Benefits of Common Vocabulary in Hearing Aid Fitting

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Background:

Modern hearing aids are very sophisticated devices and through the fitting process they can be adjusted to fit the hearing loss of a large variety of people. However, in order to set the fitting parameters right, the communication between the hearing aid professional and the user has to be successful. The challenge here is to understand and map the experience of the user in order to transfer it to the fitting software.

Today, hearing aid manufacturers has taken up the challenge by designing software handles whose function is less technical and more related to commonly experienced hearing aid problems. They have also added expert assistants to the software, mapping common user complaints into the traditional technical software handles. When it comes to perceived sound quality however, the challenge lies first and foremost in understanding the user's perception, to decode the sound experience of the user so to speak.

Optimal hearing aid sound
quality
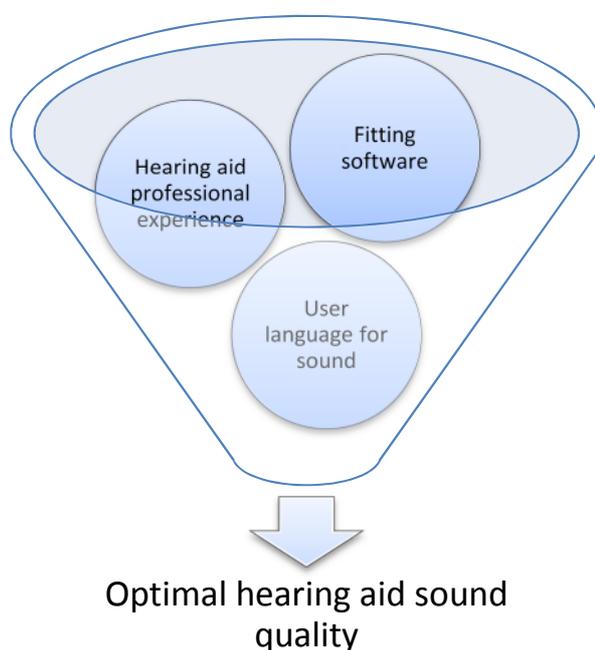
For this challenge the hearing aid professional must be experienced enough to understand the user's language of sound perception. Hearing aid professionals know that this can prove to be a complicated problem. As with many other perceptual experiences we are not used to express sound experiences in many more words than soft, loud, annoying or pleasant.

A common vocabulary between the user and hearing aid professional would probably make the task easier so rather than relying on the hearing aid professional's skills to understand the user's desire,

the user's vocabulary of sound perception could be trained (Figure 1). Inspiration for this alternative approach can be found in the sensory evaluation discipline, where selected panels train their ability to express differences in selected sound attributes [Bech & Zacharov].

This article describes some experiments based upon the idea of training the vocabulary in hearing aid fitting. It is based upon a preliminary report and the work on a master's thesis in Technical Audiology on University of Southern Denmark (SDU), by Lone Elmelund as well as work carried out at DELTA in the SenseLab and Technical-Audiological laboratories.

Attributes in Sensory Evaluation

Sensory evaluation is a systematic approach to assess the sensory impression of a given object, i.e. food products, perfumes, sound. The goal of sensory evaluation is to have a panel of trained assessors, known as a listening panel, which is able to consistently and repeatable evaluate objects on a range of attributes, describing the object. In other words, to establish a "sense-o meter" to evaluate how humans experience the object to be tested.
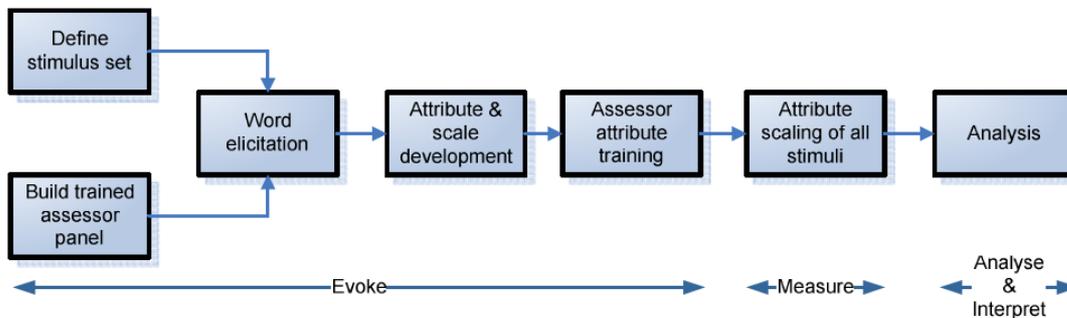
(Figure illustrating the descriptive analysis process (taken from Pedersen & Zacharov)

A central part of the descriptive analysis process of sensory evaluation is to establish specific traits of the object that can be explained and evaluated on a scale. Every sensory exposure, regardless whether that is food, sound, smell or a picture, stimulates our senses in a number of ways. We can experience complex sensory stimulation, but also break it down into more uni-dimensional experiences, i.e "Were the potatoes salty ?", "Did you hear that bass ?", "Was there a touch of strawberry in that smell ?" Each of these characteristics objectively describes an impression of the object, as opposed to preference statements such as "It tastes good" or "Something in here smells funny". A sensory experience is comprised of a number of these characteristics, - often called attributes. They are objective descriptors and they will typically be scalable, and the quantity of each attribute will influence the sensory experience. Often the scale of the attribute is defined with one or more so-called "anchor points", explained using text and sometimes practical examples.

Perhaps the most prominent example of a scale used in sensory evaluation is the so-called "Wine-wheel" developed by Ann C. Noble. It is shaped as a circle, covering all of the acknowledged tastes experienced in red wine. A tool widely used in tasting and classification of wine.

As opposed to wine evaluation, basic attributes in the sensory evaluation of sound are not very well defined, therefore sound evaluation panels are typically trained in developing attributes. This can be done individually or in a group oriented word elicitation process. In the word elicitation process descriptors for a set of sound stimuli are generated. The process starts by generating all the descriptive words a given set of stimuli gives rise to. Then in a consensus meeting the generated

words are grouped into attributes, and a scale and anchor points is defined. DELTA often prefers to explain anchor points in text and exemplify them with - sometimes manipulated- sound examples.

After the word elicitation the panel is often given the opportunity to train on the assessment of the attributes on a number of sound examples exercising the scales. Then the panel will be ready to evaluate the actual sound stimuli.

Such a process will naturally be much too time consuming in hearing aid fitting. However, some of the thoughts behind describing sounds with words might be applicable also in the real world hearing aid fitting situation.

A central part of the sensory process that could be applied in hearing aid fitting is the training. Working with sensory evaluation emphasizes the challenge of mapping sound impressions to descriptive words and scales consistently. This is not so different from the fitting situation, where the user must describe in objective terms the sound experience through the hearing aids. If the user was provided with a tool: Descriptive words and scales, perhaps the task would be easier.

The sensory evaluation process is a well-controlled "laboratory" process in principle only valid for the family of stimuli evaluated in the process. That is, a change in stimuli could give rise to a change in the set of attributes. The number of attributes describing a given stimulus is only limited to the vocabulary and imagination of the listening panel.

The Danish vocabulary describing sound is quite rich. In 2005 DELTA established "The semantic space of sounds" - a lexicon of words describing sound [Pedersen & Zacharov]. This volume comprises of 450 words (in Danish and in English), collected from literature in the field as well as the dictionary of synonyms and the thesaurus. The meaning of many of the words is not precisely defined. They may not cover the description of all attributes equally well, and they may not be one-dimensional in terms of describing the attributes.

The words in the lexicon are sorted in seven classes and after a so-called semantic space (the Euclidian distance of the words described in 17 descriptors). The seven classes are:

1) Direct sound descriptors (e.g. loud, bassy, shrill)
2) Words relating to perceptions from other senses than hearing (e.g. bright, dark, colorless.)
3) References to events and sound sources (e.g. howling, roaring, rattling)
4) Changes or differences in perceptions (e.g. colored, compressed, muffled)
5) Affective responses to sounds (e.g. pleasant, annoying, boring)
6) Connotative associations (e.g. sporty, luxurious, powerful)
7) Onomatopoeia (e.g. woof-woof, yap-yap)

The classes 1-4 are words related to perception, classes 5-6 are affective words and class 7 is imitating words.
In the lexicon more than 30% of the words are of class 3, followed by almost 25% of class 6, and 20% of class 1. Looking at the descriptions from hearing aid users from the test which is described later it is seen that also here class 3 words are frequently used.

As we are dealing with hearing impairment, it is fair to assume that some attributes will be more prominent due to the hearing aid amplification, and that some words will represent characteristics of the sound, which are basically inaudible. In fact, recent work in sound sensory evaluation shows that as in the case with the wine-wheel a few basic attributes are often prominent descriptors.

Attributes in Sound Evaluation

When comparing the attributes of a number of studies of sound reproduction a certain pattern of "native" attributes seems to emerge. Although the names of the attributes naturally vary between studies the dimension they are describing seem to be the same. In a comparison of attributes from five different studies, dimensions like "clarity", "width", "tone colour", "distance" and "noise/distortion" seem to emerge [Pedersen & Zacharov]. It is interesting to note that also "naturalness" is a dimension selected in two of the studies, as it is one of the parameters the un-trained hearing aid users in the study which is described later, often refer to.

Two other studies performed by the main author on hearing aids and active noise cancelling(ANC) headphones reveal attributes fairly comparable to the earlier studies although the attributes "loudness" and "dynamic range", both of which are related to amplification, only make sense in the case of the hearing aid, because they are important factors of the hearing aids' functionality. In the table below the attributes are listed in an attempt to align similar attributes. This of course is biased by the authors' subjective idea of the sound the words are describing.

Summary of five earlier studies of sound reproduction	Hearing aids	ANC headphones	Gabrielsson & Sjögren
Clarity	Details	Precision	Clearness
Width/broadness			
	Resonance/Tin Can	Can sound	Fullness-Thinness
Naturalness	Distortion/overload	Linearity	
Tone colour/ brightness	Treble	Treble	Brightness-darkness
		Bass	Sharpness-softness
		Treble range	
Nearness/distance			Nearness
Space	Reverberation	Stereo Room	Feeling of space
Noise/distortion	Background noise	Background noise	Disturbing sound
	Background noise tone colour		
Localisation/direction			
	Dynamic range		
	Loudness		Loudness
	Speech reproduction		

From the comparison, it seems plausible that a handful of attributes are dominating, although the naming of these is not always identical. The attributes listed in the table from Gabrielson and Sjögren are from one of the first papers published on the subject. These attributes are also included in the five studies in Pedersen and Zacharov. It is using slightly different words, but seems to align well to the other studies. The attributes from Gabrielsson and Sjögren have been used as the basis of the training in the hearing aid fitting experiment described later in this article.

Hearing Aid Evaluation Based on Sound Attributes

Based upon the knowledge from the descriptive analysis process of word generation and training, a project was defined with the goals of selecting sound-descriptive words usable in a fitting situation and testing if training using these words would be beneficial in the evaluation of sound stimuli during the fitting process.

Words Describing Hearing Aid Sound

As it is important that the describing words are meaningful to the user, an attempt was made to establish a word list on the basis of a kind of word elicitation where each user was asked to describe a number of sounds presented to him or her.

The sound examples were taken from the Acta Acoustica real life sound examples [Johannsen og Prante]. The aim was to select sound examples with peaks in different frequency areas, as it would be helpful in the fitting process to be able to map certain expressions to certain frequency areas. Another selection criterion was that the sound would carry as little information as possible. The aim is to describe the nature of the sound, not derive information from the sound. However, all sounds are based upon one or more natural sound source(s), and a common reaction when asked to evaluate these sounds is to determine their origin and evaluate their fidelity.

Results

The participants were selected randomly among users at a private dispenser of hearing aids on Funen, Denmark.

All participants wore hearing aids and had no other disabilities than hearing loss.

The results from the word generation can be seen in the table listed below. It can be seen that not all are objective descriptors, and some also seem to point in different directions of the same dimension. The result indicates that a more controlled approach with basis in familiar attributes from the sensory work, might be a better solution.

Looking at the span of words generated from a relative homogeneous group of hearing aid users indicates the challenge in evaluating and describing sound impressions, when very little guidance to the task is offered. The situation in this test setup is very similar to a real world fitting situation.

The table below shows the users' words describing 11 sound stimuli, prior to training (the number following the numbering of [Johannsen & Prante]). The original Danish words are given in parenthesis.

Sound stimuli number	Description
2	**Children** Screaking, noise, pure, clear, distant, shrill, whining (Skrigende, larm, ren, tydelig, fjern, skinger, hvinende)
3	**Church bells** Resounding clear, good, sonorous, low tone, noisy (Runger, klar, godt, klangfuld, dyb tone, larmende)
4	**Circular saw** Scratchy, shrill, natural tone, hard metallic, annoying, uniform, nerve wrecking, hard (Skrattende, skinger, naturlig klang, hård metallisk, generende, ensartet, enerverende, hård)
5	**Compressed air** Hissing, swooshing, good natural, noise, low (Hvæsende, susende, god naturlig, larm, lav)
7	**Dentist's drill** Swooshing, noisy, muffled (mixing together), unclear, hard, metallic, uniform, hissing

	(Susende, støjende, ulden (løben sammen), utydelig, hård, metallisk, ensartet, hvæsene)
9	**Horses hooves** Clopping, pulsating, sonorous, good, soft, cozy, calm, horse-shoe like (Klaprende, pulserende, klangfuld, god, blød, hyggelig, rolig, hesteskolignende)
10	**Howling wind** Swooshing, humming, weak, low, distant (Susende, summer, svag, lav, fjern)
13	**Ringing glass** Shrill (high), sonorous, pure, clear, high, hard, high tones, short (Skinger (høj), klang(fuld), ren, klar, høj, hård, højtonet, kort)
15	**Scotch tape** Hiss, wrong, remote, clear, hard, short, hissing (Hvæser, forkert, fjern, tydelig, hård, kort, hvæsende)
20	**Tin can** Noisy, hissing, clear, clear, mild, hard, plastic sound (Støjende, hvæsende, klar, tydelig, mild, hård, plastiklyd)
24	**Tyre on gravel** Rattling, blend, unclear, mixed, not good mixes together, hard/soft, comfortable, crispy (Rasler, mat, utydelig, blandet, ikke god, flyder sammen, hård/blød, behagelig, knasende)

Training of Non-experienced Listeners

Training program

14 different sounds were created on the basis of the two anchor points of the seven attributes listed below. The selection of these attributes was based upon the investigations of Daugaard et. al.

Attributes preselected for the test (adapted from Gabrielsson & Sjögren). The Danish translation is given in parenthesis:

Parameter	Anchor point	Achor point
Softness (Blødhed)	Soft (Blød)	Sharp (Skarp)
Fullness (Fyldighed)	Full (Fyldig)	Thin (Spinkel)
Loudness (Hørestyrke)	High (Kraftig)	Low (Svag)
Tone Balance (Klangbalance)	Light (Lys)	Dark (Mørk)
Clarity (Klarhed)	Clear (Klar)	Muddled (Rodet)
Distance (Nærhed)	Far (Fjern)	Near (Nær)
Spaciousness (Rummelighed)	Enclosed (Indelukket)	Spacious (Rummelig)

Loudness is of course easily adjustable in the reproduction of the stimuli and in the hearing aid, but is important for perceived quality and thus included.

During the training of the test persons it was clear that some attributes were more understandable than other. The characteristics of "softness" and "fullness" were much easier to relate to, than "distance", which during training seemed to be less obvious. Curiously enough, in the after-training evaluation the words "near" and "distant" were often used.

Effect of Training

To investigate the effect of training of non-experienced listeners a small test was set up.

The participants were first presented for the set of 11 stimuli and asked for at description of what they heard. Then they were trained with the set of 14 sound stimuli generated from the anchor points of the seven attributes from Gabrielsson & Sjögren. Then they were asked to evaluate the set of the first 11 stimuli again.

During the second evaluation there was no encouragement to use the training, and there was no connection between the 11 stimuli of the evaluation and the 14 stimuli of the training. In the second sound evaluation all seven test persons choose to use their new vocabulary to describe the characteristics of the sound, rather than the interpretation of the sound source.

It might seem a pretty straight-forward result (presenting a list of words makes it natural to use them as descriptors afterwards), but an interesting point is that presenting the test persons with a selection of descriptive words immediately sharpens their attention towards the nature of the sound instead of its origin.

It could indicate that when evaluating the sound quality of their hearing aids, the untrained users in general do not focus on the sound characteristics but rather the ability of their hearing aids to reveal the naturalness of a sound source or a soundscape. Introducing the user to another set of words, and thus refining the scope of the task for the user, might help to put the communication between the user and the hearing aid professional on the same mindset.

Examples of the user evaluation vocabulary before and after training (sound stimuli number still referring to the Acta Acoustica numbering). The original Danish words are given in parenthesis.

Soundfile	User 1		User 2	
	Before training	After training	Before training	After training
2 Children	Happy sounds (glade lyde)	Light, distant, sharp (lys, fjern, skarp)	Whining (hvinende)	Sharp (skarp)
3 Church bells	Church, christmas (kirke, jul)	Loud, sharp, clear, distant (kraftig, skarp, klar, fjern)	Sonorous, spacious, comfortable (klangfuldt, rummeligt, behagelig)	Full, spacious (fyldig, rummelig)
4 Circular saw	Sawing (savende)	Sharp, light, near (skarp, lys, nær)	Shrill, noise, unpleasant, metallic (skinger, støj, ubehagelig, metallisk)	Light, near (lys, nær)
5	Quiet, thin	Weak, muddled,	Swooshing, hissing	Thin, distant,weak

Compressed air	(stille, spinkel)	enclosed (svag, rodet, indelukket)	(susende, hvæsende)	(Spinkel, fjern, svag)
7 Dentist' drill	Indeterminable (ubestemmelig)	Muddled, weak near (rodet, svag, nær)	Blowing (blæsende)	Enclosed (indelukket)
9 Hooves	Hard , clear (hård, klar)	Clear, sharp, near (klar, skarp, nær)	Rattling (Klaprende)	Near, enclosed (nær, indelukket)
10 Howling wind	Swooshing, weak (susen, svag)	Weak, soft, distant (svag, blød, fjern)	Swooshing, blowing (susende,blæsende)	Distant, weak, thin (fjern, svag, spinkel)
13 Ringing glass	Clear, sonorous, thin, clean (klar, klangfuld, spinkel, ren)	Sharp, clear, light, near (skarp, klar, lys, nær)	Tone (klang)	Sharp, near (skarp, nær)
15 Scotch tape	Not nice (ikke rart)	Soft, thin, muddled, near (blød, spinkel, rodet, nær)	Jarring (skurrende)	Near (nær)
20 Tincan	Low (lav)	Weak, muddled, enclosed svag, rodet, indelukket	Hammering, noise (bankende, støj)	Spacious, near (rummelig, nær)
24 Tyre on gravel	Chrushing, Chrispy (knasende, sprød)	Soft, muddeled, weak (blød, rodet, svag)	Crackling (fire), chrunching Knitrende (ild), knasende	Weak, distant (svag, fjern)

Providing a few attributes and some training will probably not make the fitting process a walk in the park, but in the answers displayed above it is evident that after the training the users are utilizing their new vocabulary to express their experience. The feeling of a better understanding of the task is very prominent in the comments from the test persons in the evaluation after the test. Of course this is a very simple set-up only indicating a small progress; larger studies have to be conducted in order to fully explore the effect of training.

Naturalness

Quite a number of the test persons evaluated the sound stimuli by assessing the sound source and relating it to normality/fidelity. Therefore, another experiment was conducted where hearing aid users were asked to evaluate sound recordings in terms of naturalness/normality.

Twelve sounds were selected for their natural reproduction of a sound event commonly occurring. Three of them were from the Acta Acoustica, the rest were DELTA's own recordings and from other sound compilations. The sounds are listed in the table below:

1	Church bells	Acta Acoustica
2	Hooves	Acta Acoustica
3	Ringing glass	Acta Acoustica
4	Ambulance siren	Compilation
5	Coins on a dish	DELTA Rec.
6	Birds	Compilation
7	Fountain	DELTA Rec.
8	School yard	Compilation
9	Traffic noise	DELTA Rec.
10	Hand Washing	Compilation
11	Passing train	Compilation
12	Stirring in a cup	DELTA rec.

The test participants are selected from "well fitted" hearing aid users, this means that the fitting process is concluded and the users are satisfied with their hearing aids. They have been daily hearing aid users between 0 and more than 10 years, and they were all from the audiological department of University Hospital of Odense (OUH), Denmark. Of the 30 invited test persons 13 participated in the test.

Their task was to evaluate the stimuli on a seven point scale where the end points were labeled "normal" and "not normal" The sound stimuli were presented at a realistic sound level.

Results

As to be expected some sounds were evaluated more normal/natural than others. On the basis of the current test, however, it is difficult to establish any pattern in the relationship between sound stimuli and test persons in terms of judging normality.

Contrary to normal scaling it might be expected that – provided good recording quality, hearing aid quality familiarity of sound event etc. - the sound stimuli would generally be rated as normal.

The test shows that one of the participants seems to be experiencing normal different from the others or using the scale differently. Disregarding test person 13, a few of the sound stimuli are judged generally as normal (2, horse hooves and 10, handwashing), while all other stimuli have one or sometimes two test persons evaluating them as non-natural. Looking at the test persons three of them are judging all natural or close to normal, while the majority have one or two stimuli that they don't experience as really normal.

Sound	tp1	tp2	tp3	tp4	tp5	tp6	tp7	tp8	tp9	tp10	tp11	tp12	tp13
1	7	4	2	7	7	7	7	7	7	3	7	4	7
2	7	7	7	7	7	6	5	6	6	6	5	7	4
3	7	7	4	4	7	7	6	7	5	7	5	4	4
4	7	4	2	3	7	7	6	7	7	6	5	6	3
5	7	7	7	6	4	7	7	6	6	7	3	7	4
6	6	7	6	7	6	7	7	2	4	7	7	7	5
7	7	7	7	7	7	5	7	5	7	6	6	7	7
8	7	7	6	7	7	7	7	7	4	7	5	7	4
9	7	7	7	7	7	7	7	7	7	4	7	7	6
10	7	7	7	7	7	6	7	7	5	7	6	6	3
11	7	7	1	7	7	7	7	7	7	7	6	7	7
12	7	7	6	7	7	7	7	7	4	7	7	7	5

A low judgment on the normal-scale could of course be due to a bad recording quality or poor choice of sound stimuli, but the non-systematical distribution of judgments low on the scale indicates that this is not the real problem.

Basically this test underlines the problem of establishing a common ground of reference. Although the term "normal" often shows up in the fitting situation the reference for this parameter seems to have large individual variations and therefore cannot be used as a shortcut in evaluating sound quality or hearing aid performance.

Discussion

The knowledge of sensory practice along with the experiments described here has indicated that obtaining a vocabulary for sound impressions might be a good idea in hearing aid fitting. It is, however, a time consuming and quite difficult task if it is to be done properly with the tools we know today.

The most challenging problem might be to establish the right scale for the evaluation. To use a judgment of normality as a fast obtained reference, is not possible, since this parameter has shown to have considerable individual variances.

A more pragmatic solution could be to establish a system with "high fidelity" sound. A system where the reference will be the state of the art, not the natural sound, but the best possible reproduction. In the case of hearing aid fitting, perhaps a high-end stereo system with enough power to compensate for the hearing loss.

Litterature:

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