DOI: 10.61782/fa.2023.0450

INDIVIDUAL FACTORS UNDERLYING PREFERENCE FOR PROCESSING DELAY IN OPEN-FIT HEARING AIDS

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ABSTRACT[*]

Background and aim: In open-fit hearing aids (HAs), the processing delay is crucial for the perceived sound quality, as it determines the magnitude of the comb-filtering effect that occurs when the direct and processed sound interact. Research has shown individual differences in the preferred length of this processing delay. This study investigated if basic spectral and temporal processing abilities as well as self-reported listening habits can explain these differences.

Methods: Groups of listeners with normal hearing (NH) and mild-to-moderate sensorineural hearing loss (HL) were tested. Temporal processing ability was assessed using gap detection threshold measurements. Spectral processing ability was assessed using spectral ripple discrimination measurements. Additionally, a subscale of a questionnaire for assessing personal listening traits and habits was administered. Sound preference for different HA delays was assessed using a realistic HA-simulator with processing delays ranging from 0-10 ms.

Results and conclusions: We hypothesize that good temporal and spectral processing abilities will correlate with a preference for shorter processing delays. Furthermore, we hypothesize that higher scores for questionnaire items will have a preference for shorter processing delays. The obtained results are expected to provide input for improved HA-solutions.

Keywords: *Hearing aids*; *Sound quality*; *Processing delay*.

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1. INTRODUCTION

According to the World Health Organization, 20% of the global population have a HL, of which ~98% have a mild to moderate HL [1]. Mild-moderate hearing losses are usually treated with open-fit HAs. Open-fit HAs are often preferred due to less occlusion and higher physical comfort. Although HAs have been the primary treatment option for irreversible HL, many people with a HL do not use a HA. In Denmark, for example, ~37% of individuals with a HL use HAs [2]. In a MarkeTrak survey study, Kochkin identified several reasons for why individuals do not use their HAs. Five out of the top-10 reasons were sound quality-related [3].

In open-fit HAs, both the unprocessed and the delayed, processed sound enter the ear canal leading to comb-filtering and reduced sound quality [4]. Nonetheless, open-fit HAs are often preferred. The perceptual consequence of the comb-filtering is a coloration of the sound.

Lelic and colleagues [5] investigated preference for processing delay in listeners with NH and HL. They found that good low-frequency hearing thresholds were correlated with a preference for the shortest processing delay that was tested (0.5 ms). However, some individuals with good low-frequency hearing thresholds preferred longer delays.

The aim of the present study was to investigate if frequency selectivity and temporal processing abilities as well as listening habits could explain these individual differences. Frequency selectivity was assessed using a spectral ripple discrimination (SRD) task. Temporal processing was assessed using a temporal gap detection (GDT) task. Listening habits were assessed using a subset of the Sound Preference and Hearing Habits Questionnaire (SP-HHQ) [6]. Here, we provide a short overview of this study.

2. METHODS

2.1 Participants

To this date, nine NH participants (three females, mean age: 42.5, range: 26 – 55 years) and 12 participants (three females, mean age: 64, range: 51-76) with HL have participated in the study. The inclusion criteria for the NH individuals' thresholds of max. 20 dB HL at all audiometric frequencies between 0.25-4kHz. Thresholds at 6 and 8 kHz could exceed 20 dB HL, but no more than 30 dB HL. Average PTA4 (pure tone average for audiometric thresholds 0.5, 1, 2, and 4 kHz) for the NH group was 3 dB HL (range: -2 – 7).
The inclusion criterion for the HL group was a mild-moderate sensorineural HL. An average of the left and right thresholds is plotted in Fig. 1. Average PTA4 for the HL group was 32 dB HL (range: 19 – 39).

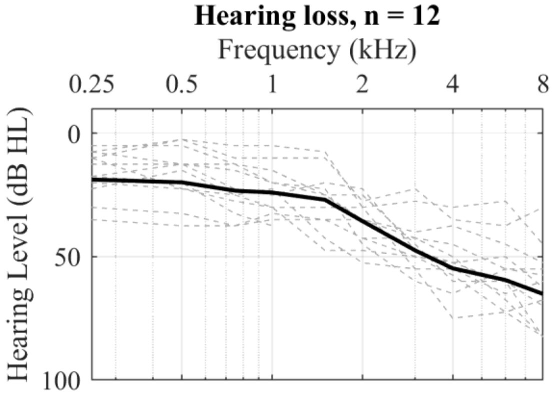

Figure 1. Individual (dashed lines) and average (thick line) hearing thresholds for the participants in the HL group.

2.2 Preference judgments

A paired-comparison task was used to evaluate preference for five HA processing delays.

2.2.1 Test signals

Three signals were included: (1) Rain on an umbrella, (2) male speech, and (3) a bouncing ping-pong ball.
The first two signals (i.e., rain and male speech) were also used in the study by Lelic and colleagues [5].

2.2.2 Signal processing

Five frequency-independent processing delays were tested. The processing delays were 0, 0.5, 2, 5, and 10 ms. The signals were generated using a HA stimulator [4] that mimicked the acoustics of an open-fit HA. The signal processing was identical to the approach used in the study by Lelic and colleagues [5]. Linear amplification was applied to all signals. For the NH group, the insertion gain corresponded to the N2 standard audiogram [7] derived from the NAL-NL2 rationale with a 65 dB SPL pink noise as the input signal. For the HL group, individual insertion gains also corresponding to the NAL-NL2 were used. To avoid uncomfortable presentation levels for the NH group, the presentation level was lowered to 65 dB SPL.

2.2.3 Procedure

Using a 2-alternative forced choice (2-AFC) procedure, the participants were instructed to choose the signal they preferred. The signals had a length of 30 s and were played back in a loop. During the test, the participants had the option to select specific portions of the sound.
For each of the three signals, pairwise comparisons of all five processing delays were made. This resulted in 10 possible pairs. Each pair was presented three times, resulting in 30 comparisons per signal and a total of 90 comparisons per participant.

2.3 GDT and SRD tasks

2.3.1 Test signals

SRD. Noise was generated in Matlab with a sampling rate of 48 kHz and a duration of 1.5 s. The stimulus generation was similar to the procedure described by Neher and colleagues [8], but with ripples alternating every 0.25 s.
GDT. Noise was generated in Matlab with a sampling rate of 48 kHz and a duration of 0.5 s. In the target interval, a silent gap was introduced in the middle of the signal. The reference signal was the same noise without the gap.

2.3.2 Procedure

A 3-alternative forced choice paradigm with a 1-up 2-down tracking procedure [9] was employed. The measurement phase for threshold estimation included six reversals.

SRD. The tracking variable was the ripple spacing. The initial step size was 225 Hz for the individuals with HL and 150 Hz for the NH individuals.
GDT. The tracking variable was the gap length. The initial gap length was 50 ms for the individuals with HL and 20 ms for the NH individuals.

3. RESULTS

3.1 Preference judgments

The preference scores were converted into scores ranging from 0-1, following a procedure described by Neher [10]. Briefly, across all three test signals as well as for each of them individually, the total number of times a given processing delay was preferred was divided with the total number of comparisons. If a shorter delay was always preferred over a longer delay, this conversion would result in a maximum value of 0.4.

The proportional scores are shown in Fig. 2. Generally, the NH group (filled black circles) prefers 0 ms of delay, while the HL group (open squares) prefers 0.5 ms of delay for the rain signal (Fig 2b), and 0 and 0.5 ms of delay for the speech and ping-pong signals (Fig. 2c and 2d).

An ANOVA was used to test for significant differences among the variables: hearing status (NH / HL), test signal, and processing delay, as well as interactions between the variables. Processing delay was the only significant variable, $F(4,310) = 17.2$, $p < 0.005$. A tendency for an interaction between hearing status and processing delay was also observed ($p = 0.07$). To follow up on the effect of processing delay, a post-hoc analysis with Bonferroni correction was performed. The results are displayed in Fig. 3.

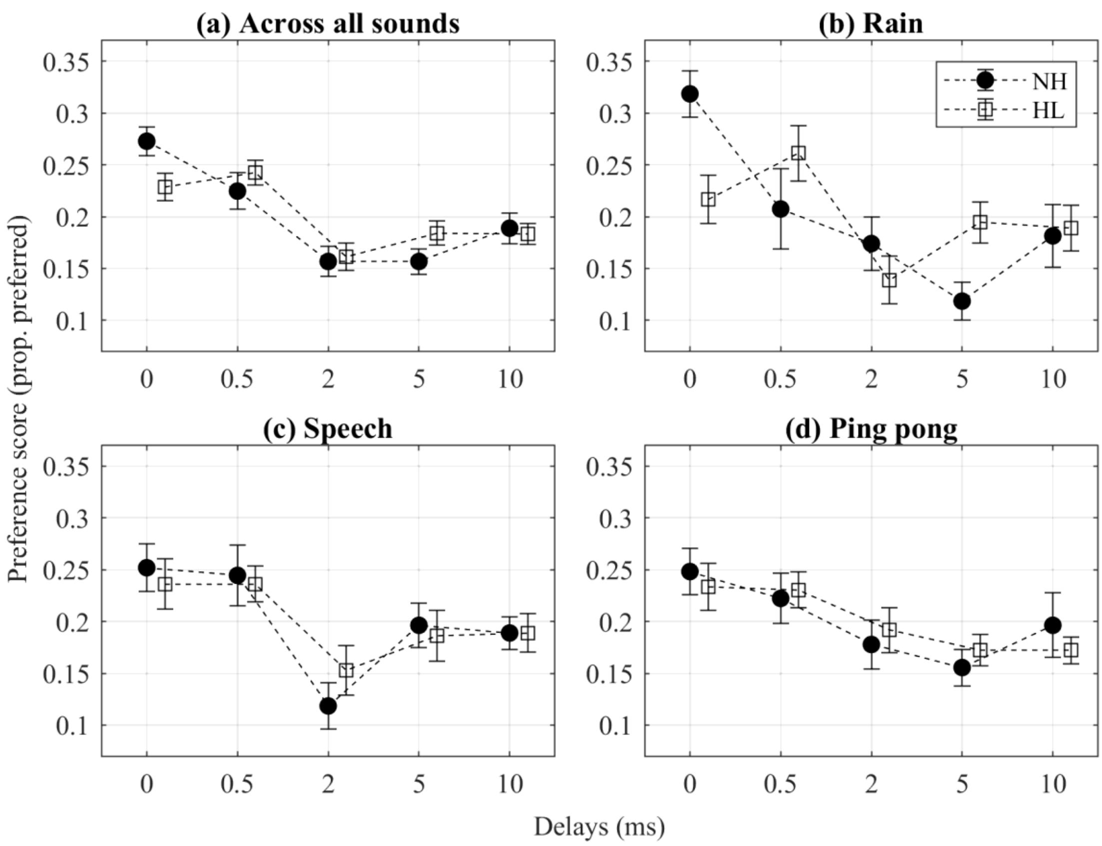

Figure 2. Mean preference scores for the 5 processing delays for the NH individuals (filled circles) and individuals with HL (open squares). **(a)** All test signals combined. **(b)** Rain on umbrella. **(c)** Male speech. **(d)** Bouncing ping-pong ball. Error bars show ±1 standard error.

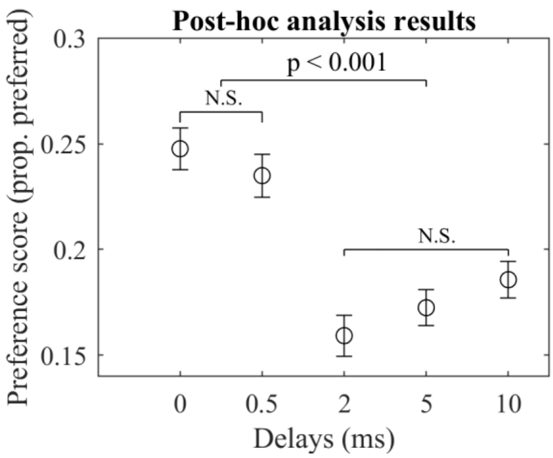

Figure 3. Results from post-hoc analysis. N.S.= not significant

4. DISCUSSION

These preliminary results suggest that there may be a 'breaking point' between the two shortest processing delays (0 and 0.5 ms) and the longer delays (2, 5, and 10 ms). Apparently, the participants tested so far were unable to distinguish between no delay and 0.5 ms of delay. This is in accordance with results by Yost and Hill [11] who found that NH participants were most sensitive to sound coloration effects for delays in the 2-5 ms range. An influence of hearing status might emerge when the data collection is completed. Potential relations between the preference scores and basic auditory processing abilities (SRD and GDT) as well as self-reported listening habits will then also be explored.

5. ACKNOWLEDGEMENTS

The authors thank Anne Roslyng-Jensen and Lamis Abdallah for their contribution to the data collection, Dina Lelic for her input to the statistical analyses. This study was supported by the Innovation Foundation Denmark and WS Audiology.

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