

White Paper

Comparing time-domain and frequency-domain processing: Preference across platforms

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ABSTRACT

Previous research has shown that many listeners with hearing loss have systematic preferences for a sound design based either on time-domain processing or on frequency-domain processing. In this paper, two studies are reported that investigate whether such preferences generalize beyond the two sound designs previously compared. Comparing the same industry-unique time-domain processing architecture against two different implementations of frequency-domain processing, we observe that preferences for time-domain processing are generally stable, though many listeners also change their preference when comparing against a weaker frequency-domain alternative. These results confirm the necessity of offering distinct sound designs to serve the preferences of individual hearing aid wearers and support the implementation of sound preference in the clinical workflow.

Main results

- Two studies confirm that listeners have systematic preferences for either time- or frequency-domain processing architecture, with at least 40% showing moderate or strong preference for one or the other.
- For one frequency-domain alternative, preference for time-domain processing is even stronger than previously observed, at 68% overall and 41% stronger preferences.
- The preference for time-domain processing is mostly stable irrespective of which frequency-domain alternative is used as a comparison.

Clinical opportunities

- WSA's Widex sound design is unique in the hearing aid industry by employing a time-domain processing architecture.
- A substantial proportion of listeners indicate moderate and strong preferences for time-domain processing when compared to different implementations of frequency-domain processing.
- WSA is the only hearing aid manufacturer to give clinicians the choice between time- and frequency-domain processing, allowing the professional to offer truly personalized fittings and cater to clients' personal and important preferences for sound.

Introduction

Preference is ubiquitous across domains, co-determining our responses to stimuli, objects, people, and activities, but preference for hearing aid sound has only recently begun to be systematically investigated and implemented in clinical audiology (Balling et al., 2026; Fischer & Engelund, 2026; Engelund & Fischer, 2026). As argued by Fischer and Engelund (2026), sound preference is a complex phenomenon, arising from the interaction of sensory comfort, emotional reward, cognitive ease, and social meaning. Together, these four elements co-determine whether a hearing aid sound is accepted and used over time. Sound preference may therefore be the root cause in many cases where hearing aids are rarely used or outright rejected.

One reason why preference has not been systematically accounted for may be the fact that most major hearing aid manufacturers – even those offering multiple brands – are limited to a single processing architecture. However, as Balling et al. (2026) showed, up to 40% of listeners indicate a strong and consistent preference when choosing between two fundamentally different processing architectures: time-domain processing and frequency-domain processing. By offering only one processing architecture, hearing aid manufacturers are limited in which preferences, and therefore which hearing aid users, they can serve.

At the core of the difference between time- and frequency-domain processing architectures are the analysis filter banks that split up the input signal for processing and in this way set the stage for all operations that the hearing aids perform on the signal, including key factors like compression and noise reduction. Crucially, filter banks are subject to the unavoidable trade-off in signal processing between frequency resolution and time resolution. Filters that are broader in frequency allow a lower processing delay while longer processing windows are required for narrow-frequency filters.

Looking at choices made on this trade-off, Widex is the only manufacturer in the industry that uses a time-domain filter bank. This filter bank operates with frequency bands – or filters – that are narrower in the lower frequencies, where small differences in frequency are audible, and broader in the high frequencies, where small frequency differences are not audible. In this way, the filter bank mimics how the human ear works and enables all signal processing – fundamental things like compression, noise reduction and directionality – to be tailored to natural hearing. This approach also allows low signal processing delay (Balling et al., 2022).

The rest of the industry relies on frequency-domain processing. This comes with advantages in terms of high frequency resolution and advanced processing power. In WSA's portfolio, Signia, Rexton, AudioService and more use this processing power to enable all their innovative features, including the multi-stream processing architecture that allows the user to focus on all the important sounds in a complex scene.

In this way, there are advantages and drawbacks to both types of processing architecture, but these are often considered only in terms of technical specifications. Balling et al. (2026) instead focused on the human preference angle. Taking Signia as the specific example of frequency-domain processing and Widex as the industry-unique sound design that uses time-domain processing, Balling and colleagues established a 20-60-20 split of listeners' sound preferences: up to 20% of listeners have a strong preference for frequency-domain processing, up to 20% for time-domain processing, while 60% have weak or no preferences. Crucially, this 20-60-20 split was seen across two studies, one with hearing aid recordings and one with hearing aids worn in real life. It reflects a clinical reality where many hearing aid users may be well served by different sound designs as long as the hearing aids in question are well fitted, but where a large minority struggle with sound designs that do not fit their preference.

While time-domain processing is unique to Widex, frequency-domain processing is used across the industry, though implemented in different ways and differing in the algorithms and functionalities built on top of the filter banks. This raises the question of how the Widex time-domain sound design compares to other implementations of frequency-domain processing than Signia's in terms of preference, and more broadly whether the time- vs. frequency-domain preference distribution holds in general. Our goal in this paper was to investigate that by comparing Widex to two other leading manufacturers' implementations of frequency-domain processing (Manufacturer A investigated in Study 1, Manufacturer B investigated in Study 2). In order to focus as much as possible on the effects of the processing, we used recordings of the same sound scenes as Balling et al., which were designed to identify people's sound preferences, not to show the advantages of any specific hearing aid platform. Additionally, by recruiting many of the same study participants as Balling et al. (2026), we were able to investigate the stability of listener preference for time- vs. frequency-domain processing.

Method

Participants

Participants were recruited via the Prolific platform (<https://www.prolific.com/>). Participants were only invited if they had reported having hearing difficulties on Prolific. In addition, we used the Shoebox Online hearing screening as a screening tool, excluding potential participants if the Shoebox screening showed them likely to have normal hearing. Data for the two studies reported in this paper were collected sequentially with 1-2 weeks in between. About half the participants in Study 1 were returning participants from Study 1 of Balling et al. (2026); the other half were new participants. All participants in Study 2 were returning participants from the current paper's Study 1. The participants who did not participate in Study 1 of Balling et al. (2026) completed a five-minute questionnaire-based hearing test (Kochkin et al., 2010; Koike et al., 1994), while the other participants had already completed this questionnaire for the original study. The five-minute hearing test from Koike et al. (1994) is a questionnaire that presents a selection of potentially difficult hearing situations and asks participants to report the frequency with which each situation causes difficulty. The questionnaire's summary score (summing up the answers to all questions) has been shown to correlate with pure-tone audiometry (Koike et al., 1994). When assessing hearing loss with this test, we have used the summary score to categorize the participants in one of five groups: very mild (summary score between 0 and 9), mild to moderate (between 10 and 19), moderate (20 to 31), moderate to severe (32-42), and severe to profound (43-60).

Since we cannot directly monitor how focused participants are in an online test, we embedded an attention check in the middle of each test run to maintain data quality. Data for participants who failed this check were discarded, which was the case for 35% of the original sample for Study 1 and 22% of the original sample for Study 2. Participants who failed the attention check in Study 1 were not barred from volunteering for Study 2, but their data were only analyzed if they passed the attention check for that study.

The final samples consisted of 217 participants for Study 1 and 129 participants for Study 2. In both studies, the mean age was 65 years (standard deviation 6 years), and the participants were 48% female and 52% male. The distribution of hearing loss, derived from the summary score based on Koike et al. (1994) as described above, is illustrated in Figure 1, which shows a wide spread from mild-to-moderate to severe-to-profound, with only a handful of participants having a very mild hearing loss.

Hearing aids, fittings and recordings

Both studies tested the preference for different sound designs, using recordings of different hearing aid brands to represent different processing architectures. Time-domain processing was represented by the Widex Allure RIC, and frequency-domain processing by premium RIC devices from two other major hearing aid manufacturers (Manufacturer A and Manufacturer B). In addition, preferences identified in the current studies were compared to the data collected by Balling et al. (2026), which used the Signia Integrated Xperience (IX) Pure C&G to represent the frequency-domain processing.

To create the recordings, the devices were fitted to a KEMAR manikin using M-receivers and vented sleeve eartips and programmed to an N3 hearing loss (Bisgaard et al., 2010). The fitting was done using the relevant proprietary fitting rationales, following a default fitting flow with settings for an experienced user (when available).

The recordings were created in the WS Audiology Spatial Audio Lab in Lyngø, Denmark. The Spatial Audio Lab consists of a 45-channel spherical loudspeaker array, which uses fourth-order Ambisonic encoding and decoding to recreate a variety of real-world scenarios in a highly realistic way. The source sound scenes being recorded were extracts from the HOA-SSR sound library (FORCE Technology), which are real-life recordings made with 4th order ambisonics microphones, providing very detailed and highly realistic scenarios.

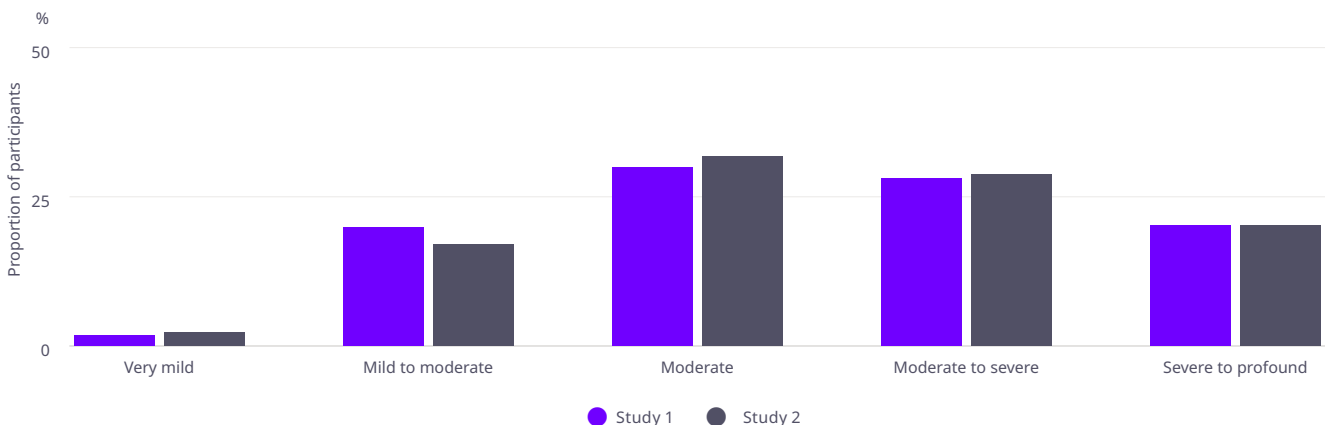


Figure 1: Distribution of hearing loss derived from the five-minute hearing test, for the 217 participants of Study 1 and the 129 participants of Study 2.

Table 1 provides an overview of the recorded sound scenes, which were selected by consensus between several experts. Importantly, the goal when selecting scenes was not to make a specific hearing aid sound design appear superior, but to select scenes that could identify people’s preferences for either time-domain processing or frequency-domain processing.

After recording, the audio files were post-processed to optimize them for headset playback by compensating for the double ear canal resonance caused by the sound being recorded at the manikin’s eardrum and listened to via headphones, and by adjusting the gain for an appropriate listening level when presented in the online experiment. The recordings matched in overall sound level, ensuring that differences in loudness would not drive differences in preference.

Study 1 : Recorded scenes

1. Classical chamber music
2. Restaurant ambience away from occupied tables
3. Restaurant ambience recorded at an eight-people table
4. Sounds of nature: Rain
5. Sounds in a large fitness room with music
6. Classroom with target speech from teacher
7. Classroom with students chatting

Table 1: Overview of the 7 recorded sound scenarios evaluated in the present study. All of them were also evaluated in Balling et al. (2026), except for the first scene, which replaced another music scene.

Procedure

The experimental procedure is illustrated in Figure 2. Participants recruited for the first time (“new” participants in Study 1) started by taking the Shoebox Online hearing screening and were only directed to the SenseLabOnline platform (FORCE Technology) for the listening test if confirmed to be likely to have hearing loss by the Shoebox screening. In SenseLabOnline, new participants in Study 1 completed the five-minute hearing test of (Kochkin et al., 2010; Koike et al., 1994) described above. Then, the main listening test began. All other participants (Study 1 participants returning from Balling et al. (2026), all

participants in Study 2) were taken directly from Prolific to the main listening test in SenseLabOnline.

During the main listening test, participants evaluated the seven different sound scenes listed in Table 1, switching back and forth as often as they liked between the two different sound designs investigated in each study to compare them. The two sound designs were anonymized as Sound System A and Sound System B, with half of the participants seeing one sound design as System A and the other half seeing the other sound design as System A to balance potential bias. The order of the scenes was randomized between participants.

For each scene, participants were asked to indicate their preferred sound design and to rate the strength of their preference on a scale from 1 (very weak preference) to 5 (very strong preference). Preferences were collected as forced-choice responses: participants did not have the option of not indicating a preference. This was done as a parallel to a clinical setting, where a specific hearing aid platform will always have to be chosen (by the hearing aid wearer or, more often, their HCP).

At the end of the experiment, participants were asked to indicate which sound design they preferred overall, and to rate the strength of their overall preference. This was based on the logic that not everyone would weigh the seven scenes equally, and that this should be acknowledged when determining the overall preference of the participant (which in turn, in a clinical setting, would guide the choice of the hearing aids), rather than automatically calculating a fixed summary score based on the preferences in individual scenes.

Data analysis

The 1-to-5 preference ratings were rescaled from 1 to 3 for comparison with Balling et al. (2026), with ratings of 4 and 5 grouped as “Strong”, 3 as “Moderate”, and 1 and 2 as “Weak”. When interpreting the results, we mostly focus on the “Moderate” and “Strong” preferences, as the forced-choice design means that at least some of the “Weak” preferences are likely to correspond to cases when participants did not actually have a preference. In this paper, we only report the overall preference results; the

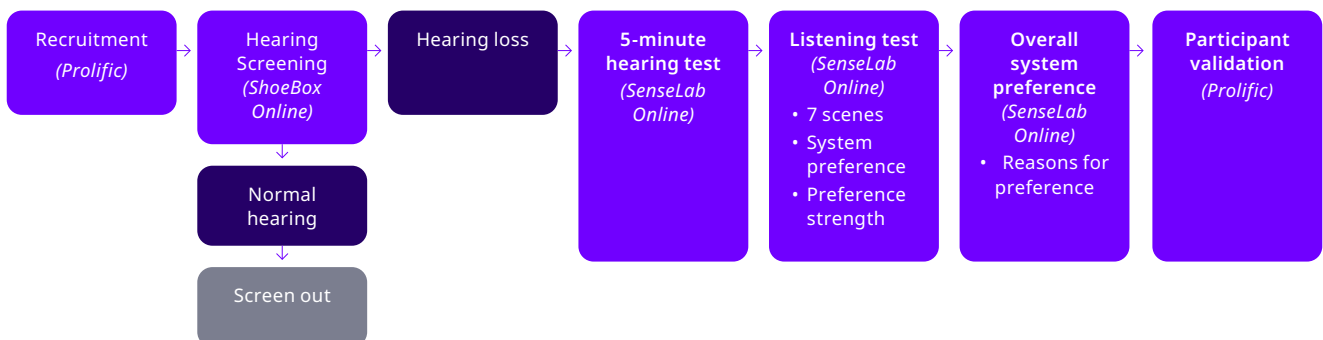


Figure 2: Summary description of the experimental flow. The “Hearing screening” and “5-minute hearing test” steps only applied to the new participants in Study 1, as these data were already available for returning participants from Balling et al. (2026), and all participants in Study 2 were returning participants from Study 1.

by-scene preferences were mostly consistent with the overall preference.

In addition to analyzing the preferences in the current studies, we also compared preferences in the current studies with preferences for returning participants reported by Balling et al. (2026). This allows us to assess the stability of preference for time-domain vs. frequency-domain processing, investigating whether participants who preferred time-domain processing when comparing to one frequency-domain alternative would also prefer it when compared to other implementations of frequency-domain processing.

RESULTS

Study 1: Sound preference for Widex's time-domain processing vs. Manufacturer A

Figure 3 shows how participants' overall preferences were distributed between Widex and Manufacturer A. Considering all preference strengths, there was a 68/32 split in favor of Widex, and the distribution of strong and moderate preferences was strongly skewed with 41% for Widex and only 13% for Manufacturer A. In other words, Widex with its unique time-domain sound design is strongly preferred over Manufacturer A.

Study 1: Sound preference for Widex's time-domain processing vs. Manufacturer A

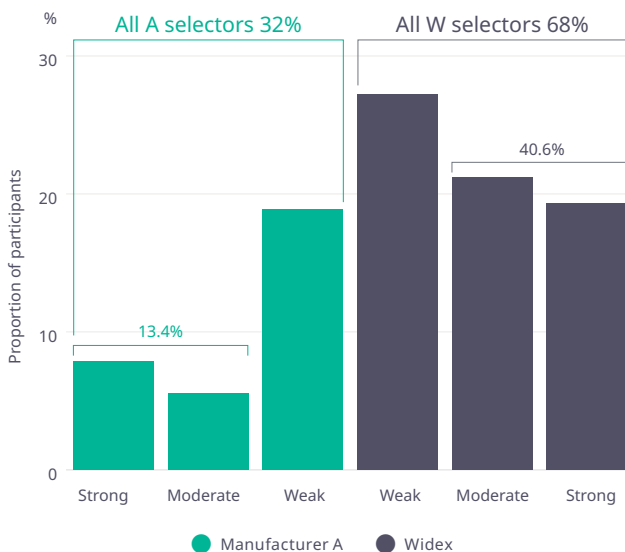


Figure 3: Distribution of preferences for Widex's time-domain processing vs. Manufacturer A.

Study 2: Sound preference for Widex's time-domain processing vs. Manufacturer B

Figure 4 shows how participants' overall preferences were distributed between Widex and Manufacturer B. Preferences overall were evenly split (51/49), and the distribution of strong and moderate preferences was similar to the 20-60-20 distribution observed by Balling et al. (2026) when comparing Widex to Signia.

The stability of the time-domain preference

Ninety-nine participants completed both Study 1 of Balling et al. and Study 1 of this paper, while 69 participants completed both Study 1 of Balling et al. and Study 2 of this paper. This allows us to investigate the stability of the time-domain preference against different frequency-domain alternatives for those two groups of participants.

The results are shown in Figure 5. For Study 1, 53% of the 99 returning participants had a time-domain preference in Study 1 of Balling et al. (2026). Of these, 77% also exhibited a time-domain preference when comparing against Manufacturer A's implementation of a frequency-domain processing architecture. For Study 2, 52% of the 69 returning participants had a time-domain preference in Study 1 of Balling et al. (2026), with 61% also preferring time-domain processing when comparing against Manufacturer B.

Study 2: Sound preference for Widex's time-domain processing vs. Manufacturer B

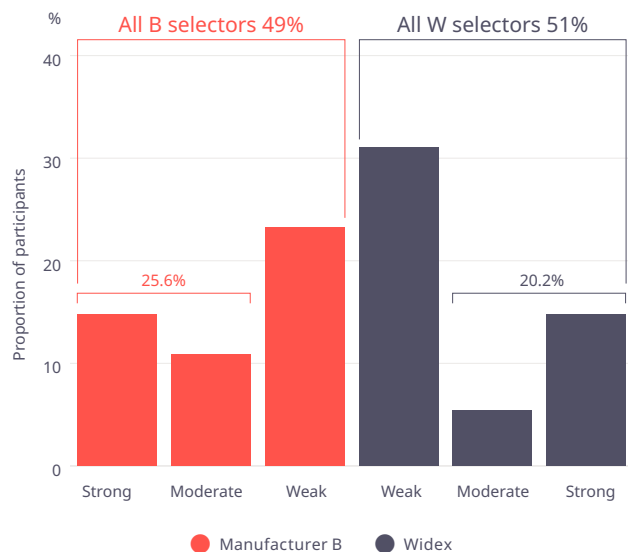


Figure 4: Distribution of preferences for Widex's time-domain processing vs. Manufacturer B.

With respect to frequency-domain preferences, these are somewhat less stable, especially for Manufacturer A, where only 36% of those who preferred Signia in Study 1 of Balling et al. (2026) retained their frequency-domain preference in the current study. For Manufacturer B, 55% showed a stable frequency-domain preference.

Thus, sound preferences are overall stable, though we also observe some changes in preference. These changes may occur for different reasons: Firstly, as evidenced in Study 1, Manufacturer A especially is a weaker frequency-domain alternative than the Signia frequency-domain platform investigated by Balling et al. (2026), so many participants changed their preference from frequency-domain in Balling et al. (Signia) to the Widex time-domain architecture in Study 1 of this paper. Secondly, some of the changes are driven by participants indicating weak preferences who, given the forced-choice design, may not have had a preference at all, but used the low strength-of-preference rating to indicate no preference. Thirdly, we would expect preference to be dynamic for some people, changing over time with their experiences. The ratings were performed with four to five months between the studies reported by Balling et al. (2026) and the studies reported here. Finally, of course a certain amount of randomness in this kind of rating is to be expected.

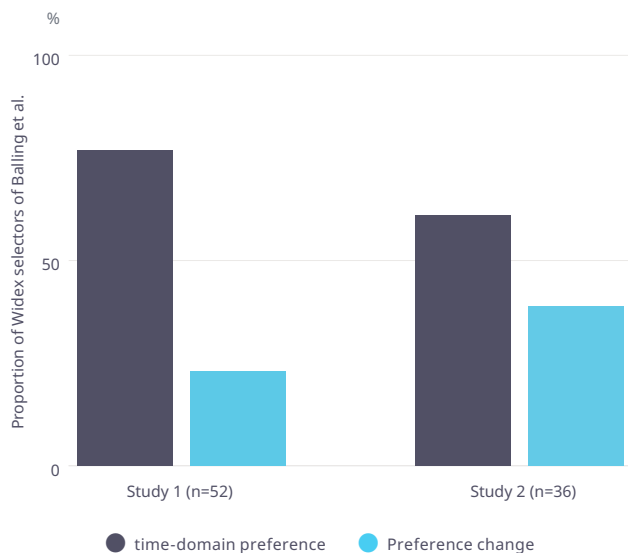


Figure 5: Stability of time-domain preferences. The plot shows how the Widex selectors in Balling et al. (2026) split their preferences between Widex and the frequency-domain alternative in the two studies reported in this paper (Manufacturer A in Study 1, Manufacturer B in Study 2).

CONCLUSION

The studies reported in this paper investigated listeners' sound preferences for time-domain vs. frequency-domain processing architectures, confirming that listeners often form systematic preferences for one or the other. Comparing Widex's unique time-domain processing architecture against different frequency-domain sound designs confirms that at least 20% have a moderate or strong preference for Widex, irrespective of the platform compared to (across the two studies reported here and those of Balling et al., 2026). When compared to Manufacturer A, this time-domain advantage is even stronger, with 68% overall preference for Widex and 41% strong and moderate preferences. The comparison to Manufacturer B shows a more balanced distribution of preferences. Across studies, the preference for time-domain processing was mostly stable, though preferences may also shift, when comparing against a weaker frequency-domain alternative, if preferences are weak, or due to changes over time. Crucially, the comparisons were done for scenarios designed to determine listener preferences, rather than to show specific advantages of specific platforms.

Clinically, this confirms that listeners' preferences should be considered, and that different processing architectures are necessary to account for different sound preferences. With the Widex sound design being unique in the industry by employing a time-domain processing architecture, and with Signia being a strong frequency-domain alternative (Balling et al., 2026), WSA is the only hearing aid manufacturer to give hearing care professionals the choice between time- and frequency-domain processing. This allows professionals to offer truly personalized fittings and cater to clients' personal and important preferences for sound.

Acknowledgement

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