Tinnitus Assessment
The key to successful tinnitus patient management

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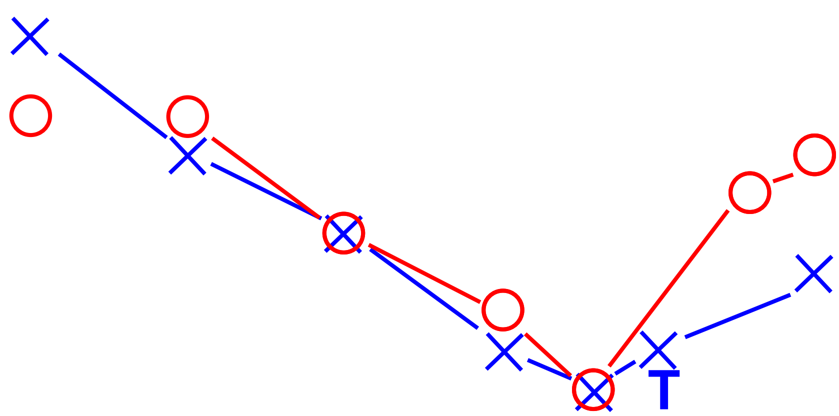


1. Introduction

An audiologist meeting a patient complaining of tinnitus needs to identify and quantify the subjective symptom. This is necessary both to establish the clinical type of tinnitus and to recommend the correct instrumentation to manage the tinnitus. According to Richard Tyler, PhD, Professor of Otolaryngology at the University of Iowa, "the quantification of a symptom is fundamental to understanding its mechanisms and treatments. If we cannot measure it, we cannot study it," (Tyler, 2000). Researchers, clinicians, and others interested in the symptom of subjective idiopathic tinnitus have attempted to make the measurement of the complaint more objective and to search for reliable methods for its quantification. This paper reviews the reasons for conducting a tinnitus evaluation and describes how a tinnitus evaluation can be enhanced using the psychoacoustic measurements and the tinnitus questionnaires available in the MADSEN Astera² audiometer.

2. Reasons for conducting a tinnitus evaluation

There are several reasons why a tinnitus assessment – as an integral part of the audiological examination of a tinnitus patient – can be beneficial for both the patient and the clinician.

Improve communication between patient and clinician
A tinnitus evaluation can provide a valuable basis for communication between the examiner and the patient about the symptoms. An evaluation gives the clinician an objective picture of the tinnitus rather than relying on the patient's subjective description of the sound or sounds they hear. The "quality" of the tinnitus (ringing, clicking, hissing) may not always be diagnostically relevant, but it may at times help alert the otologists to vascular (rhythm, ocean roar) and/or middle ear (clicking) problems. Overall, however, the correlation between quality and etiology has proved non-specific (Goldstein, Shulman 1981).

Provide reassurance and a basis for effective counseling
The evaluation also provides reassurance to the patient that their tinnitus is real. For many patients the presence of the tinnitus makes them feel insecure as others cannot hear it. Measuring the tinnitus reassures them that it is indeed real. An assessment also helps to reproduce a similar sound to demonstrate to the patient's family some of the characteristics of the tinnitus that the patient is experiencing.

Establish a reference point
The tinnitus assessment parameters provide a common reference point from the time of initial diagnostic evaluation throughout treatment and control. This helps to determine whether the tinnitus has changed and if the treatment is effective.

Provide guidelines and support diagnosis
The measurements also can provide treatment guidelines. Measurement of the maskability or the pitch matching can help the professional to set the level and spectrum of the stimulation used in the sound therapy. An assessment might also provide some clues for the otologists to determine the site of origin of the tinnitus. According to Douek and Reid (1968), in general, pitch matches were 125 to 250 Hz in Ménière´s disease and from 2 kHz to 8 kHz in case of presbyacusis.

Categorize
A tinnitus assessment allows the distinction between different subcategories of tinnitus. Although two patients may indicate that their tinnitus is of a ringing quality, maskability may be present for one of them and not for the other resulting in clear subcategories. This may suggest which treatments could be more effective.

Select treatment
The assessment can help determine whether the client can benefit from certain types of treatment. Many patients react differently when listening to the same acoustical stimulus.

Document the presence of tinnitus for legal reasons
Finally, tinnitus assessment can be useful in situations that require documentation. For legal reasons some points may need to be validated, such as the presence of the tinnitus, the degree of impairment, disability and/or handicap.

3. Using psychoacoustical measurements and questionnaires

The following section explains how tinnitus can be evaluated, not only in terms of psychoacoustical components, but also to assess its impact on the daily life of the client. Through both psychoacoustical measurements and questionnaires, the tester identifies and quantifies the subjective complaints of tinnitus, and the results establish the clinical types of tinnitus and form the basis for specific audiologic recommendations for instrumentation to control the tinnitus.

Note: it is important to note that a complete cochleo-vestibular evaluation needs to be performed prior to tinnitus assessment.

3.1 The psychoacoustical measurements

Psychophysics deals with the relation between sense organs and physical worlds. Psychoacoustics is the branch of psychophysics that studies the relationship of the perceptual world and acoustics. Psychoacoustic effects elicited by acoustic stimuli that form the foundation for tinnitus evaluation include:

- Pitch Matching
- Loudness Matching
- Masking
- Residual Inhibition

The equipment

To perform these measurements the professional needs a two-channel audiometer with pure tone, narrow band noise and broadband noise stimuli. This audiometer should allow stimulating both unilaterally and bilaterally, in high frequencies (up to 20 kHz) and propose a 1 Hz resolution, 1 dB step, and an Octave Confusion Test (OCT).

The measurement method

Stevens described in 1938 seven measurement methods of pitch and loudness (adjustment, limits, paired comparisons, constant stimuli, quantal, order of merit and rating scale) (Stevens, 1938). The purpose of these psychophysical methods is to find reliable methods for assessing what the individual is experiencing perceptually. Today the most popular is the method of paired comparisons where the patient is asked to choose the closest tone among two different ones. After choosing one the second trial is presented using the selected tone and a higher one until the patient confirms a level or a frequency. This two-alternative forced choice method was also suggested (Vernon and Fenwick, 1984) as the most reliable method for tinnitus measurement.

The test ear

The test ear selected can have an influence on the results. The pitch may vary according to which ear receives the tones (Tyler & Conrad-Arms, 1983). If the stimulation is ipsilateral, the tinnitus may change in response to the presentation. However, inaccurate results may be obtained when stimulating the contralateral ear. Finally, binaural presentation can be problematic for these reasons and because the patient likely hears differently from each ear. However, there is a consensus among professionals to recommend the monaural ipsilateral testing with the examiner noting the test ear (Goldstein, 1997, Tyler, 2000).

The stimulation

The recommendations are to use a pure tone, but narrow band noise is also used despite the potential problems of using this as a stimuli. An alternative solution is to use the FRESH (FREquency Specific Hearing assessment noise, Walker, Dillon & Byrne, 1984). This noise is a narrow band noise signal that has been designed with extremely steep filter slopes. The continuous stimulation is preferred instead of the pulsed one as the latter seems to be more difficult for the patient (Mineau & Schlauch, 1997). The time presentation should be around 500 ms with 5 seconds intervals.

Measurement #1: Pitch matching

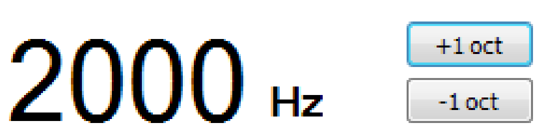
The pitch is the psychoacoustical outcomes that correspond closest to the physical dimension of frequency and is the most common measurement that attempts to quantify tinnitus for frequency. Pitch matching can be used as a reference point for discussion, for selection and fitting of acoustical instrumentation, or to find the site where the tinnitus originates. Despite the fact that the description of the tinnitus can be very different from patient to patient, Meikle reported that 92% of 1.033 patients could complete a pitch match. The subjective pitch estimates using a visual scale from 0 to 10 are typically rated as high. For example, Stouffer and Tyler (1990) reported an average rating of 7.12

with 65% of the patients rating their tinnitus as a seven or higher (Slater and Terry, 1987). In most patients, the tinnitus pitch is matched about 3 kHz (Reed, 1960; Vernon, 1987; Meikle, 1995). It is highly related to the fact that most patients with tinnitus have a high frequency hearing loss. For several researchers there is a link between the tinnitus pitch and the frequency region of maximum hearing loss (Minton, 1923; Fowler, 1940; Fraham and Nerby, 1962; Douek and Reid, 1968; Penner, 1980; Meikle et al., 1999).

Typically the measurement of the pitch matching will follow the procedure as shown in the table below. A consistent loudness between frequencies should be reached. To do so the clinician can use the Most Comfortable Thresholds (MCL) from the tone audiometry results.

	Comparison tones	Tone judged most like tinnitus
Trial 1	1 kHz vs 2 kHz	2 kHz
Trial 2	2 kHz vs 3 kHz	3 kHz
Trial 3	3 kHz vs 4 kHz	4 kHz
Trial 4	4 kHz vs 5 kHz	4 kHz
Trial 5	4 kHz vs 4.5 kHz	4 kHz
Trial 6	4 kHz vs 4.25 kHz	4.25 kHz
Trial 7	4.12 kHz vs 4.25 kHz	4.12 kHz
Trial 8	4.12 kHz vs 4.18 kHz	4.12 kHz
Trial 9	4.12 kHz vs 4.125 kHz	4.125 kHz

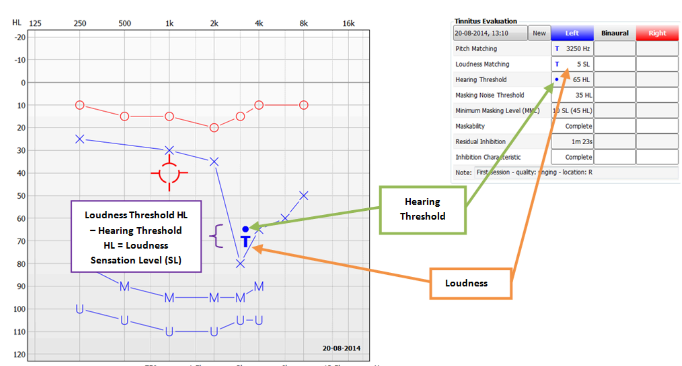
When a pitch matching is performed it is recommended to confirm the results with an Octave Confusion Test. Octave confusion appears when an individual identifies a specific frequency as the pitch match of his tinnitus; but with further testing, the identification tinnitus is actually identified at one octave above the pitch match. In the example above the pitch 4.125 kHz is compared with 8.250 kHz.



Measurement #2: Loudness Matching

The Two-alternative forced choice (2-AFC) method can be substituted for the ascending limits method starting slightly below the absolute threshold comparing the presentation loudness to the tinnitus loudness. This method minimizes the effect of residual inhibition. The result should also be discussed with regard to the presence of recruitment. The test frequency is the same as the pitch previously reported. The studies of Reed, Donaldson, Bailey, Roeser and Price, and Shailer et al., all have found that loudness-balance techniques usually results in a finding of 0 to 20 dB SL. We express the results in dB SL (Sensation Level) as it is the difference between the results in dB HL and the absolute hearing threshold at the pitch match. Generally, the pitch match does not fall into the standard audiometric frequencies, so a threshold at the specific pitch match frequency needs to be obtained. Once this is completed, the result of loudness matching converts from dB HL to dB SL as shown in the example below.

	Comparison tones	Tone judged most like tinnitus
Trial 1	55 dB vs 60 dB	60 dB
Trial 2	60 dB vs 65 dB	65 dB
Trial 3	65 dB vs 70 dB	65 dB
Trial 4	65 vs 68 dB	65 dB
Trial 5	65 vs 66	65 dB



Measurement #3: Masking

The masking of tinnitus is often considered the most important part of the tinnitus evaluation. This procedure enables the professional to evaluate whether the patient is a candidate for sound generator to control the tinnitus. It also specifies the ears to be fitted and helps to identify the cause and the lesion site. However, the correlation between the condition and the masking effect is not totally proven. According to Goldstein (2000) and Vernon (1987) the tinnitus population for which there is no masking effect is about 18%, and 9% and these patients are definitely not candidates for either acoustic masking or electrical stimulation. The fact that the tinnitus can be masked suggests that the tinnitus and the response to the acoustic stimulus share the same neural channels somewhere in the nervous system.

Masking threshold of tinnitus has been initially described by Feldmann in Audiology (10:140) in 1971 where different masking curves were classified in six types. The masking curves are established ipsilaterally and contralaterally using narrow band noise tones and white noise. Masking in normal psychoacoustics differs from masking with tinnitus in the following ways:

1. In normal hearing systems, the signal to mask and the masking stimulus have well-defined parameters and the sensation is predictable. In a defective hearing system with tinnitus, the sensation is unpredictable (Feldmann, 1984) as the signal to mask is unknown.
2. In tinnitus, masking frequency dependency is not present or may be reversed e.g., the high frequencies are more effective in masking low frequencies.
3. In normals, one cannot mask white noise by presenting a tone; in tinnitus, one can mask white noise with a minimal tone.
4. With normal hearing the masking has to be applied ipsilaterally; otherwise, the level of the masking stimulus needs to be very high to be effective (Liden, Nilsson & Anderson, 1959). In tinnitus ears, a low-level noise presented in one ear can be very efficient at masking tinnitus in the other ear. This is known as 'central masking' (Zwislocki, Buining, & Gantz, 1968, Penner, 1987).
5. The after effect of masking (or post masking or residual inhibition) lasts for less than 1 second; in tinnitus patients, this effect can be prolonged.

Noise and tones can be used during this measurement. Maskability is considered as positive or negative according to whether or not there is an effect on the tinnitus.

The measurement of the masking can be done at the tinnitus pitch frequency only, through the whole tone audiometry frequency range, or both. All type of masking noise stimulus can be used, but it is usually recommended to use the narrow band noise, the tone, or the FRESH noise. There is no clear preference between ipsilateral and contralateral masking, so either method can be performed. The comparison between ipsilateral and contralateral masking suggest that central mechanisms are involved in many patients (Tyler, 2000) and could help distinguish patients with peripheral and central components. The ascending method is usually used with presentation of masking stimulus for 1-2 seconds, then asking the patient if the noise can mask the tinnitus. The response defines the minimum masking level (MML). In order to get the value in dB SL, prior to obtaining the MML, the tester can obtain the hearing threshold using the masking stimulus as the signal.

Measurement #4: Residual Inhibition

Forward masking, also termed residual inhibition by Vernon and Schleuning (1978), is defined as the temporary suppression and/or disappearance of tinnitus following a period of masking. A recommended measurement procedure is to present the sound that has been identified at the pitch match at a level corresponding to the MML + 10 dB for 1 minute. The stimulus is the same as used for the MML measurement. The patient is asked to report the effect on their tinnitus as well as how long it takes the tinnitus to return to previous levels. A variation has been described by Goldstein and Schulman using the loudness match + 10 dB SL. Classification of the post masking effect follows these four categories:

1. Positive – Complete
   The tinnitus is completely absent. This may vary from 1s to several hours. According to Goldstein and Shulman, it is not usual for their patients to experience 30 to 90 s of positive-complete residual inhibition.
2. Positive – Partial
   Here the patient reports the tinnitus loudness as less than what it was before the measurement. The quality may have changed as well.
3. Negative
   The patient reports no change in the tinnitus loudness.
4. Rebound or Exacerbation
   The patient reports an increase in the tinnitus loudness level in response to the masking presentation. For these cases, the time it takes the sound to return to its original level is recorded (Shulman, 1985).

3.2 The Questionnaires

While specific objectives are supported by the questionnaire chosen, the overall goal of using tinnitus questionnaires is to assess the impact of the tinnitus on the patient's daily life. The information can also be used to guide treatment decisions and also to monitor progress over time.

The most common questionnaires are:

- Tinnitus Handicap Inventory (THI)
- Tinnitus Functional Index (TFI)
- Tinnitus and Hearing Survey (THS)

Questionnaire #1: Tinnitus Handicap Inventory (THI)
Developed by Newman, Jacobson, and Spitzer (1996), the THI is a frequently used questionnaire that not only defines self-reported handicap to determine which patients require treatment but also can be applied to assess outcomes for various approaches.

The THI is comprised of 25 items that are answered with a selection of Yes, Sometimes, or No. These items include inquiries about the impact of tinnitus on concentration, emotional reactions, and the effects on life and relationships. The patient's answers to these questions provide a result that defines a handicap severity score, ranging from 'Slight' to 'Severe/Catastrophic'. This score can guide the clinician towards the most appropriate intervention approaches, including determining those patients that may be in need of further medical and/or psychological evaluation.

Questionnaire #2: Tinnitus Functional Index (TFI)
Introduced by Meikle et al in 2012, the TFI also consists of 25 items. Applicable for both clinical and research uses, this questionnaire is used to determine the severity of the tinnitus as well as define what negative impacts the patient is experiencing in response to it.

Questions cover eight subscales that summarize the areas of intrusiveness, sense of control, cognitive effects, sleep disturbance, auditory difficulties, interference with relaxation, reduction in quality of life, and emotional distress. Patients respond to the items using a 10-point scale. An overall score that ranges from 0-100 is calculated along with subscale scores.

Questionnaire #3: Tinnitus and Hearing Survey (THS)
Unlike the THI and TFI questionnaires, the THS is not a validated measure and therefore should not be used as a primary outcome measure. Instead, the THS should be used as a supplement to a validated questionnaire. Described by the National Center for Rehabilitative Auditory Research (NCRAR), the THS is used to differentiate issues that are arising from tinnitus versus those that are caused by hearing challenges.

The THS consists of 10 items. Four of these relate to tinnitus-specific issues, four relate to common hearing problems, and the final two are inquiries about sound tolerance issues. Patients answer using a 5-point scale that correlates to 'No problem at all' to 'A very big problem' in response to a range of hearing and tinnitus challenges. Reviewing these results can be useful in counseling patients with co-existing hearing loss and tinnitus to define the boundaries of these issues. The results can also help define the options and potential benefits of treatment for each of these issues.

4. Conclusion

Hearing care professionals are meeting more and more tinnitus patients in their practice every day. Fortunately, there has been increasing tinnitus research and awareness over the last five years and hearing instrument manufacturers are providing advanced solutions for tinnitus management. However, professionals are still in doubt about how to talk with the patient about their specific tinnitus and the solution options available to them. Building trust with all patients is important, but it's even more crucial with a tinnitus patient. Many tinnitus patients are embarrassed about their tinnitus. They can also be frightened and even desperate to find an explanation and "cure." While there is no cure for tinnitus, it is possible to help tinnitus patients by providing empathy and concrete ways to manage the condition.

A tinnitus evaluation is the first step to establishing trust between the tinnitus patient and clinician. A complete tinnitus evaluation – from psychoacoustics measurements to targeted questionnaires – helps clinicians to identify, quantify, and manage the tinnitus while establishing an open and constructive relationship with the patient. MADSEN Astera² from Otometrics is the only clinical audiometer with a dedicated tinnitus evaluation module and tinnitus-specific questionnaires and psychoacoustical tests built in. The module includes all the above- mentioned tests and questionnaires and is available for free in OTOsuite® since version 4.65. With solutions such as MADSEN Astera², clinicians are better able to meet their tinnitus patients where they are – and succeed in helping them to manage it in a positive way.

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