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Audiology

Hearing attention and quality of listening in children with unilateral hearing loss with and without hearing aid

Attenzione uditiva e qualità dell'udito in bambini affetti da ipoacusia monolaterale con o senza protesi

Francesca Yoshie Russo[1], Daniele De Seta[2], Maria Patrizia Orlando[1], Massimo Ralli[1], Maria Gloria Cammeresi[1], Antonio Greco[1], Marco de Vincentiis[1], Giovanni Ruoppolo[1], Patrizia Mancini[1], Rosaria Turchetta[1]

[1] Department of Sense Organs, ENT Department, Sapienza University of Rome, Rome, Italy; [2] Department of Surgery, ENT Unit, University of Cagliari, Cagliari, Italy

SUMMARY

Objective. To analyse hearing attention and quality of listening in a cohort of children affected by moderate to severe unilateral hearing loss, comparing a group of hearing aid users to children with no hearing aid.

Methods. Twenty-four children (12 hearing aid users, and 12 without hearing rehabilitation) underwent audiological evaluation with speech audiometry in quiet and noise, hearing attention tests, and the speech, spatial and quality of hearing questionnaire in the version for parents.

Results. Concerning speech audiometry in noise, in the most difficult condition no one in the unaided group achieved a normal speech recognition threshold score (0% *vs* 11.6 ± 2.7% in the aided group). The selective hearing attention and shifting tests showed fewer errors in the aided group vs. the non-aided group. The questionnaire showed a significant difference between the quality of listening perceived by the parents of the two groups. The mean total scores were 152.8 ± 2.7 in the aided group and 116.1 ± 2.6 in the non-aided group ($p > 0.001$).

Conclusions. Children with unilateral hearing loss without hearing rehabilitation show a lower quality of hearing, especially with regards to divided auditory attention. Hearing rehabilitation should be proposed as soon as possible in children with moderate to severe unilateral hearing loss.

KEY WORDS: hearing aid, unilateral hearing loss, hearing attention, cognition, hearing loss

RIASSUNTO

***Obiettivo**. analizzare l'attenzione uditiva e la qualità di ascolto in bambini affetti da ipoacusia unilaterale da moderata a grave, confrontando un gruppo di pazienti portatori di protesi acustica con bambini non riabilitati.*

***Metodi**. Ventiquattro bambini (12 portatori di protesi acustiche e 12 non protesizzati) sono stati sottoposti a valutazione audiologica con audiometria vocale, test di attenzione uditiva e questionario sulla qualità dell'udito nella versione per genitori.*

***Risultati**. Nella condizione più difficile, in audiometria vocale nel rumore i bambini non riabilitati avevano delle performance scarse (0% vs 11,6 ± 2,7%). L'attenzione selettiva e i test di shifting hanno mostrato un numero significativamente inferiore di errori nel gruppo dei protesizzati rispetto ai non protesizzati. Il questionario ha mostrato una differenza significativa tra la qualità dell'ascolto percepita dai genitori dei due gruppi (152,8 ± 2,7 protesizzati e 116,1 ± 2,6 non protesizzati $p > 0,001$).*

***Conclusioni**. I bambini con ipoacusia unilaterale senza riabilitazione uditiva mostrano una peggiore attenzione uditiva, soprattutto per quanto riguarda l'attenzione uditiva selettiva. La riabilitazione protesica dovrebbe essere proposta il prima possibile nei bambini con ipoacusia unilaterale da moderata a grave.*

PAROLE CHIAVE: *ipoacusia unilaterale, protesizzazione acustica, attenzione uditiva, qualità dell'ascolto, sforzo cognitivo*

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Correspondence
Francesca Yoshie Russo
Department of Sense Organs, Sapienza University of Rome, viale del Policlinico 155, 0161 Rome, Italy
Tel. +39 06 49976854
E-mail: Francescayoshie.russo@uniroma1.it

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Introduction

The incidence of unilateral hearing loss (UHL) is estimated to be between 1 and 6% in school aged children with a high variability based on the assessment method of hearing loss [1,2]. This condition has been widely underestimated in the past, but is currently matter of attention as its diagnosis is made earlier due to universal newborn hearing screening and to stricter follow-up of children at risk [3,4]. It is now recognised that sensory deprivation of an auditory pathway leads to the loss of binaurality, and patients affected by this condition clearly manifest a lesser ability to localise sounds and discriminate the signal in noise [5]. In addition, we are beginning to understand the complex effects of these disadvantages on psycho-cognitive development in children and young adults, although there are currently no universally accepted guidelines concerning hearing rehabilitation for UHL. In past decades, the common knowledge among medical and educational professionals was that the presence of one normal hearing ear was sufficient for the correct development of language [6]. Nevertheless, we now know that these children are at risk of psychoeducational difficulties, with an augmented rate of failing a grade, and with increased perceived behavioural issues [7]. This may be mostly due to the considerable amount of time that children spend in adverse acoustic environments, with high levels of background noise and reverberation [8,9]. Indeed, the capacity to understand degraded speech is crucial in the developmental processes that lasts until adolescence [10]. Several studies have shown that the need to spend energy to focus attention on the signal leads to a lower availability of cognitive resources and therefore to a decrease in performance in contexts of multi-activity and learning [11]. In developing children, the loss of audibility is a great challenge in everyday life, and the primary contributor to a delay in maturation of cognitive and linguistic skills [12].

Another issue arising in this context is the diminished auditory attention as a contributing factor to problems of cognitive and linguistic development, but also of quality of life. Certainly, compared to their normal hearing peers many of these children have difficulty in direct selective attention during multi-talker listening [11].

Options for management of UHL in children include conventional hearing aids (HA), bone-conduction hearing devices, contralateral routing of signal (CROS) aids, and Remote Microphone Hearing Assistance Technology systems [13].

To date, there is no agreement on which degrees of UHL require amplification, and there are conflicting studies on the hearing benefit in children in whom normal perception of the signal has been restored through hearing aid [14,15].

The main goal of the present prospective study is to analyse the hearing attention and quality of hearing in a cohort of children affected by UHL, comparing a group of HA users to children with no HA.

Materials and methods

A prospective, clinical study was conducted at a University hospital. Children and their families were enrolled in the study between April 2017 and September 2019. The study group included 24 patients affected by moderate to severe UHL selected in the records among all patients followed at the Otolaryngology Department, Paediatric Audiology Unit. Among more than 80 patients followed in the center since 2014, subjects corresponding to the inclusion criteria and whose parents agreed to enter the protocol were selected. Twelve patients were HA users for at least 1 year (HA group), and 12 patients did not benefit from hearing rehabilitation because the family previously chose to not use hearing aids (non-HA group). All patients in the study had an air conduction HA, and had to use the device for at least 8 hours a day.

Inclusion criteria were: permanent unilateral moderate to severe conductive, sensorineural or mixed hearing loss, age comprised between 6 and 11 years old, native Italian speaker. Patients with concomitant otitis media with effusion, diagnosis of developmental delay, or concomitant severe pathologies were excluded. For UHL, we considered the definition of the National Workshop on mild bilateral and unilateral hearing loss [16]: average pure tone air conduction threshold at 0.5, 1, 2 kHz of any level greater than or equal to 20 dB HL or pure tone air conduction thresholds greater than 25 dB HL at two or more frequencies above 2 kHz in the affected ear with an average pure tone air conduction threshold in the good ear less than or equal to 15 dB.

All patients underwent audiological evaluation and auditory attention test, and parents underwent the SSQ questionnaire (speech, spatial and quality of hearing) in the adapted version for parents [17].

Audiological examination

Patients underwent anamnestic interview and a full ear, nose and throat examination. Hearing ability was evaluated using age-appropriate behavioural audiometric assessment techniques. Audiological evaluation included: pure tone audiometry with headphones or play audiometry with headphones at the frequency range 500-4000 Hz; tympanometry; speech audiometry in sound field, in a sound-proof cabin, with lists of 10 disyllabic words, in quiet and in noise. For the test in noise, we used a broad band noise at SNR+10, with speech and noise coming from the frontal speaker (0°) positioned

at 1 metre from the subject (S0N0 configuration). For both quiet and noise tests, speech was presented at 60 dB, 50 dB, 40 dB, 30 dB and 20 dB HL, while in noise test the noise varied accordingly. Patients in the HA group underwent speech audiometry wearing their HA.

Hearing attention test

All patients underwent the auditory attention tests developed by Bertelli and Bilancia in 2006 [18]. These tests are methodologically based on the scheme of the attention tests developed in 1983 by Cherry and Kruger [19].

The battery tests for evaluation of auditory attention (AA) separately analyse the different procedural components of AA. In this study, our interest focused on selective attention (TS1 and TS2) and the shifting process or divided attention (SH1 and SH2).

One training list was administered before starting the test.

TS1 and TS2 consisted of two tests for selective attention, in which the weight of the distraction factor and the cognitive load were differentiated. The two tests were administered in a dichotic listening configuration with the signal on the hearing loss side and the noise on the normal hearing side (ShlNnh configuration) with the speakers positioned at +90° and -90° 1 metre apart from the head of subject. TS1 consisted of a list of 46 disyllabic words in which the target (the word *dog, disyllabic word in Italian*) was presented eight times, and 19 distractors presented twice in casual order; TS2 consisted of a list composed of the same distractors and 8 animal names that constitute the target to be identified as a category. In both tests the list of words was opposed to 3 different background noises (melody, news, tale) in three successive tests lasting 1' and 15'' each.

The two shifting tests (SH1 and SH2) were also administered in dichotic listening, built with a double target: in SH1, the background noise was a musical theme, the distractors were the verses of 14 different animals, the targets to be identified were the word *flower* and the verse of the cat (each one repeated 8 times). In SH2, a musical theme and a list of 27 words were presented, and the targets were the verse of a sheep and the word *moon* (each one repeated 8 times). The duration of each of the two tests was 3'22''.

For each test, the examiner noted the correct and incorrect answers.

Questionnaire

The parents' subjective perception of the children's quality of hearing was evaluated using a questionnaire derived from SSQ designed for adults [20]. To date, there is no validated paediatric questionnaire that explores the quality of hearing and its relevant domains in sufficient detail. Therefore, we administered the modified version by Galvin et al. and previously published [17].

The three sections of the scale examined speech perception (in quiet, on the telephone, in groups and/or in noisy or reverberant environments), spatial hearing (the location and direction of sounds), and other qualities of hearing (segregating and identifying sounds and listening effort). In order to maximise the accuracy of the answers, parents were asked to observe the children for 5 days before answering the questionnaire. For each situation described, the parent indicated a score of the child's listening skill on a scale from 1 to 10. The questionnaire was translated and administered in Italian.

Statistical analysis

Results were reported as means ± Standard Error of Mean (SEM). Considering the small number of the sample non-parametric tests were used. Mann-Whitney U test was used to analyse the results and differences between the two groups (aided *vs* unaided). Spearman's test was used for correlation between SSQ questionnaire and auditory attention tests. All statistical analyses were performed with IBM SPSS Statistics for Windows (v 22.0, IBM Corp., Armonk, NY, USA). The cut-off level for statistical significance was set to 0.05.

Results

All patients completed the protocol. The participants in the two groups were matched for sex and age (Tab. I). Mean pure tone averages (PTAs) for the worse ear were 69.9 ± 4.0 dB *vs* 69.3 ± 4.2 dB for aided and non-aided group respectively (p = 0.8, Mann-Whitney U test). In the no HA group, 7 patients had moderate hearing loss and 7 severe hearing loss, and in the HA group 6 patients had moderate and 8 patients severe hearing loss.

The mean speech perception scores of the two groups in quiet and noise are reported in Table II. In noise, in the most

Table I. Patient characteristics.

	Age (y)	Sex (m:f)	PTA worse ear (dB)	HA use (y)
HA group	9.3 ± 0.56	8:4	69.9 ± 4.06	2.3 ± 0.3
Non-HA group	9.4 ± 0.49	8:4	69.3 ± 4.29	-

Patients were matched for sex, age and PTA use. Results are reported as means ± SEM. PTA: Pure Tone Average; SEM: Standard Error of Mean.

Table II. Audiological results.

	WRS in quiet (% correct)					WRS at SNR +10 dB (% correct)				
	60 dB	50 dB	40 dB	30 dB	20 dB	60 dB	50 dB	40 dB	30 dB	20 dB
HA group	100	98.3 ± 1.66	84.2 ± 5.56	61.7 ± 7.57	35.8 ± 5.28	98.3 ± 1.12	87.5 ± 5.2	75 ± 5.18	32.5 ± 5.52	11.7 ± 2.7
Non-HA group	98.3 ± 1.12	95.8 ± 1.92	79.2 ± 5.96	49.2 ± 5.14	17.1 ± 5.56	97.5 ± 1.3	81.7 ± 3.65	56.7 ± 6.55	20.0 ± 6.51	0

Results are reported as means ± SEM. Signal varied from 60 to 20 dB both in quiet and in noise. WRS: Word Recognition Score; SNR: Signal-to-Noise-Ratio; SEM: Standard Error of Mean.

difficult condition no one in the no HA group achieved a normal Speech Recognition Threshold (SRT) score (0% *vs* 11.6 ± 2.7% in the aided group). Statistical analysis showed significantly better performance in quiet at 20 dB ($p = 0.02$, Mann-Whitney U test) and in noise at 20 dB speech level ($p = 0.005$, Mann-Whitney test). For aided patients, no difference was found for the other conditions, while a non-significant trend for better scores in the HA vs no HA group was evident, even in the easier test conditions in both quiet and in noise (Fig. 1).

The auditory attention tests showed a clear difference between the two groups (Fig. 2). The selective attention and shifting tests showed in all trials fewer errors in the HA group vs the no HA group of children ($p < 0.01$, Mann-Whitney U test).

The SSQ questionnaire showed a significant difference in the quality of listening perceived by the parents of the two groups. The mean total score for the HA group was 152.8 ± 2.7, while the mean total score for the no HA group was 116.1 ± 2.6 ($p > 0.001$ Mann-Whitney U test). Figure 3 shows the total and subscales scores for the two groups of children; a higher score designates a better hearing quality. In detail, the speech component of the questionnaire was relevantly different between the two groups.

The SSQ questionnaire was correlated with the auditory at-

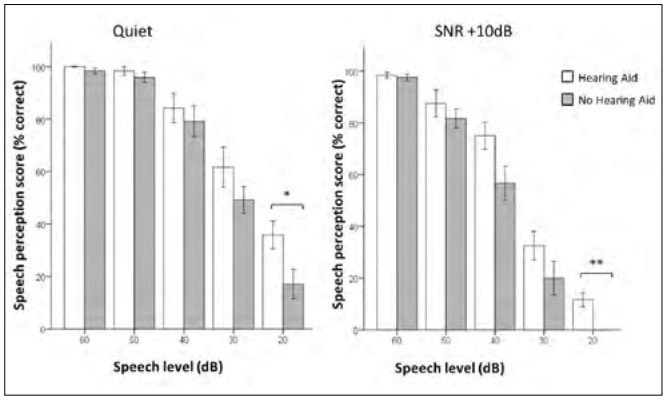

Figure 1. Speech perception scores in quiet and in noise (SNR +10; S0N0) in HA and no HA patients. SNR: Signal-to-Noise-Ratio.

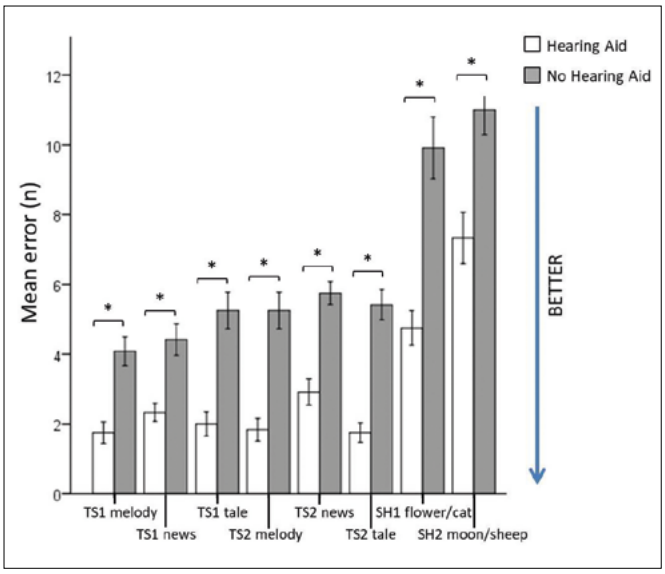

Figure 2. Mean number of errors in selective and shifting attention tests in HA and no Ha patients.

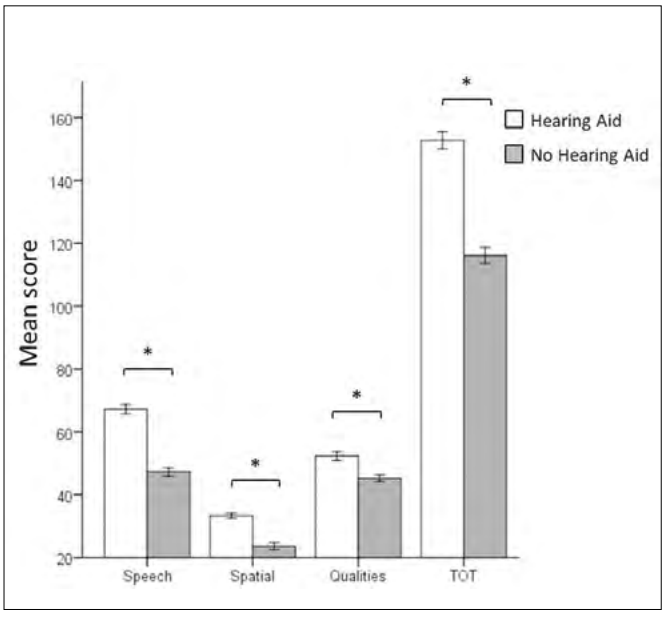

Figure 3. Results of SSQ questionnaire for parents, total and subscales scores for the two groups of children. A higher score designates a better hearing quality.

tention test. A negative correlation was found between all the subdomains of the test and the three subdomains and the total score of the questionnaire ($-0.47 < r < -0.73$, $p < 0.01$, Spearman test), thus indicating that the lower number of errors in the test was correlated with higher scores in SSQ questionnaire. Figure 4 shows the scatterplot for the correlation between TS2 tale and SSQ Speech.

Discussion

The results of the present study demonstrate that children with unilateral hearing loss, with or without hearing rehabilitation have a low level of auditory attention. This outcome is more significant in children without hearing aids, in which difficulties are more evident with regards to selective and divided auditory attention.

In both groups, parents seem to have a correct perception of the hearing state of their children, perceiving a greater difficulty in no HA children, especially in noisy environments and difficult situations (speech subscale).

The creation of the auditory attention is crucial in a developmental age, especially in the early stages of the acquisition of lexical language skills [21]. An alteration in auditory attention, as noted by several authors [21,22], also diminishes the expansion of the properties of the lexical repertoire, and the elaboration of the semantic component of the language, and therefore the acquisition of new knowledge.

Among the different mechanisms that participate in the creation of auditory attention in the developmental age, we investigated selective attention (TS1, TS2), which is the process by which a subject focuses attention on a specific stimulus to process information by ignoring other potentially distracting stimuli; divided attention (SH1, SH2), which is the process that allows to simultaneously manage two or more streams of stimuli, requires the ability to make rapid shifts from one information channel to another [23].

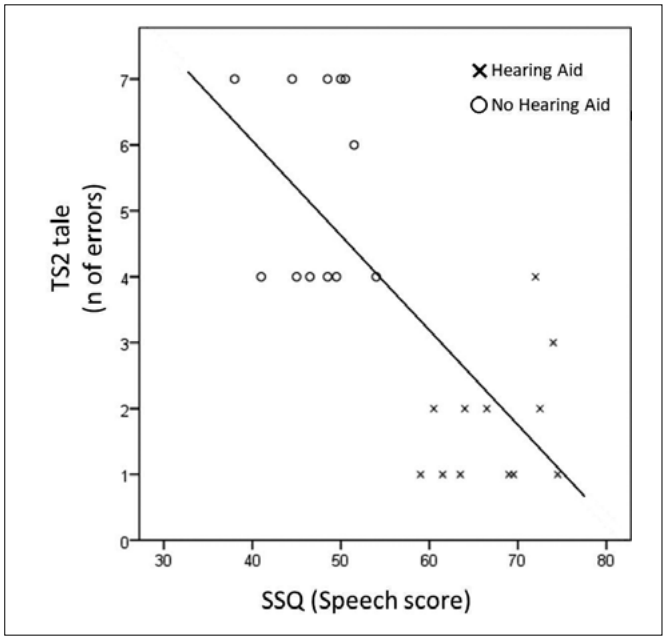

Figure 4. Correlation between TS2 tale test and results of the speech subscale in HA and no Ha groups.

We demonstrate that in unaided children with UHL these two types of attention are significantly impaired compared to their peers using HAs for at least one year, further demonstrating that binaurality has a paramount importance in auditory attention processes especially in presence of competitive sounds, a circumstance that reflects the more frequent listening conditions of these subjects (school, canteen, sport facilities). However, one limit of the present study is the absence of a healthy control group performing the auditory attention battery, which could have given useful information on the auditory attention capacities in normal hearing children compared to, for example, rehabilitated children with unilateral hearing loss.

One of the objectives of the construction of the battery for auditory attention was the possibility of using the tests early enough (starting from 6 years), considering the cruciality of this phase for the development of language and cognitive abilities of the child. In fact, normal hearing subjects are able to analyse the acoustic scene and identify auditory objects properly, even in the presence of competing sounds, while degraded central processing due to unilateral hearing loss is likely to increase the time required to form auditory objects and focus selective attention, leading to a loss of the capacity to switch attention rapidly, a skill that is essential in complex hearing situations (noisy environment, conversation).

These difficulties also emerge from the results of questionnaires administered to parents, showing a significant difference between the two groups in the results of all three subscales. Parents' ability to identify childrens' difficulties denotes the impact of unilateral hearing deprivation in everyday life situations. In particular, the subscale regarding speech understanding is strongly impaired and is also correlated with lower performance in selective attention tests. This result is consistent with what also occurs in adult subjects with unilateral hearing loss; in fact, it is now widely recognised that adults reliant on a single ear are disadvantaged in all aspects of everyday listening and communication [24].

To date, unilateral hearing loss is a crucial issue in the management of childhood hearing loss, as well as in the adult; the latest report of the American Academy of Audiology states that children with aidable unilateral hearing loss should be considered as candidates for amplification in the

impaired ear due to evidence for potential developmental and academic delays [25]. However, there is no universally accepted consensus for the rehabilitation of this condition, and further clinical studies are needed to allow audiologists and health care professionals to direct parents and the patient towards the best choice.

Conclusions

We assessed that unilateral hearing-impaired children experience a consistent impairment in hearing attention, possibly leading to marked disabilities in realistic communication situations, particularly in speech understanding. These difficulties are clearly overcome by their peers wearing HAs for at least one year, in which the restored binaurality allows better results in auditory attention tests and the SSQ questionnaire administered to parents.

These results lead us to conclude that unilateral hearing loss, once considered not worthy of attention and for which there are still no rehabilitation guidelines, deserves greater consideration in the field of paediatric hearing rehabilitation, which should be performed as early as possible as in all other forms of bilateral hearing impairment.

Conflict of interest statement

The authors declare no conflict of interest.

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Authors' contributions

FYR: study conception and design, carried out the examinations, writing of the manuscript, developping of the theory and performing of the computations. DDS: have made a substantial contribution to the concept of the article; writing of the manuscript, analysis of the data. MPO: acquisition of data, interpretation of data. MR: revised the article critically for important intellectual content. MGC: carried out the experiment and the examinations of the patients. AG: analysis of data, approved the version to be published. MdV: analysis and interpretation of data for the article. GR: have made a substantial contribution to the concept of the article; performed analysis of the data. PM: agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved, contributed to the analysis of the data. RT: conceived the original idea, supervised the project, performed writing and correction of the manuscript, approved the final version to be published. All authors discussed the results and contributed to the final manuscript.

Ethical consideration

This study was approved by the Institutional Ethics Committee (Department of Sense Organs) (approval number/ protocol number 7.10-2019 /23.07.2019).

All parents gave their informed written consent and the study was performed according to the principles of the Declaration of Helsinki.

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