



FP6-004171 HEARCOM
Hearing in the Communication Society

INTEGRATED PROJECT
Information Society Technologies

**D-6-1: Report on the analysis and evaluation of
current fitting procedures used throughout
Europe**

Contractual Date of Delivery: June 1, 2005 +45 days
Actual Date of Delivery: June 28, 2005
Editor: A. Faulkner.
Sub-Project/Work-Package: SP3 / WP6
Version: 1.0
Total number of pages: 67

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	
Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		

Deliverable D-6-1

VERSION DETAILS	
Version:	1.0
Date:	28 June 2005
Status:	Revised after internal review and Accepted

CONTRIBUTOR(S) to DELIVERABLE	
Partner	Name
DE-HZO	Kirsten Wagener, Corinna Pelz, Berit Jütz, Volker Hohmann, Markus Meis
UK-RNID	Elizabeth Davey
NL-AMC	Rolph Houben, Wouter Dreschler
BE-CTC	Bas van Dijk
UK-UCL	Andrew Faulkner

DOCUMENT HISTORY			
Version	Date	Responsible	Description
0.1	January 19, 2005	Kirsten Wagener	First draft, formal
0.2	April 6, 2005	Kirsten Wagener	Second draft, including material from UK-RNID and NL-AMC
0.3	April 15, 2005	Kirsten Wagener	Third draft, adaptations due to NL-AMC and UK-RNID
0.4	May 3, 2005	Kirsten Wagener	Fourth draft, minor changes
0.5	May 10, 2005	Andrew Faulkner	Integrate CI report from CTC Revise introductory text Revisions main report
1.0	June 28, 2005	Andrew Faulkner	Revisions following project internal review.
DELIVERABLE REVIEW			
Version	Date	Reviewed by	Conclusion*
0.5	May 10, 2005	S. Arlinger, N. Dillier	Revisions required
1.0	July 7, 2005	M. Vlaming	Accept

* e.g. Accept, Develop, Modify, Rework, Update

Table of Contents

1	Rehabilitation procedures for hearing aids	6
1.1	Common rehabilitation procedures	6
1.2	Optimal rehabilitation procedures	8
1.2.1	Initial views from HearCom partners on optimal procedures	8
1.2.2	Plans to collect professional opinion	16
1.3	Dissemination and Exploitation	16
1.4	Conclusions.....	16
1.5	References for part 1	16
2	OVERVIEW OF FITTING PROCEDURES FOR COCHLEAR IMPLANTS	18
2.1	Introduction	18
2.2	Classical T and C level fitting	20
2.2.1	Adults	20
2.2.2	Children.....	21
2.3	Recent developments in fitting methods	23
2.3.1	Interpolation	23
2.3.2	Streamlined fitting	24
2.3.3	Fitting based on objective measures	24
2.3.4	The objective offset (or 'Brown') method	25
2.3.5	The preset map series (or Almqvist) method	26
2.3.6	Shift method (or Smoorenburg) with ECAP profile.....	27
2.3.7	Shift and tilt without ECAP profile	28
2.3.8	NRT vs Rate preference	29
2.3.9	Genetic algorithms	29
2.3.10	Self-fitting	30
2.3.11	PCIMAR	30
2.3.12	Self-fitting	30

2.4	Summary and conclusions: current fitting methods.....	30
2.5	Identified needs for new fitting methods.....	31
2.6	Synergies in fitting methods for cochlear implants and hearing aids ...	31
2.7	References (for part 2)	32
3	Appendixes	34
3.1	Appendix 1: Model procedures	34
3.1.1	Germany (DE-HZO).....	34
3.1.2	England (UK-RNID)	38
3.1.3	Netherlands (NL-AMC)	40
3.1.4	Fitting rules available in hearing aid company software.....	44
3.2	Appendix 2: Questionnaire	49
3.3	Appendix 3: Further details of HearCom proposals on optimal procedures by partner	53
3.3.1	DE-HZO	53
3.3.2	NL-AMC	57
3.3.3	Plans to collect hearing-aid user opinion	62
3.4	Appendix 4: Conversion of Nucleus (Cochlear Corporation) current level (CL) units to microamps.....	67

Executive Summary

This report includes an inventory of individual rehabilitation procedures for both acoustic hearing aids and cochlear implants. The report is in two parts, the first covering hearing aids, the second cochlear implants.

Current practice in rehabilitation differs considerably between these two types of auditory prosthesis, and the principal issues addressed by HEARCOM are also rather different for these different prostheses.

Cochlear implants are complex devices while hearing aids are relatively simple. The basic issues in fitting hearing aids are relatively well understood, while there are many unknowns in the fitting of cochlear implants. For this reason our coverage of cochlear implants is very much focussed on device fitting, while the coverage is much broader for hearing aids and covers not only fitting procedures but the whole rehabilitation process, including the management and evaluation of hearing aid benefit.

Summary for hearing aids

The purpose of the hearing aid procedures inventory is to provide a starting point for a European-wide model of good practice that can be disseminated widely through the internet. The inventory for hearing aid provision includes both the status quo of rehabilitation procedures as well as a proposal for consultation on a more optimal approach to hearing aid rehabilitation. The views of HearCom Partners in Germany, the Netherlands and the UK on the ideal rehabilitation setup are presented, as is the approach that is proposed to seek professionals' and hearing-aid users' opinions. It is recognised that the scope of this review needs to be widened, and it is expected that future work will extend the coverage to other European countries.

Summary for cochlear implants

This document gives a 'state-of-the art' overview of fitting procedures for cochlear implants. It assumes only rudimentary CI knowledge from the reader. It covers standard methods of fitting and reviews recent research into fitting methods. It also briefly indicates new areas of research in fitting that require investigation.

1 Rehabilitation procedures for hearing aids

Primary Author: Kirsten Wagener, DE-HZO.

One ultimate outcome of HearCom WP6 will be an account of optimal (ideal) rehabilitation procedures, which will feed into the e-rehabilitation activities of WP12. The present task reflects the initial stages of work towards this goal. In this report the current status of rehabilitation methods in three countries (DE, NL and UK) is overviewed. As well as this overview of the status quo, the report sets out a proposed method for gathering views on optimal approaches. The target groups for this information gathering are scientific researchers, hearing aid professionals, and hearing-impaired users of hearing aids.

Given the goals of the HearCom project the rehabilitation procedures focus on adults. For young children many aspects of the rehabilitation process would need to be treated differently.

Section 1.1 describes the status quo of rehabilitation procedures. Section 1.2 describes the HearCom proposals for ideal rehabilitation procedures as well as the approach to be used determine professionals' and hearing-aid users' opinions.

1.1 Common rehabilitation procedures

The partners were asked to describe the common rehabilitation procedures of their country in order to determine the status quo. There are large differences in rehabilitation procedures between the countries. This is due to different rehabilitation systems and different service structures and philosophies. In the UK there are two separate services, one within the state-funded National Health Service (NHS), and the other in the private sector. Within the NHS the provision of hearing aids and associated services is fully state-funded. The procedures used in the NHS are nationally determined, and have been developed from a Health Services Research base reflecting both scientific and medical views and the views of audiologists working in the NHS. In the private sector the costs are met wholly by the individual receiving the hearing aid. There is a nationally agreed code of practice for professionals in the private sector, but this concentrates more on professional conduct than specifics of rehabilitation tests and procedures. In other countries, insurance schemes require certain tests to be carried out at fitting to prove benefit, in order for costs to be claimed for the hearing aid. In the UK NHS system, because there are no costs to the recipient, the approach of assessing benefit is not the same as in other countries. For example, in the UK speech intelligibility tests are not usually performed during hearing aid provision and the approach used to assess benefit is by looking at a client's everyday life using a questionnaire. In Germany, however, speech intelligibility tests (mostly in quiet) are used to indicate the benefit of the hearing aid.

In the Netherlands, the hearing impaired person goes to a medical audiological centre for diagnosis and prescription of a suitable hearing aid or aids (covering

both type of aid and a first pass at the setting of the aid for the individual). Then they go to a professional hearing aid dispenser who issues and fine-tunes the hearing aid(s). The hearing-impaired person returns to the audiological centre for evaluation measurements. From 2004 on, clients have been allowed to bypass the audiological centre and go straight to a hearing aid dispenser. Hearing aids themselves are (partly) paid by health insurance. There is a maximum reimbursement.

The Dutch system is similar to the German system. In Germany, the hearing impaired person has to visit an ENT doctor for diagnosis. Then they go to the hearing aid professional to get hearing aids fitted and fine-tuned. Since fitting is performed by the hearing aid professional, the professional also performs all unaided measurements that are needed for fitting. The hearing impaired person has to return to the ENT doctor to get a reimbursement from health insurance. As in the Netherlands, hearing aids themselves are (partly) paid by health insurance. There is a maximum reimbursement.

The descriptions of the common rehabilitation procedures in the different countries are given in Appendix 1.

Appendix 1 also includes an inventory of fitting rules available to the professional by the hearing aid companies' software. This inventory gives an overview of the scope to adapt the standard fittings that are preset by the fitting software (so called "quick fit" options). Only those hearing aids that can be fitted by the quick fit options are listed in the inventory. Since there are an enormous number of different hearing aids available, this inventory is not exhaustive.

The names of hearing aids may differ across countries. Most hearing aids listed in the inventory are given with their German names.

The inventory can also be used to identify the generic fitting procedures that are most commonly used by different hearing aid companies. These are the National Acoustics Laboratory Non-Linear 1 (NAL-NL1¹: Byrne, Dillon et al., 2001) and the Desired Sensation Level Input/Output (DSL_{i/o}: Cornelisse, Sewald & Jamieson, 1995) fitting rules. The DSL_{i/o} formula aims at normalizing loudness in different frequency channels. The NAL-NL1 fitting procedure aims to provide the gain-frequency response that maximizes speech intelligibility while keeping overall loudness at a level no greater than that perceived by a normal-hearing person listening to the same sound. The broadly similar POGO (Prescription of gain and output: McCandless & Lyregaard, 1963; Schwartz, Lyregaard, & Lundh, 1988) procedure is also used by some hearing aid companies.

In order to confirm the status quo in hearing aid rehabilitation, a questionnaire has been produced to be sent out to hearing aid professionals. This questionnaire looks at the fitting process of hearing aids. It covers different aspects of the fitting process: influence of earmould, fitting rules (proprietary and generic rules), verification measurements, fine tuning, intention for fitting (e.g. maximizing intelligibility or normalization of loudness perception). Since the common rehabilitation procedures differ between different countries, this

¹ <http://www.nal.gov.au/Products/NAL-NL1.htm>.

questionnaire has to be adapted to the respective country. This includes the questions about specific speech tests (questions number 1 and 3 of evaluation measurements, see Appendix 2) as well as questions that are connected to the hearing aid service (question number 3 of goal of rehabilitation).

The questionnaire suitable for Germany is shown in Appendix 2 (translated into English).

1.2 Optimal rehabilitation procedures

An achievable optimum in rehabilitation procedures should take account of the gap between the 'ideal' and 'real world'. Since the 'real world' is rather different in different countries (as shown by the comparison of rehabilitation procedures, section 1.1), the gap will also differ between countries. The outcome of the focus group discussions can be used as an input for work package 12, which aims to provide an Internet-based resource for professionals and hearing-aid users.

HearCom aims to recommend more optimal procedures for different target groups. A first step in this endeavour has been based on the views of researchers involved in this project. In order to determine the expectations and opinions of professionals and hearing-aid users, our views on optimal fitting will be the subject of focus group discussions. The focus group discussions aim at collecting the professionals' and hearing-aid users' opinion about rehabilitative procedures and rating the value of each procedure. In order to yield comparable results across countries, DE-HZO has worked out the details of the focus group discussions and distributed them to the WP6 partners, so each partner can use a similar approach in their own country to gather the information (DE-HZO supports the discussions by preparing a well documented 'cookbook' and presented the approach to the partners at the HearCom meeting in March).

1.2.1 Initial views from HearCom partners on optimal procedures

WP6 partners were asked for their scientifically-informed opinions on ideal rehabilitation procedures. Their responses will be used as input for the focus group discussions. The rehabilitation procedures should cover;

- Pre-fitting procedures
- Defining goals for rehabilitation and technical options
- Hearing aid fitting and verification of fitting
- Evaluation measurements
- Follow-up.

The ideal procedures under these sub-headings as presented in the following table represent both broadly shared opinions across different countries, and some distinctive proposals advocated by each partner. The UK response is based on the view that current best practice in the UK within the state (NHS) sector has been established very recently by the state funded "Modernising NHS Hearing Aid

Report on the analysis and evaluation of current fitting procedures: Part 1 Hearing Aids

Services” programme. <http://www.mhas.info/>, which was based on considerable research.

1.2.1.1 Proposals for optimal rehabilitation procedures

Pre-fitting	Shared views on optimal procedures	DE-HZO	NL-AMC	UK-RNID
Counselling and preliminary audiological talk	Counseling/information about course of hearing aid provision. General information about assets and drawbacks of hearing aids, specific characteristics, possible applications. Open interview about problems and expectations			
Anamnesis and otological examination	Structured interview about medical history and complaints (e.g. sudden deafness, otitis media, ear pain, ear surgery, tinnitus, congenital hearing loss, dizziness). Otoscopy, Tuning fork testing (optional), Tympanometry (optional)			
Questionnaire	Collecting individual problems and aims	HörTech inventory "Oldenburg Inventar I" or COSI (to be used during conversation with client) + if necessary HörTech inventory "Oldenburg Inventar R" (can be completed at home)	Glasgow Hearing Aid Benefit Profile (GHABP: Gatehouse, 1999) initial assessment; Speech, Spatial and Qualities of Hearing Scale (SSQ).	Glasgow Hearing Aid Benefit Profile Part 1
Standard audiometry in quiet (headphones)	Pure tone audiogram air and bone conduction with adequate masking			
Speech audiometry in quiet	Test of patient's ability to recognise speech unaided in a quiet situation. Specific tests and parameters vary.	Hearing loss for numbers; UCL for numbers/speech; with masking of better ear. Performance-intensity function, intelligibility at 65 dB SPL, optimal intelligibility; left/right. Comparison with predictions based on pure tone thresholds	Speech audiogram with monosyllabic words (complete performance intensity functions from threshold to uncomfortable loudness level, materials from Bosman and Smoorenburg (1995). Comparison of pure tone audiogram and speech audiogram.	No proposals to use speech tests prior to fitting
Speech audiometry in noise	Test of patient's ability to recognise speech unaided in a noisy situation. Specific tests and parameters vary.	1 sentence test S0N90 or S0N-90 (whichever side would be aided monaurally). Set-up: Adaptive Göttingen (Kollmeier & Wesselkamp, 1997) or Oldenburg (Wagener, Kuhnelt, & Kollmeier, 1999) sentence test Noise presentation level 65 or 75 dB SPL depending on hearing loss (noise has to be perceived) Stationary speech shaped noise +	Assessment of the critical signal to noise ratios for sentences per ear in both stationary and fluctuating noise with the same long-term average spectrum as the speaker. We use sentence materials from Plomp and Mimpen (1979), or Versfeld et al. (2000) with an adaptive procedure.	No proposals to use speech tests prior to fitting

		(additionally) one measurement with speech simulating fluctuating noise		
Pre-fitting continued	Shared views on optimal procedures	DE-HZO	NL-AMC	UK-RNID
Loudness scaling	Vary	Adaptive loudness scaling (ACALOS: Brand & Hohmann, 2002) left/right narrow band at 0.5, 1.5 & 4 kHz (if 4 kHz not measurable, 3 kHz) & left/right/binaural broad band (sentence). Plug ear not in use in sound field measurements	Adaptive loudness scaling per ear using the ACALOS-procedure for the following signals: narrow band Low-Noise Noise (Pumplin, 1985) at 0.75 and 3 kHz; broad-band low-noise noise (speech spectrum). Preferred setting through headphones. In case of sound field measurements, earplug in ear contralateral to test ear.	
Goals and options	Shared views on optimal procedures	DE-HZO	NL-AMC	UK-RNID
Defining goals	Defining goals for rehabilitation based on anamnestic and otological data, the unaided measurements, and the questionnaire results. Counseling about realistic expectations			
Technical options	Choice of ear(s) to be fitted. Choice of type of hearing aid(s). Specification of type of earmould			
Hearing aid fitting	Shared views on optimal procedures	DE-HZO	NL-AMC	UK-RNID
Earmould	Taking ear impression; creation of earmould or earshell. Final fitting of earmould			
Fitting and fine tuning	Prescriptive fitting according manufacturer or current fitting rules. Verification of hearing aid fitting using Real Ear Measurements. First rating of speech intelligibility, sound quality.	Trial fitting of at least 3 hearing aids at least one without available without extra payment.	Prescriptive fitting of one or two hearing aids according to manufacturer or generic fitting rules (usually one basic aid with full reimbursement of the costs and one more complex hearing aid with an own financial contribution).	Often only one hearing aid model is selected and fitted per ear in UK.
Handover fitted aid	Explain handling and care of the hearing aid to the user. Arrange regular checkups. Present information about accessories to the user			

Trial use period	Trial period in everyday listening situations and counseling during trial period. Fine tuning of at least one hearing aid (in several sessions). If necessary. Real Ear measurements if necessary, gradual build-up of amplification to adapt new users to hearing aid.			
Evaluation measurements	Shared views on optimal procedures	DE-HZO	NL-AMC	UK-RNID
Selection	Vary	The subjectively favoured hearing aid is measured. If several hearing aids are rated subjectively the same, a sentence test in noise or a loudness scaling can be comparatively performed.	As HZO	In NHS service, generally only one aid fitted to each ear at a time. This is constrained by state funding of hearing aid provision.
Speech audiometry in quiet (sound field)	Single words measured for each individual aided ear (contra-lateral ear blocked) and for both ears bilaterally fitted	Propose testing at 65 and 80 dB SPL; the hearing aids are used in the preferred gain setting. Freiburg test (one syllable words) at 65 and 80 dB SPL	CVC-words (Bosman and Smoorenburg, 1995) at 65 dB SPL, with hearing aids used in the preferred gain setting.	Not likely to be adopted for routine use in UK, but could be adopted as a valuable investigative tool.
Speech audiometry in noise (sound field)	Adaptive sentence testing to determine speech-to-noise ratio at intelligibility threshold	Monaural fitting: 1 sentence test S0N90 or S0N-90. Bilateral fitting: 3-5 sentence tests S0N90 or S0N-90. Adaptive Göttingen or Oldenburg sentence test. Noise presentation level 65 or 75 dB SPL (same as unaided). Stationary speech shaped noise + (additionally) one measurement with speech simulating fluctuating noise	Both stationary and fluctuating noise with the same long-term average spectrum as the speaker. Sentence materials from Plomp and Mimpen (1979), or Versfeld et al. (2000).	Not likely to be adopted for routine use in UK, but valuable as investigative tool. Adaptive sentence intelligibility similar to USA HINT protocols (Nilsson, Soli, & Sullivan, 1994) likely to be well accepted in UK (NB HINT based on well-established UK BKB sentence materials, Bench, Kowal and Bamford, 1979).
Loudness scaling (sound field)	Adaptive loudness scaling (ACALOS) left/right. Plug ear not in use in sound field measurements	Stimuli: narrow band noise at 0.5, 1.5 & 4 kHz (if 4 kHz not measurable, 3 kHz) & left/right/binaural broad-band speech (sentence).	Stimuli: narrow band "Low-Noise" Noise (Pumplin, 1985)) at 0.75 and 3 kHz; broad-band low-noise noise (speech spectrum).	

Horizontal localization (sound field)			Short noise bursts are presented from different azimuths (usually presented by nine to thirteen loudspeakers in half a circle from -90 to +90 degrees). The measurements are performed both aided and unaided.	
Evaluation measurements continued	Shared views on optimal procedures	DE-HZO	NL-AMC	UK-RNID
Insertion gain measurements	The selected hearing aids are characterised with real ear measurements using broadband speech noise at 55, 65, and 80 dB SPL. The hearing aids are used in the preferred gain setting. The hearing aids are measured after deactivation of noise reduction circuitry in an omnidirectional mode. The curves obtained are compared with generic prescription rules for non-linear hearing aids (usually NAL-NL1 or DSL i/o).			
Documentation of settings	Print and save settings, if necessary coupler measurements. Hearing aid with trimpots: test box results			
Questionnaire	The hearing aid benefit is rated by questionnaires.	HörTech inventory "Oldenburg Inventar I" or COSI+ optional HörTech inventory "Oldenburg Inventar R" & "Hörgeräte-Bewertung" (rating of hearing aid system) Overall rating by means of International Outcome Inventory for Hearing Aids (IOI-HA: Cox, Alexander, & Beyer, 2003) proposed for 6 months after fitting	Inventory of hearing aid benefit in real life with Glasgow Hearing Aid Benefit Profile. Comparison of the GHABP results with a reference group of users in terms of use, benefit, residual disability, and satisfaction. Overall rating by means of International Outcome Inventory for Hearing Aids (IOI-HA: Cox, Alexander, & Beyer, 2003). For more detailed measures of auditory disability and handicap, the Amsterdam Inventory of Auditory Disability and Handicap (AIADH) can be used (optional).	Glasgow Hearing Aid Benefit Profile part 2. UK philosophy is that the most important evaluation measure is of the real-life benefit as an outcome of the entire rehab process (including counselling etc) - since ultimate benefit depends on how well device is used as well as how well it is fitted.

Follow-up	Shared views on optimal procedures
Additional rehabilitation needs	Counseling about other training (speech-reading, hearing strategies and communication training). Strategies to encourage the client to wear the hearing aids. Determine need of other action (compare expectation with achieved aims), e.g. audiological therapy, psychosocial consulting.
Closing of provision	Remind clients about handling and care of the hearing aid and respond to problems raised. Arrange future care and support. Present information about accessories to the user. Complete formal fitting documentation
Open access repair service	Users may come without an appointment if they are having any problems

1.2.1.2 Comparison of proposals for optimal procedures with status quo

A comparison of the proposals for optimal procedures with the status quo set out in Appendix 1 indicates a number of recommendations for improvements and additional procedures. The major areas where the HearCom proposals go beyond standard practice are as follows.

1.2.1.2.a Benefit Questionnaires.

While this is part of standard UK practice for NHS provision (as part of the MHAS standards) there is no consistent use of this approach in Dutch and German practice. The NL-AMC proposal matches the procedures already used in the UK NHS in the use of the Glasgow Hearing Aid Benefit Profile (Gatehouse, 1999).

1.2.1.2.b Speech audiometry.

Standards for speech tests vary greatly. German and Dutch practice involve simple word and number-based speech audiometry in the quiet. UK standards make no use of speech testing. Two of the three HearCom partners recommend standards for speech testing in noise and specific methods for speech tests in quiet that are not generally used at present. While UK standards do not provide for any speech testing, it seems likely that practice in the UK could be extended to make use of standard speech testing methods in cases where routine fitting and evaluation seem to give less than ideal results and professionals' views on speech testing will be investigated in the focus groups. For example, there will be some cases where subjective benefit is less than expected, or where there is a need to choose between several alternative hearing aids or fits of one hearing aid.

1.2.1.2.c Insertion gain measures.

Indications are that insertion gain measures are not standard in the Netherlands, while they are part of the routine procedures in the UK and Germany. Common standards throughout Europe would be desirable.

1.2.1.2.d Loudness scaling.

Loudness scaling measures (Brand & Hohman, 2002) are not part of status quo but are advocated by both DE-HZO and NL-AMC.

1.2.1.2.e Sound Localisation.

Measures of binaural hearing are not evident in the status quo. A sound localisation procedure is advocated by NL-AMC which could be of particular importance in optimizing the fitting of binaural hearing aids.

1.2.2 Plans to collect professional opinion

The opinions of hearing aid professionals will be assessed during focus group discussions. Within these focus group discussions the procedures suggested by HearCom WP6 for adoption as good practice will be rated and view on additional needs will be collected. The guidelines of the focus group discussions with the professional target group were determined by DE-HZO and are presented here. The focus group discussions will be performed at DE-HZO first. In this way, possible optimization of the HearCom proposals can be performed based on the professional's views.

1.3 Dissemination and Exploitation

The status quo and future vision of rehabilitation procedures throughout Europe for hearing aids will be presented at different conferences about Audiology and hearing aids (Erlangener Kolloquium 2006, DGA 2006).

1.4 Conclusions

The status quo of procedures for hearing aid rehabilitation was reviewed on the basis of practice in Germany, the Netherlands, and the UK (NHS). HearCom partners from these three countries have also proposed their views on a more optimal set of procedures. There are significant differences between countries in current approach and procedures. Section 1.2.1.1 summarised several suggestions for other rehabilitation procedures that might also be rated in the focus groups.

The views of professional audiologists/hearing aid dispensers and hearing-aid users on their perception of the status quo and the HearCom proposals for important procedures will be sought in focus group studies to be carried out in task 2 of WP6.

1.5 References for part 1

Bench, J., Kowal, A., & Bamford, J. M. (1979). The BKB (Bamford-Kowal-Bench) sentence lists for partially-hearing children. *British Journal of Audiology*, 13, 108-112.

Brand, T. & Hohmann, V. (2002). An adaptive procedure for categorical loudness scaling. *Journal of the Acoustical Society of America*, 112, 1597-1604.

Bosman, A. J. & Smoorenburg, G. F. (1995). Intelligibility of Dutch CVC syllables and sentences for listeners with normal hearing and with three types of hearing impairment. *Audiology*, 34, 260-284.

Byrne, D., Dillon, H., Ching, T., Katsch, R., & Keidser, G. (2001). The NAL-NL1 procedure for fitting non-linear hearing aids: characteristics and comparisons with other procedures. *Journal of the American Academy of Audiology*, 12, 37-51.

Cornelisse, L. E., Seewald, R. C., & Jamieson, D. G. (1995). The input/output formula: A theoretical approach to the fitting of personal amplification devices. *Journal of the Acoustical Society of America*, 97, 1854-1864.

Cox, R., Alexander, G. C., & Beyer, C. M. (2003). Norms for the International Outcome Inventory for Hearing Aids. *Journal of the American Academy of Audiology*, 14, 403-413. <http://www.ausp.memphis.edu/harl/ioiha.html>

Gatehouse, S. (1999). Glasgow Hearing Aid Benefit Profile: Derivation and validation of a client-centered outcome measure for hearing-aid services. *Journal of the American Academy of Audiology*, 10, 80-103.

Kollmeier, B. & Wesselkamp, M. (1997). Development and evaluation of a German sentence test for objective and subjective speech intelligibility assessment. *Journal of the Acoustical Society of America*, 102, 2412-2421.

McCandless, G. & Lyregaard, P. E. (1963). Prescription of gain/output (POGO) for hearing aids. *Hearing Instruments*, 35, 16-21.

Nilsson, M. S. S. D. & Sullivan, J. (1994). Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and noise. *Journal of the Acoustical Society of America*, 95, 1085-1099.

Plomp, R. & Mimpen, A. M. (1979). Improving the reliability of testing the speech reception threshold for sentences. *Audiology*, 18, 43-52.

Pumplin, J. (1985). Low-noise noise. *Journal of the Acoustical Society of America*, 78, 100-104.

Schwartz, D., Lyregaard, P. E., & Lundh, P. (1988). Hearing aid selection for severe/profound hearing losses. *Hearing Journal*, 41, 13-17.

Versfeld, N. J., Daalder, L., Festen, J. M., & Houtgast, T. (2000). Method for the selection of sentence materials for efficient measurement of the speech reception threshold. *Journal of the Acoustical Society of America*, 107, 1671-1684.

Wagener, K., Kuhnel, V., & Kollmeier, B. (1999). Entwicklung und Evaluation eines Satztests für die deutsche Sprache I: Design des Oldenburger Satztests. *Zeitschrift für Audiologie*, 1, 4-15.

Cox RM., Alexander, GC. and Beyer CM. "Norms for the International Outcome Inventory for Hearing Aids" *Journal of the American Academy of Audiology*, 14(8): 403-413, (2003).

2 OVERVIEW OF FITTING PROCEDURES FOR COCHLEAR IMPLANTS

PRIMARY AUTHOR: BAS VAN DIJK (BE-CTC)

2.1 Introduction

Cochlear implant (CI) fitting can be a time consuming and difficult task. This document aims to describe the issues with CI fitting and the solutions that currently exist in the field.

There are three major manufacturers of cochlear implants. The Australian Cochlear Corporation, of which the partner BE-CTC is a part, has the largest market share. The other two major suppliers are the US-based Advanced Bionics Corporation, and the Austrian-based MED-EL company. While these manufacturers have, in the past, advocated rather different speech processing methods, their current products all use broadly similar processing methods, based on the Continuous-Interleaved-Sampling (CIS) method first described by Wilson and colleagues (Wilson et al, 1991). This processing is intended to simulate the temporo-spatial coding of the acoustically-stimulated cochlea. The speech processor implements a bank of band-pass filters, covering a frequency range bounded at 100 to 300 Hz at the low frequency end, and extending to an upper limit at 5 to 8 kHz. The Cochlear Corporation device uses 24 electrodes spaced along its array, the current Advanced Bionics implant has a 16 element array, while the MED-EL electrode has 12 pairs of electrodes (each pair sharing the same position along the array). The speech processor filter-bank generates amplitude envelope signals representing the output of each of the filter-bands. In the standard CIS method, the resulting set of amplitude envelopes are used to modulate the electrical currents delivered to the individual electrode sites, such that the lower frequency speech processor filters control apical electrode levels, and the higher frequency filters control basal electrode levels. The Cochlear Corporation and MED-EL also use, as an alternative to standard CIS, an “ n -of- m ” strategy (Wilson, 1993) which differs from CIS in one important respect. Here there are m filters (where m is typically the same as the number of usable electrodes) but only the n channels showing the highest signal levels at that instant of time are selected for stimulation in any given analysis time frame. For the Cochlear Corporation device, m is maximally 24, and n is a fitting parameter, typically set between 8 and 12.

A Cochlear implant generally stimulates the auditory nerve with series of short biphasic electrical pulses². The pulses are biphasic because the net current

² A few alternative schemes exist although these are not used in current devices. For example, the SAS processing scheme of the Clarion implant presented continuously

through the tissue should be zero to avoid unwanted long-term electrochemical effects. Since stimulating multiple electrodes at the same time can give an unpredictable loudness percept because of channel interactions (addition of stimulus voltage fields) current commercial coding strategies use sequential stimulation. The rate of pulse stimulation to an electrode depends on processing strategy. The slowest pulse rates in use are 200 pulses/s (pps). A pulse rate of around 800 pps is common to several strategies, while higher rates of up to 5000 pps can be used in some recent strategies. With pulsatile stimulation within these ranges of rate, the percept is not of a burst of pulses, but rather as a continuous signal. The most crucial aspect of fitting for a cochlear implant is to establish the lowest and highest usable stimulation level for each electrode in the array, and this is a common feature of all cochlear implants.

Since the auditory nerve may have only about 6-12 dB dynamic range for electrical stimulation, we need to compress the +100 dB acoustical window available to normal hearing considerably. This is done by first 'selecting' a small part of the acoustical window (normally about 30 dB; the speech dynamic range) by means of an Automatic Gain control. The width of this window is referred to as the instantaneous input dynamic range (IIDR). The IIDR is further compressed in an instantaneous non-linear compression to match the very small dynamic range for electrical stimulation.

Fitting methods can only be implemented through tools provided by the manufacturer. This is essential for device safety. It also ensures that the basic fitting methods use the same parameters are in every country. The most important fitting parameters are listed below. It must be noted that these parameters are somewhat strategy and device dependent, some parameters will occur in different devices under different names. Almost all of these parameters are used in the fitting of all three manufacturers; implants.

T level: Threshold level – the minimum stimulation level that the subject can detect (i.e. hear) on a channel.

C level: Comfort level – the loudest comfortable stimulation level on a channel.

Number of channels: The total number of stimulation channels available (depends on the device and also on the number of electrodes that are usable for any given Implant recipient).

Number of maxima: The number of stimulated channels in each cycle for *n*-of-*m* strategies such as Nucleus ACE™ (only for Cochlear Corp. and MED-EL implants)

Rate: The rate of sequential stimulation.

C-SPL: Determines the input dB SPL value at which the infinite compression starts to operate and the implant stimulates at C-level.

varying current waveforms to each electrode. Other schemes are in development that consider triphasic or other more complex pulse patterns. In general, however, the fitting approaches for these forms of stimulation are similar to those for biphasic pulses.

T-SPL: The input SPL level where the implant starts to stimulate at T-level. Note that C-SPL is equivalent to sensitivity and C-SPL minus T-SPL is equal to IIDR.

Compression curve: The steepness of the infinite instantaneous compression curve that maps filterbank output to dynamic range (Q factor in Nucleus terminology).

FAT The Frequency Allocation Table determines which frequency range is connected to which electrode/channel.

Stimulation mode: Defines how the channels are formed, for instance we can stimulate between two neighbouring intra-cochlear electrodes (bipolar mode) or between an intra-cochlear and an extra-cochlear electrode (monopolar). Monopolar stimulation is the default and by far the most commonly-used mode..

One of the main problems in implant fitting, unlike the fitting of hearing aids, is that the inter-subject variation of T and C levels is much larger than the average dynamic range (C-T) for an individual subject. This means that a map for one recipient may be either inaudible, or far too loud for another individual. When a map is far too loud, this may even cause painful stimulation of non-auditory nerve fibres, hence it is something to avoid at all times. The latter remark is especially true for children because over-stimulation can create anxiety about the implant/hospital/audiologist and in this way hamper the rehabilitation process. This means there is no way one can start with a 'default' fitting in all subjects. As an example: the average T level can vary between roughly 100 and 1000 μA , a 20 dB difference³, while the average dynamic range is only about 4 dB.

T and C levels are by far the most important map parameters, since this is what makes a map audible/comfortable. All the other parameters can be considered fine-tuning for audio quality. But we do know that some recipients do much better with one setting of for instance rate, while others may do better with a different setting, and yet others do equally well in both settings.

This document first describes the classical fitting method and after that some new ways that are being used today. It will focus primarily on T and C levels setting. While the examples refer to work using the Cochlear Corporation devices, the principles are widely applicable. Other CI fitting research forming part of the HEARCOM project is outlined in final section of this report.

2.2 Classical T and C level fitting

2.2.1 Adults

The classical way of setting map level is the following procedure, which is based on single-electrode psychophysics:

³ The Nucleus implants use the logarithmic CL scale: 1 CL is about 2% increase in current, 6 CLs is about 1 dB. Other manufacturers use similar logarithmic current scales but with different reference values.

The clinician stimulates a specific electrode with a burst of pulses that occurs at the desired rate. This stimulation starts at a very low level (<100 CL (= $100 \mu\text{A}$) in the Nucleus devices) and the stimulation is slowly increased in small steps (e.g. 1 dB or 6 Nucleus CL units). The recipient is asked to report any auditory sensation. The stimulation is increased until the recipient hears the sound, then, using finer steps, an up-down procedure (very similar to audiometry) is used to find the threshold of sensation for this burst. The level at the threshold is used as T-level. Unlike classical audiometry, which aims to find the 50% detection point on the psychometric curve, we usually aim for the 100% detection point on the psychometric curve. Once the T level is established, the clinician increases the stimulation in small steps (1 dB) until the recipient indicates that the sound is loud but comfortable. This is used as C-level.

The above procedure is repeated for all electrodes on the array.

When all electrodes are tested, generally a balancing procedure is performed to make sure that all C-levels generate approximately the same loudness, which, in turn, ensures that equal-levelled audio input generates equal-levelled electrical stimulation. For instance, in the 22 channel Nucleus device, balancing is usually performed by stimulating 5 consecutive electrodes in turn at C level or a specific (fixed) percentage of the dynamic range and asking the recipient if one is softer or louder than the others.

When this is done, the implant is put into speech processing mode, and the map is tested with speech input. If needed the clinician can globally lower or raise the T- and or C-levels to adjust the loudness perception of live speech.

Advantages: Precise, each electrode tested, very low chance of over-stimulation.

Disadvantages: Time-consuming, often unnecessarily precise. Also, due to the effect of temporal-spatial summation of stimuli, it may be a bit arbitrary to test on single electrodes at a time.

Remarks: Classically, audiologists tend to spend considerable time in setting T-levels, however, research and experience indicate now that C-level, or balance in the upper regions of the dynamic range may be more important for the map quality, both in terms of subjective judgement and objective speech scores.

2.2.2 Children

When fitting children⁴, the above procedure cannot be used since children are not able to (reliably, depending on age) give feedback on the audibility of stimuli. A number of procedures can be used:

⁴ In this document the term "children" refers to subjects who are too young to give reliable feedback on audibility and loudness of presented stimuli.

2.2.2.1 Play audiometry

When a child is old enough (roughly it should be possible to do play audiometry at the age of 2 years, but obviously it depends on the developmental skills of the child in question), he or she can be conditioned to perform a certain task upon hearing the stimulus, for instance putting a peg in a board. This can be a very reliable indicator for thresholds if the task is performed well, but is very time consuming since the child needs to be trained and each electrode needs to be tested. Also, for setting C-levels the method is less reliable since most children will not have the cognitive skills and/or auditory experience to judge 'comfortable loudness'. One option is to have the child point to 'scaling pictures' such as the ones displayed below, but this may be very hard to do with very small children, scaling loudness is more difficult and requires more skill from the child than just indicating threshold through play audiometry.

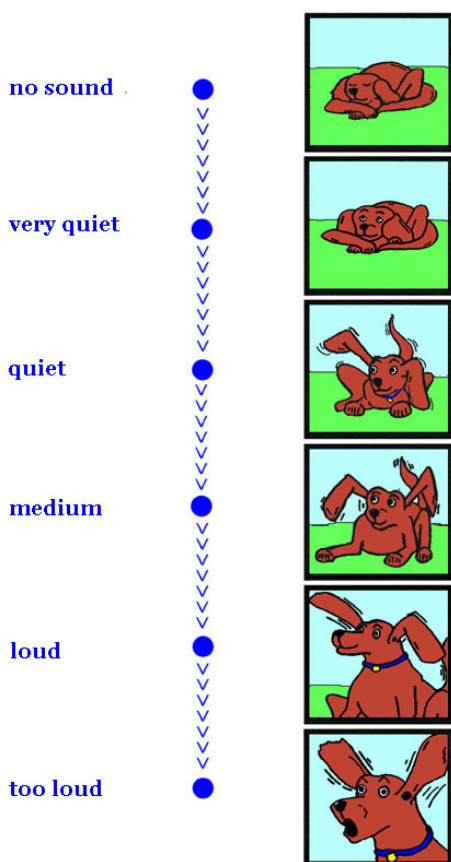


Figure 1: Example of paediatric loudness scale pictures.

Advantages: Can be reliable in setting T-levels.

Disadvantages: Time consuming, not suitable for the youngest children, setting C-levels is more difficult.

2.2.2.2 Visual reinforcement audiometry

In Visual Reinforcement Audiometry (VRA) the stimulus is followed by a visually attractive cue (a moving toy, a picture on a screen,..). The idea is to use classical conditioning techniques to train the child to look in a certain direction

when he/she hears the stimulus. This method can be successfully used to determine thresholds in children between 9 months- 2 years. The method is less suited for setting C-levels.

2.2.2.3 Observation

With even smaller children it may be necessary to rely completely on observation to set both T- and C-levels. This is done by slowly increasing stimulation until a reaction is observed; this should be supra-threshold stimulation. A reaction can be a conscious attention-related movement (e.g. looking up while playing), or an unconscious (so called ideo-motive) movement like eye-blinking, change in breathing rhythm, etc. After setting a threshold in this way the stimulation can be increased until signs of discomfort are seen to get an idea of C-level. Typically the observation or behavioural threshold found in this way is above the real threshold since children tend to respond to a clearly audible level. As a first map, the audiologist could for instance set the T-level 2 dB below the observation threshold, and the C-level 1 dB above. This should give a map that is soft but audible, which is acceptable for a first setting.

Advantage: Can be used with very small children.

Disadvantage: Difficult to interpret, requires skill and experience, does not get the real threshold but rather a 'mid-dynamic range' indication that needs to be refined at a later stage.

2.3 Recent developments in fitting methods

2.3.1 Interpolation

Nowadays most maps are made using monopolar stimulation, which has the advantage that there is less current needed and that the T and C levels across the array show less variation. The apparent disadvantage of less localized (i.e. less selective with respect to frequency) stimulation is not found clinically.

The smooth appearance of T and C level curves in monopolar mode has led to the rise of interpolating techniques: When using interpolation the clinician does not measure every single electrode but measures a subset and uses interpolated values for the intermediate (not-measured) electrodes.

It has now become almost standard to use interpolation between every second electrode for both T- and C-levels, often followed by the usual full array loudness-balancing sweep. Some clinicians use even wider interpolation.

This method can be used equally well in children and adults. In children the balancing is often not possible, but looking for signs of discomfort while sweeping along the array at least rules out the possibility of over-stimulation.

Advantage: Saves time

Disadvantage: In some cases the interpolated levels could deviate from the true T and C levels, may not be accurate enough for some.

2.3.2 Streamlined fitting

Since this method was developed for Nucleus implants the terminology in this section is Nucleus focused. See Appendix 4 for a conversion from CL to μA .

A study in Melbourne (Plant & Psarros, 2002) showed that when using interpolation on every second electrode, followed by true balancing, no adjustments were needed in a group of 9 implantees. When using 5 measured electrodes distributed across the array and interpolation on the remaining 17, for some (3 out of 9) recipients very small adjustments were needed (2-6 CL). Based on this finding the streamlined method was proposed. This method works as follows:

- 1) Measure T-level in the normal way on 5 electrodes (1,6,11,16, and 22).
- 2) Interpolate the intermediate T-levels.
- 3) Set the C-levels slightly above T-level and switch on the processor in live mode.
- 4) Increase C-levels globally (all electrodes at the same time) until speech sounds comfortable.

A study with recipients showed no significant change in speech performance when comparing these maps to standard maps (Plant et al., 2004).

Advantage: Very fast, C-levels determined in live mode rather than arbitrary bursts of stimulation: taking into account temporal-spatial integration.

Disadvantage: Some recipients need finer control; every electrode ends up with the same dynamic range. May not be accurate enough for some.

2.3.3 Fitting based on objective measures

Since this method was developed for Nucleus implants the terminology in this section is Nucleus focused. See Appendix 4 to convert CL to μA .

The idea that there exist objective measures that correlate well enough with psychophysical data to allow a fitting based on such objective measures is an attractive one. The most obvious candidate for this is Neural Response Telemetry (NRT™). NRT is a method whereby the Electrically Evoked Compound Action Potential (ECAP) is measured using only a Nucleus implant, external speech processor and a PC. One might suppose that the ECAP threshold (lowest stimulation level that elicits a visible ECAP) has some relation to the map T- and/or C-levels. Similar measures are possible with other manufacturer's devices.

Unfortunately, research shows that the direct correlation between T and C levels and ECAP threshold is not good enough to warrant a map based directly on ECAP thresholds. For example, Brown et al. (2000) found only a moderate correlation between T ($r=0.55$) and C ($r=0.57$) levels and ECAP thresholds, other authors found similar numbers (see Cafarelli Dees et al., 2005 for recent data). Also with

different objective measures (E-ABR, stapedius reflex, etc) only weak correlation are generally found (see, for example, Brown et al., 2000).

There are two important reasons for this weak correlation:

- 1) The ECAP is a purely peripheral measure and does not take into account central loudness effects (summation, masking, etc).
- 2) The C-levels set in a map are highly subjective and differ between subjects and even between audiologists making the measurements. A variance analysis of a large dataset of clinical data showed that apart from subject and electrode, the CLINICIAN is the only significant factor determining C-level (van Dijk, unpublished data). This means that it may not even be useful to correlate objective data to C-level data, and one must focus purely on performance results.

The above discussion shows that it is very difficult to determine what the best fitting method is, certainly the best fitting method is not necessarily the one that gives the best prediction of classical T and C levels, since it is not clear at all if we can take this as a golden standard, besides, T and C levels contain a high level of arbitrarily and subjectivity.

The best evaluation of a new fitting method remains the clinical performance in terms of speech understanding and client satisfaction; this means that fitting studies take time and require care.

2.3.4 The objective offset (or 'Brown') method

Since this method was developed for Nucleus implants the terminology in this section is Nucleus focused. See Appendix 4 to convert CL to μA .

Carolyn Brown noted that in her data the weak correlation between T and C levels and ECAP is mostly determined by large individual shifts in the profiles, this means that the ECAP cannot predict the *absolute* level of T and C levels, but it could predict the *shape* of the profile (Brown et al., 2000). Brown et al. proposed a method in which the ECAP profile was used in combination with one classical T and C level measurement in the centre of the array. By adding/subtracting a constant offset to each channel, the profile was shifted to match the measured T and C level. Using this method they found (not surprisingly) that the average group correlation between the 'predicted' T and C level and the measured T and C level was higher than when using the uncorrected ECAP. However, Cafarelli-Dees et al. (2005) showed that the expected difference between predicted and real T and C level (the mapping error) was still unacceptably large. Furthermore it was shown that when using a profile determined by the average across a large group of subjects instead of the ECAP profile, the mapping error was even less. Surprisingly, clinical studies showed no significant drop in performance with maps made following the method proposed by Brown et al. (see for instance Craddock et al., 2003). This is another indication that the measure of how well a mapping method predicts measured T and C level is not a good measure for the quality of the mapping method itself in terms of clinical benefit.

Advantage: Quick, easy to do. Only 1 T and C measurement needed.

Disadvantage: Fixed dynamic range across array. May not be accurate enough for some.

2.3.5 The preset map series (or Almqvist) method

Since this method was developed for Nucleus implants the terminology in this section is Nucleus focused. See Appendix 4 to convert CL to μA .

When mapping children we assume that methods we know to work for adults should work equally well for children. However, this may not always be the case: first of all congenitally deaf children have no sense of loudness and probably their final C-level is determined by a combination of what is offered to them and how well they adapt to that. Almqvist (personal communication) amongst others put forward the notion that congenitally deaf children have no optimal map but can get accustomed to any map provided:

- 1) The map is audible to them (i.e., elicits neural responses).
- 2) The map has sufficient dynamic range to code loudness differences.

Now, in spite of the weak correlation between ECAP thresholds and T and C levels, we do know that the ECAP threshold always corresponds to an audible level. Furthermore, we also know, that, on average, the offset between ECAP and T-level is about 30 CL (assuming 80 Hz NRT measurement and default 900 Hz map rate).

Based on these notions, the preset map series method uses ONLY the ECAP information to create initial maps for children: The ECAP profile is shifted down 40 CL to determine the T-levels, the C-levels start at T-level+10 CL and are increased over time until they are at the ECAP thresholds. Then after some time the T-levels are checked by measuring a sound field audiogram.

A multicentre study with 100 subjects (children) is ongoing (Ramos et al., 2003). The preliminary results (60 children) show no difference between preset map series and conventional mapping but a significant time saving, especially in the first fitting. This was a randomized trial (randomized for treatment) where the quality of the map was measured both with parental questionnaires and with sound field audiograms.

In adults this method does not work so well, presumably because they have some memory of the sound and dislike any map that is very different from what they remember. In other words: maybe they do not have the plasticity in their brain to adapt to the map, so we have to adapt the map to their brain.

Advantage: very quick, especially for the first map, no behavioural input needed.

Disadvantage: does not always give the best map, so that sometimes specific fine-tuning is needed and such maps should be checked at a later date. Not suitable for adults.

2.3.6 Shift method (or Smoorenburg) with ECAP profile.

Since this method was developed for Nucleus implants the terminology in this section is Nucleus focused. See Appendix 4 to convert CL to μA .

The shift and tilt method is based on a number of ideas and principles

First, Smoorenburg, like Plant et al, (2002), assumed that live mode fitting would give better results than arbitrary single-electrode bursts (Smoorenburg et al., 2002). However, Smoorenburg argues to apply this method not only to the C-levels but also to the T-levels.

Second, Smoorenburg assumed (as Brown et al., 2000) that although the correlation between T and C levels and ECAP thresholds is weak, the profile *shapes* have some correlation.

In an initial study, Smoorenburg et al. (2002) tested a fitting method that is based on these two assumptions. In this fitting method the following happens:

- 1) The ECAP threshold profile is measured.
- 2) The T-levels are set to the ECAP profile but dropped down until sub-threshold.
- 3) The C-levels are set just above T-level.
- 4) The processor is switched on in live mode.
- 5) Both T and C levels are increased until a soft auditory sensation is heard.
- 6) At this moment the T-level profile is fixed and only the C-level profile is increased further until the live sound is comfortably loud. This requires some sound input in the form of the audiologist speaking or a CD playing etc.

This fitting method resulted in some very interesting findings:

- A) The T-levels of the maps set in this way were on average very much lower (by around 25 CL) than conventional T-levels. This effect was mainly caused by temporal integration.
- B) In a group of 7 experienced users, there was no group mean significant change in performance, although 2 individuals performed better with their old map.

This is a clear indication that the exact position of the T-levels is not very important for the quality of the map.

A second study used a prospective balanced crossover design (AB/BA) and showed no significant difference between this mapping method and conventional mapping. A third study applied this mapping method to young children and the outcome was again the same: no difference in performance (most children

preferred the ECAP based map) but a large difference in required fitting time (Battmer et al., 2004).

Advantage: Fast. Takes temporal integration into account.

Disadvantage: Effect of very low T-levels may be suboptimal speech scores at very low levels, although data does not support this (Smooenburg et al., 2002). May not be accurate enough for some recipients.

2.3.7 Shift and tilt without ECAP profile

In the earlier study by Smooenburg et al. (2002) the T and C and ECAP data was also analysed using a principal component analysis. This analysis showed that more than 96% of the total variance in the data could be described by 2 components: one relating to the overall level of the profile (shift) and one related to the slope or tilt. It must be noted that although we use the terms shift and tilt, these are not linear straight shifts or tilts: they are profiles that come from the data of the group. For instance, a tilt will result in less tilt at the complete extremes of the array than what would be expected from a straight tilt.

The next step was not to look at the correlation between ECAP and T and C levels but to look at the correlation between shift and tilt in the ECAP and T and C level profile. As expected the correlation between ECAP and T and C shift was very low (0.64/0/39), however, the correlation between the T-level tilt and the ECAP tilt was significant and in the 0.82 range. This means that the ECAP could 'predict' the shape (albeit not the level) of the T-profile, which supports the ECAP based methods described above. However, a follow-up analysis on a larger dataset (Cafarelli Dees et al., 2005) did not show a significant correlation.

From these results Smooenburg proposed to use a method based on the average profile across clients (assuming the ECAP profile does not give any additional information) and using the shift/tilt:

- 1) T-level is set to the average profile.
- 2) C-level set just above T.
- 3) Whole profile (T and C) is dropped down until subthreshold.
- 4) In live mode the complete profile is increased (shifted up) until just audible.
- 5) T level is fixed; C level is increased (applying shift) until sound is comfortable.
- 6) To adjust for optimal sound quality a tilt to the C and or T levels can be applied.

Effectively it means we are describing the map as a linear combination of the two principal components.

There is no scientific approach to setting the tilt values yet, but anecdotal results show that a change in the tilt is clearly connected to a sense of 'timbre'.

Note that if better NRT becomes available and we DO find a significant predicting value in T-NRTs, the above method can be used also with the T-NRT profile instead of the average profile.

Advantage: Fast, no need for ECAP. Takes temporal integration into account.

Disadvantage: Effect of very low T-levels may be suboptimal speech scores at very low levels, although data does not support this (Smooenburg et al., 2002). May not be accurate enough for some recipients.

2.3.8 NRT vs Rate preference

As mentioned in the introduction, besides T and C levels there are other parameters that could be important for performance and client satisfaction. An important one is the rate of stimulation, we know that faster is not always better and that one person can do better with an 1800 Hz map and another can do better with an 500 Hz map. Shpak et al. (2004) performed a study where they tried to correlate auditory nerve recovery times (measured with NRT) to rate preference. Indeed, it was observed that in two groups, one that preferred faster rates, and one that preferred slower rates, there was a significant difference in average recovery time between the two groups.

However, the group that preferred slower rates (N=6) contained 4 congenitally deaf recipients, and the faster group (N=5) contained none, this may mean that the correlation is spurious, meaning that duration of deafness is the predictor for rate preference, not recovery. This needs further investigation.

2.3.9 Genetic algorithms

Cochlear (US) performed a study where they used a genetic optimisation algorithm to optimise map parameters (Lineweaver et al., 2004). T and C levels were not included in this method but a 'T-level modifier' of 20% was included. Furthermore it included things like rate, number of maxima, Q-level, etc. Genetic optimisation also includes spontaneous mutations.

Genetic optimisation means that you select a subset of parameters from a set that give the best results and then create descendents that are a combination of the parameters that were selected. This process is designed to mimic a natural evolution process (survival of the fittest).

In practice, in the study, the recipients needed to select 4 maps from a group of 8. The software then creates 8 new maps and the process repeats.

In the first pilot experiment 5 experienced subjects were tested. All 5 converged to a map that was different from their original map but had no significantly different speech score. Convergence took up to 20 generations.

The fact that users converge to a map different from their own is a promising outcome, since generally recipients prefer the map that they are accustomed to.

This means that in theory they have the ability to find a map that is not just the default.

A second study is ongoing.

2.3.10 Self-fitting

There has been a lot of discussion over the years as to whether or not subjects can set their own (initial) map but very little data is available. The idea that a recipient sitting behind a PC can set his/her own map is attractive to some but for others seems unneeded, impersonal and even risky.

With the new arriving fitting techniques (streamlined, live fitting, etc) it has become a lot simpler to make maps so self-fitting should come closer. Only one study has been done to our knowledge, which is explained below.

2.3.11 PCIMAR

PCIMAR stands for Parametric Cochlear Implant Map Adjustment by Recipients (Roos et al., 2005). It was a project run at CTC in collaboration with Prof. Smoorenburg's group in Utrecht. A research processor was programmed in such a way that recipients could vary their own shift and tilt values (see section 2.3.6). In a small pilot trial 5 recipients were tested: they were first fitted with a standard 'ECAP shift' map by an audiologist and 3 weeks later they were tested. Then we 'unlocked' the shift and tilt profile buttons on the SP and asked people to optimise their own map. Speech testing was done before and after the recipient's own map adjustment period. Button presses were logged in the speech processor.

Although some took many more button presses than others, the results seem to indicate that they all converged to a map eventually. There was no performance difference between the original map, the audiologist shifted map and the PCIMAR map. However, most recipients preferred their own map and are still using it today.

2.3.12 Self-fitting

At CTC we are working on a simple user interface that allows people to set their own map using an adaptation of the streamlined fitting method (See section 2.3.2). No data is available at this point.

2.4 Summary and conclusions: current fitting methods

This document does not intend to give an opinion on which fitting method is best, the idea of this document is to summarize the available ideas so the reader can have an informed opinion and is pointed to locations for further study. However there are a few general remarks we can make in summary.

There are a lot of different fitting options and none of them have proven to be superior in terms of performance (not even classical 'all-electrode' fitting). For

setting T and C levels, live fitting methods seem to hold the biggest promise since they are quick and use a realistic signal for fitting. The combined data point towards the fact that *for a group* the exact setting of T-levels are not all that important and that individual electrode psychophysics testing is not per se better than any other method. Anecdotal evidence however, does indicate that for some individuals a precise setting of T and C levels can be important. There seems to be no obvious indicator at the moment to which recipients need manual fitting and which can be helped with fast fitting methods. This is an important research field for the future. There is no conclusive answer to the question whether or not using an NRT profile creates a better map, however, NRT certainly has its value in fitting since it can give guidance for initial map setting. Only one method has been tried so far (to my knowledge) that optimises parameters other than T and C levels. This genetic optimisation method may prove to be useful but we need more data to conclude this.

There seems to be some merit in self-fitting but it seems unlikely that we can ever create the perfect map from objective measures only; interaction with the recipients will remain needed.

2.5 Identified needs for new fitting methods

Two interrelated recent developments in the CI field raise the need for additional approaches to fitting. These are A) the increasing use of two bilateral cochlear implants (e.g., Long et al., 2003; Muller et al., 2002; Nopp et al., 2004; Tyler et al, 2002) and B) a major increase in interest in the combined use of a cochlear implant with a contralateral or ipsilateral acoustic hearing aid (e.g., Ching et al., 2001, Ching et al., 2004, Hamzavi et al., 2004). The main challenge of these developments for fitting is to ensure that the implant user can effectively combine and integrate information from the two prostheses. One promising approach to a more optimal combination of information from two prostheses is to develop a more complete understanding of the effects of any mismatching of acoustic frequency to cochlear place mapping between two prostheses. Even with a single cochlear implant it is clear that acoustic frequency to cochlear place mapping can have major effects on benefit (e.g., Fu and Shannon, 1999, 2002; Shannon, Zeng & Wygonski, 1999). However these effects appear to be substantially reduced with experience (Rosen, Faulkner and Wilkinson, 1999). The importance of mismatches between two ears, with either two bilateral implants or with an implant combined with a bilateral hearing aid, is little understood and merits investigation.

2.6 Synergies in fitting methods for cochlear implants and hearing aids

As the joint fitting of cochlear implants and acoustic hearing aids becomes more common, it is likely that fitting approaches for these two classes of prosthesis will become more closely linked. This seems especially likely in the use of perceptual testing methods (e.g. speech reception in noise) in the fine-tuning of prostheses.

2.7 References (for part 2)

- Battmer et al. (2004), Evaluation of Nucleus NRT based Speech Processor fitting in Children, poster presentation at the 8th international CI conference, Indianapolis 2004.
- Brown, C.J., Hughes, M.L., Luk, B., Abbas, P.J., Wolaver, A. & Gervais, J. (2000) The relationship between EAP and EABR thresholds and the levels used to program the Nucleus 24 speech processor: data from adults. *Ear and Hearing*, 21, 151-163.
- Cafarelli Dees et al. (2005) Normative findings of ECAP Measurements, *Audiology and Neurotology* 10:105-116.
- Ching, T. Y. C., Psarros, C., Hill, M., Dillon, H., & Incerti, P. (2001). Should children who use cochlear implants wear hearing aids in the opposite ear? *Ear and Hearing*, 22, 365-380.
- Ching, T. Y. C., Incerti, P., & Hill, M. (2004). Binaural benefits for adults who use hearing aids and cochlear implants in opposite ears. *Ear and Hearing*, 25, 9-21.
- Craddock et al. (2003) Comparison between NRT-based maps and behaviorally measured maps at different stimulation rates- A multicentre investigation. *Cochlear Implants International*, 4:161-170.
- Fu, Q. J. & Shannon, R. V. (1999). Recognition of spectrally degraded and frequency-shifted vowels in acoustic and electric hearing. *Journal of the Acoustical Society of America*, 105, 1889-1900.
- Fu, Q. J. & Shannon, R. V. (2002). Frequency mapping in cochlear implants. *Ear and Hearing*, 23, 339-348.
- Hamzavi, J., Pok, S. M., Gstoettner, W. F., & Baumgartner, W. D. (2004). Speech perception with a cochlear implant used in conjunction with a hearing aid in the opposite ear. *International Journal of Audiology*, 43, 61-65.
- Iwaki, T., Matsushiro, N., Mah, S. R., Sato, T., Yasuoka, E., Yamamoto, K. I., & Kubo, T. (2004). Comparison of speech perception between monaural and binaural hearing in cochlear implant patients. *Acta Oto-Laryngologica*, 124, 358-362.
- Lineweaver et al. (2004). Patient driven map optimization using Genetic Algorithm. CI2004 conference, Indianapolis 2004, USA.
- Long, C. J., Eddington, D. K., Colburn, H. S., & Rabinowitz, W. M. (2003). Binaural sensitivity as a function of interaural electrode position with a bilateral cochlear implant user. *Journal of the Acoustical Society of America*, 114, 1565-1574.
- Muller, J., Schon, F., & Helms, J. (2002). Speech understanding in quiet and noise in bilateral users of the MED-EL COMBI 40/40+cochlear implant system. *Ear and Hearing*, 23, 198-206.
- Nopp, P., Schleich, P., & D'Haese, P. (2004). Sound localization in bilateral users of MED-EL COMBI 40/40+cochlear implants. *Ear and Hearing*, 25, 205-214.
- Plant, K & Psarros, C. (2002) Comparison of a standard and interpolation method of T- and C-level measurement, using both narrowly-spaced and widely-spaced electrodes, Cochlear White paper, Jan 2002.

- Plant et al., (2004) Evaluation of streamlined programming procedures for the Nucleus 24 Contour, 2004 Cochlear Collaborative Research Report, p.28.
- Ramos et al. (2003), Evaluation of initial fitting of children based on intra-operative NRT, poster presentation at CIAP 2003.
- Roos et al. (2005) Parametric Map Adjustment by Recipients. Meeting of the Dutch Society for Audiology. Jan 2005, Utrecht, the Netherlands.
- Rosen, S., Faulkner, A., & Wilkinson, L. (1999). Perceptual adaptation by normal listeners to upward shifts of spectral information in speech and its relevance for users of cochlear implants. *Journal of the Acoustical Society of America*, 106, 3629-3636.
- Shannon, R. V., Zeng, F.-G., & Wygonski, J. (1998). Speech recognition with altered spectral distribution of envelope cues. *Journal of the Acoustical Society of America*, 104, 2467-2476.
- Shpak et al. (2004) Objective measurements of auditory nerve recovery function in Nucleus CI24 implantees in relation to subjective preference of stimulation rate. *Acta Otolaryngology*, 124; 582-586.
- Smooenburg et al. (2002) Speech perception in Nucleus CI24M Cochlear Implant Users with Processor Settings based on Electrically Evoked Compound Action Potential Thresholds, *Audiology and Neurotology*, 7:335-347.
- Tyler, R. S., Gantz, B. J., Rubinstein, J. T., Wilson, B. S., Parkinson, A. J., Wolaver, A., Preece, J. P., Witt, S., & Lowder, M. W. (2002). Three-month results with bilateral cochlear implants. *Ear and Hearing*, 23, 80S-89S.
- Wilson, B. S. (1993). Signal processing. In R.S.Tyler (Ed.), Cochlear Implants: Audiological Foundations (San Diego: Singular Publishing Group.
- Wilson, B., Finley, C., Lawson, D., Wolford, R., Eddington, D., & Rabinowitz, W. (1991). Better speech recognition with cochlear implants. Nature, 352, 2.

3 Appendixes

3.1 Appendix 1: Model procedures

3.1.1 Germany (DE-HZO)

The description of common German rehabilitation procedures was given by the partner DE-HZO. The description is based on the content of teaching hearing aid professionals in Germany.

Pathway hearing aid rehabilitation:

1st date: 1-1.5 hours

- Welcome
- Anamnesis
- Otoscopy
- Audiometry: Pure-tone and speech (via headphones)
- Counselling interview
- Taking impression
- Hearing aid selection
- Prescriptive fitting due to pure-tone audiogram

2nd date: 45-60 min

- Checking earmould (finishing if necessary)
- First fine tuning
- Speech audiometry via loudspeakers with and without hearing aid, possibly aided tone audiogram
- Explaining and training handling

3rd date and further dates (until user is satisfied): 30 min

- Comparative fitting with different hearing aids
- Prescriptive fitting due to pure-tone audiogram
- Fine tuning
- Speech audiometry via loudspeakers with hearing aid

Between 2nd and final date the hearing aids are tested at home for 1 to 2 weeks

Final date: 1 hour

- Final speech audiometry
- Possibly real-ear measurements or loudness scaling

- Fitting documentation
- Handing out warranty certificates and invoice

Status quo measurements at hearing aid acoustician in Germany

Pure-tone audiometry: air and bone conduction thresholds, UCL

Speech audiometry:

Headphones: Hearing loss in dB with numerals in quiet (difference individual SRT to normal SRT), intelligibility in percent with monosyllabic words, UCL for speech (numerals or monosyllabic words)

Loudspeakers: Intelligibility at 65 dB with and without hearing aid (monosyllabic words)

Aided audiogram

Real-ear measurements: Open ear gain at 65 or 70 dB; insertion gain (1m distance) at different levels, often 50, 65, 80 dB; input-output function

Loudness scaling

Test box: input-output function, gain frequency response at 50, 65, 80 dB

Aim of hearing aid fitting

„The aim of hearing aid fitting could not be globally formulated because of different characteristics of hearing deficits and different expectations of the hearing aid. However, the extensive reconstruction of the ability to communicate should be mentioned in the first place.“ (Lehnhart, 2001)

Inexperienced hearing-aid users

Aim: acceptance of hearing aid, therefore fitting based on loudness perception rather than maximizing intelligibility

Theory:

6 point program by Keller:

3 points should be fulfilled for a successful fitting

1. Maximum intelligibility in quiet should be reached at 65 dB (via loudspeakers)
2. SRT in quiet (numerals) should be reduced by minimum 10 dB
3. Maximum intelligibility in quiet should not be less than unaided
4. Intelligibility functions for monosyllabic words and numerals in quiet should be steeper than unaided and be closer together

5. Numerals should be tolerated at 90 or 100 dB (via loudspeakers)
6. Intelligibility function for monosyllabic words in quiet should be monotonically increasing

Practice:

- Loudness perception
- Usability of hearing aid
- One hearing aid: Maximum intelligibility in quiet should be reached at 65 dB (via loudspeakers)
- Two hearing aids: Intelligibility in noise (monosyllabic words, noise level 60 dB or 40 dB if discrimination loss exceeds 30%, SNR: 5dB) should increase by minimum 10% compared to one hearing aid

Variations possible in earmoulds

Vent size:

0.5-0.8 mm: ventilation, pressure equalisation

1.0-1.8 mm: frequency shaping (low cut)

2.0-4.0 mm: high frequency hearing loss (low cut), gain reduction at 500 Hz up to 30 dB

If own voice too dull: extending venting

Y-vent: vent and sound bore converge; only applied if space is tight

Sound bore profile:

Libby horn: diameter increases from 2 mm to 3, 4, or 5 mm: passive amplification of high frequencies up to 15 dB

Bakke horn: bracket with diameter increases from 2 mm to 3 mm, sound bore increases to 4 mm: same effect as Libby horn

Tubing: diameter 1, 2, or 3 mm: better transmission of high frequencies with increasing diameter

Dampers: to be introduced in earhook to reduce resonance peaks; sometimes integrated in special earhook

Material:

Acrylic: hard earmould, possibly with anti-allergenic surface coating

Silicone: soft earmould, often used for children, but not if often otitis media

Thermotec: hard earmould that softens in contact with ear canal.

Gold or titanium in case of allergies

Literature

Lehnhardt, E. (2001), „Praxis der Audiometrie“, 8. Auflage, Thieme, Stuttgart

Voogdt, U. (1998) „Otoplastik“, 2. Auflage, Medion-Verlag von Killisch-Horn GmbH

Jens, U. (2001) Hörgeräte-Akustik, 1. Auflage

Documents of Vocational School for Hearing Aid Acousticians, Lübeck

Documents of University of Applied Science Oldenburg, Ostfriesland, Wilhelmshaven, subject hearing technology (Prof. Dr. Holube)

3.1.2 England (UK-RNID)

In the UK there are two types of hearing aid service – the public sector and the private sector. The public sector service is free of charge. The service in the UK has recently undergone a change and the procedures detailed below are currently being carried out by public sector staff in England. The private sector is completely separate and involves payment for hearing aids. Hearing aid dispensers who work in the private sector are regulated by a different professional body to those in the public sector. However, exact procedures tend to vary throughout the country in the private sector and so only the public sector procedures are summarised below.

1. First Assessment visit (at least 45 min)

Medical history, including manipulation ability, vision

Glasgow Hearing Aid Benefit Profile Part 1

Otoscopy

Pure Tone Audiometry (Air and bone conduction)

Uncomfortable loudness levels – are optional, according to local protocol

Tympanometry where indicated

Pre-fitting counselling, including modifying expectations if necessary

Discuss hearing aid options and agree type/model with client

Impression taking, choice of venting/tubing

2. Fitting (at least 45 min)

Check earmould for comfort/insertion ease – modify/file if necessary

Perform Real Ear Measurements (REM) to verify fitting to target by agreed protocol; adjust to target if required

Evaluate subjective sound quality (including own voice) and fine tune hearing aid if necessary

With aids on, teach client how to

- change battery
- operate controls
- switch between programmes
- insert and remove

- use loop

take care of aids

Advise on using and getting used to aids

Issue written information on the aids, local services, etc

Refer to Volunteer/user support service if exists

3. Follow up 8-12 weeks (at least 30 min)

Ask how client is getting on with their hearing aid(s)

Glasgow Hearing Aid Benefit Profile Part 2

Follow up on Glasgow responses, and ask about problems with insertion, comfort, sound quality, adequacy of loudness, loudness discomfort, noise intrusiveness, telephone use, battery life, cleaning.

Check use of different programmes, loop

Fine tune if necessary based on client's comments

REM if necessary

Assess need for hearing therapy or Assistive Listening Devices, further follow-up visits.

Modify programming of aid if necessary

Repeat REIR if programming changed

Check high level output (optional) using an 80dB stimulus

4. Aftercare

Clients are offered an open-access repair service, which they can use if they are experiencing any problems with their hearing aid.

Literature

MHAS Patient journey

(http://www.mhas.info/documents/Combinedsitepack/3.1_pxjourney.pdf)

Best Practice Standards document for adult audiology

(http://www.rnid.org.uk/pdfs/adult_audiology.pdf)

3.1.3 Netherlands (NL-AMC)

The procedures listed here represent the typical procedures used in an advanced Audiology centre in the Netherlands. Some less advanced centres may not make use of all of these procedures.

1 First assessment

At least 1 hour (ENT physician / Audiologist / Hearing aid professional)

Medical anamnesis

- Structured interview about medical history and complaints (e.g. sudden deafness, otitis media, ear pain, ear surgery, tinnitus, congenital hearing loss, dizziness).
- Otoscopy (optional)
- Tuning fork testing (optional)
- Tympanometry (optional)

Standard audiometry in quiet (headphones)

- Pure tone audiogram air and bone conduction with adequate masking.
- Uncomfortable loudness level (optional)
- Speech audiogram with monosyllabic words (complete performance intensity functions from threshold to uncomfortable loudness level)
- Comparison pure tone audiogram and speech audiogram.

Counselling and preliminary audiological talk

- Counselling/information about course of hearing aid provision.
- General information about assets and drawbacks of hearing aids, specific characteristics, possible applications.
- Free interview about problems and expectations.

Defining goals

- Defining goals for rehabilitation based on anamnestic data and the unaided measurements.
- Counselling about realistic expectations.

Technical options

- Choice of ear(s) to be fitted.

- Choice of type of hearing aid(s).
- Specification of type of earmould.

2 Hearing aid fitting

60 – 120 minutes in different sessions (usually the Hearing Aid professional)

First fitting can take place at the audiological centre (on the subject's previous earmould or on a temporary earmould) during the first visit, or at the hearing aid professional (usual procedure).

Preparation of the trial period (Hearing aid professional)

- Taking ear impression(s) by hearing acoustician.
- Ordering of appropriate hearing aid(s) and programming according to the desired settings.

First fit and fine tuning (Audiologist/Hearing aid professional)

- Prescriptive fitting of one or two hearing aids according to manufacturer or generic fitting rules (usually one basic aid with full reimbursement of the costs and one more complex hearing aid with an own financial contribution).
- First rating of speech intelligibility and sound quality.
- Fine tuning of at least one hearing aid (in several sessions).
- Insertion-gain measurements (optional, only at a few places).
- Transfer of preferred hearing aid(s) and settings to hearing aid acoustician (if fitting is conducted by audiologist).

Trial period

- Explanation of handling and care, service, and usage.
- Start of trial period in every day listening situations and counselling during the trial period.
- Based on the subject's feedback during the trial period the hearing aid settings can be fine-tuned.
- During the trial period different steps of the adaptation manager can be followed.

Selection

- The subjectively favoured hearing aid is measured as result of fitting. If several hearing aids are rated subjectively the same, a sentence test in noise or a loudness scaling can be comparatively performed (optional).

3 Evaluation measurements

At least 15 minutes (Audiologist/Hearing aid professional)

Speech audiometry in quiet (sound field)

- Intelligibility scores for CVC-words measured for each individual aided ear (contra-lateral ear blocked) and for both ears bilaterally fitted with hearing aids, if applicable. The speech is presented at 65 dB SPL, and the hearing aids are used in the preferred gain setting.

Insertion-gain measurements (only in a few centres)

- The selected hearing aids are characterised with real-ear measurements using a broadband speech noise one or two levels: 65, and 80 dB SPL. The hearing aids are used in the preferred gain setting. The hearing aids are measured after deactivation of noise reduction circuitry in an omni-directional mode. The curves obtained are compared with generic prescription rules for non-linear hearing aids (usually NAL-NL1 or DSL i/o).

Additional rehabilitation needs

- Counselling about other training (speech-reading, hearing strategies and communication training).
- Strategies to encourage the client to wear the hearing aids.
- Determine need of other actions (compare expectation with achieved aims), e.g. audiological therapy, psychosocial consulting.

4 Follow up

Duration is difficult to estimate for the 5 –7 years of the lifetime of the hearing aids (Hearing aid professional)

Closing of provision

- Explain handling and care of the hearing aid to the user
- Arrange regular checkups
- Hearing pass as documentation for the user
- Present information about accessories to the user
- Complete formal fitting documentation

Follow-up appointments along 5 years

- 2 check-up dates (hearing device) per year
- 2 check-up dates (handling) per year

- 2 check-up dates (outer ear with and without hearing device with regards to dents and skin irritation)
- Service

3.1.4 Fitting rules available in hearing aid company software

Hearing aid company	Hearing aid type	Acoustic parameters to be filled in fitting software	Available fitting rules	Is other input necessary besides the audiogram?	Extra features of fitting software
Audio Service	Targa, Protecvoyage, Protec Mezzo, KaratTechnoD, Karat ProLingo, Karat Millenium, Arena	Venting, horn, rest volume	DSLi/o, NAL-NL		Choice of acclimatization steps 1 to 4; loudness correction; Gain reserve; Children provision
	Karat compra 703	Venting, horn, rest volume	Berger, NAL-NL1, NAL-RP POGO II, HV/2, HV/3 FIG6, DSLi/o,		Choice of acclimatization steps 1 to 4; loudness correction; Gain reserve; Children provision
Bernafon	Symbio, Smile, Neo, Flair, Audioflex	Proposal of venting, tube, rest volume, hook	NAL-NL1, DSLi/o, NAL-RP, Bernafon Loudness Normalisation		Feedback manager; Gain reserve
GNResound	Danalogic 163 D, Danalogic 501D	Venting, tube	Logic, Logic 1 st (for inexperienced user), Custom		Noise Reduction light/strong; Feedback manager; Directional, Telecoil, 3Progamme; Scal-Adapt = loudness scaling
	Danalogic 501, Danalogic 181	Venting	See Danalogic 163 D		Noise Reduction light/strong; Feedback manager; Directional, Telecoil, 3Progamme; Scal-Adapt = loudness scaling
	Danasound 163	Venting, tube	S2000R, NAL+WDRC, POGO+WDRC Loudness, HL-MCL-UCL, DSLi/o, NAL-NL1, POGOII, Berger, HV/2, HV/3, Custom		Noise Reduction light/strong; Feedback manager; Directional, Telecoil, 3Progamme; Scal-Adapt = loudness scaling
	Danasound 163S, Danasound 173	Venting, tube	See Danasound 163		Scal-Adapt = loudness scaling

Hearing aid company	Hearing aid type	Acoustic parameters to be filled in fitting software	Available fitting rules	Is other input necessary besides the audiogram?	Extra features of fitting software
GNResound	Danasound 151, Consertina	Venting	See Danasound 163		Scal-Adapt = loudness scaling
	Danasound 163 V	Venting, tube	NAL, POGOII, Berger, HV/2, HV/3, Custom		
	NewTon		Audiogram+, Custom		Aventaguide
	Canta 2, Canta 4		Audiogram+		Adaptive feedback manager ; Directional; In situ scaling
	Canat 7		Audiogram+		Laser, Adaptive feedback manager; Light/moderate/strong noise reduction; In situ scaling
	Resound Air		Audiogram+		Expansion, Stabilizer; light noise reduction; In situ scaling
Hansaton	Vital , Activo	Venting, horn rest volume, hook	NAL-NL1, DSLi/o		Acclimatization steps 1 to 4; Loudness correction; Gain reserve; Children provision
	StarLite	Venting, horn rest volume, hook	NAL-NL1, DSLi/o + gain reserve by potentiometer		Trimpots SP-F, SP-LE
	Premio, Leonardo	Venting, horn rest volume, hook	NAL-NL1		Acclimatization steps 1 to 4; Loudness correction; Gain reserve; Children provision
Interton	Bionic, IQ EVO, Staris, D	Venting	DynaGraph, DynaGraph-HF, DSLi/o, NAL, Berger, POGOII		Acclimatization steps 1 to 3

Hearing aid company	Hearing aid type	Acoustic parameters to be filled in fitting software	Available fitting rules	Is other input necessary besides the audiogram?	Extra features of fitting software
Oticon Software Oticon	DigiFocus II	Proposal of venting	ASA2 (adaptive speech fitting), Ski		Acclimatization steps 1 to 3; Cosi questionnaire
	DigiFocus	See DigiFocus II	See DigiFocus II		Acclimatization steps 1 to 3
	DigiLife	See DigiFocus II	WDRC+, MF+		Acclimatization steps 1 to 3
	Digilife com	See DigiFocus II	WDRC+, MF+		Acclimatization steps 1 to 3
	Ergo, Swift	See DigiFocus II	NAL-RP, POGOII, SSM, Corell		Acclimatization steps 1 to 3
Oticon Software Genie	Go	Venting, tube	NAL-NL1		Fitting manager steps 1 to 3
	Sumo	Venting, tube, hook	DSL _i /o, POGOII + BC, NAL-RP, Corell2, SSM		Fitting manager steps 1 to 3
	Atlas	Venting, tube, hook	DSL _i /o, NAL-NL		Choice with/without potentiometer; Fitting manager steps 1 to 3
	Gaia	Venting, tube, hook	Gaia, DSL _i /o, ASA2, NAL-NL1		Fitting manager steps 1 to 3
	Adapto	Venting, tube, hook	Fast, SKI, Slow, Linear MC		Fitting manager steps 1 to 3 , VoiceFinder
	Synchro	Venting, tube, hook	Fast, SKI, Slow, Linear MC		Fitting manager steps 1 to 3; Directional modi
Philips	D71, D61		DSL _i /o		Algorithm spaceline 10, 20, 40 (different gains)
	D71S, D70E		NAL 90		Algorithm spaceline 10, 20, 40 (different gains)
Phonak	Astro	Venting	NAL-RP, POGO, Libby 1/3 – 2-3, Berger, Keller, proprietary, target gain MPO		
	Eprom, Pics, Pics 2	Venting, tube, hook	NAL-RP, POGO, Libby 1/3 – 2-3, Berger, Keller, proprietary, target gain MPO		

Hearing aid company	Hearing aid type	Acoustic parameters to be filled in fitting software	Available fitting rules	Is other input necessary besides the audiogram?	Extra features of fitting software
	Solo, Maxx, Aero, Valeo	Venting, tube, hook	Phonak Digital, Phonak Digital Ski Lope/Open, DSLi/o, NAL-NL1		RECD measurement
Phonak	Supero	Venting, tube, hook	Phonak Digital Power, Phonak Digital Power+, DSLi/o, NAL-NL1		RECD measurement
	Claro, Perseo	Venting, tube, hook	Phonak Digital, Phonak Digital Ski Lope/Open, DSLi/o, NAL-NL1	Loudness profile as an option	RECD measurement
Siemens	Triano, Signia, S3, S2, S1	Venting, rest volume, hook, tube	NAL-NL1, NAL-RP, DSLi/o, POGO, HV/2, HV/3, FIG6, Berger		Acclimatization steps 1 to 4; Children provision? Simulated insertion gain display, 2cc coupler display, ear simulator display
	Music, Prisma	Venting, rest volume, hook, tube	NAL-NL1, DSLi/o		See Triano
	Acuris	Venting, rest volume, hook	NAL-NL1, DSLi/o + Reserve + Potentiometer area		Acclimatization steps 1 to 4; Children provision? Simulated insertion gain display, 2cc coupler display, ear simulator display; REUG, RECD
Unitron	Liason, Conversa, Unison C/3/E	Query of venting and hook	DSLi/o, NAL-NL1		Query if inexperienced/experienced user Linear/WDRC; Long term user Linear/WDRC Gain reserve Gain by potentiometer
	Unison 4/2	See Liason	DSLi/o, NAL-NL1		Query if binaural fitting, inexperienced user or prior linear hearing aid
Widex	Diva, Vita, Senso C, Senso C+		Proprietary	Sensogram feedback test	Children provision?
	Senso P3 Kanal, Senso P 2 Kanal		Proprietary	Feedback test	See Vita

3.2 Appendix 2: Questionnaire

The following questionnaire was proposed by DE-HZO and sent to the partners. The questionnaire is intended to determine the status quo in hearing aid fitting. The adaptations of the partners will be incorporated in the questionnaire.

Goal of hearing aid rehabilitation			
1) Which strategy do you use for hearing aid fitting?			
<input type="checkbox"/> Maximising speech intelligibility (to reach maximum intelligibility at 65 dB in quiet in sound field) <input type="checkbox"/> Normalisation of loudness perception <input type="checkbox"/> Maximising subjective benefit <input type="checkbox"/> Trade off between speech intelligibility and normalisation of loudness perception <input type="checkbox"/> Other (please indicate the strategy below)			
2) How many different hearing aids per ear do you use on average in fitting one hearing impaired person?			
<input type="checkbox"/> 1 hearing aid	<input type="checkbox"/> 2 hearing aids	<input type="checkbox"/> 3 hearing aids	<input type="checkbox"/> more
3) Do you let hearing impaired customers try high quality hearing aids even though they have said that they do not want to spend an own financial contribution?			
<input type="checkbox"/> yes	<input type="checkbox"/> no	<input type="checkbox"/> depending on customer	
Earmould			
1) Do you follow the recommendation of the hearing aid company about the earmould? E.g. venting, horn, hook			
<input type="checkbox"/> yes, always	<input type="checkbox"/> yes, sometimes	<input type="checkbox"/> no	
Reasons:			
2) Do you include the earmould characteristics in the gain calculation, if the hearing aid company asks for it?			
<input type="checkbox"/> yes, always	<input type="checkbox"/> yes, sometimes	<input type="checkbox"/> no	

Reasons:		
Choice of fitting rule		
1a) Do you use the fitting rule proposed by the hearing aid company?		
<input type="checkbox"/> yes, always	<input type="checkbox"/> yes, sometimes	<input type="checkbox"/> no
1b) Do you use another fitting rule of your choice?		
<input type="checkbox"/> yes, always	<input type="checkbox"/> yes, sometimes	<input type="checkbox"/> no
2) If the hearing aid company provides both proprietary and generic fitting rules like e.g. NAL, do you use the proprietary or the generic fitting rules?		
<input type="checkbox"/> Proprietary	<input type="checkbox"/> Generic	<input type="checkbox"/> both
2a) Which fitting rules except the proprietary rules do you use?		
Answer:		
2b) Would it help you if all hearing aid companies would use the same fitting rule for a better comparison of hearing aids?		
<input type="checkbox"/> yes	<input type="checkbox"/> no	
3) If the hearing aid companies provide extra tests or materials, do you use these?		
<input type="checkbox"/> yes, always	<input type="checkbox"/> yes, sometimes	<input type="checkbox"/> no
Reasons:		
Fitting		
1) Do you change the preset of the hearing aid companies already before the fitting? E.g. increase the gain		
<input type="checkbox"/> yes, always	<input type="checkbox"/> yes, sometimes	<input type="checkbox"/> no
1a) If you change the preset, what do you mostly change?		
Answer:		
2) Do you use the expert/enhanced mode for hearing aid fitting?		

<input type="checkbox"/> yes, always	<input type="checkbox"/> yes, sometimes	<input type="checkbox"/> no
Reasons:		
Fine tuning		
1) What are the most common reasons why you perform fine tuning? Please order by numbering		
<input type="checkbox"/> Unnatural own voice <input type="checkbox"/> Speech in quiet not intelligible well enough <input type="checkbox"/> Speech in noise not intelligible well enough <input type="checkbox"/> Sound of hearing aid <input type="checkbox"/> Difficulties in traffic		
Others:		
2a) On average, how often do you perform fine tuning per hearing aid?		
<input type="checkbox"/> 1 – 2 times	<input type="checkbox"/> 3 – 4 times	<input type="checkbox"/> more than 4 times
2b) What do you change during fine tuning?		
<input type="checkbox"/> Setting of hearing aid	<input type="checkbox"/> Rectification of earmould	<input type="checkbox"/> both
2c) What do you change more often?		
<input type="checkbox"/> Setting of hearing aid	<input type="checkbox"/> earmould	
Evaluation measurements		
1) Do you use the Freiburger speech test (monosyllables) in quiet at 65 dB in sound field?		
<input type="checkbox"/> yes	<input type="checkbox"/> no	
2) Do you use another speech test in quiet?		
<input type="checkbox"/> yes	<input type="checkbox"/> no	
2a) If yes, which speech test do you use?		
Answer:		

3) Do you use the Freiburger speech test (monosyllables) at 65 dB in sound field with noise?	
<input type="checkbox"/> yes	<input type="checkbox"/> no
4) Do you use another speech test in noise?	
<input type="checkbox"/> yes	<input type="checkbox"/> no
4a) If yes, which speech test do you use?	
Answer:	
5) Do you perform real ear measurements?	
<input type="checkbox"/> yes	<input type="checkbox"/> no
5a) If yes, which measurements do you perform?	
Answer:	
6) Do you perform loudness scaling?	
<input type="checkbox"/> yes	<input type="checkbox"/> no
7) Do you measure the aided audiogram?	
<input type="checkbox"/> yes	<input type="checkbox"/> no
8) Do you use questionnaires?	
<input type="checkbox"/> yes	<input type="checkbox"/> no
8a) If yes, which questionnaires do you use?	
<input type="checkbox"/> benefit	<input type="checkbox"/> satisfaction
Others:	
9) Do you perform other measurements that have not been mentioned here?	
<input type="checkbox"/> yes	<input type="checkbox"/> no
9a) Which ones?	
Answer:	

3.3 Appendix 3: Further details of HearCom proposals on optimal procedures by partner

3.3.1 DE-HZO

Loudness scaling

ACALOS: Adaptive CAtegorical LOudness Scaling that updates the individual dynamic range estimate on line within the measurement in order to optimally place the presentation levels. Curved model functions are used to describe the individual loudness curves (Brand, T. and Hohmann, V. 2001. Effect of Hearing Loss, Center Frequency and Bandwidth on the Shape of Loudness Functions in Categorical Loudness Scaling. *Audiology*. No 40 (2), p. 92-103 ; Brand, T. and Hohmann, V. 2002. An adaptive procedure for categorical loudness scaling. *J. Acoust. Soc. Am.* No 112 (4), p. 1597-1604)

Questionnaires:

Oldenburg Inventar I: Description of five individual situations where hearing and understanding is important for the hearing impaired user. Rating of hearing problems in these situations.

Oldenburg Inventar R: Rating of hearing problems in 12 given situations (hearing in quiet, in noise, directional hearing)

Hörgeräte-Bewertung: 17 questions about overall rating of hearing aid provision (with regard to usage, adaptation, effort of listening, handling, wearing comfort, design, speech intelligibility, sound, own voice, loudness, wind sounds, feedback, telephone, overall satisfaction)

Speech tests:

Freiburg numbers and monosyllabic words: Word lists with either 10 double-digit numbers or 20 monosyllabic words each. (Hahlbrock, K. 1953: Über die Sprachaudiometrie und neue Wörtertete. *Archiv Ohren-, Nasen- und Kehlkopfheilkunde*. No 162, p. 394-431)

Göttingen sentence test: Sentence lists with meaningful sentences (Kollmeier, B. and Wesselkamp, M. 1997: Development and evaluation of a German sentence test for objective and subjective speech intelligibility assessment. *J. Acoust. Soc. Am.* No 102 (4), p. 2412-2421)

Oldenburg sentence test: Sentence lists with syntactically fixed but semantically unpredictable sentences (Wagener, K., Brand, T., Kühnel, V. and Kollmeier, B. 1999. Entwicklung und Evaluation eines Satztests für die deutsche Sprache I-III: Design, Optimierung und Evaluation des Oldenburger Satztests. *Zeitschrift für Audiologie*. No 38 (1-3), p. 4-15, 44-56, 86-95)

Adaptive Procedure to determine SRT in noise: adaptive procedure with decreasing step size converging to 50% intelligibility within 20 sentences (Brand, T. and Kollmeier, B.. 2002. Efficient adaptive procedures for threshold and concurrent slope estimates for psychophysics and speech intelligibility tests. *J. Acoust. Soc. Am.* No 111 (6), p. 2801-2810)

Performing unaided and aided measurements:**3 to 5 measurements**

Benefit verification of monaural or binaural hearing aid provision

Sentence test, adaptive SRT, noise presentation level 65 to 75 dB SPL depending on hearing loss, same noise level for all measurements

Stationary speech shaped noise.

Benefit must exceed twice the intra-individual standard deviation of the test to be significant.

Monaural fitting: Measurements 1 and 2

If result of aided measurement 2 is significantly better than unaided measurement 1, finished.

If result of aided measurement 2 is worse than unaided measurement 1, refitting.

Binaural fitting: Measurements 1-3, if necessary, measurements 4-5

Example benefit of binaural fitting versus monaural fitting left side:

1. S0N90 unaided

2. S0N90 monaurally aided (left side), right side unaided

3. S0N90 bilaterally aided

If result of 3. better than 2., finished (= benefit in all situations)

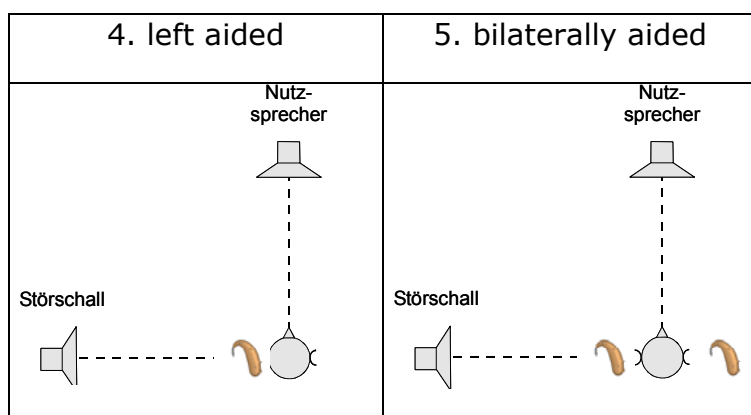
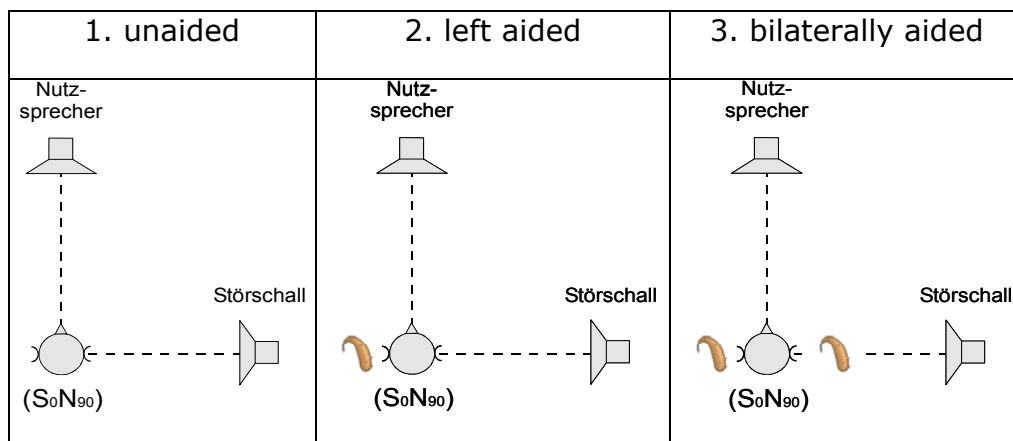
If result of 3. worse than 2., additional measurements:

4. S0N-90 monaurally aided (left side), right side unaided

5. S0N-90 bilaterally aided

If result of 5. better than 4. = benefit in some situations

If result of 5. worse than 4., refitting or only one hearing device due to the speech tests



Performing unaided and aided measurements:

3 to 5 measurements

benefit verification of monaural or binaural hearing aid provision

Göttingen or Oldenburg sentence test, adaptive SRT, noise presentation level 65 to 75 dB SPL depending on hearing loss, same noise level for all measurements

Stationary speech shaped noise.

Benefit must exceed twice the intra-individual standard deviation of the test to be significant.

Monaural fitting: Measurements 1 and 2

Binaural fitting: Measurements 1-3, if necessary, measurements 4-5

Example Monaural fitting left side:

1. S0N90 unaided
2. S0N90 monaurally aided (left side), right side unaided
3. S0N90 bilaterally aided

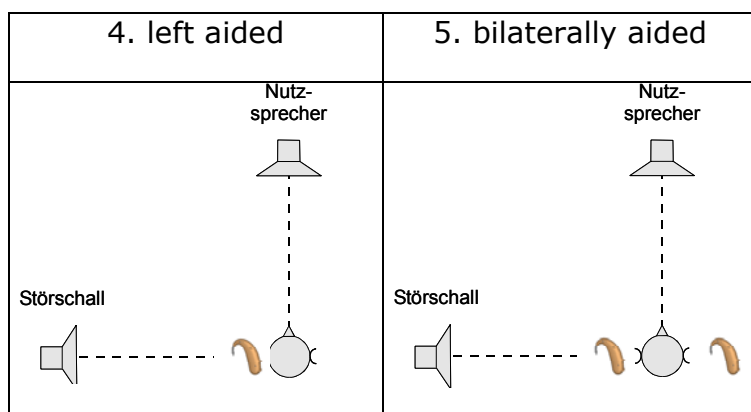
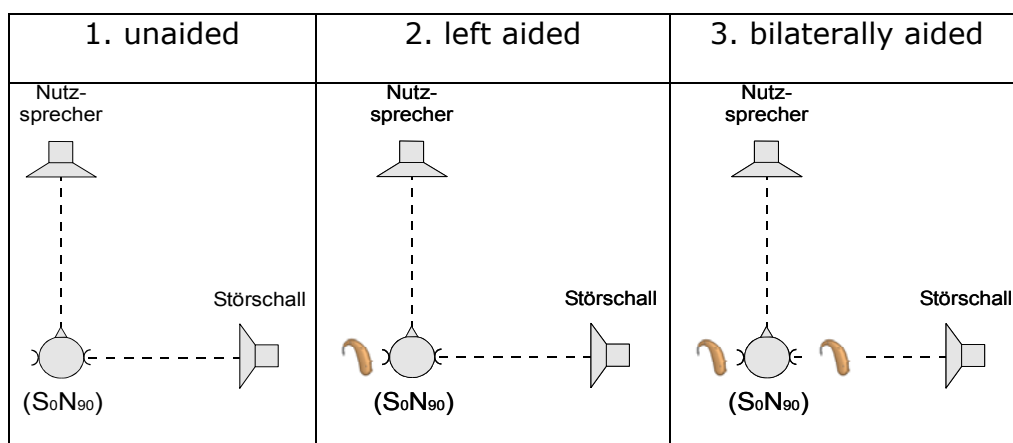
If result of 3. better than 2., finished (= benefit in all situations)

If result of 3. worse than 2., additional measurements:

4. S0N-90 monaurally aided (left side), right side unaided
5. S0N-90 bilaterally aided

If result of 5. better than 4. = benefit in some situations

If result of 5. worse than 4., only one hearing device due to the speech tests



3.3.2 NL-AMC

Further details of proposed methods for questionnaires and tests:

- Dutch version of the Glasgow Hearing Aid Benefit Profile (GHABP).

The GHABP is a self-report questionnaire for assessing aspects of auditory disability, auditory handicap, and hearing-aid benefit. The questions cover scales of initial disability, handicap, hearing aid use, hearing aid benefit, satisfaction, and residual disability.

Gatehouse, S (1999) "Glasgow Hearing Aid Benefit Profile: Derivation and validation of a client-centered outcome measure for hearing-aid services", *J Am Acad Aud*, Vol 10, 80-103.

- Speech, Spatial and Qualities of Hearing Scale (SSQ)

The SSQ is a questionnaire that was developed to measure influences of cochlear function on auditory disability and handicap. It is designed to be administered by interview instead of by self-completion.

Gatehouse S, Noble W (2004) "The Speech, Spatial and Qualities of Hearing Scale (SSQ)." *Int J Aud*, Vol 43, 85-99.

- Speech materials from Bosman and Smoorenburg

Bosman and Smoorenburg (1995) developed Dutch speech materials obtained from a female speaker. The materials consist of words of the consonant-vowel-consonant type (CVC syllables, both sense and nonsense words). The masking noise consists of stationary noise with the same long-term average spectrum as the speaker.

Bosman AJ, Smoorenburg GF. (1995) "Intelligibility of Dutch CVC syllables and sentences for listeners with normal hearing and with three types of hearing impairment.", *Audiology*, 34(5), 260-284.

- Speech materials from Plomp and Mimpen

Plomp and Mimpen (1979) developed Dutch speech materials for measuring the speech reception threshold (SRT) for sentences in quiet or noise. The materials consist of 10 lists uttered by a female speaker and include a stationary masking noise with the same long-term average spectrum as the speaker.

Plomp, R, Mimpen, AM (1979) "Improving the reliability of testing the speech reception threshold for sentences." *Audiology*, 18:43-52.

- Speech materials from Versfeld et al.

Versfeld et al. developed a large set of Dutch speech materials (both male and female speaker, each comprising 39 lists) for measuring the speech reception threshold (SRT) for sentences in quiet or noise. The masking noise

consists of stationary noise with the same long-term average spectrum as the speakers.

Additionally, fluctuating noise is available. This noise has the same long-term average spectrum as the speakers, and is modulated with a speech envelope in two independent frequency channels. The noise is constructed using the same procedure as Festen and Plomp (1990).

Versfeld, NJ, Daalder L, Festen JM, Houtgast T (2000) "Method for the selection of sentence materials for efficient measurement of the speech reception threshold." *J Acous Soc Am*, 107, 1671-1684.

Festen, JM, Plomp, R (1990) "Effects of fluctuating noise and interfering speech on the speech-reception threshold for impaired and normal hearing." *J Acous Soc Am*, 88, 1725-1736.

- ACALOS-procedure

The Adaptive CAtegorical LOudness Scaling (ACALOS) is an adaptive procedure for loudness scaling. The procedure adjusts the presentation levels to the subject's individual auditory dynamic range without employing any pre-measurement and presents levels in randomized order.

Brand T, Hohmann V (2002) "An adaptive procedure for categorical loudness scaling." *J Acoust Soc Am*, 112,1597-1604.

- International Outcome Inventory for Hearing Aids (IOI-HA)

The International Outcome Inventory for Hearing Aids (IOI-HA) is a seven-item survey for evaluation of hearing aid fitting outcomes.

Cox, R.M., Stephens, D., and Kramer, S.E. (2002) "Translations of the International Outcome Inventory for Hearing Aids (IOI-HA)." *International Journal of Aud*, 41(1), 3-26.

Kramer, S.E. Goverts, S.T., Dreschler, W.A., Boymans, M. and Festen, J.M. (2002) "International Outcome Inventory for Hearing Aids (IOI-HA): results from the Netherlands." *Int J Aud*, 41(1), 36-41.

- Amsterdam Inventory of Auditory Disability and Handicap (AIADH)

The Amsterdam Inventory of Auditory Disability and Handicap (AIADH) is designed to identify factors in hearing disability affecting individuals in daily life and assess the handicapping effect resulting from the disability.

Kramer, SE, Kapteyn, TS, Festen (1998). "The self-reporting handicapping effect of hearing disabilities." *Audiology*, 34, 167-199.

3.3.2.1 Guideline for focus groups with hearing aid professionals

1. Introduction (30 min)

a) 'Get-to-know-the-group-Matrix' (to be filled in on a poster)

My name is...	I have been a hearing aid professional since...	My expectations for this meeting...

All participants have to complete the Matrix after arriving.

b) Presenting intention and aim of the focus group, for example:

- To find out the ideal procedure for rehabilitation and fitting hearing aids
- Improvement of the situation for hearing impaired people
- Simplification and improvement of daily work

c) Introduction of the moderator (Name, profession, institute)

d) Introduction of the different roles in this meeting... (Flip chart)

Organizer:

- HearCom (short explanation: 'what is HearCom?')
- Institute Hörzentrum Oldenburg or analogue

Participants:

- Knowledge and experiences with the rehabilitation of hearing aids
- Ideas and visions are important for the discussion

Moderator:

- Leads the discussion
- Gives the structure
- Notes the outcomes
- Does not add content

e) Time schedule (Flipchart)

Duration: 4.5 hours with two breaks (20 min each) e.g.

„How we work together within this meeting...“

3 pm – approx 4.30 pm: part 1

4.30 pm – approx 4.50 pm: 1. coffee break → provide indication of snacks, drinks, toilets...

4.50 pm – approx 5.50 pm part 2

5.50 pm – approx 6.10 pm 2. coffee break

6.10 pm – approx 7.20 pm part 3

f) Rules and Organisation

- Character of the meeting: all participants account for the conclusion, everybody should participate in the discussion, every opinion is wanted
- Benefit: active exchange of different opinions, creative discussion, everyone has the possibility to articulate his ideas
- Outcomes are visualized on flip charts and posters
- The discussion is recorded on video/audio tape (letter of agreement has to be signed that the outcome is used for research purposes)

g) Presentation of the participants with the 'Get-to-know-the-group-Matrix'

2. Split up into two groups

2 moderators are needed (ca 60 min)

1. group discusses the unaided measurements and the hearing aid fitting
2. group discusses the aided measurements and the follow-up

First the groups should think about some higher ranking categories and their elements. All aspects are discussed and the group consensus is written on a poster. If important features of the HearCom proposals are overlooked by the group, the moderator should pick this out as a central theme.

-Break (20 min)

3. Presentation of the outcomes (ca. 60 min)

Both groups present their outcomes of the teamwork. The groups discuss and complete the findings. The additions are written on posters.

-Break (20 min)

4. Comparison HearCom Proposals vs. model of hearing aid professionals (60 min)

Someone presents the HearCom proposals – especially the differences to the model of the hearing aid professionals. Additions and interleaves are discussed and written on posters.

5. Final evaluation (10 min)

The participants should rate the value of the elements of the HearCom proposals (including the ideas of the hearing aid professionals).

Everybody gets e.g. 20 glue dots to arrange in their sole discretion to the elements.

6. Closing (10 min)

- Aspects of optimal rehabilitation that were not discussed yet?
- Acknowledgment of the results
- Short statements about the teamwork in the focus group and the conclusions.

3.3.3 Plans to collect hearing-aid user opinion

The outcome of the professional focus group discussions will be used in order to adapt the HearCom proposals. This will be done to ensure that nothing important is missing in the HearCom proposals. This extended opinion will be used as basis for the hearing-aid user focus group discussions at all partners. Within these focus group discussions the extended opinion is rated and additional hearing-aid user needs are collected. The focus group discussions will be performed with two different groups: experienced hearing aid users with hearing aids and inexperienced hearing impaired listeners without hearing aids. The satisfaction of the experienced hearing aid users with their current hearing aid fitting will be assessed by a questionnaire prior the discussion. The guidelines of the focus group discussions with the professional target group were determined by DE-HZO and are presented here.

DE-HZO plans to create short video sequences of some measurement procedures to support the explanation of these procedures to the hearing-aid users. It is important that the person who describes the procedures tries not to bias the hearing-aid users by describing the tests.

3.3.3.1 Guideline for focus groups with hearing impaired persons

0. Questionnaire on consumer satisfaction of hearing aid fitting (10 min), only for experienced hearing aid users

All ratings of the participants should be possibly related to the questionnaires.

1. Introduction (30 min)

a) 'Get-to-know-the-group-Matrix' (to be filled in on a poster)

My name is...	I have experienced hearing problems since...	I use hearing aids because... and since...	My expectations for this meeting...

All participants have to complete the Matrix after arriving.

b) Presenting intention and aim of the focus group, for example:

- To find out the ideal procedure for rehabilitation and fitting hearing aids
- Improvement of the situation for hearing impaired people
- Simplification and improvement of daily work of hearing aid professionals

c) Introduction of the moderator (Name, profession, Institute)

d) Introduction of the different roles in this meeting... (Flip chart)

Organizer:

- HearCom (short explanation: 'what is HearCom?')
- Institute Hörzentrum Oldenburg or analogue

Participants:

- Knowledge and experiences with the rehabilitation of hearing aids for hearing impaired people
- Ideas and vision are important for the discussion

Moderator:

- Leads the discussion
- Gives the structure
- Notes the outcomes
- Does not add content

e) Time schedule (Flipchart)

Duration: 3.5 hours with one break (30 min) e.g.

„ How we work together within this meeting...“

3 pm – approx 5 pm: part 1

5 pm – approx 5.30 pm: coffee break → provide indication of snacks, drinks, toilets...

5.30 pm – approx 6.30 pm part 2

f) Rules and Organisation

- Character of the meeting: all participants account for the conclusion, everybody should participate in the discussion, every opinion is wanted
- Benefit: active exchange of different opinions, creative discussion, everyone has the possibility to articulate his ideas
- Outcomes are visualized on flip charts and posters
- The discussion is recorded on video/audio tape (letter of agreement has to be signed that the outcome is used for research purposes)

g) Presentation of the participants with the 'Get-to-know-the-group-Matrix'

3. First appraisal (15 min)

Someone explains the parts of rehabilitation (unaided measurements, hearing aid fitting, aided measurements, follow-up).

The participants should appraise how much time they would spend for each step of the rehabilitation.

4. Rating by participants of rehabilitation elements

(150 min – incl. 30 min break)

It is important that the elements are colourfully described - with multi media.

The benefit of every element should be clearly defined.

First the participants should think about how much time they would spend for each element. Then the real time needed for the elements is described.

Example:

“One element is counselling and an audiological preliminary talk. Thereby the following will be brought up: ... How much time should be spend on this according to your opinion? ”

Estimate by the participants





Presentation of time effort needed







After one category is discussed the participants rate the value of the information gained from each element

Everybody gets e.g. 15 glue dots and can arrange them in their sole discretion to the elements.

Example:

Individual rating of value of unaided measurements (measurements should be explained in easy words)

	Duration	Individual rating of value
Counselling about hearing aid fitting, general information about advantages and disadvantages of hearing aids, special characteristics, possible applications	30 min	
Free interview about anamnesis (acute hearing losses, prior hearing-aids, analogue questionnaire short anamnesis)	10 min	
Definition of hearing aids to be considered	5 min	
Questionnaire to collect individual problems and aims:	5-10 min	

Interview professional/client: questionnaire about situations with existing hearing problems and with needs of better hearing (HörTech inventory I or COSI)		
+ questionnaire at home (HörTech inventory R: specific situations and associated hearing problems are collected)	5-10 min	
Examination of the ear: looking in the ear through a microscope, determination of hearing thresholds with pure tones via headphones and bone conduction (masking better ear with noise when asymmetric hearing loss), determination of level where pure tones become uncomfortable loud (via headphones)	20 min	
Determination of loudness perception: 3 noises with different pitches and a spoken sentence are presented at different levels; their loudness should be rated	10 min per ear	
Determination of ability to understand speech in quiet: 10 numerals are presented at two levels each (at least); determination of level where half of the numerals are correctly repeated; comparison with normal hearing result and with prediction of pure tone audiogram	5 min	
Determination of ability to understand speech in quiet: Level where spoken numerals are uncomfortable loud	5 min	
Determination of ability to understand speech in quiet: Intelligibility of single words at 65 dB SPL	5 min	
Determination of ability to understand speech in quiet: Optimal level for maximum intelligibility (20 single words at different levels each)	10 min	
Determination of ability to understand speech in noise: 20 sentences in total are presented via loudspeaker from the front, from the side a second loudspeaker presents noise; determination of speech level where half of the words are correctly repeated.	3 min	

5. Closing (10 min)

- Aspects of optimal rehabilitation that were not discussed yet?
- Acknowledgment of the results
- Short statements about the teamwork in the focus group and the conclusions.

3.4 Appendix 4: Conversion of Nucleus (Cochlear Corporation) current level (CL) units to microamps.

The conversion from μA to CL and vice versa is different between the CI22/CI24M/R family implants and the CI24RE (Nucleus Freedom) implant. All Nucleus Implants have a logarithmic current law as to ensure an increase of a certain amount of CL is always a multiplication of the current, in other words, a change in CL can always be linearly transformed in a current increase on the dB scale.

For the CI22 and CI24M/R implants (the implants used to do the research described in this document) the current law is:

$$I(\mu A) = 10 * 175^{CL/255}$$

and the inverse:

$$cl = \frac{255 * (\log(I(\mu A)) - 1)}{\log(175)}$$

a step of 1 CL therefore equals a 2.05% increase of current, which translates into 0.176 dB.

For the Nucleus Freedom implant the current law has been changed to give make finer tuning possible. It becomes:

$$I(\mu A) = 17.5 * 100^{CL/255}$$

Which translates into a 1.82% increase (or 0.157 dB) increase in current per CL step.

Figure A4 shows the CL vs Current relation graphically.

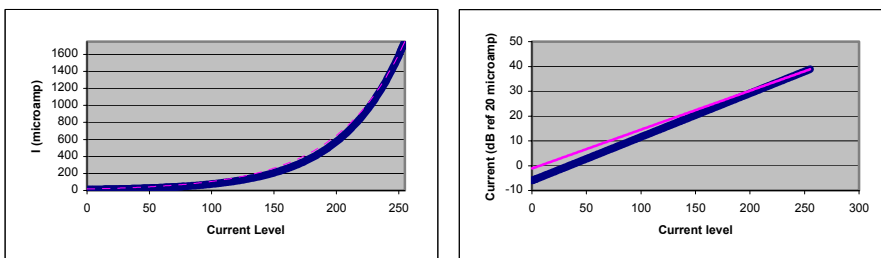


Figure A4: Current level vs Current (left) and dB Current (right) for the CI22/CI24M/R implant (heavy line) and the CI24RE (Freedom) implant (thin line).