Audiologist-Supervised Self-Fitting Fine Tuning of Hearing Aids

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Introduction

The fitting process of hearing aids (HA) is a highly individual process. Expert-guided fitting is based on diagnostic tests to derive a first fit. The subsequent fine tuning then exploits the experience of the audiologist / acoustician who, in general, has access to a large number of parameters to be fitted based on the reported subject perception. The fine-tuned HA is then worn by the user in various listening conditions in everyday life. The audiologist-driven fine tuning of the HA and the following acclimatization in everyday life is then repeated (often involving several iterations), until a satisfactory setting for the HA user is found.

This state-of-the-art fitting process is highly time consuming and not always satisfactory for the HA user. One way to improve this process could be to give the HA users more control over the settings of their hearing device, i.e., the ability to self-fit or self-adjust their HA (Convery et al. 2011). In this contribution we investigate if and how the fine tuning process could benefit when the audiologist-driven fine tuning is modified to an audiologist-supervised self-fitting fine tuning of the HA. The HA user listens to several realistic sound scenes, which are processed according to the first fit and a specific fine-tuning setting. This fine-tuning setting can be influenced by the HA user over a user interface (UI). The number of parameters to be fitted via this UI has to be considerably reduced for this self-fitting approach to be usable by the HA user. The audiologist supervises the interaction of the HA user with the UI and can intervene if necessary.

The aim of our first pilot study is to analyze the influence of the sound scenes and the variability across users on the preferred settings. The gain difference as well as the difference in speech intelligibility between the preferred setting and the first fit is investigated.

Method

Ten subjects (six male, four female) between 27 and 79 years old (median age 74 years) and with at least one year of HA experience participated in this pilot study. All of them had a symmetrical (≤ 15 dB difference between the ears) moderate to profound hearing loss. The average hearing threshold level (HT) of all subjects and both ears (air conduction (AC) and bone conduction (BC)) as well as the interindividual standard deviation values are shown in Fig. 1.

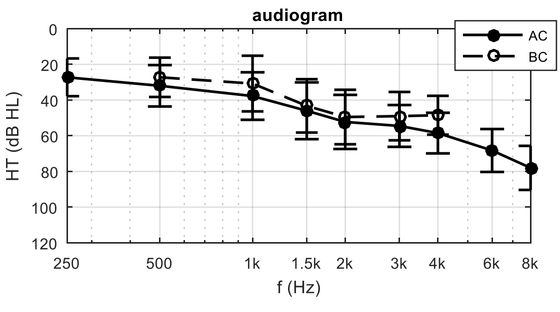

Figure 1: Mean HT of all subjects and both ears (AC and BC) as well as the interindividual standard deviation.

The subjects sat in the middle of a ring of five loudspeakers (GENELEC 8020A) with a radius of 1.5m. One loudspeaker was positioned in front (0°), the remaining loudspeakers were positioned at the front right (45°) and the front left side (-45°) and at the back right (135°) and back left side (-135°) of the subject. The subjects wore an open headphone (Sennheiser HD 600). The sound of the loudspeakers simulated the direct sound whereas the sound of the headphones simulated the sound processed by the HA. The simulated HA-processed sound was manipulated by means of a real-time five-band dynamic range compressor (center frequencies f=[200Hz, 400Hz, 1.25kHz, 4kHz, 8kHz]) and delayed by 5ms to simulate HA processing. 16 different speech signals with female, male, adult and child speakers were presented, which differed mainly in input level. Eleven of these speech signals were in quiet (two dialogs at 65 dB SPL, three monologs at 55 dB SPL, three monologs at 65 dB SPL, and three monologs at 75 dB SPL), whereas five speech signals were in noise (four dialogs at 65 dB SPL, two of them in train station noise at 70 dB SPL and two in noise at 60 dB SPL simulating a car ride, one monolog at 55 dB SPL in kitchen noise at 60 dB SPL).

The baseline of the compressor was the subject's individual first fit according to the prescriptive formula NAL-NL2 (Keidser et al. 2011). The subjects could self-adjust the deviation from this baseline using a two-dimensional touch screen as UI. On this screen, a point was moveable in both discretized directions (x-axis: left right $\mathbb{D}_x = \{x \in \mathbb{N} \mid 1 \leq x \leq 11\}$, y-axis: down up $\mathbb{D}_y = \{y \in \mathbb{N} \mid 1 \leq y \leq 11\}$). Depending on the point's position, a specific gain-frequency curve (so called "preset") was selected to be added to the baseline. These presets $g(f,x,y)$ were calculated as follows (Dreschler et al. 2008):

$$g(f,x,y) = \begin{cases} -3\text{dB}\, x + 3\text{dB}\, y & \text{for } f \leq 400\text{Hz} \\ \left(\dfrac{x-6}{600\text{Hz}}\right)(f - 4\text{kHz}) + 3\text{dB}(x + y - 12) & \text{for } 400\text{Hz} < f < 4\text{kHz} \\ 3\text{dB}\, x + 3\text{dB}\, y - 36\text{dB} & \text{for } f \geq 4\text{kHz} \end{cases}$$

Differently from Dreschler et al. (2008), the gain values between 400Hz and 4kHz were linearly interpolated on a linear frequency scale rather than a logarithmic one, and were changed in 3dB steps rather than 2dB steps. The presets were corrected with an offset equal for all frequencies in such a way, that the broadband output level was preserved when moving the point along the x-axis. The corrected presets are shown in Fig 2. The gain values were interpolated for point positions in-between the discrete grid points, so that a subjective continuous perception was achieved.

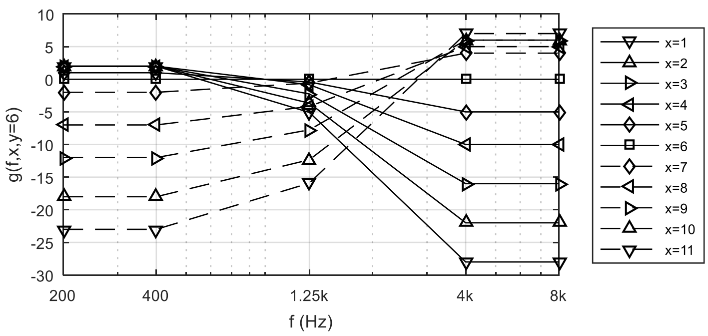

Figure 2: Presets as function of the frequency and the x- position of the point on the 2D touch screen while the y- position is fixed on 6. A change on the y- position leads to a linear shift of all presets for all frequencies of 3dB ($\Delta g(\forall f, \forall x, \Delta y=1)=3dB$, $\Delta g(\forall f, \forall x, \Delta y=-1)=-3dB$).

The subjects were instructed to self-fit the 16 sound scenes in two different ways: First in a way that the sound scene was perceived as most comfortable (comfort), second in a way that the speech of the sound scene was most intelligible (SI). The procedure was then conducted as follows: In the first session, the supervised self-fitting of N=16x2=32 sound scenes was performed by the subjects, followed by a retest in the second session. In the second session, additionally a sound-scene-independent preferred gain setting was determined by averaging preferred gain settings for several sound scenes with different input levels. The validation of the preferred settings followed in the third session: A paired comparison and a speech intelligibility test (OLSA) were conducted. For the paired comparison, the 16 sound scenes were processed with either the first fit, the sound-scene-specific gain settings (mean value across test and retest) (denoted as MANY) or the one gain setting found in the second session (denoted as ONE). The speech intelligibility test was conducted with the first fit and the ONE setting.

Results

The gain differences between the first fit and the self-fitted settings are analyzed according to two parameters: overall gain and gain slope. The overall gain is defined as the averaged gain across 400Hz and 4kHz whereas the gain slope is calculated between these two frequencies. The mean preferred overall gain and gain slope re NAL-NL2 for all subjects are shown in Fig. 3 in dependency of the sound scenes. The box bars represent the gain values whereas the line bars represent interindividual standard deviations. There is a big difference in preferred overall gain between the two instructions (top panels). When instructed to maximize comfort (left), the subjects prefer on average a less loud setting than NAL-NL2 (cf. Fig. 3a), whereas when instructed to maximize SI, the subjects prefer on average a louder setting except for the loud monolog triplet (75 dB SPL input level) (cf. Fig. 3b). Focusing on the overall gain settings for the three monolog triplets, a trend for a more "level normalizing" gain setting than NAL-NL2 can be observed for both instructions, i.e., the largest negative gain change is observed for the loudest monolog, and the smallest gain reduction (comfort) / largest gain increase (SI) is observed for the softest monolog. The gain slope (bottom panels) is on average set shallower than NAL-NL2 for both instructions, even though less pronounced for the SI instruction (cf. Fig. 3d) than for the comfort instruction (cf. Fig. 3c). In general, the subjects do not on average differ substantially from NAL-NL2. However, the high interindividual standard deviations show that there are individual preferences, which indeed can differ highly from NAL-NL2.

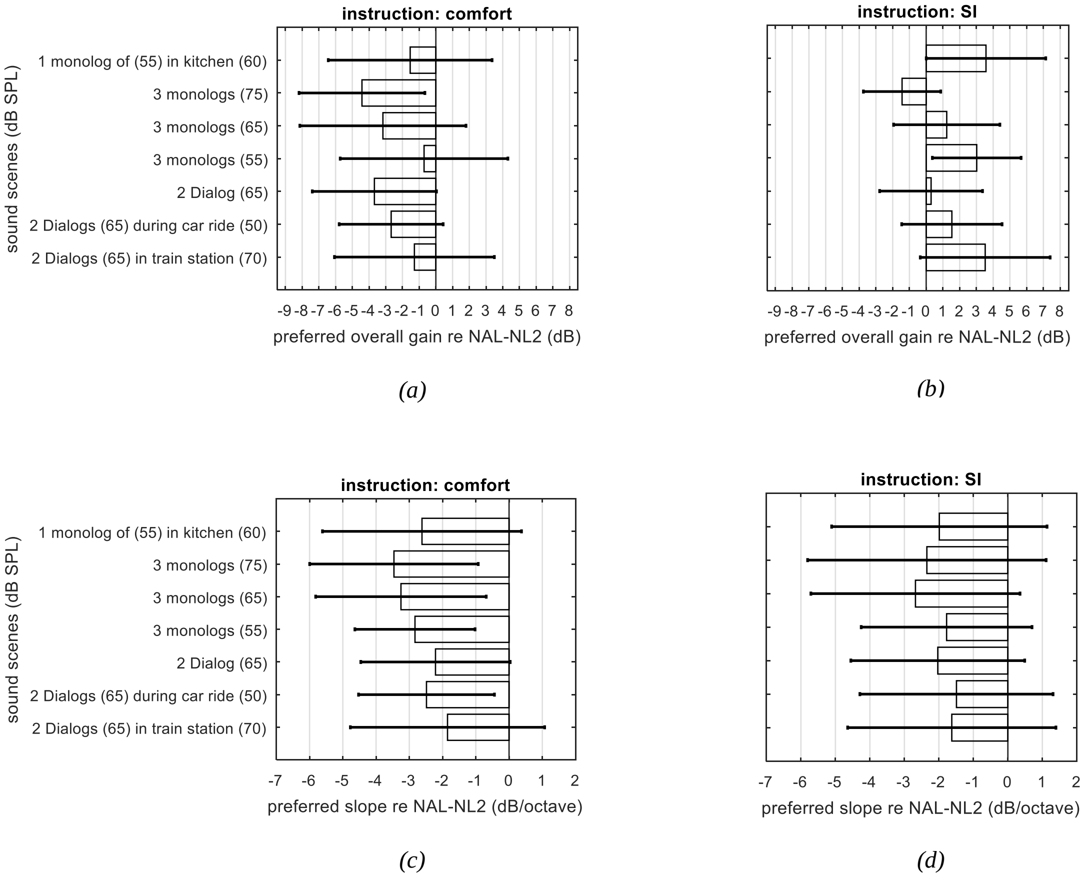

Figure 3: Mean preferred overall gain re NAL-NL2 (box bars) for all subjects (upper row) as well as the mean preferred slope re NAL-NL2 (box bars) for all subjects (lower row) for the instruction comfort (left column) as well as SI (right column) with the respective interindividual standard deviations (line bars) in dependency of the sound scenes, which differ mainly in input level (number in brackets).

The speech intelligibility does not deteriorate considerably with the self-fitted setting in comparison with the first fit as shown in Fig. 4. The speech reception threshold (SRT) for 50% speech intelligibility relative to the first fit is shown for all ten subjects. In most cases the SRT change stays within about ±1dB. The instruction “comfort” leads in two cases to a slight worsening of the SRT (for subject #6 and #8, cf. Fig. 4a) whereas the instruction “SI” leads in three cases to a slight improvement of the SRT (for subject #7, #8 and #9, cf. Fig. 4b).

The subjects prefer on average the self-fitted settings (MANY and ONE) over the first fit in the paired comparison test. Fig. 5 shows the results of the complete paired comparison test (first fit vs. MANY, first fit vs. ONE and MANY vs. ONE respectively) on a Bradley-Terry-Luce (BTL) scale with corresponding confidence intervals. The sum of wins for the different processing types and instructions are the following: first-fit comfort 142, MANY comfort 162, ONE comfort 176, first-fit SI 135, MANY SI 165, ONE SI 180.

Conclusion

The subjects were able to use the proposed method to find a preferred gain setting. The reproducibility (test/re-test accuracy) was reasonably high (not shown in this short paper). In a blind test, the subjects preferred the self-fitted settings to the first fit, while the SRTs remained constant on average. Overall, the subjects tended to prefer a more level normalizing gain setting and shallower gain slope than NAL-NL2. The instructions seem to be important, since very different results were obtained. The preferred overall gain as well as the SRT differs substantially between the two instructions while the preference remains with the self-fitted setting.

Future research could include real hearing aids instead of open headphones to create a more realistic simulation of real world situations. It still remains an open question to what degree a deeper involvement of the HA users into the fine tuning process may benefit the overall fitting success, but this initial study suggests that the general concept is feasible and may be promising for future solutions.

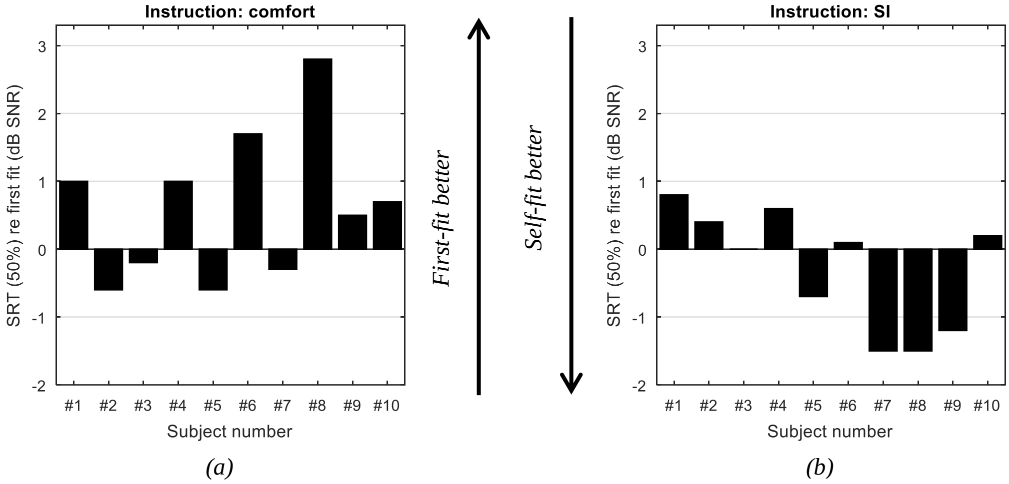

Figure 4: SRT for 50% speech intelligibility re first fit for all subjects and for both instructions: comfort (left) and SI (right).

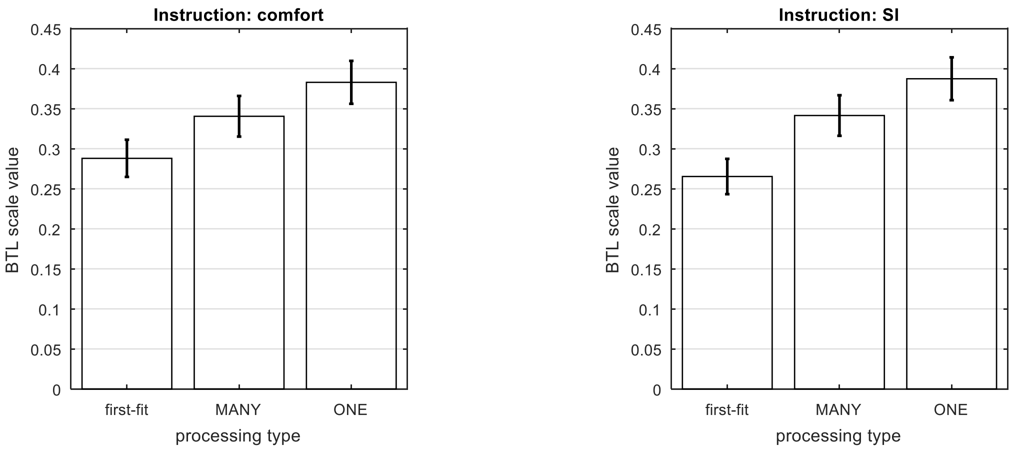

Figure 5: The result of the paired comparison test: the subjects' preference regarding the three processing options first fit, MANY and ONE for the instruction comfort (left) and SI (right) on a BTL scale.

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