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Titel

Ensidig sensorineural dövhet – Resultat av tre interventioner för ensidig sensorineural grav hörselnedsättning: En randomiserad klinisk studie.

Författare
Jonas Fogels

Handledare
Traci Flynn
André Sadeghi
Radi Jönsson

Examinator
Milijana Malmberg

Sammanfattning
Syfte: Att jämföra tre tekniska interventioner för svår ensidig sensorineural dövhet (SSD).
Studiedesign: Prospektiv, randomiserad crossover-studie
Patienter: Femton deltagare med ensidig sensorineural dövhet.
Interventioner: Tre tekniska interventioner jämfördes: Contralateral Routing of Signal (CROS), portabel mikrofon (RM) och benförankrad hörapparat (BCD). Varje intervention användes under en utvärderingsperiod på tre veckor av alla deltagarna i en randomiserad ordning. Mellan varje intervention fick deltagarna en veckas viloperiod i syfte minska påverkan av tidigare intervention.
Utfallsmått: Taluppfattningstest i brus testades i fyra högtalarvariationer i ljudfält (brus-störning, maskering, huvudskugga och optimal uppställning). Validerade frågeformulär användes i syfte att undersöka patientens upplevelse av interventionerna. Utfallsmåtten samlades in efter varje utvärderingsperiod.
Resultat: Totalt var RM den interventionen med bäst resultat vid taluppfattningest i brus. Frågeformulären visade inte på att någon intervention var bättre än någon annan. CROS var den interventionen som åtta av 15 deltagare (53 %) valde att fortsätta använda efter studiens avslut. Majoriteten av deltagarna (80 %) valde att fortsätta med en utav interventionerna.
Konklusion: Alla interventioner visar på någon form av förbättring i jämförelse med ingen intervention alls. Personer med SSD är en heterogen population med olika besvärsgrad. I framtida studier föreslås en större grupp av deltagare samt en uppdelning baserad på etiologi och ålder när dövheten inträffat. På så vis skulle kanske en mer individuell klinisk praxis för denna patientgrupp utformas på sikt.
Nyckelord: Ensidig sensorineural dövhet, SSD, CROS, benförankrad hörapparat, portabel mikrofon

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Title
Single Sided Deafness – Outcomes of Three Interventions for Profound Unilateral Sensorineural Hearing loss: a randomized clinical trial

Author
Jonas Fogels

Supervisor
Traci Flynn
André Sadeghi
Radi Jönsson

Examiner
Milijana Malmberg

Abstract
Objective: A comparison of three interventions for profound unilateral sensorineural hearing loss.
Study Design: Prospective, Crossover Randomized Clinical Trial.
Patients: Fifteen participants with profound unilateral sensorineural hearing loss.
Interventions: Three technical interventions were compared: Bone Conduction Device (BCD), Contralateral Routing of Signal (CROS), and Remote Microphone (RM). Each intervention was randomly trialed for a period of three weeks, separated by a one week washout period.
Outcome measures: Speech in noise recognition test performed under four conditions (squelch, masking, head shadow, and optimal condition) following each intervention. Standardized questionnaires were used in order to evaluate amplification benefit at baseline and following each intervention.
Results: In total RM was the intervention with best significant results in the speech recognition in noise test. Participants did not rate a particular intervention as significantly better than any other on questionnaires of benefit. Following the study, CROS was the intervention preferred by the eight of fifteen participants (53%). The majority of participants (80%) chose to continue with an intervention.
Conclusion: All interventions presented better speech recognition in noise and subjective benefits in comparison to baseline. People with SSD are a heterogeneous population when looking at perceived difficulties. Future research should focus on segmenting the population of SSD depending on etiology and age of acquired loss for the poorer ear. This would possibly benefit patient in terms of more individual-based clinical routines.
Keyword: Single Sided Deafness, SSD, CROS, Bone Anchored Hearing Aid, Remote Microphone

Manuscript

Single Sided Deafness – Outcomes of Three Interventions for Profound Unilateral Sensorineural Hearing loss: a randomized clinical trial

Jonas Fogels, University of Gothenburg, Institute of Neuroscience and Physiology, Sweden*
- Hearing Organization, Habilitation & Health, Unit of Audiology, Region Västra Götaland, Sweden

Radi Jönsson, Department of Otorhinolaryngology, Sahlgrenska University Hospital, Gothenburg, Sweden

André Sadeghi, The Sahlgrenska Academy, Institute of Neuroscience and Physiology, Department of Audiology, Gothenburg, Sweden* - Hearing Organization, Habilitation & Health, Unit of Audiology, Region Västra Götaland, Sweden.

Mark Flynn, Better Health, Healthcare and Treatment Global Impact Cluster, Research and Innovation, University of Newcastle, Australia

Traci Flynn, Department of Clinical Science, Intervention and Technology (CLINTEC), Karolinska Institutet, Stockholm, Sweden

* The Sahlgrenska Academy, Institute of Neuroscience and Physiology, Department of Audiology, PO Box 452, SE 40530, Göteborg, Sweden.

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Conclusion: All interventions presented better speech recognition in noise and subjective benefits in comparison to baseline. People with SSD are a heterogeneous population when looking at perceived difficulties. Future research should focus on segmenting the population of SSD depending on etiology and age of acquired loss for the poorer ear. This would possibly benefit patient in terms of more individual-based clinical routines.

INTRODUCTION

Single Sided Sensorineural Deafness (SSD), a significant or total hearing loss in one ear, primarily affects speech recognition in noise and localization of sound [1,2]. This decrease in abilities is due to the loss of binaural hearing and the head shadow effect. The head shadow effects occurs when a sound towards the poorer ear is attenuated on its path to the functional ear. [3,4]. SSD has been also associated with perceived lower quality of life due to hearing loss [5,6]. Studies have shown that different technical solutions for people with SSD could improve quality of life [7-9].

In 2015, the American Academy of Audiology introduced rehabilitation guidelines for SSD. The guidelines recommend the use of the Bone Conduction Device (BCD) or Contralateral Routing of Signal (CROS), as well as Remote Microphone (RM), either as a complementary intervention in combination with CROS or BCD or as a single solution [10]. The most common form of technological intervention currently practiced is CROS or BCD [11]. The aim of the CROS is to overcome the acoustic head shadow when the source of the signal comes towards the deaf ear. A microphone is placed behind the poorer ear and a receiver in the good ear (Harford & Barry, 1965). BCD is used in SSD by placing a sound processor on the deaf side and transmitting the acoustic signal via bone conduction to the contralateral cochlea of the normal hearing ear [12]. The sound processor is placed on a surgical drilled implant on processus mastoideus. The evaluation of BCD before surgical engagement is normally to place the processor on the processus mastoideus via an elastic softband [13,14]. A less commonly used intervention is the RM. The purpose of a RM is to increase speech perception where traditional hearing devices are insufficient by decreasing the distance, noise and reverberation [15-17]. RM is a portable microphone or transmitter held in the hand of the user, placed on a table, or hung around the neck of the speaker or the user. The sound is wirelessly sent to a receiver placed on the better ear. A previous study has recommended RM as a first hand

intervention because of better signal-to noise ratio when testing speech recognition in noise compared to CROS [18]. Comparing the effects of RM and CROS on speech recognition in noise RM has demonstrated significantly greater benefits in patient with SSD [19].

The most common outcome measurements when comparing interventions for people with SSD are speech recognition in noise and amplification benefit questionnaires [11]. Early comparison studies of these interventions demonstrated significantly better speech recognition outcomes for BCD over CROS [2,20-22]. However, these comparison studies presenting best results for BCD use non-randomized methodology and include BCD only for patients that has already reject CROS as an intervention. Also, the CROS technology used in some studies are old and only few studies include the newer technology [20-24]. More recently, comparison studies of BCD and CROS technology have demonstrated higher speech recognition performance with the use of either BCD or CROS when compared over baseline. Although, no significant benefit of one intervention over the other on speech recognition testing have been presented [25-27]. Because of advancements of the CROS technology, the need of more studies comparing the modern CROS technology with other interventions is warranted [25]. No significant improvements have been noted for any intervention using sound localization tests [26,28,29]. This can be explained by the fact that neither of these interventions can restore binaural hearing which is needed for horizontal localization abilities [30-32].

Despite the illustrated positive improvements of using the CROS or BCD, participants have reported negative opinions on the use of these interventions [33]. When wearing the CROS, users have often been dissatisfied with having an occluded earmold in the good ear [21]. On the contrary one study have presented a rate of approximately 73 percent of participants preferring the CROS system [34]. Today, wireless CROS systems do not require occluded earmolds. Instead an open mold, with no occlusion that decreases hearing input in the best

ear, is recommended. To date, only few studies have implemented CROS with open molds [25,35].

With BCD the most negative reports concern the surgical placement of an implant on the mastoid [36]. Most reason surgical approaches have made the insertion of the implant less invasive and less complicated [37,38]. Furthermore, negative effects of a detrimental squelch effect when noise is towards the microphone have been reported by users of both CROS and BCD [28,35]. No negative effects of RM have to our knowledge been reported in any previous studies among cases with SSD.

Even if the presence of several interventions may lead to benefit for the hearing related problems following SSD, several meta-analyses have emphasized the lack of evidence in comparison studies for best technical intervention for people with SSD [23,24,39,40]. Recently, a suggestion of methodological consensus for intervention studies concerning individuals with SSD was published. In the hope of higher reliability among intervention studies more knowledge can be gathered in aim towards better clinical routines [11].

In summary, a three way comparison of CROS, BCD and RM technology has, to our knowledge, not been systematically examined before. Based on recommendations from American Academy of Audiology [10] to include RM as a technical intervention for SSD, our purpose was to evaluate these three interventions among the same population. A comparison with all three interventions may lead to new insights in the field of rehabilitation for people with SSD.

The objective for this study is to investigate speech recognition performance in noise and subjective amplification benefit for the use of CROS, BCD, and RM, in individuals with SSD.

MATERIALS AND METHODS

Participants

Patients registered at the Ear-Nose and Throat (ENT) clinic, Sahlgrenska University Hospital, Gothenburg, Sweden with SSD were examined. To find these patients a search was done among all patients diagnosed with ICD-codes H.90.4 (unilateral sensorineural hearing loss, normal hearing on opposite side) in the years 2000-2001 and 2013-2014 and H91.2 (sudden idiopathic hearing loss) between the years 2012 and 2013-2014.

Patients were included based on the following criteria:

1- Pure-tone-average of four frequencies (PTA 4; 0.5, 1, 2 and 4 kHz) of > 90 dB HL on the poorer ear
2- PTA 4 of < 30 dB HL on the better ear
3- No current audiological rehabilitation
4- SSD > one year
5- >18 years of age
6- Swedish as a native language
7- Completion of all intervention trials during the study

The study was approved by the Regional Ethical Review Board - University of Gothenburg, Sweden (826-14) in accordance with the Helsinki Declaration [41]. Informed consent was signed by all participants

Procedures

The study was designed as a prospective, crossover, randomized clinical trial. Each intervention period was three weeks with a one week washout period following each intervention. The purpose of the washout period was to allow the effects of the first treatment to dissipate before starting the second treatment. Each patient served as his or her own control. All interventions were evaluated using speech in noise testing and completion of questionnaires at the end of the three week trial. Baseline data were collected during the first

session. The interventions used were CROS, RM and BCD on softband. Each participant was randomized for the three interventions at entry. Participants met a licensed audiologist four times. At the first meeting, participants completed all questionnaires and performed the speech recognition test in noise. This data is considered as the baseline. Following data collection, one of the three interventions was fitted. The trial period lasted for three weeks and participants were advised to use the intervention as much as possible and to fill in a diary of how many hours the intervention was used. The next meeting began with completing questionnaires and speech recognition test in noise with the intervention used recently. Then, one of the two remaining interventions was fitted. The participants were asked not to begin the start of the new trial period for a week. This first week is considered as a washout week. The same procedure was followed for the remaining intervention. At the end of the study, the participants were asked if they would like to continue with one of the three interventions.

A flowchart of the process is presented in figure 1.

Technical verifications

Devices were verified before each intervention. Real ear measurements were performed for CROS to measure the compensation of the head shadow [42] and to ensure there was no occlusion caused by the open earmold. In-situ measurements of the BCD on softband were made to ensure optimal fitting [43]. Maximum Power Output (MPO) was measured in a test box for the RM to verify that maximum limits were not exceeded.

Audiological measurements

All participants underwent modified Hughson-Westlake pure tone audiometry in accordance with ISO-ISO 8253-1:2010 with a calibrated Interacoustics Equinox 2.0 Audiometer. Speech

recognition tests in noise were performed with a fixed noise level of 65 dB SPL and 4 levels of speech (55-70 dB SPL) -10, -5 0 and +5 in signal-to-noise ratio (SNR) towards the fixed noise. The sentences used are from the Swedish version of Hearing in Noise Test (HINT) [44]. One list containing 10 sentences was used for every level of speech. The order of the lists was randomized at each visit. Keyword scoring was used to assess if the sentence was marked correct or incorrect. Each sentence yields ten percent correct and if all sentences of a list were correct the result is 100 percent within that list. The test was performed in a calibrated sound booth with two speakers, 90 degrees azimuth angle apart at a distance of 1.2 meters from the listener. The RM was tested by having the microphone placed on a stand towards the speech under all different conditions. The four different conditions had anticipated effects. Squelch effect is the condition where the noise is closest to the amplification and should cause a detrimental outcome. Masking effect is caused when noise in the better ear is louder than the amplified speech. Head shadow effect is when amplification of speech at the poorer ear reroutes to the better ear and compensates for the decreased gain of speech caused by the diffraction of the head. Optimal listening condition in noise is when speech is towards the better ear and should therefore be the best possible unaided listening condition for an individual with SSD.

Speech in noise testing was performed in four different conditions (see fig 2):

1- Squelch effect: Speech at 0 degrees azimuth with noise towards the poorer ear (s0/nPoorer)
2- Masking effect: Speech at 0 degrees azimuth with noise towards the better ear (s0n/Good)
3- Head shadow effect: Speech towards the poorer ear and noise at 0 degrees (sPoorer/n0)

4- Optimal: Speech at the better ear with noise at 0 degrees (sGood/n0)

The order in which these positions were held was randomized.

See Fig. 2.

Questionnaires

Amplification benefits were evaluated by using the following questionnaires: Speech, Spatial and Other Qualities 12 (SSQ12) which is a questionnaire that focuses on perceived benefit of acoustic situations concerning spatial experience, speech recognition and quality of sound. The higher score the better is the experienced benefit of the intervention [45]. The Bern Benefit in Single-Sided Deafness Questionnaire (BBSS) was developed specifically for SSD and targets if an intervention is better or worse than no intervention in specific listening situations [46]. The Abbreviated Profile of Hearing Aid Benefit (APHAB) measures the subjective benefit of an intervention in different acoustics situations before and after the trialing of a device. The situations are categorized into four subgroups: EC = Ease of communication, BN = Background noise, RV = Reverberation, AV = Aversiveness [47]. The questionnaires used were validated translations in Swedish language. An appendix with the questionnaires is attached at the end of the article.

Statistical analysis

IBM SPSS® Statistics, version 23 was used for statistical analysis. Wilcoxon signed ranks test was used to measure significant differences between outcomes. A significance level of $p=0.05$ was accepted.

RESULTS

A total of 18 participants were included in this study. Three participants were excluded from data analysis because they did not complete all intervention trials. Fifteen participants (six males & nine females) underwent all intervention trials, see table 1. The ages in the group were between 28 and 72 years (mean = 53 years ± 13.7 years). Eight participants were diagnosed with a congenital timing of hearing loss and the remaining seven participants with acquired timing of hearing loss. Seven participants presented with a poorer right ear and eight participants presented with a poorer left ear. For median score of PTA4 among participants,

See Fig. 3.

Speech in noise evaluation results

When comparing each intervention to baseline, all interventions resulted in a statistically significant improvement. For CROS there were statistically significant improvements over baseline in the head shadow condition at 0 (p=0.03) and +5 (p=0.001) SNR. In the squelch condition there was a statistically significant lower (detrimental) outcome compared to baseline at -5 (p=0.05) SNR. For RM there were significant better outcome in the masking condition at -10 (p=0.024) and at -5 (p=0.009) in SNR and the head shadow condition at -5 (p=0.06), 0 (p=0.001) and +5 (p=0.002) when compared to baseline. For BCD there was a statistically significant better outcome at +5 (p=0.019) SNR in the head shadow condition in comparison to baseline.

When comparing the different interventions, there was a significant improvement for CROS over BCD in the head shadow condition at 0 (p=0.034) and +5 (p=0.024) SNR. When participants used RM they performed statistically significantly better over CROS in the masking condition at -5 (p=0.015) and 0 (p=0.04) SNR and in the head shadow condition at -5

(p=0.04) and 0 (p=0.007) in SNR. When RM and BCD were compared, participants performed statistically significant better with the RM in the masking condition at -10 (p=0.018), -5 (p=0.033) and 0 (p=0.007) and in the head shadow condition at -10 (p=0.078), -5 (p=0.006), 0 (p=0.004) and +5 (p=0.014).

See Fig 4.

Questionnaires

For CROS there were statistically significant improvements over baseline on the SSQ12 questionnaire on question 2 (p=0.006), 3 (p=0.025), 4 (p=0.016), 6 (p=0.033), 8 (p=0.019), 9 (p=0.045) and 12 (p=0.034). For RM there were statistically significant improvements over baseline on question 1 (p=0.041), 2 (p=0.001), 3 (p=0.004), 4 (p=0.016), 5 (p=0.028), 6 (p=0.028), 8 (p=0.009), and 12 (p=0.050). For BCD there were statistically significant improvements over baseline in question 2 (p=0.007), 6 (p=0.020) and 8 (p=0.028). No significant differences were demonstrated when comparing the different interventions with each other.

See Fig. 5

BBSS had no statistically significant differences when compared to baseline or across interventions.

See Fig. 6

For CROS there were statistically significant better outcomes on the APHAB questionnaire in the subscale measuring background noise (BN) (p=0.002) and the subscale measuring ease of communication (EC) (p=0.003) when compared over baseline. For RM no significant differences were demonstrated. For BCD there was a statistically significant better outcome in the subscale measuring EC (p=0.001) compared over baseline. When comparing the different interventions over each other there were no significant differences in outcomes.

See Fig. 7.

Technology choice

Of the 15 participants, eight chose to continue with CROS, two with RM, two with BCD and two participants preferred no technical intervention.

DISCUSSION

The primary goal of this paper was to evaluate the idea that several technological interventions are available for patient diagnosed with SSD. By using a prospective cross over study design comparing different technology interventions the result has demonstrated that all interventions may be beneficial compare to baselines. Twelve out of 15 participants choose to continue with one of the interventions after the study.

CROS demonstrated statistically significant better outcomes for two signal-to-noise ratios over baseline. Overall, RM was the intervention which demonstrated the best performance in speech recognition in noise testing in comparison to baseline. Five signal-to-noise ratios in two different setups were significantly better than baseline. BCD had one SNR in one condition which was significantly better than baseline. When comparing the different interventions between each other, RM resulted in the best overall performance. When

comparing CROS and BCD, use of CROS resulted in significantly better outcomes in two SNRs in the head shadow condition.

On the SSQ12 questionnaire, CROS had seven questions that were significantly better than baseline. RM had eight questions that were significantly better than baseline. BCD had three questions that were significantly better than baseline. Question 2, 6 and 8 in SSQ12 presented a significant better outcome for all interventions compared to baseline. Question 2 concerns the ability to listen to someone talking to at the same time one tries to follow the news on television. Question 6 concerns if one is able to localize a barking dog outside without looking around. Question 8 is about whether one can tell if the sound from a bus or truck comes towards you or going away. This is somewhat contradicting since these situations involve the ability to localize sound and follow multiple talkers which primarily relies on binaural cues. Binaural cues are not available when someone has SSD as they only have one functioning ear, even when using a technical intervention [26,32]. One reason could be an experience of more overall gain that could lead to a feeling of being able to localize and follow multiple talkers. It could also be a placebo effect. In comparison between the interventions there were no significantly better outcomes.

BBSS did not demonstrate any significant differences towards any intervention. On the APHAB questionnaire, CROS presented significantly better outcomes in the subscale BN and EC. RM did not show any significantly better outcomes while BCD presented a significantly better outcome in the subscale EC. The lack of increasing results for any intervention could be due to the relatively short trial period or that the questionnaires are more sensitive in comparing two interventions rather than a three intervention crossover study.

CROS was the most preferred intervention among the participants in this study with a rate of 65 percent of the participants preferring to continue with this technology after the study. This is in line with the APHAB questionnaire and also acceptance rate for older CROS

technology that has been estimated to 72,5 percent [34]. Earlier CROS technology has suffered from audiological side effects, often due to a monaural squelch effect that partially interrupt the functioning of the normal cochlea [2]. This may still be one reason for the lack of higher numbers of significant results in speech in noise testing even if participants prefer CROS. Occlusion of an open earmold would not cause any detrimental effects in this study since verification confirmed that no gain was affected by occlusion.

Although, RM was the intervention with the best performance in speech recognition in noise, it was not the participants' most preferred technology. The speech recognition in noise results are in line with older studies comparing RM with CROS, with the use of the RM resulting in significantly improved performance [19,48]. One reason for participants' non-preference of the RM in this study could be a perception that RM did not improve listening in their daily life. SSQ12 did present significant benefits in question 2, 6 and 8 but maybe those situations were not the most desired situations for these participants to have improved. The RM consists of a portable transmitter that demands active handling in the users´ hand, placed around the neck of a talker, or placed on a table. This extra requirement of use may lead to a lesser preferred technology.

In this study, few outcomes resulted in a significant improvement with use of the BCD in speech recognition in noise and questionnaires. Previous results from evaluation studies of BCD demonstrated a 22-37 percent improvement in speech perception in noise [28,49] as well as increase quality of life and subjective amplification benefits [49,50]. Our lack of demonstrated improvement may be the use of the BCD via a transcutaneous softband instead of percutaneous implant. BCD on a softband is different in many ways from the percutaneous placement of an implant, even if the transmitting gain would be the same [13]. These differences include the aesthetics of the softband of the BCD. Evaluation on the use of the softband has been reported as a reason for rejection among participants, together with the invasive surgery

that needs if one chose to continue with a permanent solution [33,51]. Subjective benefits in questionnaires has presented significantly better outcomes for percutaneous BCD when comparing pre- and post-surgery [50]. On the contrary, other results with postsurgical participants and a control group presents no significant differences either with questionnaires or speech in noise testing, which is in line with this present study [52].

The different methodology in previous comparison studies makes it difficult to compare the results from the current study and to make any conclusion regarding interventions [11]. This may also be due to the different etiology of SSD among the participants. Individuals with SSD are a heterogeneous population and their needs of rehabilitation may depend on different etiologies or timing of hearing loss [53]. One of these factors may be the high frequency hearing levels in the better ear [54]. Four of fifteen participants in this present study had mild-moderate hearing loss in 6-8 kHz, although the PTA4 was within normal hearing limits. For future studies, analyzing the possible effects of etiology and thresholds of the better ear in high frequencies, 6-8 kHz, may lead to more evidence to be able to deliver best clinical practice.

The results for speech in noise recognition test and subjective preference was not in line with in older previous studies [2,20-22]. One reason for contradicting results in speech recognition in noise and subjective preference may be that the RM was placed on a stand towards the speaker delivering the speech. This distance from the speaker is how the RM should be used but gives an advantage in the testing situation compared to the other two interventions.

More recent studies are in line with our findings of no significant benefit for either CROS or BCD [25-27]. This indicates perhaps that the technologies for management of SSD have developed to become equal in benefits.

CONCLUSION

In general, the majority of participants (80%) chose to continue with an intervention. Participants' best speech recognition performance was when listening with the RM across SNRs and conditions. This result was not in line with the participants' subjective benefit as CROS was the most preferred technology. No consensus was shown in results from the questionnaires for a particular intervention. The methodology for future studies of people with SSD needs to take into account the heterogeneous difficulties caused by only hearing with one ear. Better segmentation of the population of SSD will perhaps lead to more individualized clinical routines in the future. This research will hopefully provide new insight for those audiologists exploring different interventions for patients with profound unilateral sensorineural hearing loss.

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Appendix

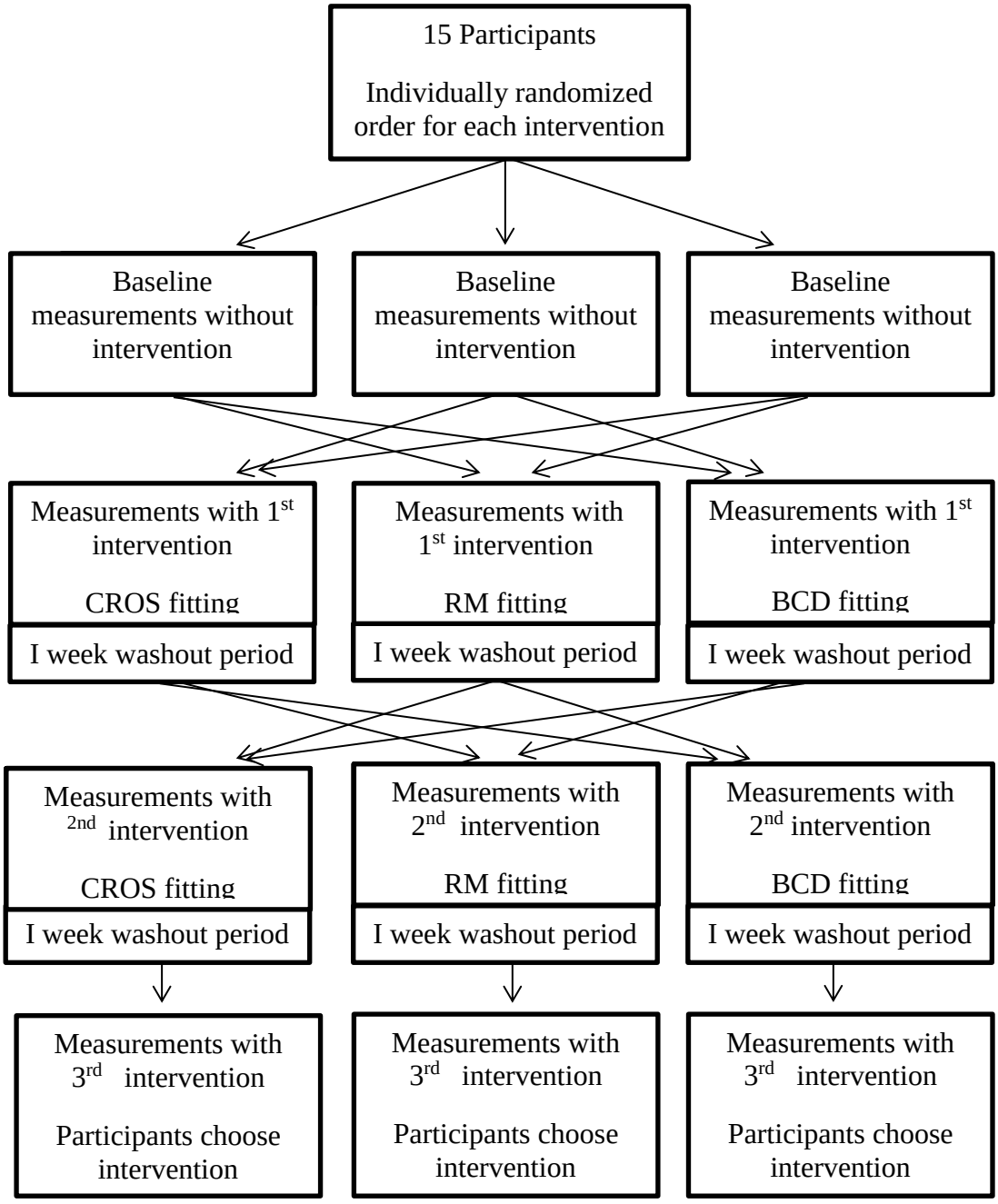


Figure 1. CROS = Contralateral Routing of Signal, RM = Remote Microphone, BCD = Bone Anchored Device. The order for each participant is randomized. After each fitting the participants use the intervention for three weeks before they come back to the audiologist. Before using the second and third intervention a washout period of one week is introduced in order to minimize the influence from the previous intervention.

Appendix

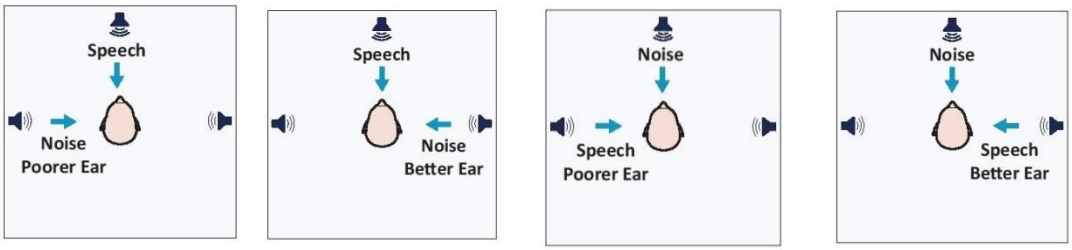


Fig. 2. Speaker settings for administration of the speech in noise test. From left to right: Squelch setup, masking setup, head shadow setup and optimal setup. The room was 2.6 m x 2.8 m. Distance from the speaker was 1.2 m.

Table 1. Demographic data of the study group

Participants	Sex	Age	Age of debut for SSD	Diagnosis	Poorer Ear
1	Male	55	0	Congenital, Idiopathic	Left
2	Female	58	0	Congenital, Mondini dysplasia	Right
3	Female	67	64	Vestibular Schwanoma	Left
4	Male	45	5	Congenital, Rubella Virus	Right
5	Male	72	50	Sudden Deafness	Left
6	Female	70	54	Vestibular Schwanoma	Right
7	Male	48	48	Head Trauma	Right
8	Female	28	5	Congenital, Idiopathic	Left
9	Female	60	46	Sudden Deafness	Left
10	Male	42	34	Sudden Deafness	Right
11	Female	32	0	Congenital, Idiopathic	Left
12	Male	53	35	Head Trauma	Right
13	Female	51	6	Congenital, Rubella Virus	Left
14	Female	72	0	Congenital, Idiopathic	Left
15	Female	43	0	Congenital, Idiopathic	Right

Appendix

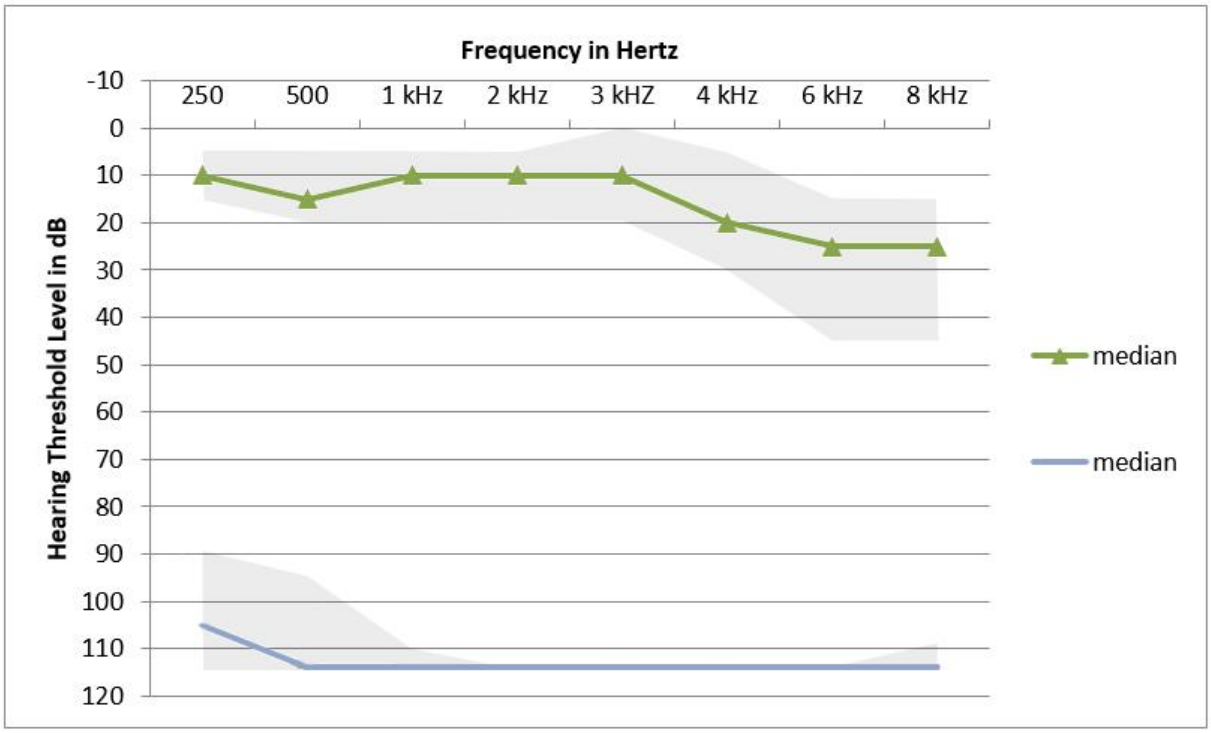


Fig. 3. Median scores of hearing thresholds for the better ear and the poorer ear. Grey areas represent the first and the third quartile.

Appendix

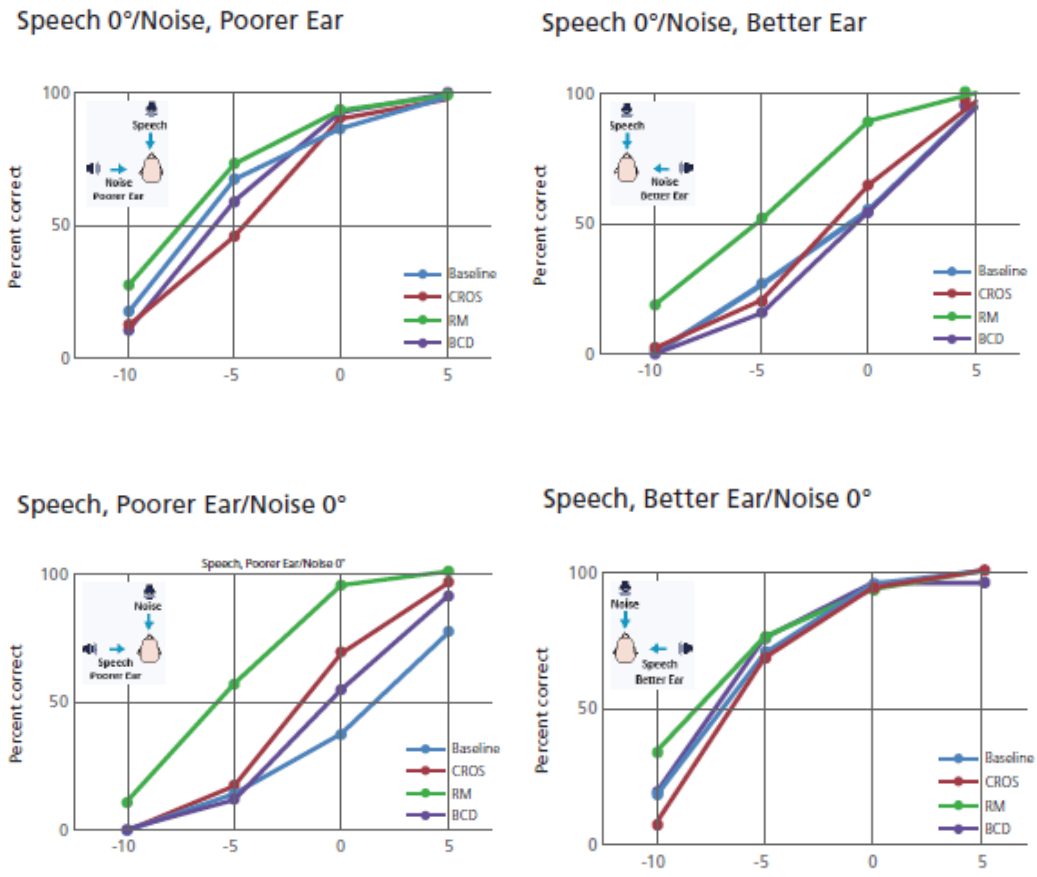


Fig. 4. Speech in Noise testing in four conditions.

Top left: Squelch effect, Top Right: Masking effect, Bottom Left: Head Shadow effect,

Bottom Right: Optimal effect. Baseline: baseline. CROS = Contralateral Routing of Signal,

RM = Remote Microphone, BCD = Bone Conduction Device

Appendix

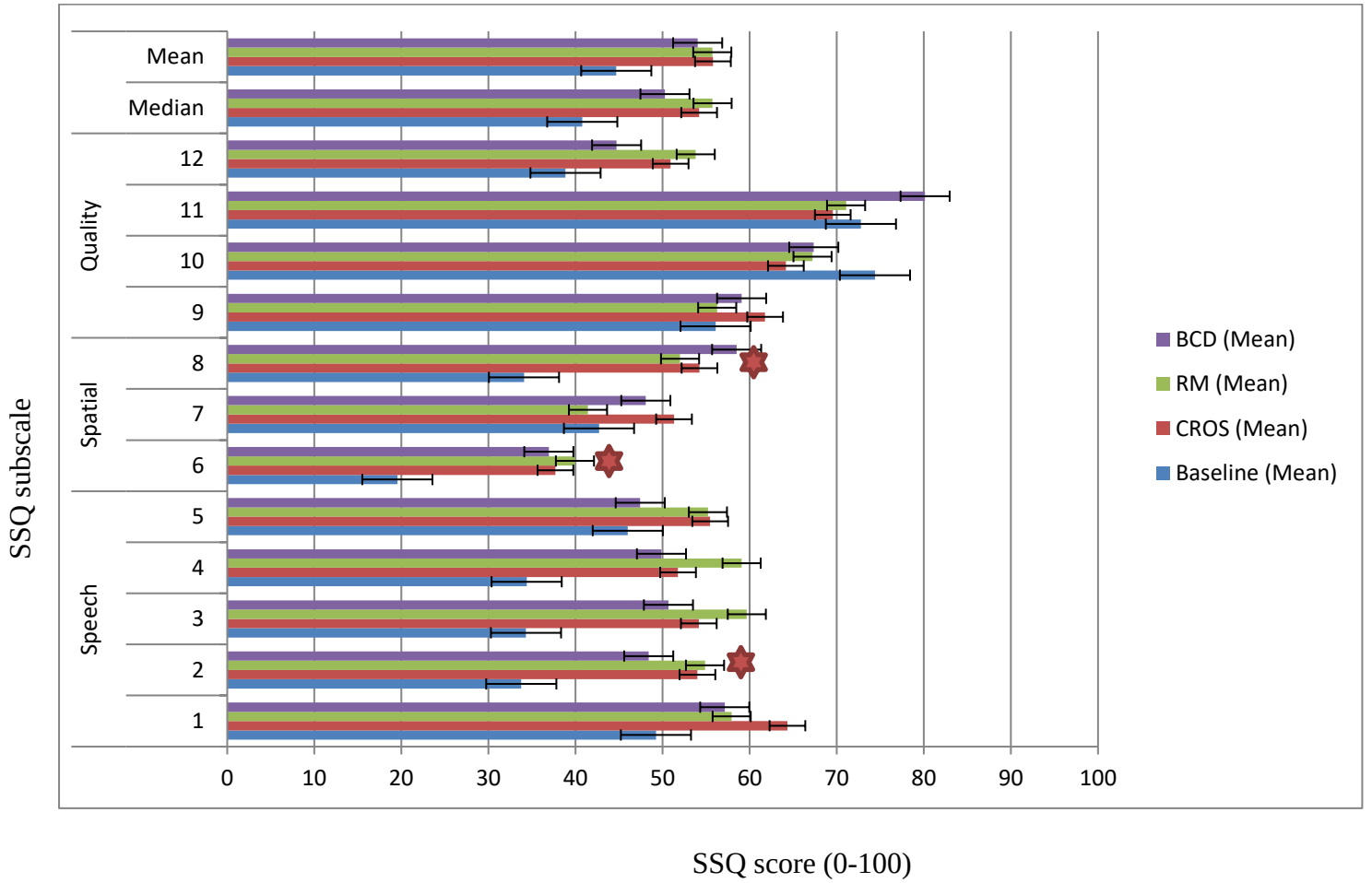


Fig 5. Results for Speech, Spatial and Other Qualities 12 (SSQ12). CROS = Contralateral Routing of Signal, RM = Remote Microphone, BCD = Bone Conduction Device. The red marker indicates the significant scores compared to baseline.

Appendix

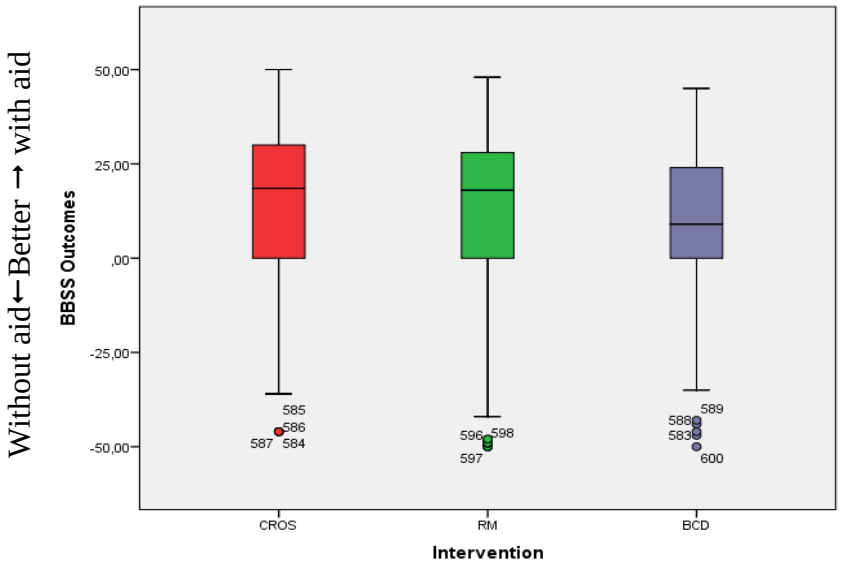


Fig 6. Subjective benefit as rated in the Bern benefit in Single Sided Deafness Questionnaire (BBSS). Boxes denote median and quartiles, ⊥ minimal and maximal CROS = Contralateral Routing of Signal, RM = Remote Microphone, BCD = Bone Conduction Device

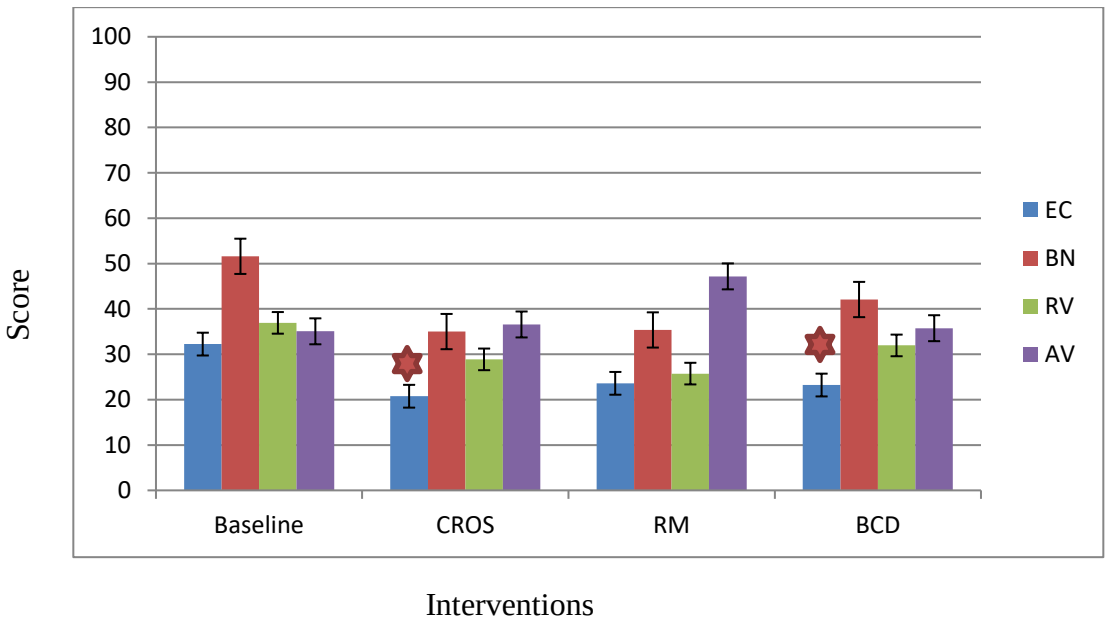


Fig. 7. Results for Abbreviated Profile of Hearing Aid Benefit (APHAB). The vertical axis is number of percentage of experienced problems. APHAB is divided in four subscales EC= Ease of communication, BN= Background noise, RV= Reverberation, AV=Aversiveness. CROS= Contralateral Routing of Signal, RM= Remote Microphone, BCD= Bone Conduction Device. The red marker indicates significant differences compared to baseline.

SSQ12 Instructions

The following questions inquire about aspects of your ability and experience hearing and listening in different situations.

For each question, put a mark, such as a cross (x), **anywhere** on the scale shown against each question that runs from 0 through to 10. Putting a mark at **10** means that you would be **perfectly** able to do or experience what is described in the question. Putting a mark at **0** means you would be quite **unable** to do or experience what is described.

As an example, question 1 asks about having a conversation with someone while the TV is on at the same time. If you are well able to do this then put a mark up toward the right-hand end of the scale. If you could follow about half the conversation in this situation put the mark around the mid-point, and so on.

We expect that all the questions are relevant to your everyday experience, but if a question describes a situation that does not apply to you, put a cross in the "not applicable" box. Please also write a note next to that question explaining why it does not apply in your case

Your name:	Today's date	Your age

Please check one of these options:

- I have **no** hearing aid/s ☐
- I use **one** hearing aid (**left ear**) ☐
- I use **one** hearing aid (**right ear**) ☐
- I use **two** hearing aids (**both ears**) ☐

If you have been using hearing aid/s, for how long?

Left ear	*Right ear*
_____ years	_____ years
_____ months	_____ months
or	or
_____ weeks	_____ weeks

1. You are talking with one other person and there is a TV on in the same room. Without turning the TV down, can you follow what the person you're talking to says?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

2. You are listening to someone talking to you, while at the same time trying to follow the news on TV. Can you follow what both people are saying?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

3. You are in conversation with one person in a room where there are many other people talking. Can you follow what the person you are talking to is saying?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

4. You are in a group of about five people in a busy restaurant. You can see everyone else in the group. Can you follow the conversation?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

5. You are with a group and the conversation switches from one person to another. Can you easily follow the conversation without missing the start of what each new speaker is saying?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

6. You are outside. A dog barks loudly. Can you tell immediately where it is, without having to look?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

7. Can you tell how far away a bus or a truck is, from the sound?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

8. Can you tell from the sound whether a bus or truck is coming towards you or going away?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

9. When you hear more than one sound at a time, do you have the impression that it seems like a single jumbled sound?

Jumbled —— *Not jumbled*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

10. When you listen to music, can you make out which instruments are playing?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

11. Do everyday sounds that you can hear easily seem clear to you (not blurred)?

Not at all —— *Perfectly*

0 1 2 3 4 5 6 7 8 9 10

Not applicable ☐

12. Do you have to concentrate very much when listening to someone or something?

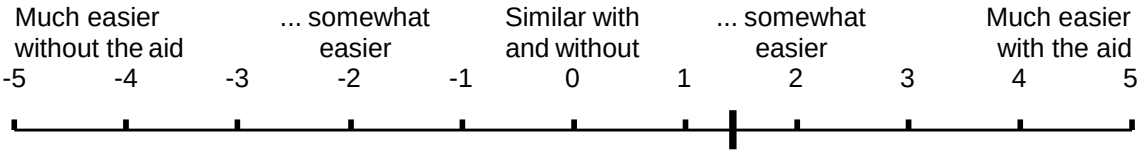
Appendix

BBSS - Bern Benefit in Single-Sided Deafness Questionnaire

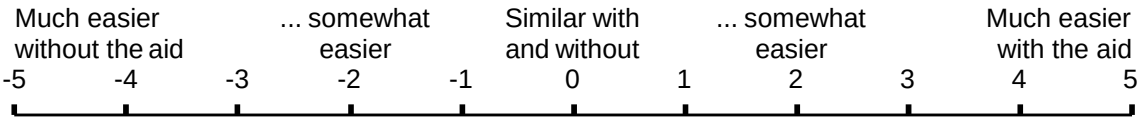
Name:..... Date of birth: …….....

Type of Baha or hearing aid used: ……. Trial period: .....

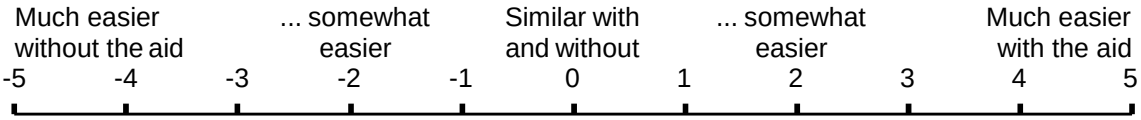
Please rate your perceived benefit from your aid in the following situations by a vertical line. Example:



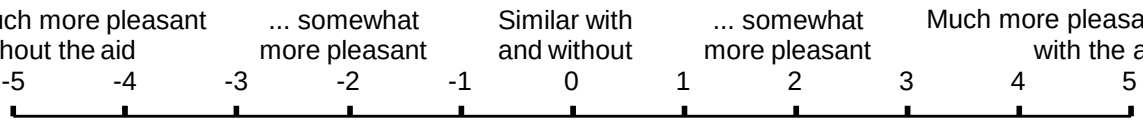
1. To hold a conversation with one person in a quiet environment. For me, this is:



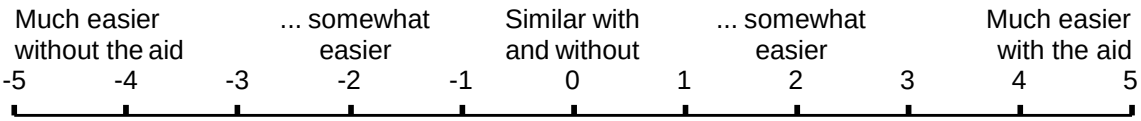
2. To understand a TV or a radio speaker. For me, this is:



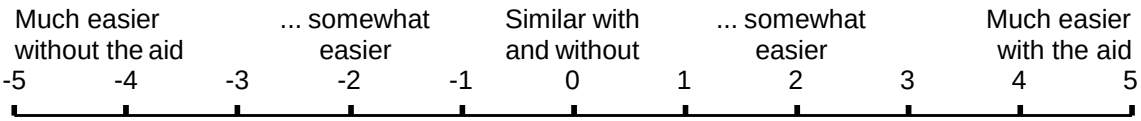
3. To listen to music. For me, this is:



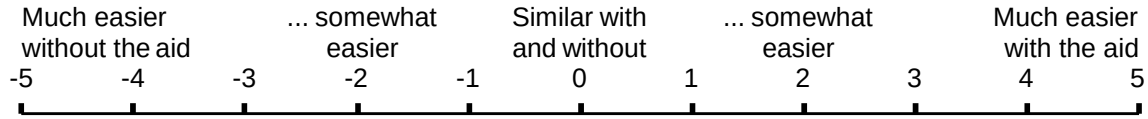
4. To follow a conversation from some distance (5 m / 15 ft or more). For me, this is:



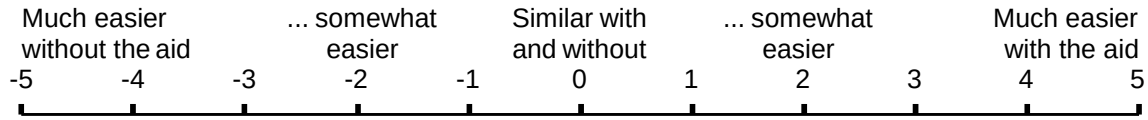
5. To follow a conversation with background noise. For me, this is:



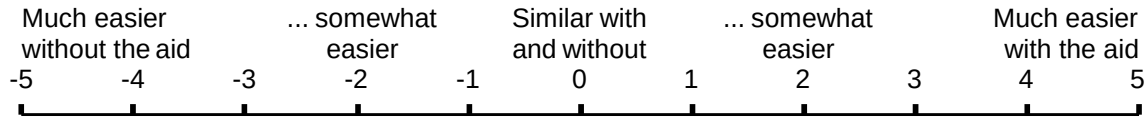
6. To hold a conversation while driving in a car. For me, this is:



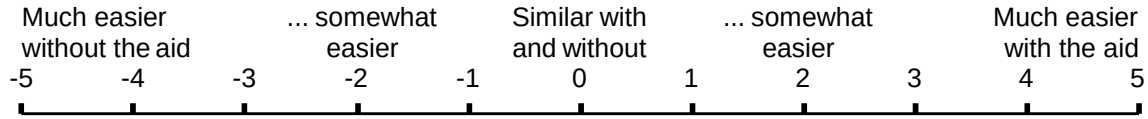
7. To understand speech in a reverberant room, such as a large entrance hall or a church. For me, this is:



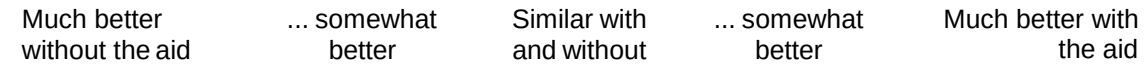
8. To participate in a group conversation with 3 or more participants. For me, this is:



9. To localize a sound source, such as a honking car. For me, this is:



10. Over all, for me hearing is:



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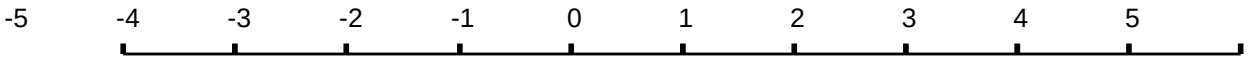

Reference: Kompis M, Pfiffner F, Krebs M, Caversaccio M. Factors Influencing the Decision for Baha in Unilateral Deafness: The Bern Benefit in Single Sided Deafness questionnaire. Adv Otorhinolaryngol 71 (2011)

Appendix

ABBREVIATED PROFILE OF HEARING AID BENEFIT A

NAME: _____ ☐ Male ☐ Female TODAY'S DATE: ____/____

Last *First*

A Always (99%)
B Almost Always (87%)
C Generally (75%)
D Half-the-time (50%)
E Occasionally (25%)
F Seldom (12%)
G Never (1%)

INSTRUCTIONS: Please circle the answers that come closest to your everyday experience. Notice that each choice includes a percentage. You can use this to help you decide on your answer. For example, if a statement is true about 75% of the time, circle "C" for that item. If you have not experienced the situation we describe, try to think of a similar situation that you have been in and respond for that situation. If you have no idea, leave that item blank.

	Without Hearing Aid	With Hearing Aid
1. When I am in a crowded grocery store, talking with the cashier, I can follow the conversation.	A B C D E F G	A B C D E F G
2. I miss a lot of information when I'm listening to a lecture.	A B C D E F G	A B C D E F G
3. Unexpected sounds, like a smoke detector or alarm bell are uncomfortable.	A B C D E F G	A B C D E F G
4. I have difficulty hearing a conversation when I'm with one of my family at home.	A B C D E F G	A B C D E F G
5. I have trouble understanding the dialogue in a movie or at the theater.	A B C D E F G	A B C D E F G
6. When I am listening to the news on the car radio, and family members are talking, I have trouble hearing the news.	A B C D E F G	A B C D E F G
7. When I'm at the dinner table with several people, and am trying to have a conversation with one person, understanding speech is difficult.	A B C D E F G	A B C D E F G
8. Traffic noises are too loud.	A B C D E F G	A B C D E F G
9. When I am talking with someone across a large empty room, I understand the words.	A B C D E F G	A B C D E F G
10. When I am in a small office, interviewing or answering questions, I have difficulty following the conversation.	A B C D E F G	A B C D E F G
11. When I am in a theater watching a movie or play, and the people around me are whispering and rustling paper wrappers, I can still make out the dialogue.	A B C D E F G	A B C D E F G
12. When I am having a quiet conversation with a friend, I have difficulty understanding.	A B C D E F G	A B C D E F G

Appendix

A Always (99%)
B Almost Always (87%)
C Generally (75%)
D Half-the-time (50%)
E Occasionally (25%)
F Seldom (12%)
G Never (1%)

	Without Hearing Aids	With Hearing Aids
13. The sounds of running water, such as a toilet or shower, are uncomfortably loud.	A B C D E F G	A B C D E F G
14. When a speaker is addressing a small group, and everyone is listening quietly, I have to strain to understand.	A B C D E F G	A B C D E F G
15. When I'm in a quiet conversation with my doctor in an examination room, it is hard to follow the conversation.	A B C D E F G	A B C D E F G
16. I can understand conversations even when several people are talking.	A B C D E F G	A B C D E F G
17. The sounds of construction work are uncomfortably loud.	A B C D E F G	A B C D E F G
18. It's hard for me to understand what is being said at lectures or church services.	A B C D E F G	A B C D E F G
19. I can communicate with others when we are in a crowd.	A B C D E F G	A B C D E F G
20. The sound of a fire engine siren close by is so loud that I need to cover my ears.	A B C D E F G	A B C D E F G
21. I can follow the words of a sermon when listening to a religious service.	A B C D E F G	A B C D E F G
22. The sound of screeching tires is uncomfortably loud.	A B C D E F G	A B C D E F G
23. I have to ask people to repeat themselves in one-on-one conversation in a quiet room.	A B C D E F G	A B C D E F G
24. I have trouble understanding others when an air conditioner or fan is on.	A B C D E F G	A B C D E F G

Appendix

Please fill out these additional items.

HEARING AID EXPERIENCE:	**DAILY HEARING AID USE**	**DEGREE OF HEARING DIFFICULTY (without wearing a hearing aid):**
None	None	None
Less than 6 weeks	Less than 1 hour per day	Mild
6 weeks to 11 months	1 to 4 hours per day	Moderate
1 to 10 years	4 to 8 hours per day	Moderately-Severe
Over 10 years	8 to 16 hours per day	Severe