Hearing recognition comparison between aided and unaided ear in hearing aid users

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LIST OF ABBREVIATIONS

BTE – Behind-the-ear

ITE – In-the-ear

MHL – Moderate hearing loss

PTA – Pure-tone average

SHL – Severe hearing loss

SRT – Speech recognition threshold

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1. INTRODUCTION

1.1. Mechanism of hearing

Auditory perception is one of the five traditional senses mentioned by Aristotle (1). It is formally defined as the ability to perceive sounds by detecting pressure changes in the air through your ear (2).

1.1.1. The external ear

The external ear (Fig. 1) constitutes of the auricle, the ear canal, and terminates at the lateral surface of the tympanic membrane (3). Due to the asymmetrical anatomical structure of the auricle, sounds will be filtered and provide a spectral shape of the sound allowing for the determination of the vertical elevation of the sound source, as well as whether it originates from the front or back of the head (4).

Another feature of the shape of the external ear is that it will selectively boost the sound pressure for frequencies around 3 kHz (5).

Seeing as the tympanic membrane is an airtight barrier, it will begin vibrating according to the waveform of the sound and further transmit it to the middle ear (3).

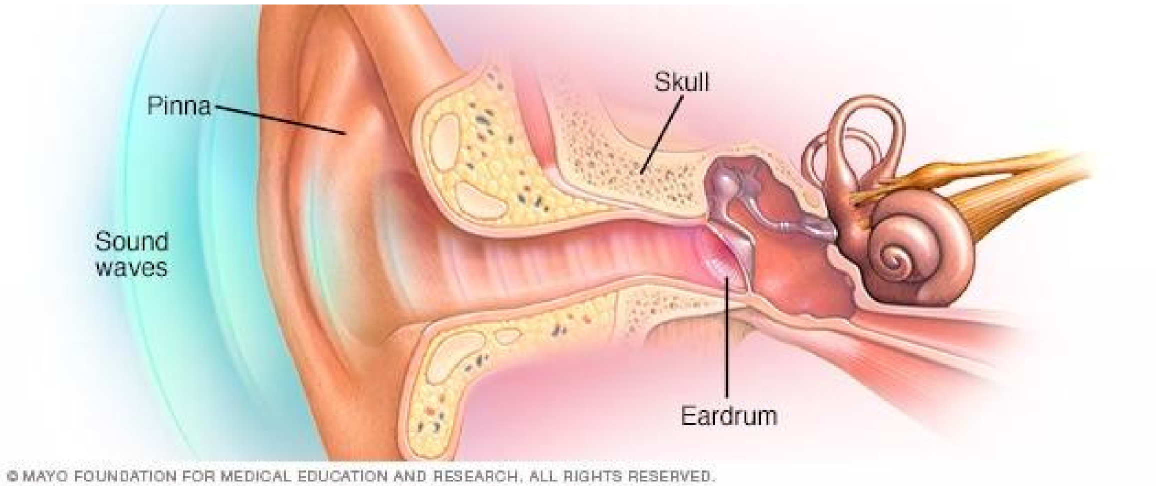

Figure 1. Schematic view of the external air (6).

1.1.2. The middle ear

The middle ear (Fig. 2), also referred to as the tympanic cavity, begins at the medial surface of the tympanic membrane. This is where the sound wave vibrations from the external ear are converted into mechanical vibrations. These mechanical vibrations are further transferred into the middle ear, and onto the auditory ossicles malleus, incus, and stapes (3).

The pressure is greatly amplified as the mechanical vibrations travel through the ossicles towards the oval window. The auricle and middle ear that act as mechanical transformers and amplifiers so that the sound waves end up with amplitudes 22 times greater than when they entered the ear. This amplification is the primary function of the middle ear. An acoustic energy loss would have been present as the sound traveled from air (a low resistance medium) to the inner ear liquid (a higher resistance medium) without the auditory ossicles (7).

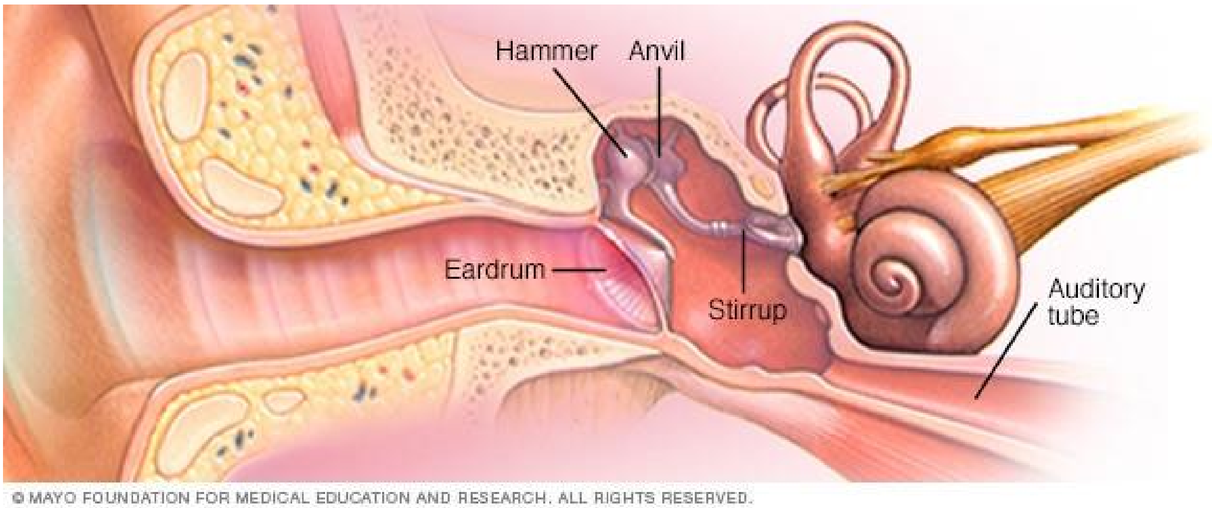

Figure 2. A schematic view of the middle ear (6).

1.1.3. The inner ear

From the oval window of the middle ear, the mechanical properties of the sound will be transformed into neural transduction in the inner ear (Fig. 3). The inner ear consists of the cochlea which is divided by the organ of Corti (8).

Signal transduction occurs when vibrations of the structures within the inner ear results in a displacement of cochlear fluid and the subsequent movement of the hair cells of the organ of Corti produces electrochemical signals (8).

An electrical signal will as such be sent through the auditory nerve and into the auditory cortex of the brain as a neural message (8).

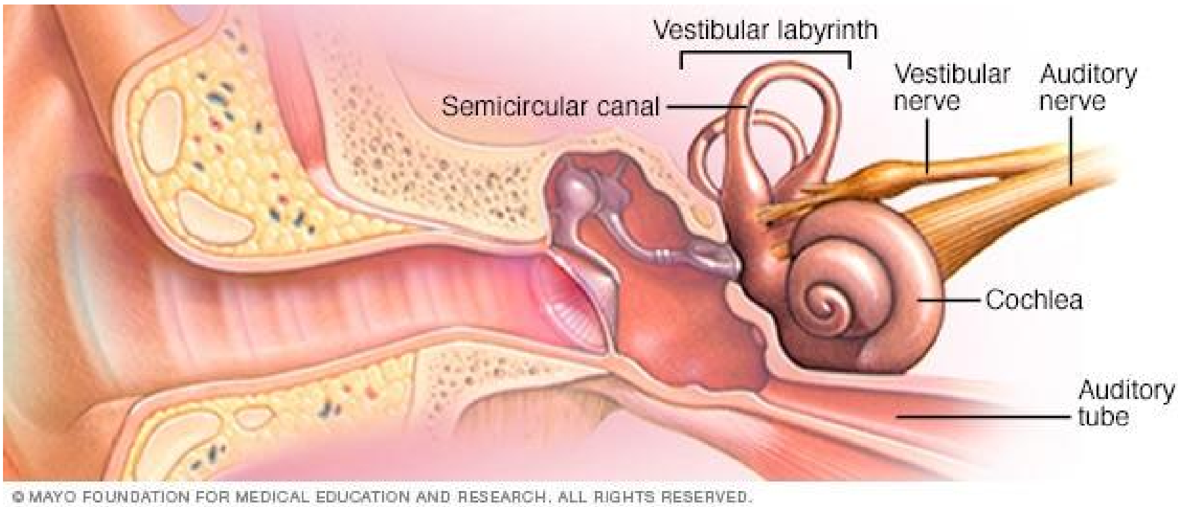

Figure 3. Schematic view of the inner ear (6).

1.1.4. The hearing path

The auditory information that has been gathered in the cochlea, will then be transported in the auditory nerve (also called cochlear nerve), which is one half of the vestibulocochlear cranial nerve VIII.

Its primary destination will be the primary auditory cortices, and this is when you first consciously perceive the sound (9).

Before reaching the auditory cortex, the auditory signal goes through the inferior colliculus of the midbrain tectum to the medial geniculate of the thalamus and then to the temporal lobe where the auditory cortices resides (Fig. 4).

Signals from the right ear travel to the left auditory cortex located in the temporal lobe on the left side of the brain, and vice versa for the opposite ear (9,10).

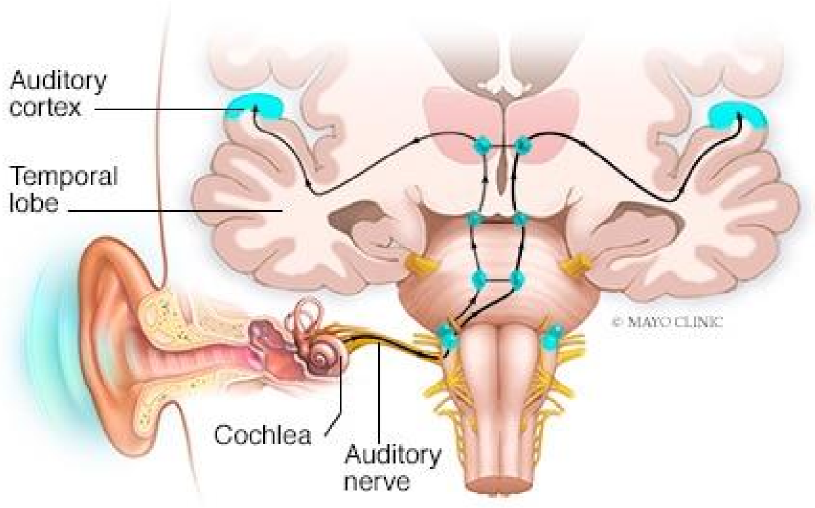

Figure 4. A schematic view of the hearing path (6).

1.2. Hearing loss

Hearing loss, or hearing impairment, is diagnosed when there is evidence of a diminished acuity for sounds that should normally be heard, and affects almost 10% of the adult population (11).

1.2.1. Types of hearing loss

There are three different types of hearing loss: conductive hearing loss, sensorineural hearing loss, and mixed hearing loss (11).

Conductive hearing loss presents when there are a problem conducting sound waves either along the external ear, tympanic membrane or the three ossicles in the middle ear (12). Some causes of external ear problem might for example be foreign bodies in the ear canal, abnormal growth of bone in the ear canal or tumors. In the middle ear, causes can be for example acute or serous otitis media, perforated tympanic membrane, tympanosclerosis or Eustachian tube dysfunction (12,13).

One of the more common causes for conductive hearing loss in children is otitis media with effusion.

Sensorineural hearing loss is defined as when the cause of hearing impairment originates from either the cochlea or the vestibulocochlear nerve. It can be caused by genetical, congenital or age-related reasons (10).

Cytomegalovirus infection is one of the more common causes of sensorineural hearing loss in children today. Congenital rubella syndrome and toxoplasmosis are other congenital causes (12).

Mixed hearing loss is when you have a condition consisting of both conductive and sensorineural hearing loss (11).

1.2.2. Signs and symptoms of hearing loss

The signs and symptoms will vary depending on the severity of impairment ranging from a mild annoyance, to severe psychological stress panic disorder, and loneliness (14).

The typical symptoms are difficulties using the telephone, loss of directional orientation of sounds, and difficulties understanding speech (15).

Although hearing loss is sensory, it might often be accompanied by pain or pressure in the ears and the feeling that they are being blocked (15).

Secondary accompanying symptoms might be vertigo, giving the individual a spinning or swaying sensation making it difficult for the patient to walk; tinnitus, the persistent ringing of in the ear when there is no external source of sound; and autophonia, the feeling that your own voice is perceived as abnormal by oneself. The latter being caused by permanently open Eustachian tube (15,16).

Classification of hearing loss based on severity is presented in Table 1.

Table 1. Classification of hearing loss based on severity (17).

Degree of hearing loss	Lowest decibel threshold (dB)	Typical Consequence
Mild	25-40	Difficulties keeping up with conversations in noisy surroundings
Moderate	40-60	Difficulties keeping up with conversations when not wearing hearing aids
Severe	60-80	Reliant on powerful hearing aids, although many rely on lip-reading
Profound	>85	Almost exclusively reliant on sign language or lip-reading

1.2.3. Causes of hearing loss

Ageing is one of the most common causes of hearing loss. Age-related hearing loss is the total effect of what age and environment does to the hearing organ. It is bilateral and irreversible, and is due to the degeneration of the cochlea and auditory nerves (18).

Noise-induced hearing loss accounts for approximately 50 percent of all hearing loss cases. The loss may either occur gradually over time as when listening to loud music through ear-phones or living in areas with high back ground noise, or it can happen abruptly as when exposed to a high frequency noise as that of an explosion or gunshot. This cochlear overstimulation will lead to the irreversible damage of the hair cells, and the hearing loss will be permanent (19).

Some ototoxic medications might also lead to a reversible hearing loss. Ototoxicity is defined as: “the tendency of certain therapeutic agents and other chemical substances to cause functional impairment and cellular degeneration of the tissues of the inner ear, and especially of the end-organs and neurons of the cochlear and vestibular divisions of the eight cranial nerve” (20). Medications like loop diuretics, NSAIDs, paracetamol and macrolide antibiotics have all some ototoxic effects. Cisplatin, a chemotherapeutical medication, is extremely ototoxic and the chances of experiencing hearing loss are almost 100% (20).

Physical trauma to the head can for example fracture the temporal bone and damage the cochlea. If there should be a fracture on any of the 3 ossicular bones, the ossicular chain will be broken and hearing loss occurs. In a labyrinthine concussion, there is no inner ear destruction, but you can still experience symptoms of hearing loss, tinnitus, and dizziness (21).

1.3. Diagnosis of hearing loss

In the process of diagnosing a patient with suspected hearing loss, it is beneficial to do a thorough patient history. Special interest should include birth and pregnancy information, what medications the patients are taking, and workplace and home environment. This is information that can lead to valuable clues to context and cause of hearing loss (12).

Routine physical examination should also include otoscopy, which will give valuable information about the external ear, ear canal, tympanic membrane and middle ear. Check to see if the ear canal is clear of cerumen, the tympanic membrane is intact, and that the middle ear is free for fluid (22). Tympanometry is the process of eliciting different air pressures into the air canal to observe the mobility of the ear drum and subsequent the ossicular chain. It is an objective measure of middle ear effusion or Eustachian tube dysfunction (23). The Weber and Rinne test can sometimes give a quick differential diagnosis for whether the condition is conductive or sensorineural (24).

Different hearing tests can also give a good objective and qualitative measurement of the individual’s type, degree and configuration of hearing loss:

1.3.1. Pure-tone audiometry

Pure-tone audiometry is used to measure hearing sensitivity. The individual to be tested is placed in a soundproofed room with over-the-ear headphones (when testing for air conduction). Frequencies from 250 Hz to 8000 Hz are played in typically 8 intervals with increasing intensity. Pure-tone threshold indicates softest sound audible to the individual at least 50% of the time. When testing for bone conduction, a small oscillator is placed on the individual’s mastoid bone, and this bypasses the external and middle air (i.e. the sound travels directly from the cochlea to auditory nerves) (10,25).

The following result of the test will be plotted on an audiogram displaying intensity as a function of frequency (Fig. 5).

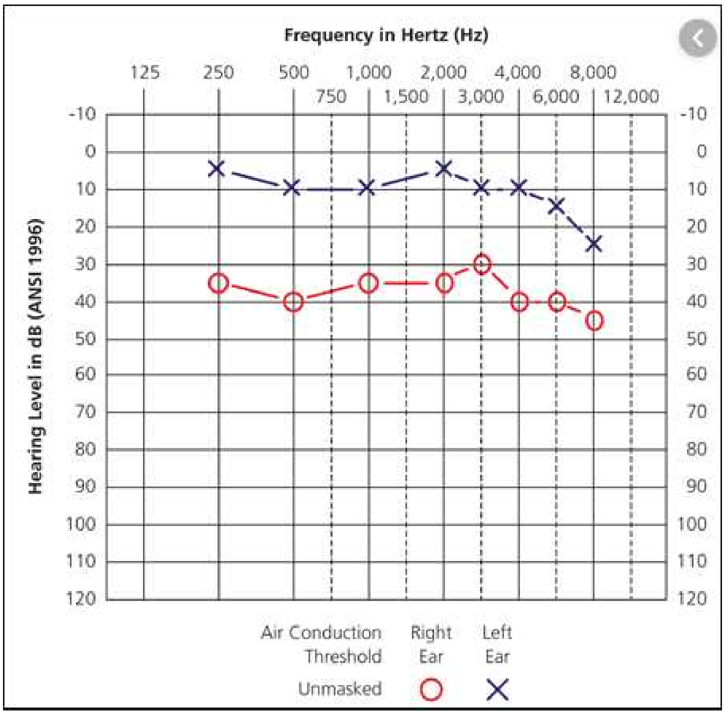

Figure 5. Example of an audiogram from a pure-tone audiometric test.

1.3.2. Speech audiometry

Speech audiometry is used to evaluate the patient's capability to perceive words. The individual is placed in a soundproof room with over-the-ear headphones, and pre-recorded words are presented and the individual will repeat the word to show how well they perceived the information (26).

This is regarded as a more accurate representation of the individual's impact of hearing loss in their everyday life, seeing as typical speech varies over a great span of frequencies and are not merely pure-tone in nature. The voiced speech of an adult male will range inbetween 85 to 180 Hz, and for an adult female it ranges from 165 to 255 Hz (27).

Spondaic words are the preferred words to be used in a test like this. Spondaic words are disyllable words which have equal stress and emphasis on every syllable. Carpark, handshake and earthquake are examples of these kinds of words. The words should have equal intelligibility across all signal levels during the speech audiometry (28).

The speech-recognition threshold (SRT) has as an objective to measure the lowest level at which speech can be identified at least 50% of the time. PB_{max} is when 100% of speech is recognized (26,29).

The following results will be plotted on a speech audiogram (Fig. 6).

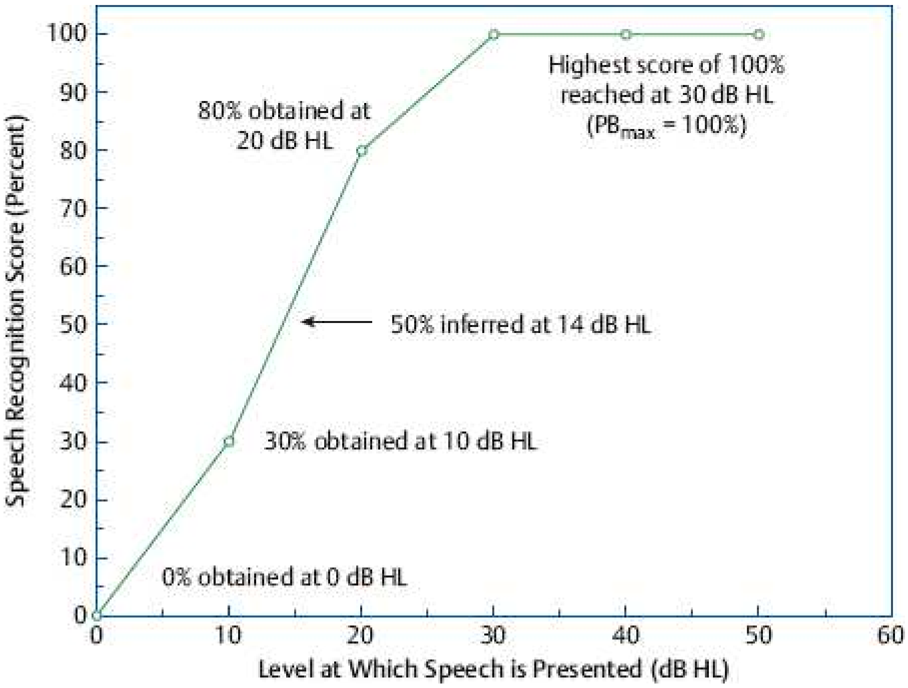

Figure 6. A descriptive example of a speech audiogram (29).

1.4. Hearing aids

A hearing aid is a small electronical medical device worn in or behind the ear, used to amplify external sound for the benefit of people with hearing loss. The hearing aid magnifies the sound waves projecting into the ear, and these larger vibrations will be easier for the remaining hair cells to detect and convert to neural signals (31).

There are several different types of hearing aids (Fig. 7), but the most commonly used are either behind-the-ear (BTE) or in-the-ear (ITE) (31).

Figure 7. The different styles of hearing aids (31).

2. OBJECTIVES

The main goal of the present study is to investigate the difference of hearing recognition between the aided and unaided ear in long-term (>5 years) single sided hearing aid users with moderate and severe hearing loss.

We hypothesize that long term hearing aid use will increase plasticity of the hearing pathway and improve functionality of the ear and their results on speech audiometry on the aided ear compared to the unaided ear.

3. SUBJECTS AND METHODS

3.1. Patients

In our study we observed 48 patients with bilateral hearing loss > 40 dB, 31 males and 17 females, which totaled 96 ears. All patients had been unilateral hearing aid users for at least 5 years.

The inclusions criteria were:

- 18 years of age or older
- bilateral hearing loss > 40 dB
- hearing aid user on only one ear for at least 5 years

The exclusions criteria were:

- bilateral or single sided deafness
- pure-tone average difference more than 20 dB between ears
- any factor that might interfere with the test, such as systemic disease or neurological conditions

3.2. Organization of the study

The study was carried out as a cross-sectional study by corresponding qualitative research and descriptively processed data.

3.3. Place of the study

This study was conducted at the Department of Otorhinolaryngology & Head and Neck Surgery, University Hospital of Split in Croatia.

3.4. Methods of data collecting and processing

This retrospective study was carried out by revising medical journals, pure-tone audiograms, and speech audiograms. We used the data from patients that underwent examination from January 2018 until June 2018.

The statistical software used was Statistica 12 (StatSoft Inc., Tulsa, OK, USA). For normality we used the Kolgomorov-Smirnov test. To test the difference between groups we used Student's t-test and ANOVA test with interaction effect. We display average and standard deviation for normally distributed variables. *P* values less than 0.05 is considered statistically significant.

3.5. Description of research

All patients underwent otoscopy, pure-tone audiometry and speech audiometry in a soundproof room without wearing their hearing aids. Frequencies from 250 Hz to 8000 Hz were tested with increasing intensity. Pure-tone average (PTA) was calculated as average of hearing sensitivity at 500, 1000, 2000 and 4000 Hz. All subjects undertook investigation of speech audiometry: speech recognition threshold (SRT; lowest intensity disyllabic word that an individual can repeat at least 50% of the time), PB_{50} (performance-intensity on phonemically balanced words where 50% of speech is recognized), PB_{max} (performance-intensity maximum on phonemically balanced words; 100% of speech is recognized)

The patients were divided in accordance to classification of moderate or severe hearing loss into 2 groups:

- Moderate hearing loss (40–60 dB)
- Severe hearing loss (60–80 dB)

No special attention were given to the type of hearing loss, i.e. sensorineural, conductive or mixed.

4. RESULTS

4.1. Pure-tone average (PTA)

Table 2. Descriptive statistics for PTA in the aided and unaided ear

	Level of - Factor	N	PTA - Mean	PTA - Std.Dev.	t	*P**
Hearing aids	aided	48	61.51	9.53		
	unaided	48	66.27	16.74	1.714	0.091

*T-test
PTA – Pure-tone average

There is no statistical significant difference in the aided (N=48) and the unaided (N=48) ear and PTA (*P*=0.091).

4.2. Speech-recognition threshold (SRT)

Table 3. Descriptive statistics for SRT in the two groups severe hearing loss (SHL), moderate hearing loss (MHL), as well as for unaided and aided ear, and combinations.

	Level of - Factor	N	SRT - Mean	SRT - Std.Dev.	*P**
Group	SHL	55	54.73	13.45	
	MHL	41	34.39	8.67	<0.001
Hearing aids	unaided ear	48	49.17	17.6	
	aided ear	48	42.92	12.2	0.028
Group and hearing aids	SHL and unaided ear	28	59.64	14.53	
	SHL and aided ear	27	49.63	10.18	0.005
	MHL and unaided ear	20	34.50	8.87	
	MHL and aided ear	21	34.29	8.7	0.938

*T-test
SRT – Speech-recognition threshold
SHL – Severe hearing loss
MHL – Moderate hearing loss

Ears with SHL (N=55) have higher SRT than ears with MHL (N=41) (P<0.001).

The unaided ear (N=48) have higher SRT than the aided ear (N=48) (P=0.028).

The SRT shows a statistical significant difference between aided and unaided ear in people with SHL (p=0.005). The SRT does not show a statistical significant difference between aided and unaided ear in people with MHL (p=0.938). See figure 8, and table 6 and 7.

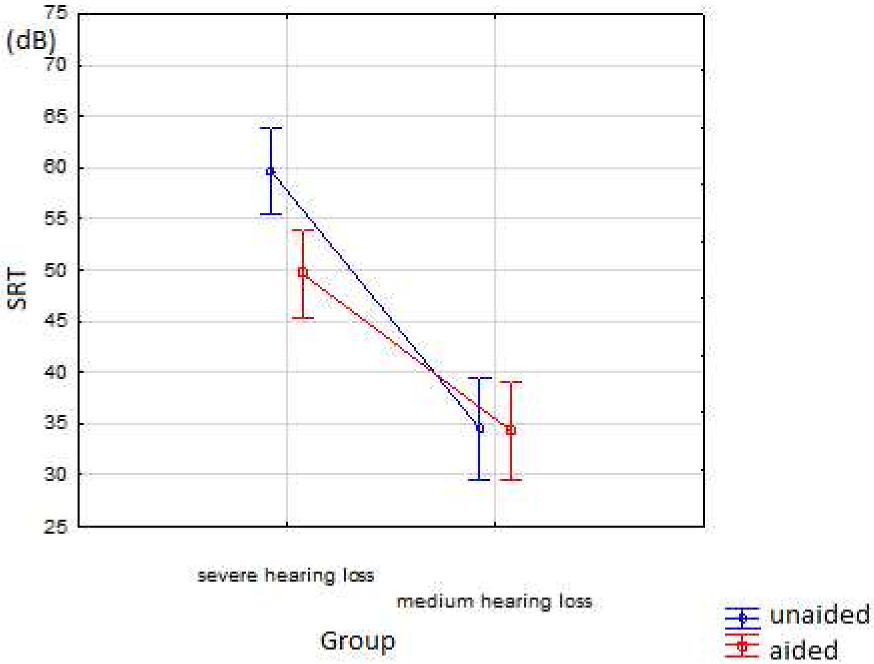

Figure 8. SRT of the unaided and aided ear between the groups with SHL and MHL.

4.3. Performance-intensity maximum (PB_{max})

Table 4. Descriptive statistics for performance-intensity maximum (PB_{max}) in the two groups SHL, MHL, as well as for unaided and aided ear, and combinations.

	Level of - Factor	N	PB_{max} - Mean	PB_{max} - Std.Dev.	*P**
Group	SHL	55	81.82	11.99	
	MHL	41	66.59	14.42	<0.001
Hearing aids	unaided ear	48	77.40	16.31	
	aided ear	48	73.23	13.55	0.245
Group and Hearing aids	SHL and unaided ear	28	85.89	11.79	
	SHL and aided ear	27	77.59	10.86	0.009
	MHL and unaided ear	20	65.50	14.32	
	MHL and aided ear	21	67.62	14.80	0.644

*T-test
PB_{max} – Performance intensity maximum
SHL – Severe hearing loss
MHL – Moderate hearing loss

Patients with SHL have higher PB_{max} than patients with MHL ($P<0.001$).

The unaided ear have higher PB_{max} than the aided ear, but difference is not significant ($P=0.245$).

PB_{max} shows a statistical significant difference between aided and unaided ear in people with SHL ($P=0.009$). PB_{max} does not show a statistical significant difference between aided and unaided ear in people with MHL ($P=0.644$). See figure 9, and table 6 and 7.

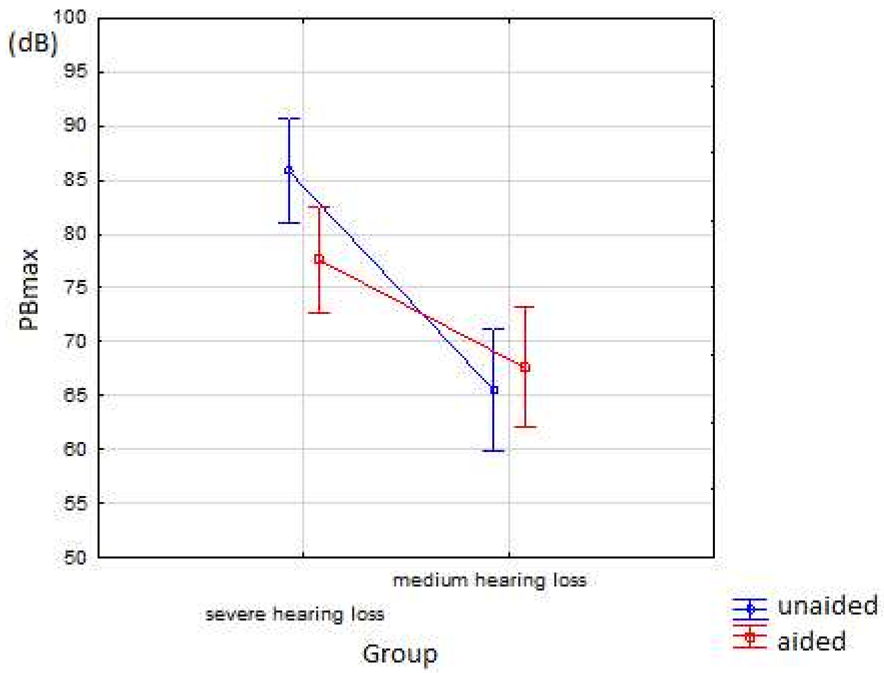

Figure 9. PB_{max} of the unaided and aided ear between the groups with SHL and MHL.

4.3. Performance-intensity 50% (PB_{50})

Table 5. Descriptive statistics for performance-intensity 50% (PB_{50}) in the two groups SHL, MHL, as well as for unaided and aided ear, and combinations.

	Level of - Factor	N	PB_{50} - Mean	PB_{50} - Std.Dev.	*P**
Group	SHL	55	66.82	15.31	<0.001
	MHL	41	45.12	10.55	
Hearing aids	unaided ear	48	60.16	19.69	0.149
	aided ear	48	54.95	14.06	
Problem and Hearing aids	SHL and unaided ear	28	71.52	16.91	
	SHL and aided ear	27	61.94	11.90	0.019
	MHL and unaided ear	20	44.25	9.80	
	MHL and aided ear	21	45.95	11.39	0.612

*T-test
PB_{50} – Performance intensity 50%
SHL – Severe hearing loss
MHL – Moderate hearing loss

Patients with SHL have higher PB_{50} level than patients with MHL (*P*<0.001).

The unaided ear have higher PB_{50} level than the aided ear, but difference is not significant (*P*=0.149).

The PB_{50} level shows a statistical significant difference between aided and unaided ear in people with SHL (*P*=0.019). The PB_{50} level does not show a statistical significant difference between aided and unaided ear in people MHL (*P*=0.612). See figure 10, and table 6 and 7.

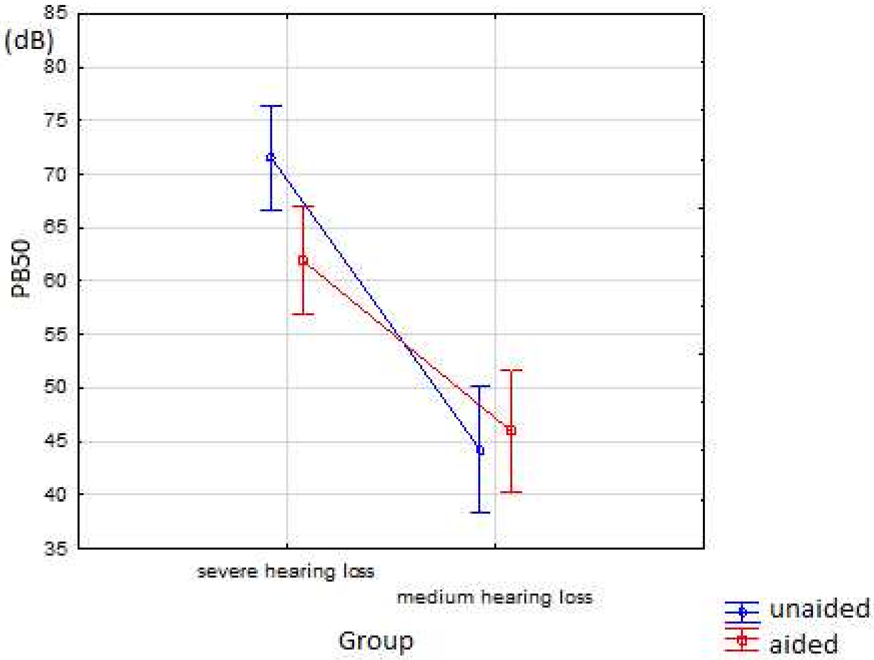

Figure 10. PB_{50} of the unaided and aided ear between the groups with SHL and MHL.

4.4. Comparison of means for SRT, PB_{max} and PB_{50}

Table 6. Comparison of means for SRT, PB_{max} and PB_{50} in the unaided and aided ear in SHL.

Severe hearing loss	**Unaided**		**Aided**				
	Mean	Std.Dev.	Mean	Std.Dev.	t-value	df	***P****
SRT	59,64	14,53	49,63	10,18	2,95	53	**0,005**
PB_{max}	85,89	11,79	77,59	10,86	2,71	53	**0,009**
PB_{50}	71,52	16,91	61,94	11,90	2,42	53	**0,019**

*T-test
PB_{50} – Performance-intensity 50%
PB_{max} – Performance-intensity maximum

There is a statistical significant difference in all 3 categories between aided and unaided air on speech audiometry in patients with SHL.

Table 7. Comparison of means for SRT, PB_{max} and PB_{50} in the unaided and aided ear in MHL

Moderate hearing loss	**Unaided**		**Aided**				
	Mean	Std.Dev.	Mean	Std.Dev.	t-value	df	**P***
SRT	34,50	8,87	34,29	8,70	0,08	39	**0,938**
PB_{max}	65,50	14,32	67,62	14,80	-0,47	39	**0,644**
PB_{50}	44,25	9,80	45,95	11,39	-0,51	39	**0,612**

*T-test
PB_{50} – Performance-intensity 50%
PB_{max} – Performance-intensity maximum

There is no statistical significant difference in aided and unaided air on speech audiometry on patients with MHL in any of the three categories.

5. DISCUSSION

To our knowledge, this study represents one of the first direct assessments of the difference between aided and unaided ear in long term unilateral hearing aid users.

Auditory plasticity refers to the possibility for anatomical or functional changes in the hearing pathway to occur due to environmental influences (31). There have been some studies on plasticity that have suggested that increased auditory stimulation because of hearing aids may induce secondary plasticity, which facilitates perceptual acclimation (32). This means that a subject's auditory abilities and speech recognition may increasingly improve over time because of new signals that become available due to the amplificatory effect of hearing aids.

In our study we see that there is no statistically significant difference in the PTA of the aided and unaided ear. This is to be expected, and important; it indicates that there is no significant difference in the level of hearing loss between the aided and unaided ears of our subjects.

We also see that our two groups (i.e. SHL and MHL) show statistically significant differences on all three parameters (SRT, PB_{max} and PB_{50}). This is to be expected as it is how we divided the group, but it shows that our grouping is correct.

We found no statistical significant differences between the aided and unaided ear for PB_{max} and PB_{50}. SRT however is significantly improved in the aided ear. It was slight surprising to see the other two parameters not showing significance, but the true result wasn't made apparent before we further divided the groups into SHL and MHL and unaided and aided ear:

In our study we found that there is a significant improvement in speech audiometry in the aided ear in hearing aid users with SHL compared to the unaided ear. However, in patients with MHL we found no such improvement between the aided and unaided ear. We propose a theory that this might be explained by there still being sufficient external sound input to the unaided ear which facilitates auditory plasticity in subjects with MHL.

In contrast, in the subjects with SHL there will be much lower external sound input to the unaided ear, and this might explain the significant difference on speech recognition compared to the aided ear. Over a 5 year period, the aided ear will have been exposed to a greater amount of auditory stimulation, which has facilitated auditory plasticity and improved speech recognition.

In addition to this, the potential benefits of hearing aids are majorly affected by the individual user's compliance, expectations, motivation and personality (33). In a study from Finland by Salonen J *et al.* investigating hearing aids compliance of the elderly, they found that only about 50% used their hearing aids daily, 25% used it more than 6 hours a day, and 10% never used their hearing aids (34).

Unfortunately, we do not have any information about actual compliance amongst our subjects, but it's not unreasonable to assume that they might show similar trends. We speculate that there might be better compliance with the use of hearing aids in the population with SHL, as their use of hearing aids more profoundly changes their day to day life. This could also explain why there are no changes in the aided and unaided ear in MHL, seeing that if the compliance of hearing aids is low, both ears would receive the same stimuli, and equally facilitate plasticity of the auditory pathway.

In a study by Petry T *et al.* with similarities to our own study, they found no statistical significant improvement in speech recognition after 14 and 90 days of hearing aids use (33). They divided their subject sample according to age: an adults group between 28 and 59 years old (N=13); and an elderly group between 61 and 78 years old (N=27). In total three speech recognitions were made at day 0, 14, and 90. No statistical significant differences were found on the consecutive tests, neither in-between the two age groups.

In a spanish study by Amorim RMC *et al.* they had 16 subjects aged from 17 to 89 years with bilateral symmetrical sensorineural or mixed moderate to severe hearing loss. The subjects underwent 3 sets of speech recognition: before fitting hearing aids, 4 weeks after, and 16/18 weeks after fitting hearing aids. Their results indicated that they saw speech recognition values increasing in line with the duration of hearing aid use, and they stated that this improvement may have been due to brain plasticity. However, their speech recognition score differences were not statistically significant (35).

Our contrasting results might indicate that 14 to 126 days is of too short duration to see statistical significant improvement in speech recognition, and that there must be a longer duration of use of hearing aids before an improvement can be witnessed. In our study the subjects had been wearing hearing aids for at least 5 years, although we cannot exclude that a difference could be apparent before this amount of time has elapsed.

Considerations for future investigations could be to include more subjects to the study to get a larger sample size and even more precise results. Experiments at the 2, 3, and 4 year intervals could also be interesting to show the progressive increase in speech recognition in the aided ear. In the future, the subjects could also be further stratified and differentiated between whether they have sensorineural, conductive, or mixed hearing loss. In addition, we could also include the subject's own subjective satisfaction, perception and benefit of the hearing aids, and also investigate the compliance of use between the groups.

We hope that our study encourages and emphasize the importance of the long term benefits of adapting hearing aids in relation to hearing recognition.

6. CONCLUSION

1. In patients with SHL, there is a statistically significant improvement in speech audiometry in the aided ear amongst long term (>5 years) hearing aid users compared to the unaided ear, likely due to increased plasticity of the hearing pathway.

2. In patients with MHL, there is not a statistically significant improvement in speech audiometry in the aided ear amongst long term (>5 years) hearing aid users compared to the unaided ear.

3. Our study has shown that the greater the hearing loss, the greater the benefit of using a hearing aid; this is manifested in the improvement of speech audiometry in long term hearing aid users.

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8. SUMMARY

Title: HEARING RECOGNITION COMPARISON BETWEEN AIDED AND UNAIDED EAR IN HEARING AID USERS

Objectives: The main goal of the present study is to investigate the difference of hearing recognition between the aided and unaided ear in long-term (>5 years) single-sided hearing aid users with moderate and severe hearing loss.

Subjects and methods: In our study we observed 48 subjects with bilateral hearing loss > 40 dB, 31 males and 17 females. All subjects were unilateral hearing aid users for at least 5 years. This retrospective study was carried out from January 2018 until June 2018 at the Department of Otorhinolaryngology & Head and Neck Surgery, University Hospital of Split. All patients underwent otoscopy, pure-tone audiometry and speech audiometry in a soundproof room. Frequencies from 250 Hz to 8000 Hz were tested with increasing intensity. Pure-tone average (PTA) was calculated as average of hearing sensitivity at 500, 1000, 2000 and 4000 Hz. All subjects undertook investigation of speech audiometry: speech recognition threshold (SRT; lowest intensity disyllabic words that an individual can repeat at least 50% of the time), PB_{50} (performance-intensity on phonemically balanced words where 50% of speech is recognized), PB_{max} (performance-intensity maximum on phonemically balanced words; 100% of speech is recognized). The patients were divided in accordance to classification of moderate or severe hearing loss into 2 groups.

Results: We found no statistically significant difference in pure-tone audiometry between aided and unaided ear (P=0.09). In subjects with SHL we found statistically significant difference between aided and unaided ear in SRT (P =0.005), PB_{max} (P=0.009) and PB_{50} (P=0.019). In subject with MHL we found no statistically significant difference between aided and unaided ear in SRT (P=0.938), PB_{max} (=0.644) and PB_{50} (P=0.612).

Conclusion: In our study we show that in subjects with SHL, there is a statistically significant improvement in speech audiometry in the aided ear amongst long term (>5 years) hearing aid users compared to the unaided ear, likely due to increased plasticity of the hearing pathway due to the use of hearing aids. We do not see a similar significant difference in the patients with MHL. Our study has shown that the greater the hearing loss, the greater the benefit of using a hearing aid; this is manifested in the improvement of speech audiometry in long term hearing aid users.

9. CROATIAN SUMMARY

Naslov: USPOREDBA SLUŠNE RAZABIRLJIVOSTI POTPOMOGNUTOG I NEPOTPOMOGNUTOG UHA KOD KORISNIKA SLUŠNOG POMAGALA

Ciljevi: Glavni je cilj ove studije istražiti razliku slušne razabirljivosti između potpomognutog i nepotpomognutog uha kod dugoročnih (>5 godina) jednostranih korisnika slušnog pomagala s umjerenom i teškom nagluhošću.

Ispitanici i metode: U našem istraživanju ispitali smo 48 ispitanika s bilateralnim gubitkom sluha > 40 dB, 31 muškarac i 17 žena. Svi su ispitanici bili jednostrani korisnici slušnih pomagala najmanje 5 godina. Ova retrospektivna studija provedena je od siječnja 2018. do lipnja 2018. godine na Klinici za otorinolaringologiju s kirurgijom glave i vrata, Klinički bolnički centar Split. Svi ispitanici bili su podvrgnuti otoskopiji te tonskoj i govornoj audiometriji u zvučno izoliranoj sobi. Frekvencije od 250 Hz do 8000 Hz testirane su s postupnim pojačavanjem intenziteta. Prosječni prag sluha (PTA) izračunat je kao prosjek praga sluha na 500, 1000, 2000 i 4000 Hz. Kod svih ispitanika učinjena je govorna audiometrija s parametrima: prag slušne razabirljivosti (SRT; disilabične riječi najmanjeg intenziteta koje pojedinac može ponoviti najmanje 50% vremena), PB_{50} (intenzitet na fonemski uravnoteženim riječima gdje je prepoznato 50% govora), PB_{max} (maksimum intenziteta na fonemski uravnoteženim riječima; prepoznaje se 100% govora). Bolesnici su podijeljeni u skladu s klasifikacijom umjerene i teške nagluhosti u 2 skupine.

Rezultati: Nismo pronašli statistički značajnu razliku u tonskoj audiometriji između potpomognutog i nepotpomognutog uha kod jednostranih dugoročnih korisnika slušnog pomagala (P= 0,09). U skupini ispitanika s teškom nagluhošću otkrili smo statistički značajnu razliku između potpomognutog i nepotpomognutog uha u SRT (P = 0,005), PBmax (P = 0,009) i PB50 (P = 0,019). U skupini ispitanika s umjerenom nagluhošću nismo pronašli statistički značajnu razliku između potpomognutog i nepotpomognutog uha u SRT (p = 0,938), PBmax (P = 0,644) i PB50 (P = 0,612).

Zaključak: U našem istraživanju pokazali smo da kod ispitanika s teškom nagluhošću dolazi do statistički značajnog poboljšanja u rezultatima govorne audiometrije na potpomognuom uhu, u usporedbi s nepotpomognutim uhom, kod dugoročnih jednostranih korisnika slušnog pomagala, vjerojatno zbog povećane plastičnosti slušnog puta kod korisnika slušnih pomagala. Statistički značajnu razliku ne nalazimo kod bolesnika s umjerenom nagluhošću.

10. CURRICULUM VITAE

Personal Data

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Higher Education

2013 –	University of Split, School of Medicine, Croatia
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2005 – 2008	Horten Upper Secondary School, Norway

Work Experience

2018 –	Paramedic in the emergency services, Hospital in Vestfold, Norway
2009	Combat medic in the Norwegian Royal Navy

Volunteering

2013 – 2016	Co-founder and vice president of ANSA Croatia (Association of Norwegian Students Abroad)
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