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Improvement of Telephone Communication in Elderly Cochlear Implant Patients

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Key Words

Cochlear implant fitting · Speech coding · Speech perception ·
Telephone use

Abstract

Introduction: Elderly patients demonstrate more difficulty in telephone communication than in direct conversation. This deterioration in comprehension is due most likely to the narrowing of frequency range of transmission (300–3,400 Hz) and the lack of specific maps in the sound processor to accommodate the reduced information. **Aims:** The goal of this study was to create a new ‘telephone map’ specific for phone use and to verify its effectiveness even in elderly patients. **Methods:** Twenty cochlear implant (CI) adult patients divided into two age groups (under 60 and over 60 years) were included in the study. All patients were assessed with a word recognition test presented via recorded, conventional telephone-transmitted voice signal while using their everyday map (SB-map) and while using the experimental map (T-map). The latter was created by lowering the current level to the minimum value for electrodes representing frequencies outside the range of the telephone signal without changing the frequency bands assigned to them. **Results:** In experimental listening conditions, the average recognition score using the SB-map was 65.5% in patients under 60 and 36.5% in patients over 60, while using the T-map it was 73.5 and 41.5%, respectively. This difference between the two maps was statistically significant in both groups ($p < 0.05$) and was confirmed by subjective assessment. After 3 months of training provided to the over 60 CI group, subjects showed further improvement. **Discussion:** The increase in comprehension skills by phone-transmitted speech with the T-map is objective and immediate in both groups of patients and proves to be improved further after training. The results demonstrate that it is possible to reduce the background noise and improve the ability to comprehend the phone message through changes to some map parameters. **Conclusions:** In light of the results obtained, we believe that our experimental map, applicable to all types of implants, currently represents a simple and effective solution to improve telephone communication in patients with CI.

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Introduction

Hearing loss is one of the most common conditions affecting elderly adults. Approximately 1 in 3 people between the ages of 65 and 74 years have some degree of hearing loss, and nearly half of those older than 75 have significant hearing difficulty. Presbycusis is linked to a host of psychosocial and physical diseases including depression, social isolation and dementia, and with research strongly suggesting that untreated age-related hearing loss may quicken physical decline [Lin et al., 2011]. Thus, the number of adults aged 60 years and older who have received a cochlear implant (CI) has increased annually over the last decade [Carlson et al., 2010].

Today, there is increasing recognition that CI can not only help older adults regain their hearing, but can also allow them to fully participate in life, and may improve their overall health status [Bertolini et al., 2011; Turchetti et al., 2011]. The majority of CI recipients, even if aged more than 60 years, are able to achieve excellent performance for verbal speech perception in suitable listening conditions, such as in the absence of background noise [Di Nardo et al., 2010].

Our findings also confirm, in agreement with many others, the indisputable utility of CI and provide evidence that elderly patients derive a substantial benefit from their CI in the quality of life, as demonstrated by improved health status, greater ease in the common activities of daily living and perceived overall satisfaction after this procedure [Di Nardo et al., 2014]. However, some listening tasks are still tremendously challenging, such as speech comprehension in noisy environments, music perception and enjoyment, and especially telephone communication, the latter having become an essential component of modern life and is always a ‘sore spot’ for all deaf subjects [Adams et al., 2004; Cray et al., 2004]. We must, in fact, consider that with regard to adults, the phone is a fundamental means to obtain professional services and also helps to keep alive the affective and interpersonal relationships among the population of advanced age.

There are many papers in the scientific literature investigating the ability to perceive telephone-transmitted speech in CI patients. In general, phone conversation is perceived as a stressful event, where CI users often require another person’s nearby presence in order to have quick assistance in case of communication failures [Anderson et al., 2006]. The reduction of social connectivity that results is often associated with a decreased quality of life, depression state and cognitive decline.

Several reasons attributed to the poor perception of telephone conversation by CI recipients have been widely described in the literature [Milchard and Cullington, 2004]. Given the assumption that a frequency band of at least 250–7,000 Hz is required to reach the maximum intelligibility in normal-hearing subjects, a leading role is certainly played by the bandwidth of The Public Telephone Network (established more than 60 years ago), which is characterized by a narrowing of the frequency spectrum in the range between 300 and 3,400 Hz. Moreover, we can add to this basic reason

the total absence of visual reinforcement, the reduced audibility of the telephone message, the signal interference and channel noise. In addition, many other external factors may affect telephone communication [Anderson et al., 2006]: voice ‘familiarity’ and its accent/cadence, the topic of discussion (enhanced understanding due to brain’s deductive skills), background noise, speed and clarity of speech, vocal intensity and appropriateness of the mapping of the speech processor.

Hearing-impaired people may not be able to rely on a satisfactory option for long-distance verbal communication, in part because of the lack of specific and dedicated maps for telephone communication. Thus, any proposed solution to improve telecommunications can greatly influence the quality of life, especially for elderly patients, who may have mobility issues, be prone to fall often and, thus, come into the category of ‘non-phone users’.

A careful spectrotemporal analysis of telephone signals was undertaken by our team showing some of the key features of the phone signal for speech understanding. Subsequently, this analysis led to the first proposal to improve telephone communication for CI recipients [Giannantonio et al., 2014]. The proposal involved creating a specific map for communication (via conventional phone and via Internet protocol, VoIP) by changing the CI speech coding strategy from ACE (Advance Combination Encoder) to MP3000/PACE (Psychoacoustic Advanced Combination Encoder). PACE uses an audio compression algorithm in which audio data are reduced to about one tenth of their original size without any decrease in sound quality, selects a limited number of channels (maxima) through a psychoacoustic masking algorithm, extracts from all auditory inputs the most significant features (fundamental frequency and main harmonics) and eliminates those components that are masked by others (adjacent frequencies/electrodes). In the experimental listening conditions, the patients performed better with the experimental maps resulting in a maximum performance improvement of 35% via telephone and 25% via VoIP; however, while the results show an encouraging trend, the increment was not statistically significant [Giannantonio et al., 2014].

In this study, we aimed to take a further step forward from the previous attempt by trying to reach two innovative goals: (1) to create a new ‘telephone map’ (T-map) specific for phone use, adaptable to all CI types without changing the strategy used (note: the MP3000 strategy is for the exclusive use of the Cochlear Ltd.), and (2) in order to assess the objective effectiveness and the subjective judgment of the experimental map compared to patients’ usual map during a telephone conversation for all levels of CI performers (i.e. not only in star patients) divided into two groups of CI recipients stratified by age in years (over 60 and under 60).

Methods and Subjects

Study Population. We enrolled 20 adult patients (aged >18 years) with postlingual, severe-to-profound, bilateral sensorineural hearing loss who underwent unilateral CI surgery in the Policlinico A. Gemelli Hospital and were Cochlear™ Nucleus® Freedom™ or Cochlear Nucleus 5 system wearers, with at least 6 months of CI use (without use of a contralateral hearing aid) and with all 22 electrodes active. They were accustomed to the use of maps created according to the subjective loudness balance criterion (subjective balanced map, SB-map), with T- and C-values relatively stable over time, and with the ACE strategy.

The inclusion criteria were as follows:

- Continuous use of the system Nucleus Freedom and Nucleus 5 for at least 6 months
- Ability to read and write in the language of verbal material presented
- Speech perception ability for open-set speech materials (sufficient to permit comparison between the strategies; i.e. absence of floor effects in performance)
- Willingness to take part in the study and to complete all the requirements of the Protocol.

The exclusion criteria were:

- Accustomed use of CIS strategy
- Bilateral CI
- Associated disability that may affect the evaluation
- Unrealistic expectations about possible benefits.

The study population was divided into two homogeneous groups named Over60 and Under60 according to the age of patients (tables 1, 2).

Creation of the Experimental Telephone Map. As stated earlier, spectrographic analysis of vocal versus telephone signal made by our research team has shown that some distortions are systematically reproduced, and that the reasons for the difficulty in understanding phone messages are attributed to a combination of several factors: (1) the reduced frequency range (300–3,400 Hz), (2) the distortions at middle frequencies, (3) the poor spectral content, and (4) the high-energy content of low-frequency noise. After noting the phone modulation of the vocal message, we empirically examined how CI systems process this information. The above empirical analysis showed that, despite the limited range of frequency (300–3,400 Hz) of the telephone signal, activation of all 22 electrodes, including those outside of this range can occur.

To eliminate the additional noise generated by the electrodes corresponding to the sound stimuli below 300 Hz and above 4,000 Hz, and to focus the listening on the frequencies involved in the phone conversation, we modified the map by resetting the T and C levels of 6 electrodes, 1 apical and 5 basal. The choice to reset but not to turn off the electrodes in question allows us to avoid redistribution of frequency bands to the remaining electrodes. The patient’s speech coding strategy was left unchanged, being the ACE strategy as routinely used in the SB-map. Volume and sensitivity settings were not modified in the T-map. Each patient was then instructed to use the new T-map for listening via conventional telephone.

Evaluation Setting and Tools. Linguistic performance was assessed for each patient via speech audiometry through the use of the Italian Turrini’s bisyllabic word recognition test [Turrini et al., 1993]. The speech recognition performance score was calculated as the percentage of correct words repeated aloud by each patient from a total of 20 items presented per test.

The test setting aimed to reproduce, as far as possible, the real-life listening situation. Firstly, the word lists were presented in the free field in an anechoic sound booth by CD-recorded voice presented at an intensity of 65 dB HL at a distance of 1 m from the patient at 0° azimuth. Secondly, the word lists were transmitted via a conventional telephone voice signal. As such, the microphone output of a conventional landline phone was placed resting on a chair and positioned at a distance of approximately 40 cm to the speaker. Two phones were used with the transmitting phone (T1) connected via the conventional telephone network (‘classical’ call) calling through to a second landline telephone (T2) located in a

Table 1. Characteristics of the younger CI recipient group

Patient	Age, years	Sex	Etiology	Years of CI use	CI electrode	CI speech processor	Side of CI	Residual hearing	Speech recognition score, %
S1	57	M	idiopathic	2.6	CI24(RE)CA	Freedom	right	yes	70
S2	51	F	genetic	8.3	CI24M	Freedom	right	no	85
S3	29	F	traumatic	2.5	CI24(RE)CA	Freedom	right	no	90
S4	54	F	genetic	0.5	CI422	CP810	left	no	85
S5	55	M	idiopathic	0.6	CI512	CP810	right	no	85
S6	55	M	autoimmune	0.6	CI512	CP810	right	yes	95
S7	51	F	idiopathic	1.8	CI512	CP810	right	yes	95
S8	53	F	autoimmune	4.2	CI24(RE)CA	Freedom	left	yes	95
S9	53	F	idiopathic	2.4	CI24(RE)CA	Freedom	right	yes	80
S10	52	M	idiopathic	4.3	CI24(RE)CA	Freedom	left	no	95

Table 2. Characteristics of the older CI recipient group

Patient	Age, years	Sex	Etiology	Years of CI use	CI electrode	CI speech processor	Side of CI	Residual hearing	Speech recognition score, %
S1	81	M	genetic	9.2	CI24R (ST)	Freedom	left	yes	65
S2	66	F	idiopathic	3.6	CI512	CP810	left	yes	70
S3	73	M	idiopathic	8.0	CI24(RE)CA	Freedom	left	yes	55
S4	70	F	idiopathic	8.7	CI24R(CS)	CP810	left	no	85
S5	64	F	autoimmune	10.5	CI24R(CS)	CP810	right	no	80
S6	82	M	autoimmune	4.3	CI24(RE)CA	Freedom	right	yes	75
S7	76	M	idiopathic	7.9	CI24(RE)CA	Freedom	right	no	50
S8	68	F	autoimmune	3.5	CI512	CP810	right	no	65
S9	69	M	idiopathic	4.8	CI24(RE)CA	Freedom	left	yes	50
S10	74	F	idiopathic	4.3	CI24(RE)CA	CP810	right	no	80

second anechoic booth. The patient was instructed to listen to the telephone (T2), positioning the receiver as they would be accustomed to do in everyday life for telephone conversations, and asked to repeat the words perceived through the T2 receiver.

Following evaluation of performance for word recognition presented via the landline telephone while listening with the usual map (SB-map) and the experimental map (T-map), study participants were asked to express their subjective opinion of the global satisfaction with the sound signal (i.e. intelligibility, pleasantness, ease of understanding). Global satisfaction was rated according to a Visual Analogue Scale from 1 (absent/minimal understanding-pleasantness) to 10 (maximum intelligibility-pleasantness).

All patients were assessed as described during the routine CI fitting session in which they used the experimental T-map for the first time. Additional training was provided to the Over60 patient group. Patients were asked to take home and use their T-map during telephone conversations only for the next 3 months, after which the tests were administered again upon return to the clinic.

Statistical Analysis. For the analysis of the performance data, STATA12 Software was implemented, performing a two-tailed Student's t test for paired data values. The limit for statistical significance was set at $\alpha = 0.05$. p values < 0.05 were considered significant.

Results

The Under60 patient group showed a mean word recognition score in the anechoic booth with their everyday SB-map and with the T-map of 92.5 and 80.5%, respectively. In the Over60 patient group, the recognition score was 67.5% with the everyday SB-map and 54.5% with the experimental T-map. As expected, the performance achieved with the SB-map in the soundbooth was higher than with the T-map.

The trend is reversed when the test is performed on the telephone. The bisyllabic word recognition percentage score via conventional telephone was higher with the T-map than with the SB-map for both groups of patients. For Under60 subjects, the mean recognition score obtained with the conventional landline, phone-transmitted voice was 65.5% when using the SB-map and 73.5% for the T-map.

Similarly, for the Over60 subjects, the recognition score was 36.5% with the SB-map and 41.5% with the T-map (fig. 1). Examination of individual performance shows that 80% (8/10) of Under60 subjects experienced an improvement using the experimental map, while 50% (5/10) of Over60 subjects improved. Analysis of the results reveals statistically significant improvement for both age groups ($p < 0.05$).

Fig. 1. a Percentage values of recognition performance via conventional telephone using SB-map and T-map in all Over60 patients. **b** Average percentage recognition score using SB-map and T-map without training in the Over60 patient group.

Fig. 2. a Percentage values of recognition performance via conventional telephone using SB-map and T-map in all Over60 patients after 3 months of training. **b** Average percentage recognition score using SB-map and T-map after training.

Subjective assessment of all 20 subjects via the Visual Analogue Scale for their overall satisfaction of the sound quality of the SB-map and T-map for intelligibility-pleasantness of the telephone signal showed an average assigned rating of 5.8 for the SB-map and 7.9 for the T-map.

Our preliminary examinations show superior performance was demonstrated when using the proposed T-map compared to when using the everyday SB-map for our study cohort. For the elderly subject group (Over60, $n = 10$), an average increase in speech recognition percentage scores of 13.6% was noted when listening to the conventional telephone voice signal while using the T-map. Furthermore, following a 3-month, take-home training period for the Over60 group, a second assessment in the clinic revealed that 80% (8/10) demonstrated improvement in performance with the T-map versus the SB-map when listening to the conventional telephone voice signal. Therefore, a further increase in speech recognition of the conventional telephone voice signal was observed using

the T-map from 41.5% before training to 49.5 after training. These values represent an average percent increase of 17.8% (fig. 2).

Discussion

Telephone conversation has always constituted a difficult listening test situation for all deaf subjects, especially for the elderly population, which represents the largest portion of the so-called 'non-telephone users' according to the literature [Adams et al., 2004]. Most likely amongst the Over60 group, other influencing characteristics of 'nonusers' may exist, such as greater dependency on lipreading, lower educational level, lower utilization of CI in terms of hours/day, and, possibly, a longer period of auditory deprivation before surgery. However, in our study population, there was no correlation between the age at the onset of hearing loss, the etiology, or the amount of residual hearing before implantation and phone voice recognition performance.

The 'telephone users', despite the unpleasantness of the task, are generally more motivated to use the phone, possibly because it is essential for their work and social contact. In contrast, very often, elderly CI recipients avoid phone conversation, even if it is considered essential for a better quality of life, because of the difficulty of the task and the resulting stress.

The main reason for this difficulty in both groups of patients is certainly the relatively reduced frequency range (300–3,400 Hz) of the telephone signal leading to a loss of frequency information outside this range. During telephone conversation for normal-hearing subjects, the voice pitch can be recovered from higher-order harmonics in the high-frequency range, a phenomenon known as 'missing fundamental' that can lead to minor problems of signal perception.

In contrast, CI recipients have a dramatic decline in speech understanding due to a serious loss of frequency information regarding fundamental frequency and higher-order harmonics; it leads to confusion between consonant pairs (e.g. B vs. D, N vs. M, S vs. F, P vs. T), extreme difficulty in fricatives identification (F, V, S, Z, SC) and 'metallic sound' during telephone communication.

To date, only a few studies have tried to develop methods to improve the perception of the phone signal in patients with CI; among the 'hardware changes' are the extension of the bandwidth (to expand the narrow band in two phases: the extension of the spectral envelope and extension of the spectrum of speech, increasing the range of the frequency transmitted by the telephone network up to 7 kHz) proposed by Liu et al. [2009] and selective amplification of speech frequencies based on digital compression techniques by Terry and Bright [1992]. Recently, Mantokoudis et al. [2010] explored the potential of Internet telephony in both normal-hearing and deaf subjects, as modern phones via the Internet have a transmission bandwidth of 100–8,000 Hz and minimal compression of the audio signal. 'Software' changes have also been proposed for CI users, including creation of T-maps through the reallocation of frequency bands to electrodes [Milchard and Cullington, 2004] or the use of algorithms that emphasize high-frequency [Liu et al., 2009] or low-frequency [Hu and Loizou, 2010] representation. Altogether, these modifications led to slight improvement in verbal recognition, although significantly lower than the performance observed with broadband stimuli.

To date, surprisingly, only a few studies have used real phones in the objective assessment of telephone voice recognition performance for CI recipients [Adams et al., 2004]. Generally, the administered stimuli were not real, but experimentally simulated by applying a band-pass filter to a broadband speech signal [Liu et al., 2009; Milchard and Cullington, 2004]. Also, after many years of study in this area, there are still no standardized tests developed specifically to assess the performance of speech recognition by phone. Another limitation of previous works is that they included only star patients in the research protocol.

In this work, we decided to present the signal in an experimental system as close to the real situation as possible in order to understand more clearly the difficulties experienced in everyday life by CI recipients, especially for the older CI users. Previously, our research team [Giannantonio et al., 2014] proposed the creation of a 'telephone map' based on the Psychoacoustic Advanced Combination Encoder (PACE – MP3000) and evaluated its effectiveness using real telephones. The encouraging preliminary results confirmed the hypothesis that the 'downstream' processing adaptation can actually have advantages compared to the normal listening

conditions for the telephone signal and that the assessment methodology was correct and reliable. In addition, it was not considered sufficient to assess only subjects who fell into the category of 'telephone-users' already familiar with phone use (e.g. star patients), but to also include older patients, who were no longer accustomed to phone use, but still highly motivated to consider the potential to engage in pleasant phone conversation again, an option that had long since been abandoned due to the difficulties encountered.

In line with the literature, our study data suggest a sharp deterioration in performance for speech recognition via the telephone when using the everyday map (SB-map) for both groups of patients (i.e. under 60- and over 60-year-olds). These data demonstrate, once again, that even for CI recipients who can typically use the telephone, their speech recognition performance is poorer via the telephone than via a broadband speech signal. As expected, the use of the experimental T-map in a setting other than the one for which it was created (e.g. anechoic booth) results in a disadvantage in performance compared to when using the normal everyday map (SB-map).

In experimental listening conditions, the advantage of the T-map compared to the SB-map was statistically significant at the first application in both groups ($p < 0.05$). In fact, the mean word recognition score via the telephone with the experimental T-map was 73.5% for the Under60 group and 41.5% for the Over60 group in comparison to 65.5 and 36.5% obtained with the usual SB-map via the telephone, respectively. This confirms the hypothesis that, in order to improve the effectiveness of telephone use, an adaptation of the signal processing by adjustment of the sound processor map, can provide a listening advantage over the usual listening conditions with the everyday SB-map.

The use of the new T-map proposed in our research produces an immediate improvement in speech recognition performance over the telephone compared to the everyday SB-map for the majority of users. Clinically and statistically significant benefits in performance were measured immediately for 8/10 Under60 patients and 5/10 Over60 patients. The measured objective benefit is further confirmed by the reported subjective judgments that the T-map provides a reduction in noise and greater intelligibility of the telephone voice signal. These results gain even greater importance as observed in our group of over 60, patients who previously reported they had always avoided telephone conversation because of the poor signal quality.

Furthermore, as observed for 8/10 over 60 patients, by using the experimental map (T-map) for all telephone conversations during an extended 3-month, take-home trial, patients are practicing continuously and experience a functional adaptation that leads to additional improvement in speech recognition performance over the telephone.

In light of these results, we can conclude that modifying the sound processor parameters by reducing the current levels to a minimum for those electrodes mapped outside of the conventional telephone communication frequency range (300–3,400 Hz) results in a reduction of 'noise' and leads to greater intelligibility of the telephone speech message.

Additionally, resetting 6/22 available electrodes, represents a stimulation strategy with lower energy expenditure. The option to retain the encoding strategy as used in the everyday SB-map (ACE strategy) for the creation of the T-map allows the patients to perceive and demonstrate immediate benefit from the experimental T-map without the need for a pre-test training or adaptation phase.

This model of amendments to the sound processor map also allows the attending clinician to consider and apply the desired map parameter changes to CI sound processor models that do not include the MP3000 encoding strategy.

Conclusion

There are very few solutions explored and offered in the literature to help improve the communication skills for CI users when telephoning and, in general, all have been unsatisfactory to date. Our research suggests that, as currently demonstrated, our T-map is an easy and effective way to potentially improve telephone communication for a wide range of CI users. Elderly patients, in particular, who may have become nonusers of the telephone, and who may even have forgotten the possible benefits and enjoyment of telephone conversations, may well hope to no longer be excluded from a form of communication that has become an indispensable part of everyday life.

Disclosure Statement

The authors state that there is no conflict of interest to be disclosed.

References

- Adams JS, Hasenstab MS, Pippin GW, Sismanis A: Telephone use and understanding in patients with cochlear implants. *ENT J* 2004;83:96–103.
- Anderson I, Baumgartner WD, Böheim K, Nahler A, Arnoldner C, D'Haese P: Telephone use: what benefit do cochlear implant users receive? *Int J Audiol* 2006;45:446–453.
- Berrettini S, Baggiani A, Bruschini L, Cassandro E, Cuda D, Filipo R, Palla I, Quaranta N, Forli F: Systematic review of the literature on the clinical effectiveness of the cochlear implant procedure in adult patients. *Acta Otorhinolaryngol Ital* 2011;31:299–310.
- Carlson ML, Breen JT, Gifford RH, Driscoll CLW, Neff BA, Beatty CW, Peterson AM, Olund AP: Cochlear implantation in the octogenarian and nonagenarian. *2010*;31:1343–1349.
- Cray JW, Allen RL, Stuart A, Hudson S, Layman E, Givens GD: An investigation of telephone use among cochlear implant recipients. *Am J Audiol* 2004;13:200–212.
- Di Nardo W, Anzivino R, Giannantonio S, Schinaia L, Paludetti G: The effects of cochlear implantation on quality of life in the elderly. *Eur Arch Otorhinolaryngol* 2014;271:65–73.
- Di Nardo W, Scorpecci A, Giannantonio S, Cianfrone F, Parrilla C, Paludetti G: Cochlear implant patients' speech understanding in background noise: effect of mismatch between electrode assigned frequencies and perceived pitch. *J Laryngol Otol* 2010;124:828–834.
- Giannantonio S, Di Nardo W, Schinaia L, Paludetti G: Adaptation of cochlear implant fitting to various telecommunication systems: a proposal for a 'telephone map'. *Acta Otolaryngol* 2014;134:802–812.
- Hu Y, Loizou PC: Effects of introducing low-frequency harmonics in the perception of vocoded telephone speech. *J Acoust Soc Am* 2010;128:1280–1289.
- Lin FR, Metter EJ, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, Ferrucci L: Hearing loss and incident dementia. *Arch Neurol* 2011;68:214–220.
- Liu C, Fu QJ, Narayanan SS: Effect of bandwidth extension to telephone speech recognition in cochlear implant users. *J Acoust Soc Am* 2009;125:77–83.
- Mantokoudis G, Kompis M, Dubach P, Caversaccio M, Senn P: How internet telephony could improve communication for hearing impaired individuals. *Otol Neurotol* 2010;31:1014–1021.
- Milchard AJ, Cullington HE: An investigation into the effect of limiting the frequency bandwidth of speech on speech recognition in adult cochlear implant users. *Int J Audiol* 2004;43:356–362.
- Terry M, Bright K, Durian M, Kepler L, Sweetman R, Grim M: Processing the telephone speech signal for the hearing impaired. *Ear Hear* 1992;13:70–79.
- Turchetti G, Bellelli S, Palla I, Berrettini S: Systematic review of the scientific literature on the economic evaluation of cochlear implants in adult patients. *Acta Otorhinolaryngol Ital* 2011;31:319–327.
- Turrini M, Cutugno F, Maturi P, Prosser S, Leoni FA, Arslan E: Bisyllabic words for speech audiometry: a new Italian material. *Acta Otorhinolaryngol Ital* 1993;13:63–77.

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