How Much Fine Tuning Does a Modern Hearing System Require?

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Abstract

For years, pre-calculation formulae have been the most sensible starting point for hearing aid fittings. After this initial setting, fine tuning requests are often initiated by the user. Therefore, an analysis of the fine tuning parameters used by the fitters is of great interest. In this study, various fitting aspects of Phonak’s hearing aid “Savia” were examined. Two research projects served as the basis for this study: A subjective evaluation of sound quality perception (referred to as field study) and an objective collection of hearing aid fitting data (referred to as export fitting files). The primary goal was the analysis of the difference between the initial pre-calculation settings and the final results (export fitting files). In addition, the results of the export fitting files were compared to the subjective customer’s statements from the field study.

The results of this work show that Phonak’s fitting formula “Adaptive Phonak Digital” met the expectations of the patients very accurately, and on the average no fine tuning was necessary. The significance of subjective patient statements indicates a high correlation with the objective data of the export fitting files.
Introduction

Besides counseling and the quality of the selected hearing system, the deciding factor for the purchase of a hearing system is the precision of the pre-calculation or fitting formula. In order to adjust the numerous parameters of modern hearing systems for an optimal initial setting, hearing aid manufacturers use existing fitting formulae or develop proprietary strategies. When the precalculation meets the expectations of the hearing impaired, so that there are no or only slight adjustments required for sound quality, loudness and speech discrimination, an ideal basis for further fitting and counseling is created. If this is not achieved, time needs to be spent on further adjustments and fine tuning.

In the last decades, pre-calculation on the basis of the hearing threshold were developed by various authors. Modern pre-calculation formulae such as the "Desired Sensation Level input/output" (DSL[i/o]) or the "National Acoustics Laboratories Non-Linear Version 1" (NAL-NL1) have, due to their non-linear characteristics, replaced classic fitting formulae such as "NAL", the "Berger Method"or "Prescription of Gain and Output" (POGO). Fitting formulae do not present an absolute and final setting of the hearing aid. They are to be interpreted as recommendations, a starting point which aims, theoretically, to represent the most ideal setting in relationship to the given hearing loss.

Despite great technical innovations and a growing understanding of how sound is processed by the human hearing organ, hearing aid fittings do not always lead to spontaneous user acceptance. It seems that the precalculated target-amplification does not always meet the desired loudness and sound impression for the hearing impaired. There can be various explanations for this phenomenon. It can be ascertained that the hearing impaired, especially when inexperienced, often do not accept the recommended hearing aid settings without a corresponding phase of acclimatization (Cox et al., 1996; Munro and Lutman 2004). The four most common reasons for this are summarized in a study by Brooks (1985):

1. Late recognition of hearing impairment (prolongs acclimatization).
2. Coping with interfering environmental noise.
3. Advanced age and health problems.
4. The opinion of the hearing impaired, that the existing hearing loss is not severe enough and therefore a hearing system is not needed.

An additional factor which defines customer satisfaction is the choice of the fitting method. Added to that are great deviations of the fitting formulas amongst each other. For example, the Berger calculation differs from the "NAL" formula by about 15 dB on average (Kießling et al., 1997). A subsequent fine tuning of the precalculated fitting can lead to satisfaction and acceptance by the hearing impaired. In practice, the desired sound requirements of the hearing impaired are also identified (e.g. through questionnaire or loudness scales) and adjusted accordingly.
Methods

Sophisticated hearing aid technology requires high performance from the fitting formulae. This study was initiated in order to analyze the amount of fine tuning required in the application of the new Phonak fitting formula “Adaptive Phonak Digital” which is implemented in Phonak’s new software (iPFG) and is used to fit “Savia”.

The digitalized data sets of “Savia” allow a conversion into other data formats and are therefore ideally suited for analysis of large data sets.

In the following, two data sets were analyzed: The first from a field study carried out from December 2004 through January 2005 which provided subjective data from questionnaires. The study was carried out in order to quantify subjectively the performance of “Savia” in real life situations and to correct possible weaknesses before market introduction. In total, 180 “Savia” users from Denmark, Germany, New Zealand, Austria, Switzerland and the USA participated. The field study included an initial fitting appointment, one to two follow-up appointments and a subsequent questionnaire.

The results of the questionnaires were compared to a second examination in which a collection of data from export fitting files has been analyzed. By using a conversion program, deviations from the initial pre-calculation settings were calculated. The total of 116 export fitting files (203 fitted hearing aids) originated from five countries (Germany, England, Austria, Switzerland, USA). They represent fittings after at least the third fitting appointment (second follow-up). It is not possible to state whether all fittings were actually completed. The first set of fitting data was collected during the validation phase of the product. These fittings were carried out with the iPFG version 1.0a.

Background/Fitting Formula

“Adaptive Phonak Digital” addresses pre-calculations for all types of hearing loss. Internally, calculations for target amplification are available for the following types of hearing loss:

- Standard hearing loss
- High frequency ski-slope hearing loss (“Phonak Digital Ski-Slope”)
- Low frequency hearing loss
- Profound hearing loss

The goal of “Adaptive Phonak Digital” is loudness restoration. The correlation between the slope of loudness function and hearing loss is often described in literature (Moore, 2003). The basis for the pre-calculations of the “Adaptive Phonak Digital” is a thorough examination of the difference between the loudness function of hearing impaired and normal hearing persons. Depending on the loudness slope, the compression thresholds for the individual hearing impaired are calculated. Once the audiogram is entered, the amplification targets are calculated based on estimated loudness scaling standard data. Generally, the “Adaptive Phonak Digital” formula classifies each audiogram into one of the four hearing loss types. For example, the pre-calculation for a “pure” high frequency ski-slope hearing loss is taken from the hearing loss category “High frequency ski-slope hearing loss”. However, when dealing with a profound hearing loss with high frequency ski-slope component, the precalculation is additionally calculated with a weighted percentage from the category “Profound hearing loss”.

The signal processing in “Savia” works in 20 channels with the amplification model “BPP” (Bionic Perception Processing). “BPP” analyses the acoustic and psychoacoustic characteristics of the sounds in 20 critical bands, in order to identify the corresponding components which
Contribute to clarity. The amplification can be controlled at the input stages of 40 dB, 60 dB and 80 dB. Altogether, seven hearing programs are available, in which the “AutoPilot” mode, which is automatically controlled by definite sound criteria, alternates between “Calm Situations” (1st hearing program), “Speech in Noise” (2nd hearing program), “Comfort in Noise” (3rd hearing program) and the music program “Music” (4th hearing program).

The shape and position of the pinna benefit frequency-dependant directional hearing. The higher the frequency, the stronger it will be attenuated, if it comes from the rear. Signals which come from the front are transmitted with nearly no attenuation. The brain uses these characteristics for front-back localization. The “Real Ear Sound” feature in “Savia” simulates this characteristic in order to restore this pinna function destroyed by the use of a BTE with an omnidirectional microphone. Studies have shown that a clear reduction in the front-back confusions is achieved through “Real Ear Sound” (Tchorz, 2005).

The Digital SurroundZoom directional microphone works in 20 channels, allowing it to address multiple noise sources.

The “Wind Noise Suppressor” reduces wind noise. Above a wind speed of approximately 2.5 m/s, turbulence occurs in the area of the pinna, which can have a disturbing effect on hearing and understanding when wearing a hearing instrument. A likewise disturbing influence on speech discrimination is caused by differences in delays between direct noise and reflective noise above approximately 100 ms (echo). “EchoBlock” determines the reverberation period through an analysis of the input signals and the tracking of their repeated patterns.

Results of the Export Fitting Data

Over 96% of all hearing aid fittings were carried out with the fitting formula “Adaptive Phonak Digital”, 2% with the manually-chosen “Phonak Digital Ski-Slope”. A small portion applied “DSL[1/0]" (<1%) or “NAL-NL1" (<1%).

In the following, those hearing aid fittings which were precalculated with “Adaptive Phonak Digital” are analyzed. In general, the deviation from the recommended precalculation is considered the most important parameter for evaluation of a fitting formula. In the examined hearing aid fittings, the average fine tuning of the gain was between 0 dB and 2 dB in the speech area (exemplified through the 1st hearing program). Figure 1 shows that the pre-calculation “Adaptive Phonak Digital” precisely met the desired loudness and sound quality requirements of the hearing impaired.

Figure 1
Average fine tuning of the gain throughout the frequency range for the calm situations hearing program (203 fittings)
The standard deviation (3–7 dB) shows that customer-specified fine tuning in various directions was carried out.

In addition, minimal deviations from the precalculated values were seen for the maximum output levels (MPO) and the knee point (based on fine tuning done for the 1st hearing program). The average correction for the MPO amounts to less than 1 dB (Figure 2). The standard deviation shows customer-specific fine tuning (2–7 dB standard deviation).

The fine tuning of the knee points averages 1–2 dB (Figure 3), the standard deviation is lower in comparison to the fine tuning of the gain and the MPO corrections (2–5 dB standard deviation).

A third of all test persons used the "AutoPilot" automatic, nearly two thirds were given in addition a choice of manual programs (three further hearing programs, "AutoPilot + Manual Programs 1–3"). Four percent of the test persons received two further hearing programs ("AutoPilot + Manual Programs (FM) 1–5"), also see Figure 4. The most commonly used additional programs are presented in Table 1. The program "Speech in Noise" is thus the most often used manually chosen additional program.
Examination of microphone settings for the first three hearing programs shows little deviation from the default settings. The standard microphone setting of “Real Ear Sound” for the 1st and 3rd hearing program was completely accepted. The digital SurroundZoom default microphone setting (dSurroundZoom) for the 2nd program, hearing in noise, was changed sporadically. Figure 5 shows that 2% chose the microphone setting “Real Ear Sound” instead of the default setting, and 1% a fixed directional microphone setting.

Table 1
Use (in %) of additional hearing programs

<table>
<thead>
<tr>
<th>Additional hearing programs</th>
<th>Use [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech in Noise</td>
<td>27</td>
</tr>
<tr>
<td>Calm Situations</td>
<td>24</td>
</tr>
<tr>
<td>Music</td>
<td>17</td>
</tr>
<tr>
<td>FM+M</td>
<td>8</td>
</tr>
<tr>
<td>FM</td>
<td>7</td>
</tr>
<tr>
<td>Mute</td>
<td>4</td>
</tr>
<tr>
<td>Custom (Calm Situations)</td>
<td>3</td>
</tr>
<tr>
<td>Custom (Speech in Noise)</td>
<td>3</td>
</tr>
<tr>
<td>Reverberant Room</td>
<td>3</td>
</tr>
<tr>
<td>Acoustic telephone</td>
<td>2</td>
</tr>
<tr>
<td>T-Coil</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
</tr>
</tbody>
</table>

The changes to the degree of activation of the “High Resolution Noise Canceler” were different for the first three hearing programs. In the 1st hearing program (Calm situations, possible settings: default setting “off” or “light”), 8% of the hearing aids were changed to the “light” setting. For the 2nd program (Speech in Noise, possible settings: “off”, default setting “light”, or “medium”), 25% of hearing aid users changed to “medium” instead of “light”. In fittings in the 2nd hearing program, the background noise suppression was never deactivated. In the 3rd program (Comfort in Noise, possible settings: “off”,

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**Figure 4**
Distribution of the hearing programs

**Figure 5**
Distribution of the microphone setting in the 2nd hearing program
“light”, default setting “medium”, or “strong”) the default setting “medium” was kept by 94% of the test persons (a further 4,5% chose “strong”, 1,5% “light”).

The “Occlusion Control” was turned on in 33% of all hearing aid fittings and set to various levels (Figure 6).

The parameter “Experience/Loudness” level has been used very actively and thus confirms its usefulness and the underlying assumption that based on experience a different gain/frequency response strategy is appropriate. In 38% of the fittings, the setting was left at the default level 2 (six months to three years of hearing aid experience). The distribution for the other levels is shown in Figure 7. If the fitter has entered into iPGF the actual amplification experience of the user, the setting of the “Experience/Loudness” parameter is automatically adjusted.

“EchoBlock” and “Wind Noise Suppressor” are offered in the 2nd and 3rd hearing programs. In the default setting both parameters are turned off. “EchoBlock” was activated in 12% (1st hearing program) and 11% (2nd hearing program) of the fittings. A similar frequency of activation is seen for the “Wind Noise Suppressor”: 9% in the 2nd hearing program, and 12% in the 3rd program.

Figure 6
Distribution of various settings in the “Occlusion Control”

Figure 7
Distribution of the parameters “Experience/Loudness”
Results of the Field Study

Subjective questionnaires show very strong correlations with the analysis of the export fitting data. The majority of users (approximately 66%) confirmed that the precalculated gain settings were just right (Figure 8).

The evaluation of the sound quality achieved with the "Adaptive Phonak Digital" precalculation was examined with respect to "shrillness", (Figure 9). This is an important parameter as often first time users with a typical high frequency sloping hearing loss do not easily accept high frequency amplification. At the same time they need sufficient high frequency gain to allow for good speech intelligibility. The results show that 87% found the sound quality "not shrill at all".

The question regarding balanced low frequency amplification ("dullness"), shows that 95% of the customers gave a favorable rating to the "Savia" sound quality, Figure 10.

The overall evaluation of Savia's sound quality is shown in Figure 11. It reveals that approximately 98% of those surveyed assessed "Savia" positively. Figure 12 shows that a positive subjective estimation for speech discrimination with "Savia" was achieved by the majority of customers (98%).

This also reflects the answers to the question of naturalness, 88% rated the sound quality as natural, while only 12% of the customers rated it as unnatural.

![Figure 8](image8.png)

User evaluation of the precalculated setting with "Adaptive Phonak Digital"

![Figure 9](image9.png)

Frequency of sensed shrillness in "Savia" precalculation

![Figure 10](image10.png)
Summary

The precalculation of the Phonak fitting formula “Adaptive Phonak Digital” met, on the average, very precisely the expectations of the customers. Necessary corrections on gain, MPO or compression knee points did not exceed 2 dB. The small standard deviation for the fine-tuning for all of these parameters (7 dB) is a sign of customer-specific fine tuning. The export data show that the Phonak standard microphone setting for the first three hearing programs ( microphone default setting “Real Ear Sound” and “dSurroundZoom”) found great acceptance. The many-faceted options of the various hearing programs were actively used. This was also true for the parameter “Occlusion Control” and the choice of “Experience/ Loudness” level. The parameter “High Resolution Noise Canceler” required no changes in the program-dependent default setting for the majority of the fittings. The various levels of the “High Resolution Noise Canceler” were occasionally used. The application of new features such as the above-mentioned “EchoBlock” or “Wind Noise Suppressor” make it clear that the interest in such options exists.

A high correlation between the results of the export fitting data and the subjective customer statements can be seen. The customers evaluated the fitting performance of “Phonak Adaptive Digital” very positively.
Literature


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Martin Lützen, Dipl.-Ing. (FH) is a trained audiologist. During his studies to become an accredited engineer (Dipl.-Ing. (FH)) in Hearing Technology & Audiology, he worked in various institutions. Since July 2005 he has been employed in Research and Development at Phonak AG in Switzerland.