Tinnitus fittings and the value of real-ear measures

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1. Introduction

Tinnitus refers to a sound percept in the ears or head occurring without any external origin (Aslesson and Ringdahl, 1989). The reported percept can vary considerably across individuals, but common descriptions include a buzzing, hissing or ringing sound in the ears/head (Yonehara et al., 2006). It is estimated that 10%-15% of people have some form of tinnitus (Axelsson and Ringdahl, 1989; Heller, 2003), of which around a quarter are annoyed enough to present clinically (Jastreboff et al., 1996). In addition, for around 2.4% of the population, tinnitus is severely debilitating (Axelsson and Ringdahl, 1989). Tinnitus is strongly associated with hearing loss and the pitch often occurs in the frequency range adjacent to (Moore et al., 2010) or within the area of hearing loss (Sereda et al., 2011). However, tinnitus can also occur in people with normal peripheral hearing thresholds (Jastreboff and Hazel, 1993). The vast majority of tinnitus is subjective, with only 4% of all cases correlating with the frequency of a somatosound (McFadden, 1982) or spontaneous otoacoustic emissions (Penner, 1990).

Various models have been proposed to try and account for the multifaceted nature of tinnitus and perhaps one of the more well-known is the neurophysiologial model (NP, Jastreboff, 1990). This model views the emergence of problem tinnitus as arising from generation of an abnormal signal in the periphery which, following detection in subcortical auditory centers, evokes annoyance and is associated with negative emotions, which leads to activation of the limbic system and development of maladaptive feelings about the tinnitus. These feelings subsequently drive a cycle of increased: attention, perceived loudness, focus and negative emotions, completing a loop that perpetuates the tinnitus throughout the system. Although thinking about tinnitus emergence has evolved, for example, generation is now considered to occur as a result of neuroplastic changes following the development of hearing loss that leads to cortical overrepresentation of frequencies adjacent to the hearing loss and associated raised synchronous spontaneous activity (Eggermont and Roberts, 2004), the NP model

continues to provide a useful framework for tinnitus management using a tinnitus retraining therapy (TRT) approach (see Jastreboff et al., 1996).

TRT comprises directive, informational counseling to help dispel any fears/negative thoughts around the tinnitus and, where indicated, sound enrichment to enhance the level of the auditory background surrounding the client to reduce the contrast between this and the tinnitus, especially in quiet situations. This in turn helps reduce the noticeability of, and facilitates habituation to, the tinnitus (Jastreboff et al., 1996). Sound enrichment from hearing devices along with counseling provides greater relief from tinnitus than counseling alone (Searchfield et al., 2010). Hearing aids are generally recommended for clients with hearing loss (Vernon and Meikle, 2000; Jastreboff et al., 1996), and with combination devices, therapeutic noise can be activated in a dedicated tinnitus program for use in quiet. When using noise, Jastreboff and Hazel (1993) suggested using a broadband noise, although they indicate a shaped signal will also be effective so long as it has energy in the frequency range of the tinnitus; the main thing is the stimulus is emotionally neutral so as not to increase anxiety or levels.

A key component of the TRT approach is that sound is delivered at the so-called "mixing point," where it is audible, comfortable and sufficiently mixing with the tinnitus to reduce noticeability. TRT views tinnitus masking as counterproductive to habituation and therefore recommends avoiding it. Supporting this are research findings showing better long-term outcomes with partial versus total masking, especially for severely problematic tinnitus (Henry et al., 2006). However, more recently, partial and total masking have been shown to be equally effective in providing relief from tinnitus (Tyler et al., 2012), and for tinnitus clients with hearing loss wearing hearing aids, total masking may actually be more beneficial (McNeil et al., 2012), although these authors acknowledge potentially differential mechanisms when masking using amplified environmental sound versus nonmeaningful broadband noise.

Collectively, these findings suggest that a reasonable start-point for sound enrichment using either hearing aids and/or noise generators is to deliver an emotionally neutral sound that is audible in the frequency region of the tinnitus at a level that provides at least partial masking to reduce noticeability, but also avoids any loudness discomfort (Tyler, 2006). The Phonak Audéo Q RIC and Phonak Venture products (excluding Sky pediatric products) support this approach by not only providing cutting-edge features that improve speech intelligibility and reduce hearing-related stress, even in challenging situations, but also through availability of the Phonak Tinnitus Balance noise generator, to help reduce the noticeability of tinnitus in quieter situations.

Important note: *Counseling is extremely important for managing problem tinnitus (Hazel, 1999; Wilson et al., 1998), and this paper assumes that counseling, and input from other professionals where relevant, is part of the management for each client.*

2. Tinnitus fittings:
Hearing aids, sound generators or a combination?

If the client has hearing loss, it is generally recommended to trial hearing aids first, unless the hearing loss is confined to >6 kHz, in which case noise generators should be considered due to bandwidth limitations of hearing instruments (Searchfield, 2006; Vernon and Meikle, 2000). Ideally, fittings should be binaural, even if tinnitus or hearing loss is unilateral (i.e., for unilateral tinnitus with normal pure-tone thresholds, fit binaural noise generators; for unilateral hearing loss and tinnitus, fit a hearing aid to the ear with hearing loss and consider a noise generator on the ear with normal pure-tone thresholds;) (Searchfield, 2006).

The short-term goal of hearing aid fitting is amplification of ambient sounds and speech to partially mask tinnitus, whereas longer term, the aim is to attenuate both attention to and awareness of tinnitus (Searchfield, 2006). Desirable hearing instrument features for tinnitus fittings are shown in Table 2.1, along with the advantages and considerations of each.

Hearing instrument characteristics	Advantages	Considerations
Open fittings	• To reduce occlusion, which can enhance tinnitus awareness • To maintain normal transmission of ambient sound, especially with a mild hearing loss	• Too much venting might lead to feedback risk and compromised soft gain.
Proven feedback management	• To facilitate venting / open fittings	• Possible artefacts at very strong settings
Multiple programs	• To address the conflicting goals of filtering noise to improve hearing in some situations whilst amplifying ambient sound to reduce tinnitus noticeability in others	
Adjustable compression knee points /Ability to disable expansion	• Enables amplification of low-level ambient sound to reduce tinnitus awareness. • Recommended setting knee points between 20 and 45 dB SPL	• Possible increased feedback risk • May be difficult to achieve audibility of ambient sounds for greater degrees of hearing loss.
Wide dynamic range compression	• Improved audibility of low-level sounds without amplifying loud sounds to uncomfortable levels • Reduces the need for manual volume adjustments, which can focus attention on hearing and tinnitus.	• High compression ratios can have an impact on speech intelligibility.
Omnidirectional microphone, mode and noise reduction disabled	• Provides more ambient sound to blend with tinnitus.	• Continued difficulty hearing and/or comfort issues in background noise (ideally have separate omndirectional and directional programs)
Availability of a noise generator	• To offer additional sound to reduce noticeability in quiet environments and/or for those with moderate to severe hearing loss • Ideally with safety net feature to ensure safe exposure	• Stimulus needs energy in frequency range of tinnitus to be effective. • Stimulus needs to be neutral.

Table 2.1. Advantages and considerations of various aspects. See Searchfield (2006) for a detailed description.

For many clients with hearing loss and tinnitus, amplification will sufficiently reduce tinnitus noticeability within everyday listening environments (Searchfield, 2006). However, for some clients, tinnitus may remain evident, especially in quiet situations, in which case a dedicated tinnitus program with the Phonak Tinnitus Balance noise generator activated may be required to provide additional relief. The Tinnitus Balance noise generator may also be useful for clients with moderate to severe hearing loss for whom gain limitations and/or feedback restrictions may prevent amplification of ambient sounds to audible levels. For these cases, the safety net feature in the Phonak Target fitting software also adds value by ensuring noise levels and wear time minimize risk of further changes to residual hearing.

3. Real-ear measures and tinnitus fittings

Best fitting practice that includes verification has been shown to improve outcomes with hearing instruments (Kochkin, 2011). Furthermore, real-ear measures for tinnitus fittings can provide useful information to help guide when to use a combination approach (i.e., amplification and noise), help achieve partial masking and to help ensure that therapeutic noise delivered in combination fittings isn't uncomfortable (Tyler, 2006) and remains at safe levels. To illustrate a technique for verifying your tinnitus fittings, we present right-ear results for two cases.

3.1: Case 1 – Tinnitus and hearing loss

Case 1 has a symmetrical, mildly to moderate, high-frequency hearing loss (see Fig. 3.1.1-A) and reports some difficulty hearing in general everyday situations; however, their primary concern is constant, ringing tinnitus. Tinnitus was pitch and level matched to 4 kHz and 6 dB SL, respectively. The tinnitus handicap inventory score (THI; Newman et al., 1996) was 60, indicating tinnitus is debilitating, and is especially disruptive during the client's favorite pastime of reading in quiet.

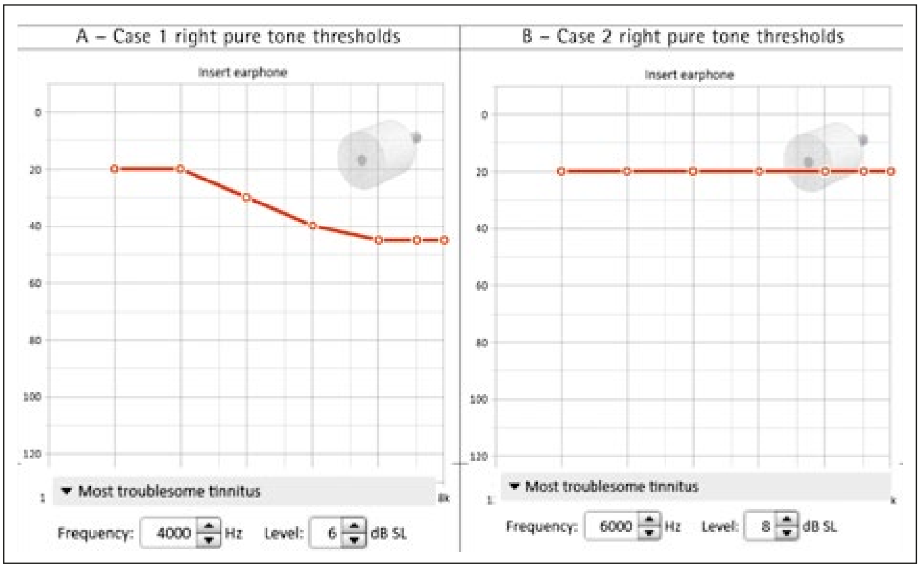
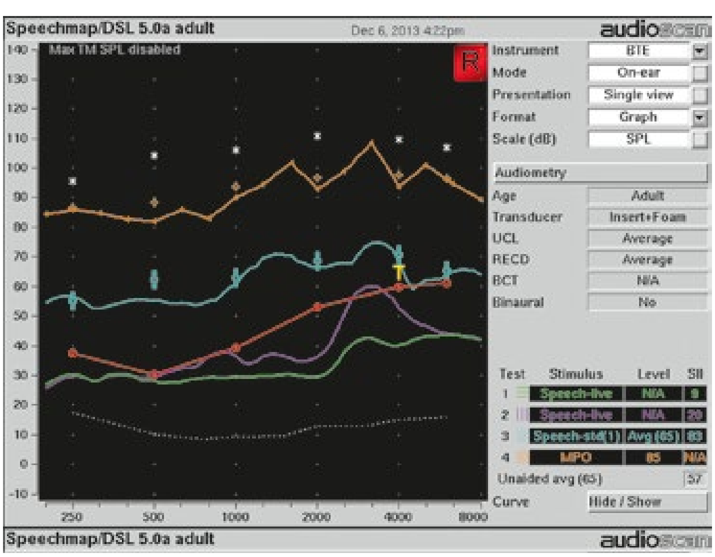


Table 3.1.1. Right pure-tone thresholds and most troublesome tinnitus information for clients.

In view of the presence of hearing loss and reported hearing difficulties, bilateral Phonak Audéo Q70 312 hearing aids were fitted with xS receivers and open domes. The DSL fitting formula was used because some evidence suggests tinnitus is less audible using DSL vs. NAL-NL 1, probably due to the additional low-level gain it provides (Wise, 2003, as cited in Searchfield, 2006). The automatic Soundflow program was set up for general everyday listening and, in line with recommendations in Table 2.1, a dedicated tinnitus program was set up for use in quiet when reading. Standard verification measures in the tinnitus program appear in Fig. 3.1.2 and show a good match to DSL targets for average speech (65 dB SPL, light blue trace), and importantly MPO is below predicted discomfort levels (orange trace).

We then overlaid the characteristics of the most troublesome tinnitus (MTT) onto the graph (4 KHz, 6 dB SL; denoted by the yellow T, where the height represents perceived tinnitus loudness in dB SL). Note that the cursor function on the real-ear machine can help with this. After disabling the stimulus from the AudioScan Verefit by selecting "Speech-Live" from the stimulus menu, we measured the output for the ambient noise level in the sound-treated booth (green curve). Given this is unrealistically quiet, as recommended by Searchfield (2006), a low-level background sound was generated at 30 dB SPL and the soft-level gain (i.e., G(20)/TKs) was adjusted to try and achieve audibility for this over as wide a frequency range as possible. Limitations on soft-level gain imposed by the open fitting meant audibility of this low-level background sound, especially in the frequency range of the MTT, wasn't really achieved.



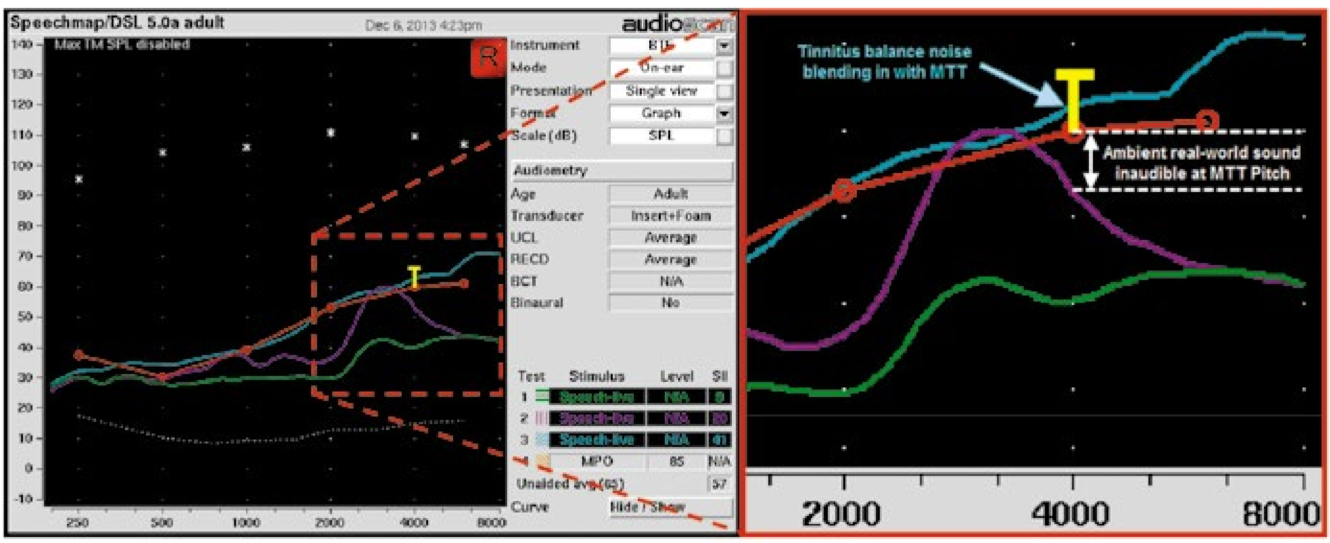
MPO
LTASSa for 65 dB SPL input
Most troublesome tinnitus (MTT)
Ambient noise level in test room
30 dB SPL background noise

Fig. 3.1.2. Standard verification measures for the dedicated tinnitus program as well as measures of output for 30 dB SPL background noise level – which shows that this would be inaudible in the range of the most troublesome tinnitus (MTT).

Accordingly, the Phonak Tinnitus Balance noise generator was activated and set to "shaped to hearing loss" and then we recorded the output as shown by the light blue trace in Fig. 3.1.3 (light blue curve). As can be seen, we are achieving good audibility of noise stimulus in quiet over a wide frequency range and, importantly, partial masking of the MTT. The client is finding this dedicated tinnitus program helpful for tinnitus relief in quiet situations, especially when reading.

3.2: Case 2 – Tinnitus and normal pure-tone thresholds

Case 2 reports reasonable hearing although notes that the loudness of their high-pitched, tonal tinnitus can fluctuate, sometimes interfering with their listening. Fig. 3.1.1-B shows essentially normal pure-tone thresholds and the tinnitus was pitch and level matched to 6 kHz and 8 dB SL, respectively. The volume of the tinnitus has recently increased and their THI score was 75 indicating a severe impact. Following counseling, the client was keen to trial noise generators to see if these would help reduce tinnitus noticeability especially in quiet.



A – Overall measure

B – Close up of tinnitus region

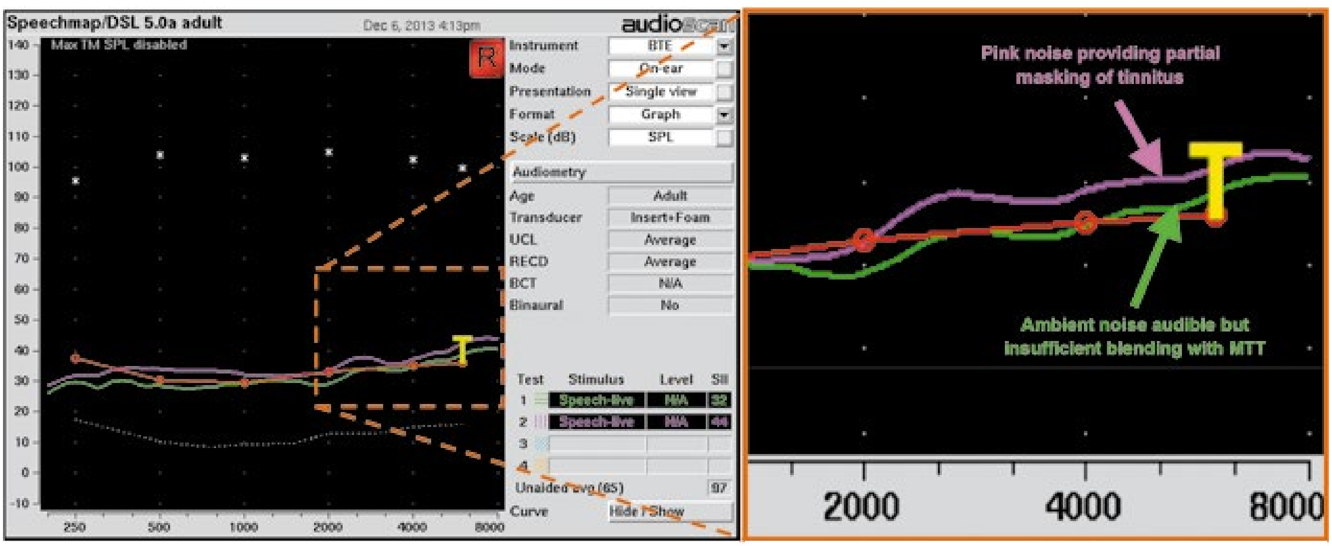
Fig. 3.1.3. Measures of Tinnitus Balance noise generator output when set to "Hearing loss" showing good audibility over a wide frequency range (A), and importantly showing partial masking/ blending in the region of the most troublesome tinnitus (MTT) (B).

Tinnitus Balance noise generator
Most troublesome tinnitus (MTT)
Ambient noise level in test room
30 dB SPL background noise

Given the essentially normal pure-tone thresholds, bilateral Audéo Q50 M13 were fitted with xS receivers and open domes and were set up as exclusive noise generators by activating the Tinnitus Balance noise generator then decreasing gain to zero. Despite the essentially normal pure-tone thresholds, these were entered into the AudioScan Verefit so we could overlay the most troublesome tinnitus (6 kHz, 8 dB SL; denoted by the yellow T in Fig. 3.2.1, where height represents perceived loudness in dB SL) and measure output relative to this. We then disabled the stimulus from the AudioScan Verefit by selecting "Speech-Live" from the stimulus menu and measured the ambient room noise (green curve, Fig. 3.2.1). Different noise profiles were tried (e.g., shaped to hearing loss, pink noise and white noise) and in this case the pink noise was preferred. Following some minor adjustments, output was measured in the ear showing good audibility of the noise stimulus across the frequency range, including in the region of the MTT – which was undergoing partial but not total masking to facilitate habituation as per the TRT approach (purple curve, Fig. 3.2.1). Given the tinnitus can vary in loudness, we set up the volume control to adjust the level of the noise, albeit within a restricted range to prevent too much masking.

4. Summary

For hearing aid fittings, real-ear measures can be used to ascertain whether amplification is likely to achieve sufficient audibility of ambient noise to partially mask tinnitus. If it doesn't, a combination approach can be considered and real-ear measures can help to ensure that the output of noise generators achieve partial and avoid total masking of the tinnitus, in line with the TRT approach. Used with Phonak Audéo Q RIC and Phonak Venture products (excluding Sky pediatric products) and Phonak Target fitting software it can also help determine which type of noise profile works best for an individual's tinnitus. Furthermore, for cases of moderate to severe hearing loss where a combination approach is required, real-ear measures can complement safety net features by providing real-ear measurement of noise levels to guide safe use time in line with accepted noise damage risk criteria. Real-ear measures are known to contribute to successful hearing instrument fittings and we have described here a technique where these measures can be applied to enhance a tinnitus program. Coupled with the appropriate counseling, devices and monitoring, being able to objectively measure tinnitus noise generator behavior adds value for your tinnitus fittings within a tinnitus program.



A – Overall measure

B – Close up of tinnitus region

Fig. 3.2.1. Measures of Tinnitus Balance noise generator output when set to "pink noise" showing good audibility over a wide frequency range (A), and importantly showing partial masking/blending in the region of the most troublesome tinnitus (MTT) (B).

Most troublesome tinnitus (MTT)
Ambient noise level in test room
Tinnitus balance – pink noise

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