about 18.5 dB, if compared to the W.on/M.off condition. To explain these data, the output of the hearing aid was measured while operating in this hybrid condition. The measurement revealed that the gain for external source was lowered of 5 dB and the gain volume for the wireless source was incremented of 5 dB. Even if the purpose of these adjustments was to maintain a favourable s/n ratio, the result seems quite faraway from that seen with microphones excluded (Fig. 1).

Listening in wireless mode: Won/M.on-Moff

In this condition, both the hearing aids are working in wireless mode, but the microphones, open in one ear and closed in the other, realize an asymmetric acoustic condition. As shown by the above results, this asymmetry is remarkable as the SRTs require s/n ratios definitely different when microphones are kept both excluded or opened. In this particular condition, the SRT is measured at a s/n ratio close to that observable with microphones excluded, indicating that the ear with the best S/N ratio actually drives the speech recognition (Fig. 1).

Discussion

A noisy environment is invariably more challenging for most hearing aid users. The primary reasons for decline in hearing aid use include difficulties in communicating in a noisy environment or difficult listening situations. In particular, elderly users of hearing aids often complain

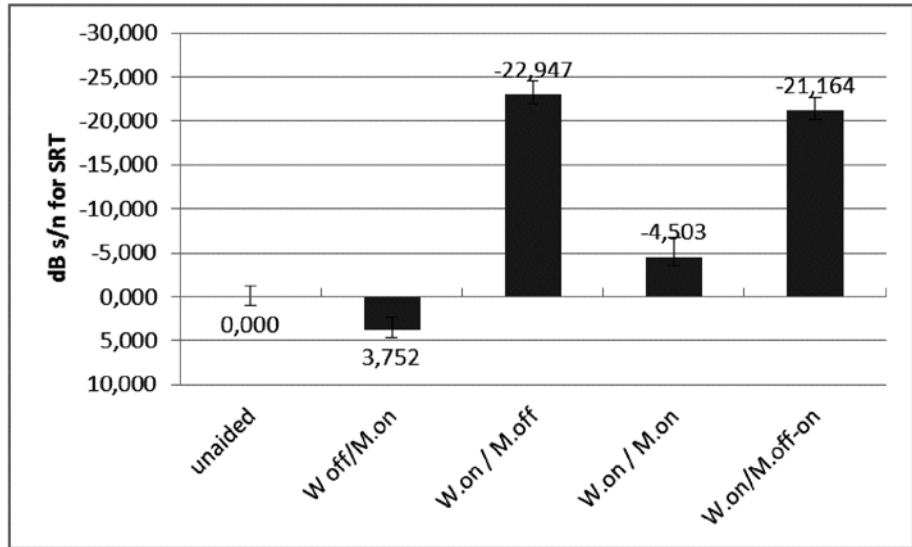


Fig. 1. Mean s/n ratios for SRT (50% correct responses) obtained in the different hearing aid settings. Vertical bars represent standard deviation. W: wireless; M: hearing aid microphone.

that listening to television is a major problem. Other than ambient noise, this may be due to speakers of low quality and non-ideal room acoustics. Naturalness and clarity of sound have been reported to be the strongest attributes for successful use of amplification⁴. The development of new hearing aid technology should improve speech understanding in complex listening environments, especially in the presence of competing talkers⁴⁻¹⁰. In particular, with the advent of wireless communication systems linking the hearing aids to different devices, it is necessary to understand the possible advantages of these tools in complex listening environments.

While the effect of these devices could be physically measured, their impact on everyday listening conditions is more elusive. This is explainable considering the numerous variables, partly attaining the nature of hearing impairment and partly the environmental acoustics. The present experience, by using normal hearing subjects, excluded the influence of factors due to hearing loss. Hence, the results may be regarded as the effect of the different set-up of a hearing aid type, while tested in a particular sound-field. Of note, laboratory conditions are difficult to reproduce in everyday life, as, for instance, noise is mostly temporary fluctuating in terms of spectral content, level, direction, with speech-when present, and changing accordingly.

We analyzed the speech reception thresholds in noise obtained by hearing aids equipped with a wireless device linked to electro-acoustic sources. The advantage of the modern hearing aid that can also manage wireless signals is that they can easily shift across a number of listening programs. The user may choose among different configurations, wireless or normal mode, also including microphones on or off, and how the source level has to be set

when transmitted wirelessly. These features allow a flexible use of hearing aids with wireless systems that can be very helpful when listening to electroacoustic sources.

Compared to the hearing aid in normal mode, the wireless mode as set up in this test allows for a very consistent improvement of SRT, which is close to 30 dB in terms of higher signal or lower masker. This is due to the combined effect of attenuation of the external noise exerted by the earmolds, and the extra-gain of 20 dB given to the transmitted signal.

While listening in wireless mode, some difficulty could arise in perceiving other environmental sounds, as for example, warning signal, or other people talking. For this reason, we tested the “hybrid” condition of listening a wirelessly transmitted source, while maintaining the hearing aid with microphones open. Although an improvement of 7 dB was measurable compared to the hearing aid in normal mode, the result was decisively below the use with microphones excluded. However, the data showed a return to a significant improvement of the S/N if one of the two microphones is off.

This realizes a condition of asymmetric hearing, where the performance is mainly driven by the ear with the better s/n ratio. In addition, other factors may also contribute to the advantage, such as the perception of spatially separated sources¹¹⁻¹⁶ and effects related to selective attention.

The use of the newest technologies may be difficult for elderly people with some cognitive impairment. However, the substantial improvement of the s/n ratio as shown by our results is expected to decisively facilitate the listening to acoustic sources like TV, one of the commonest habits in the elderly.

Conclusion

In conclusion, the examined situation demonstrates that hearing aids incorporating wireless systems can consistently improve the perception of signal emitted by a loudspeaker even within extremely noisy environments. In such challenging conditions, the wireless mode with excluded microphones can be recommended. An alternative setting may be one that exploits a condition of asymmetric listening: the wireless signal perception remains effective, while allowing for other environmental signals to also be perceived.

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