TINNITUS WORKSHOP

Psychoacoustic Measurements of Tinnitus: From Theory to Practice.

Philippe Fournier & Pierre Bourez

October 15, Blue Mountains, Ontario, Canada

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PLAN OF THE SESSION

1) Theories

2) Application

3) Clinical usefulness

Theories behind psychoacoustic measures of tinnitus

« No need of sophisticated equipment to perform the psychoacoustic measures of tinnitus »

« Every audiologists can perform psychoacoustic measures of tinnitus : it doesn't require any specialized competencies »

Theories behind psychoacoustic measures of tinnitus

Field of Psychophysics

Determine the quantitative relationships between a physical stimulus and perception *e.g., weight and the sensation of heaviness*

Measures the perception of tinnitus, not the reaction to tinnitus

Psychoacoustics does not measure distress, disability, or the impact of tinnitus on quality of life – it measures the percept.

No consensus or clinical guidelines on the use of psychoacoustic measures

Some recommend them for all patients, others only for specific cases.

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Theories behind psychoacoustic measures of tinnitus

Frequency or Pitch Matching

High vs. Low

Loudness Matching

Soft vs. Loud

Estimation of the percept

Tinnitus Masking Level

Can the tinnitus be masked? If so, at what level?

Residual Inhibition Measurement

Can the tinnitus be temporarily suppressed?

Interference with the percept

TIMBRE MEASUREMENT

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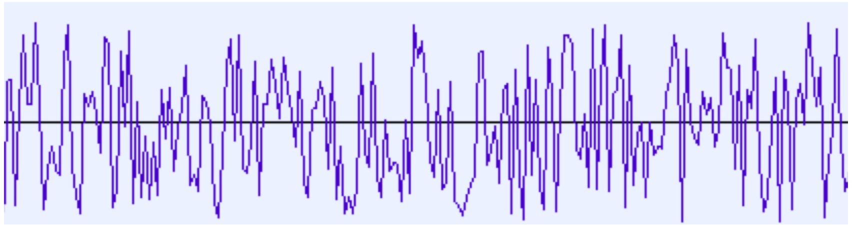
Timbre Measurement

.Does the tinnitus resemble a noise or a pure tone?

Pure tone



Noise

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Timbre Measurement

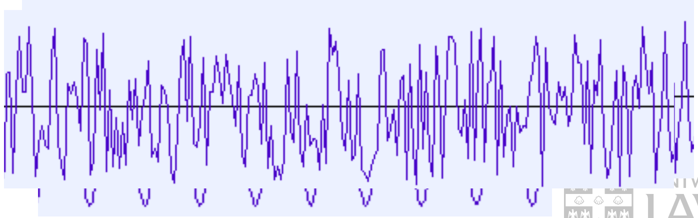
1) Explain to the patient that he will hear 3 different sounds
2) The patient must choose the sound that is closest to his tinnitus

3rd sound

Pure tone

White noise

Narrow band noise



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PITCH & LOUDNESS MATCHING

Pitch matching

Techniques:

Forced choice
Spectrum
Continuous measurement
(e.g., potentiometer)

Potential Issues:

Predominant frequency of the tinnitus?
What if more than one frequency is heard?
Noise vs. pure tone?
Ipsilateral or contralateral ear?

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Stimulation Laterality

Ipsilateral

Avoid diplacusis-related issues (difference in pitch perception between the two ears)

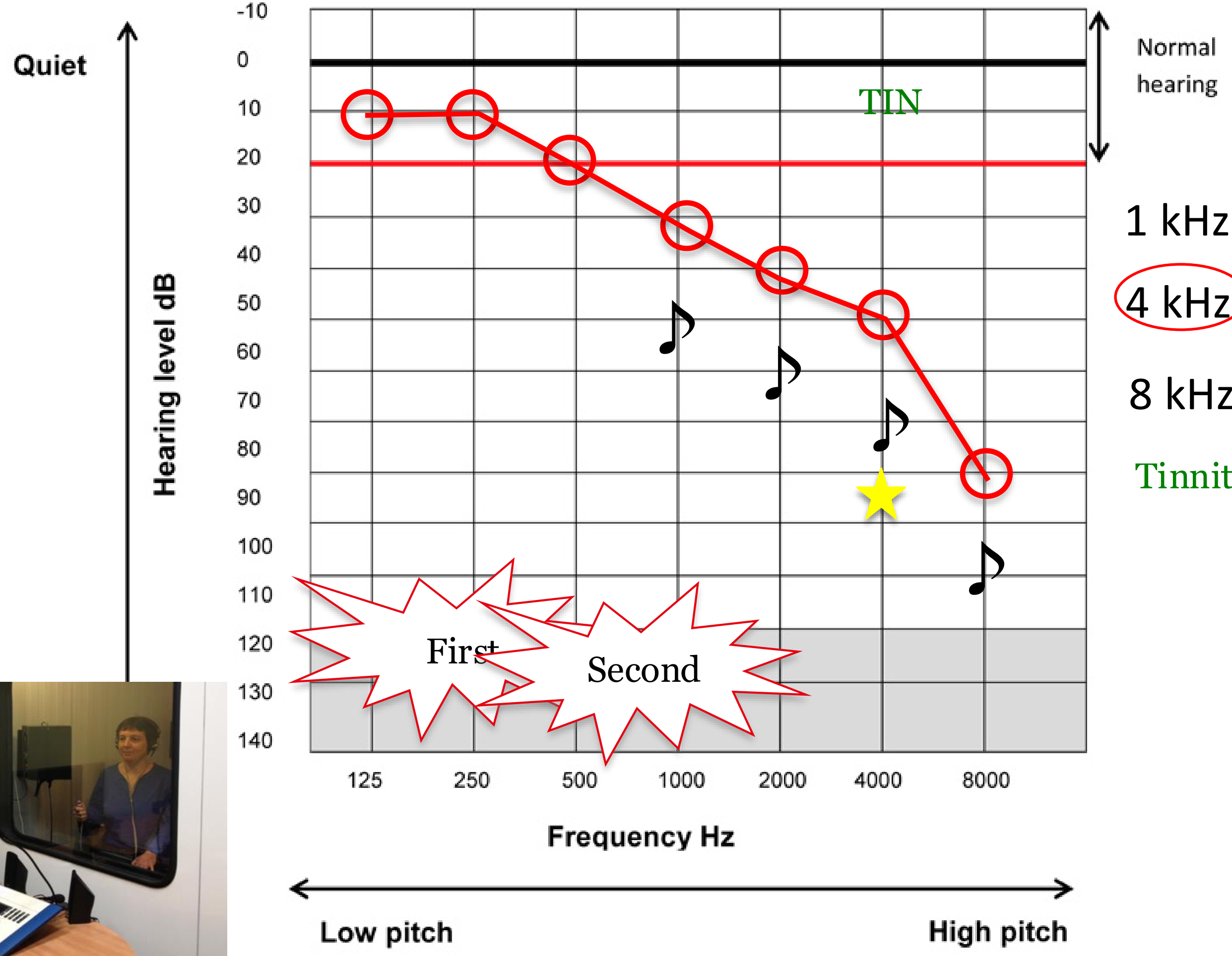
Controlateral

Avoid masking the tinnitus sound

Reduce confusion between the matched sound and the tinnitus

« No consensus »

Pitch matching: forced choice



1 kHz 4 kHz

4 kHz 2 kHz

8 kHz 4 kHz

Tinnitus : 4 kHz

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Pitch matching : forced choice

Passive Matching Method

•Test-retest reliability is low

•Difficult for the patient (sometimes reports frustration)

•Requires additional skills from the clinician

•Time-consuming

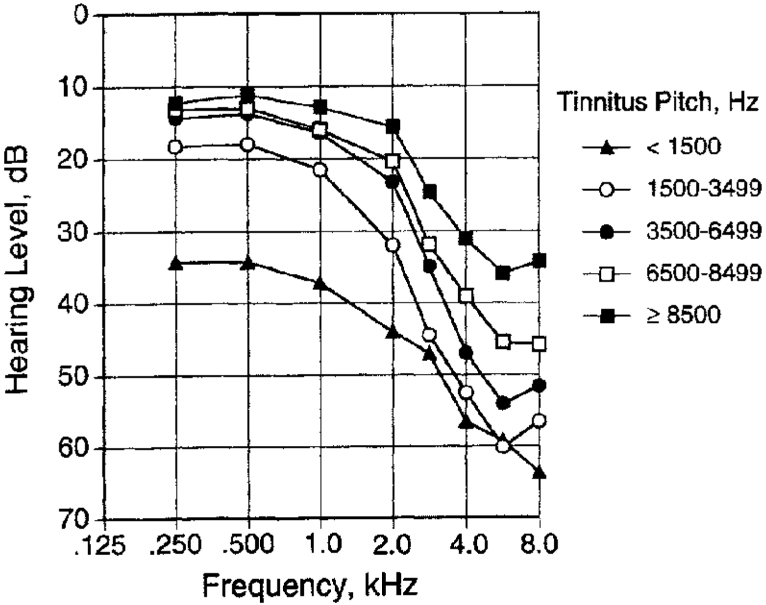
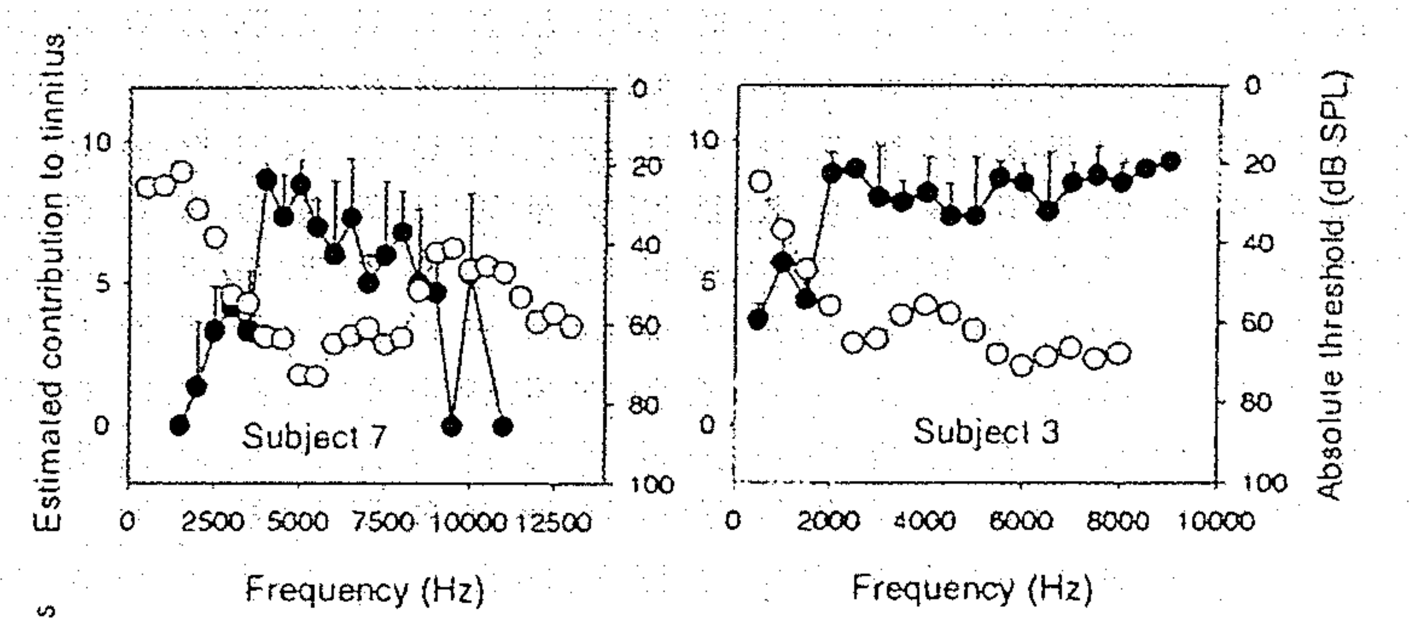


Fig. 5.5 Mean hearing threshold of the right ear for individuals in each group of patients according to the pitch of their tinnitus. Data are from patients who attended a tinnitus clinic. From Henry et al. [19]

Henry, J. A., Meikle, M., & Gilbert, A. (1999). Audiometric correlates of tinnitus pitch: insights from the Tinnitus Data Registry. In *Proceedings of the sixth international tinnitus seminar* (pp. 51-57). The Tinnitus and Hyperacusis Centre London.

Tinnitus spectrum



Norena et al. (2002) Audiol & Neurotol

0 X Ne correspond pas du tout à votre acouphène
(Does not match my tinnitus at all)

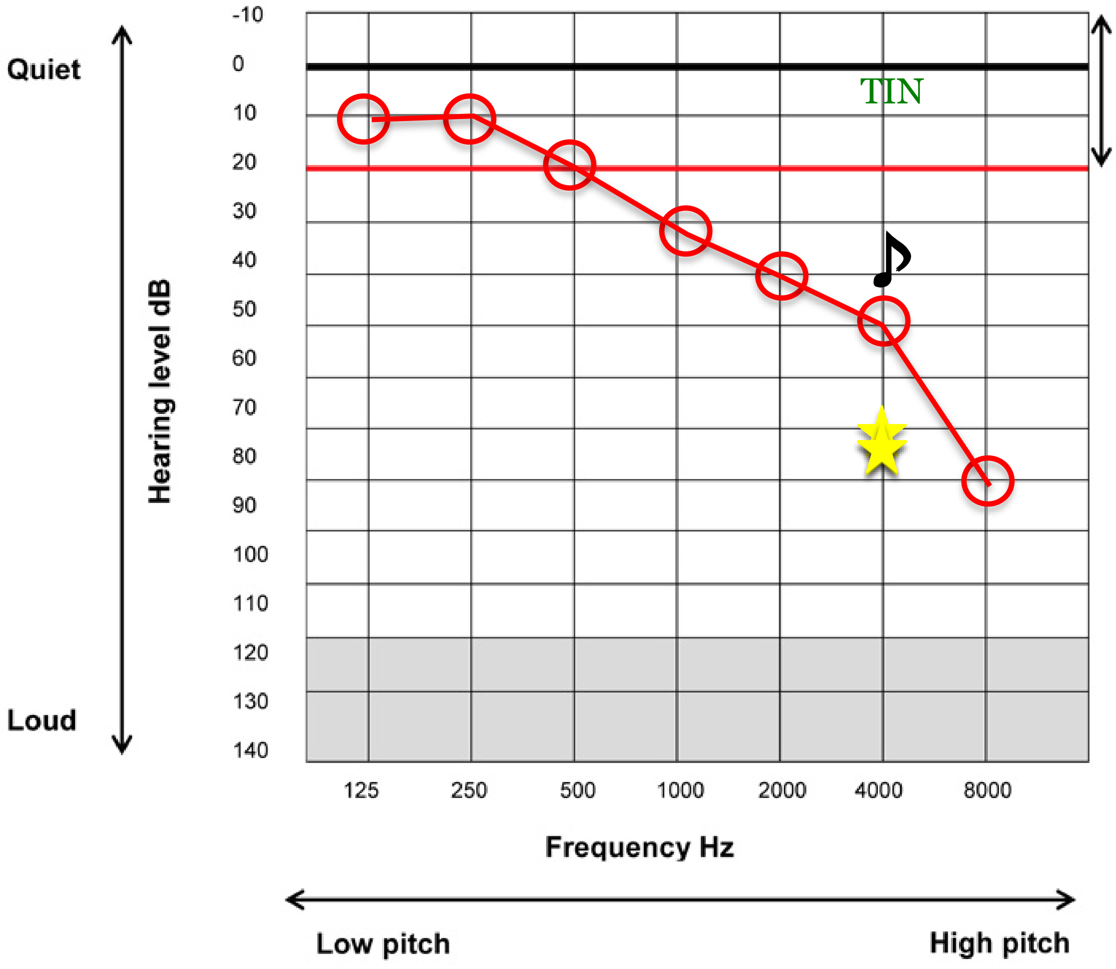
Loudness matching

Techniques:

Continuous presentation (e.g., potentiometer)
Passive vs. active method

Differences between the methods:

At the predominant frequency of the tinnitus?
At all frequencies?
At the frequency region not affected by hearing loss (e.g., 1 kHz)?
Ipsilateral or contralateral?



Predominant frequency of Tinnitus: 4000 Hz

Hearing treshold: 50 dB HL

1st attempt: 72 dB HL

2nd attempt: 76 dB HL

3rd attempt: 76 dB HL

Average: 75 dB HL

Tinnitus loudness:
75 dB HL – 50 dB HL = **25 dB SL**

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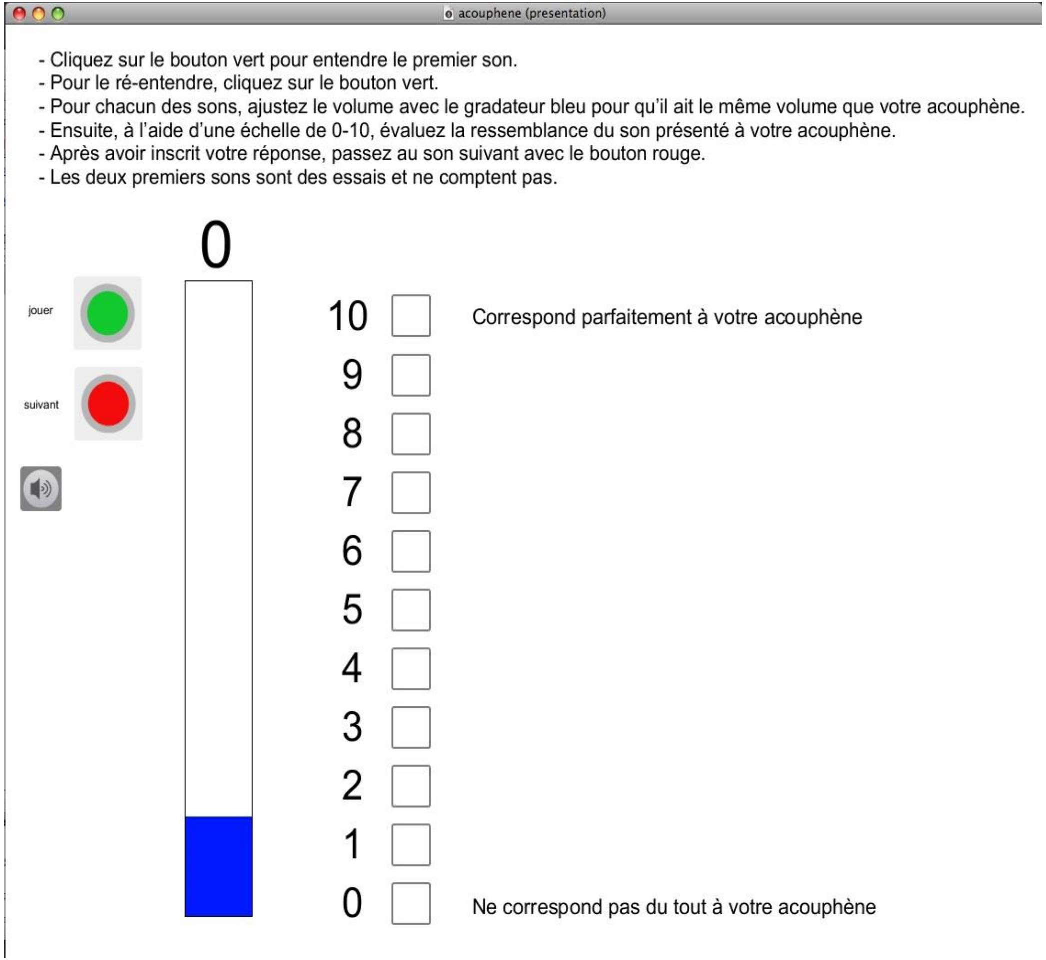

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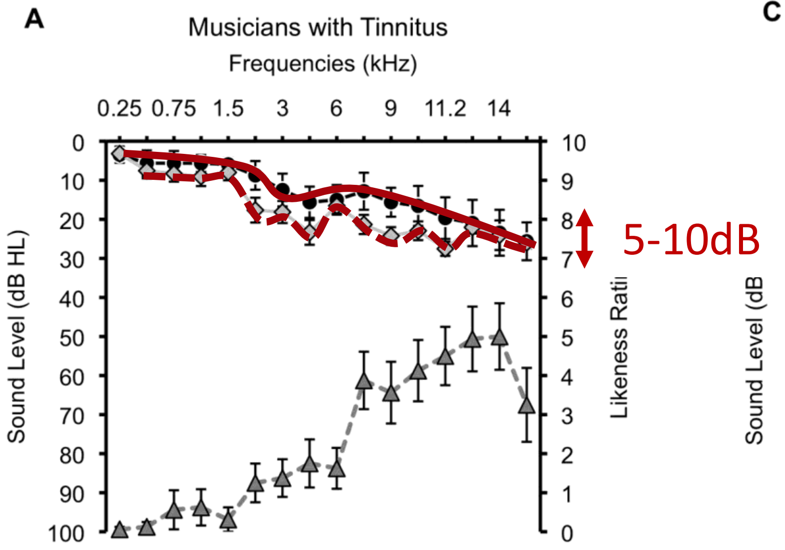
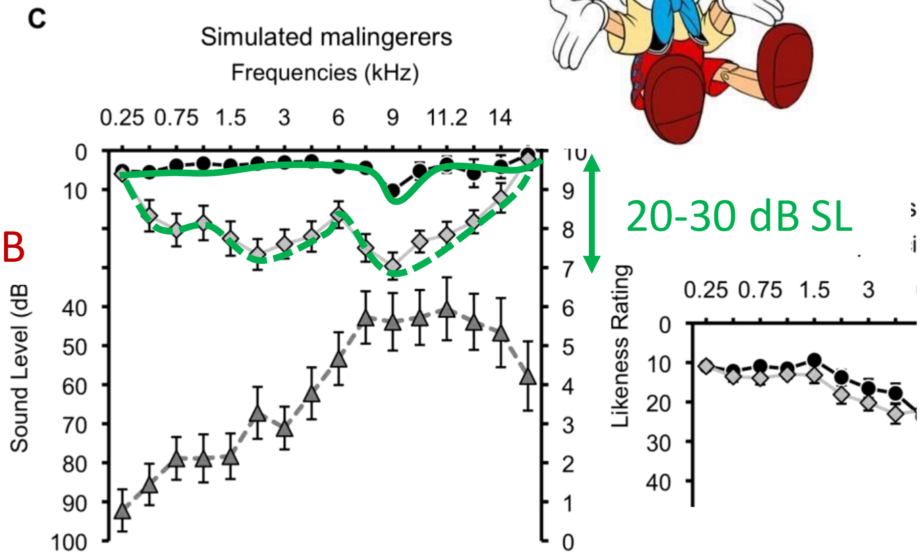
Loudness matching





« tinnitus loudness matching could be an indicator of tinnitus malingering »

Basile, C. É., Fournier, P., Hutchins, S., & Hébert, S. (2013). Psychoacoustic assessment to improve tinnitus diagnosis. *PloS one*, *8*(12), e82995.

TINNITUS MASKING

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Tinnitus masking

Techniques:

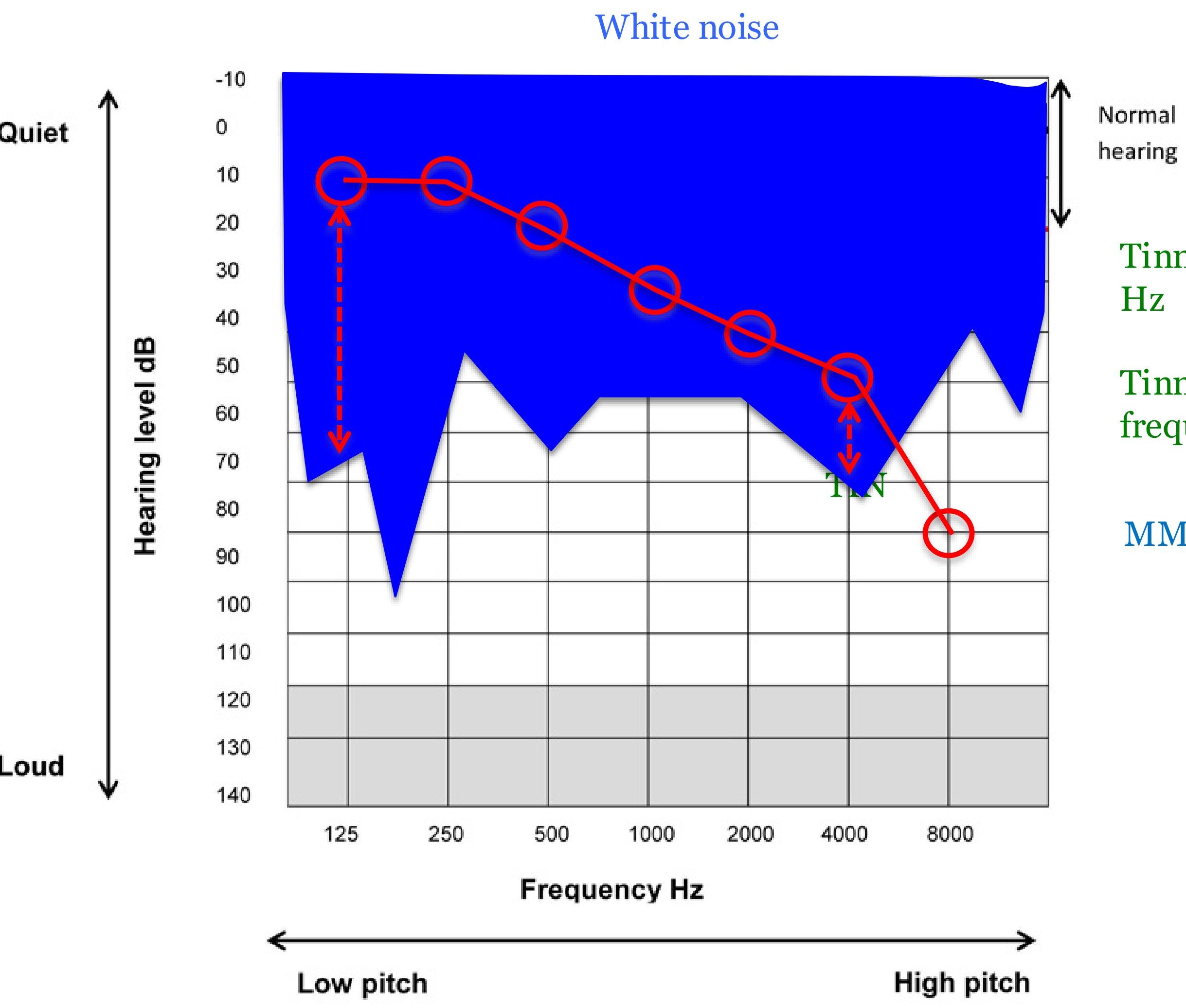
•Minimum masking level

•Masking curve

In all cases, this involves **“energetic masking”**, where the goal is to determine the minimum intensity required to mask the perception of tinnitus for a given type of stimulation (white noise, pure tone, narrowband noise, etc.).

Minimum Masking Levels

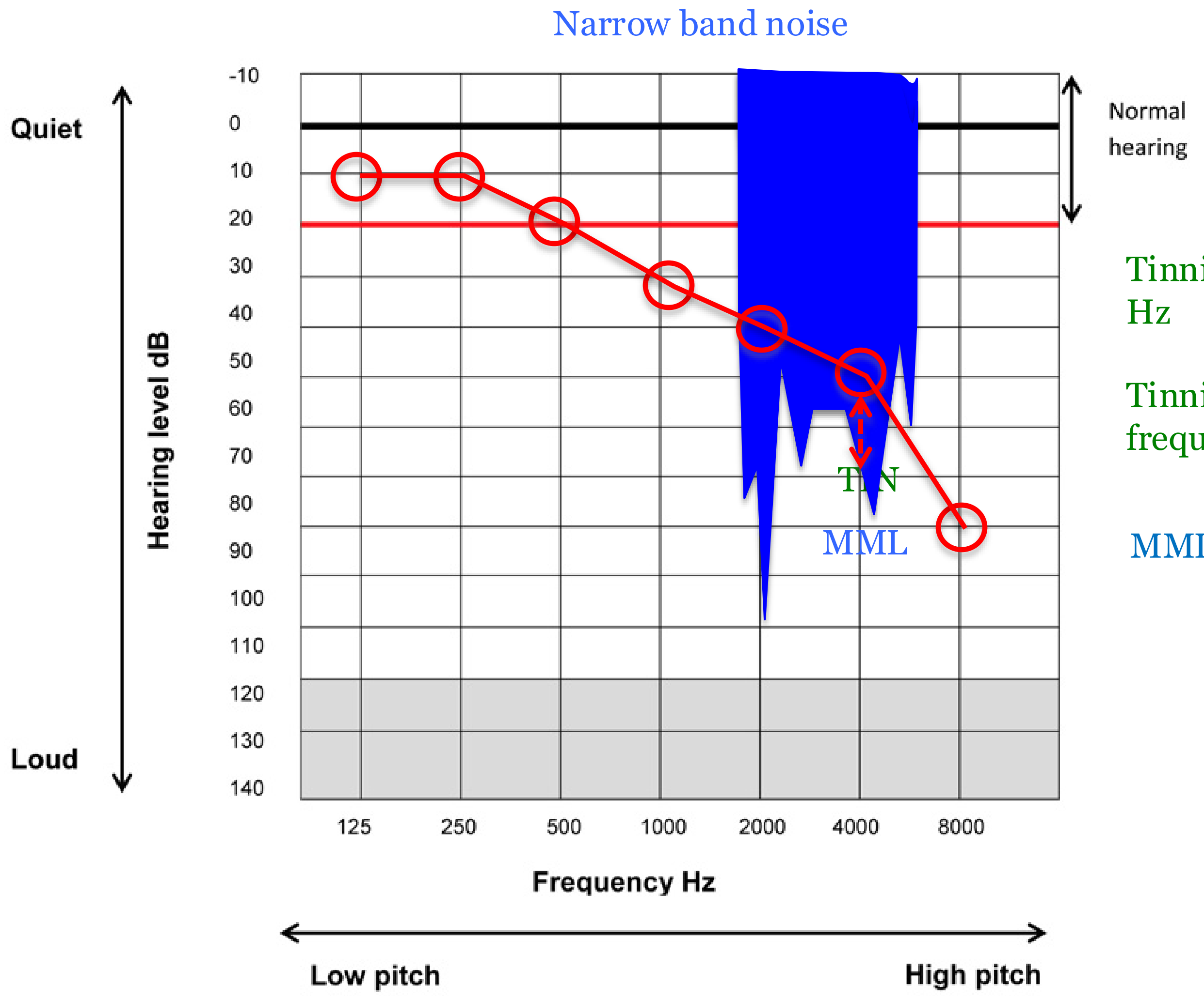
This technique determines the **lowest intensity of a sound** (e.g., white noise, pure tone) required to **completely mask the perception of tinnitus**. It provides a threshold at which the tinnitus becomes inaudible due to the masking stimulus.



Tinnitus predominant frequency: 4000 Hz

Tinnitus loudness at the predominant frequency: 20 dB SL

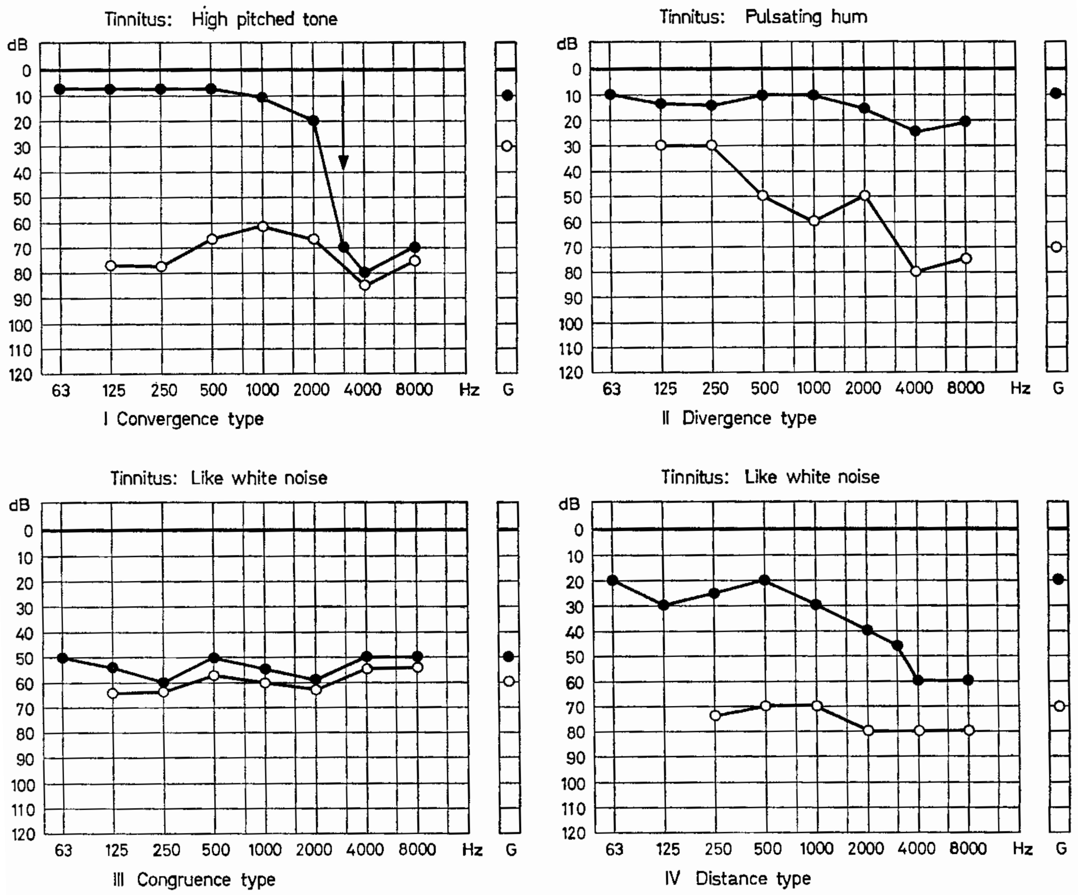
MML for the White Noise: 10 dB SL



Tinnitus predominant frequency: 4000 Hz

Tinnitus loudness at the predominant frequency: 20 dB SL

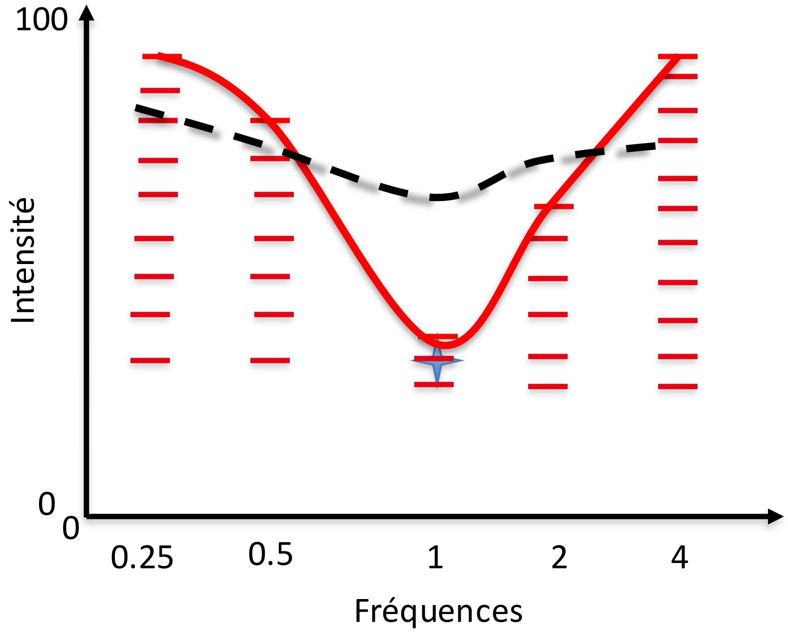
MML for NBN (4kHz) : 10 dB SL



Feldmann (1971)

Masking curves

This method involves presenting **varying intensities and frequencies** of masking sounds to map out how effectively different sounds mask the tinnitus. It helps identify the **most efficient frequency and intensity** for masking, offering a more detailed profile than MML.



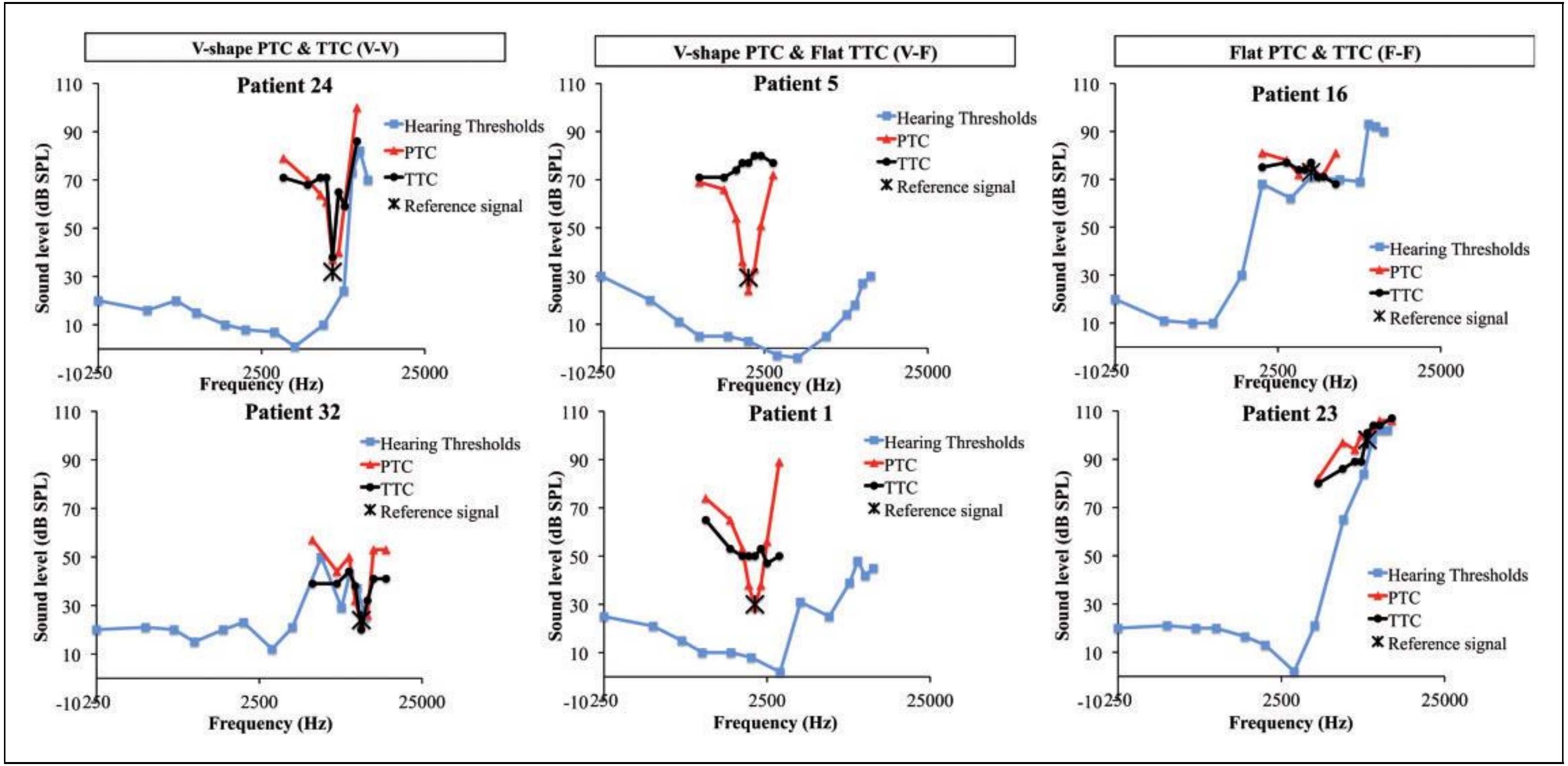


Figure 1. Individual examples of PTCs (red triangles) and TTCs (black diamonds) for each TTC and PTC subgroup (V-V, V-F, and F-F). The blue squares show the hearing thresholds.
PTC = psychophysical tuning curve; TTC = tinnitus tuning curve; SPL = sound pressure level.

Fournier et al. (2019)

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Tinnitus masking: unresolved problems

JACK A. VERNON and MARY B. MEIKLE

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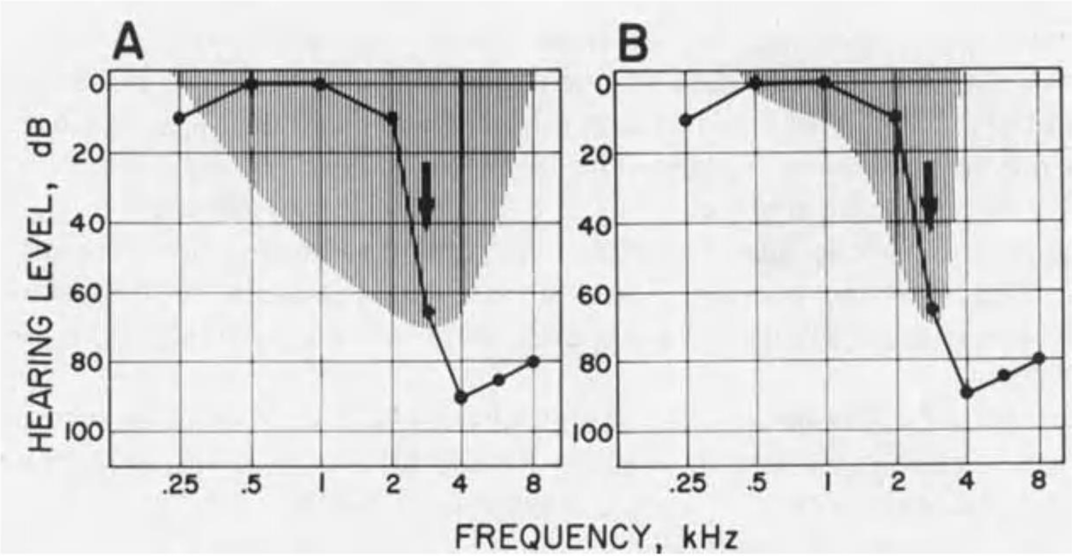

RESIDUAL INHIBITION

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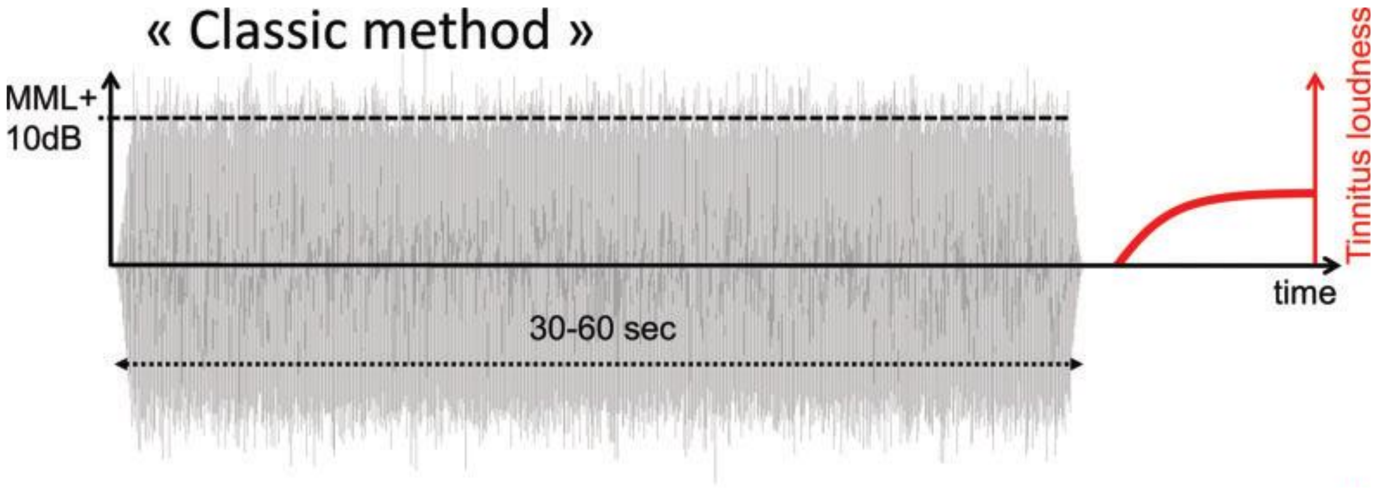
Residual inhibition

Temporary suppression or reduction of tinnitus loudness after auditory stimulation.



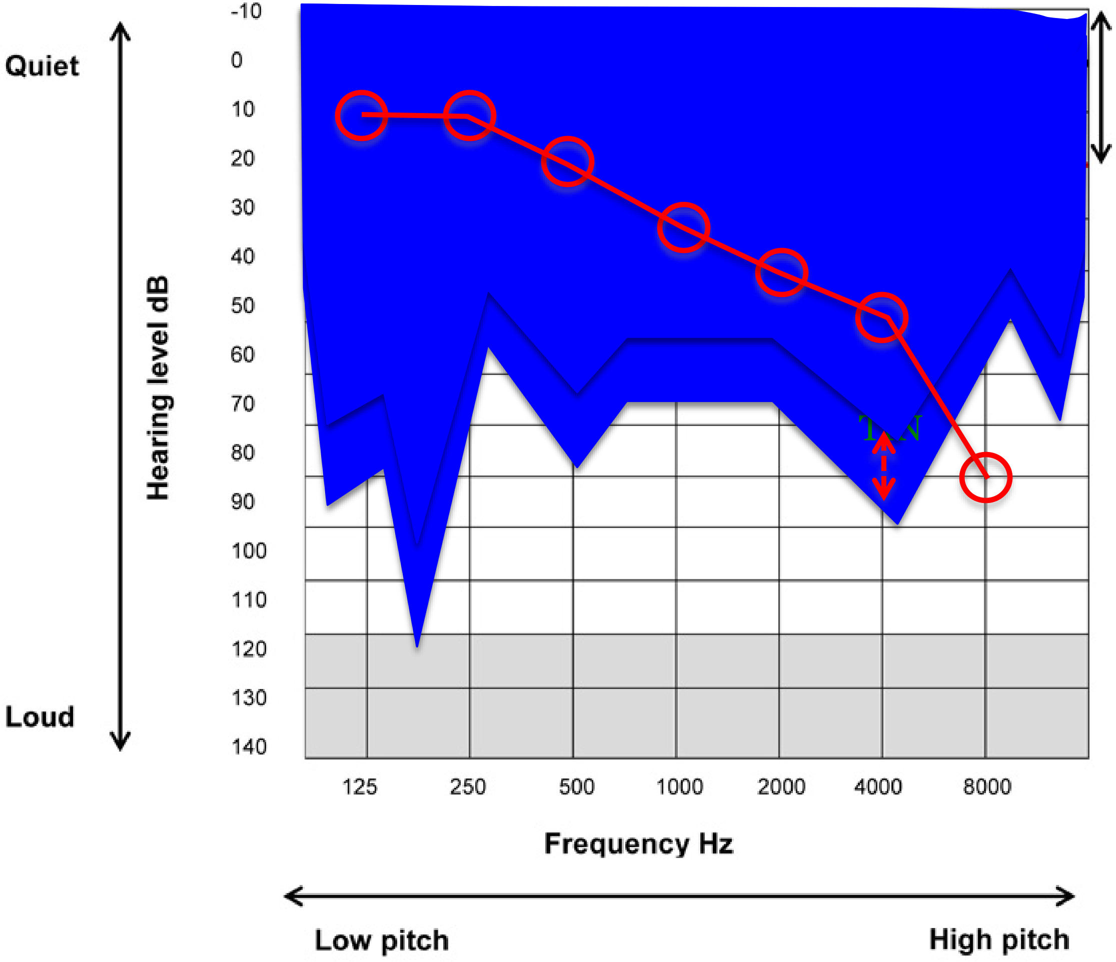
Fournier et al. (2018)

Two measures:

- Inhibition depth

- Duration of inhibition

Whit noise



Tinnitus predominant frequency: 4000 Hz

Tinnitus loudness at the predominant frequency: 20 dB SL

Minimum masking Level (BB): 10 dB SL

Residual inibition: Positive, 25 sec duration

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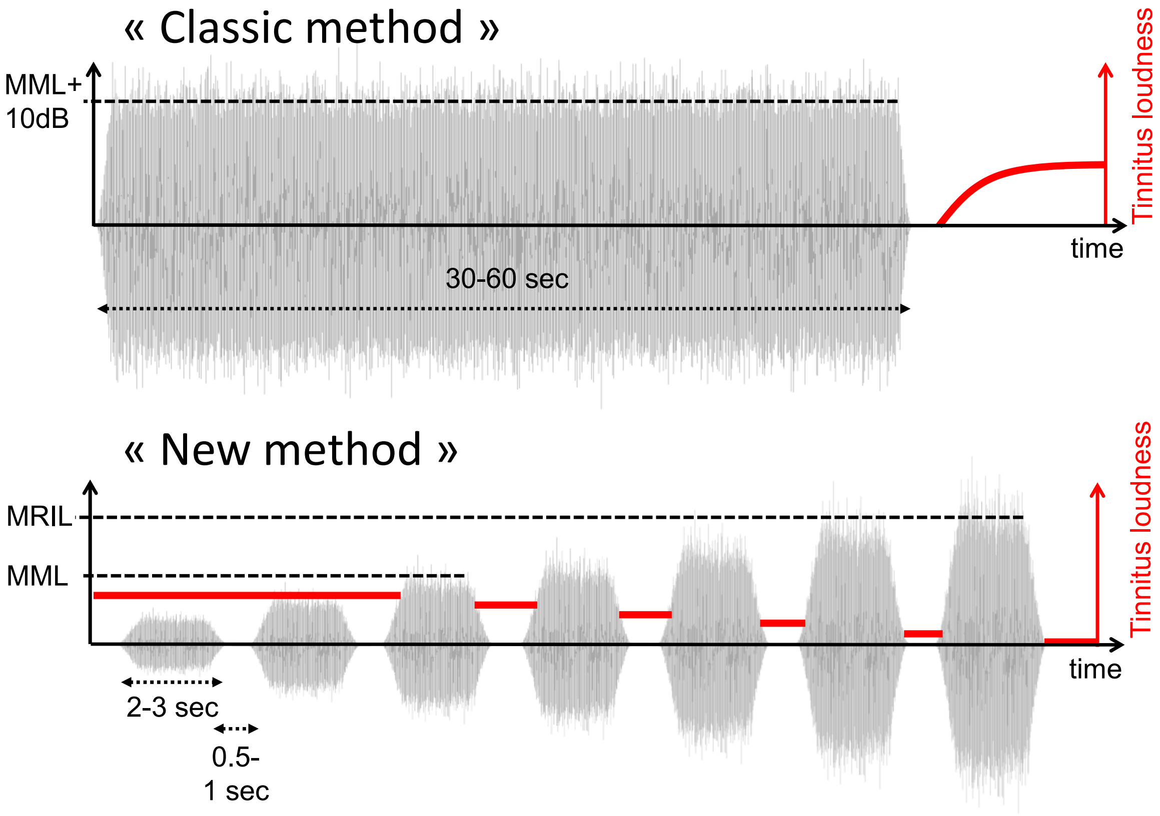
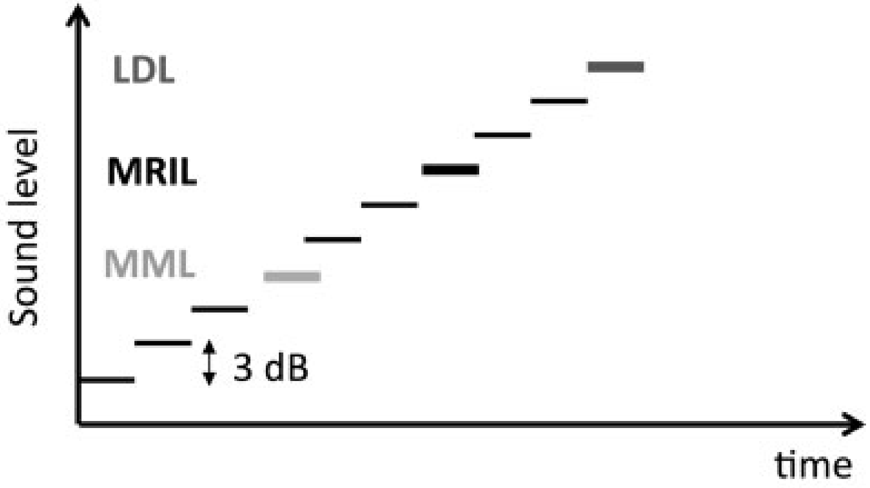
Residual inhibition



Fournier, et al. (2018) *Trends in Hearing*

Residual inhibition



- NBN (1/3 octave width)
- Noise duration: 2 sec
- Rise and fall duration: 0.4 sec
- Silence duration: 1 sec

Residual inhibition

- A total of 68 tinnitus patients tested:
  - Total MML: (n=67) 98.5 %
  - Total MRIL : (n=59) 86.7 %

- Sub-categories of residual inhibition

• Complete inhibition	69.1 %
• Partial inhibition	11.8 %
• Persistant inhibition	5.8 %
• Loudness increase	5.8 %
• Change in pitch	2.9 %
• Others (n=3)	4.4 %

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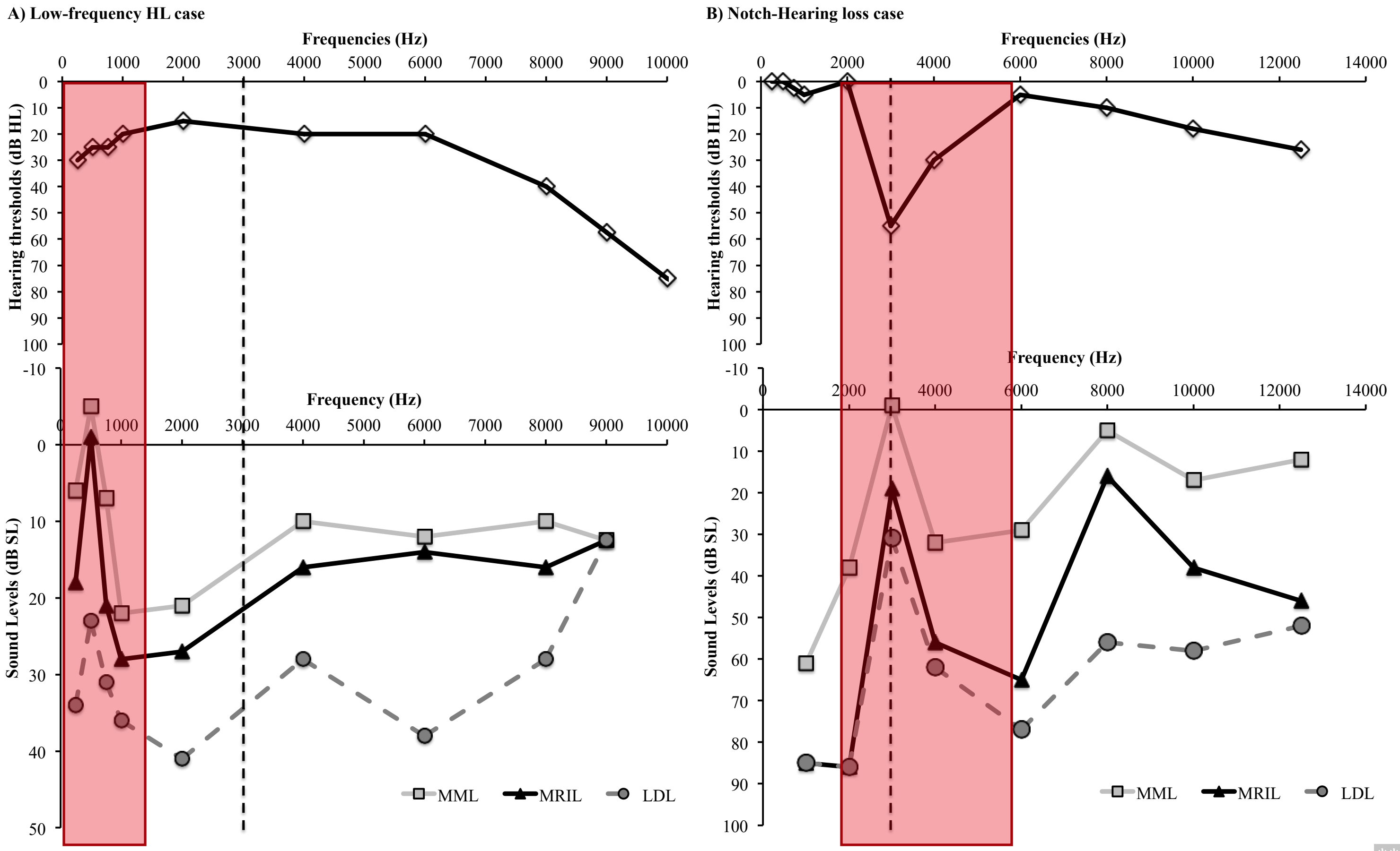

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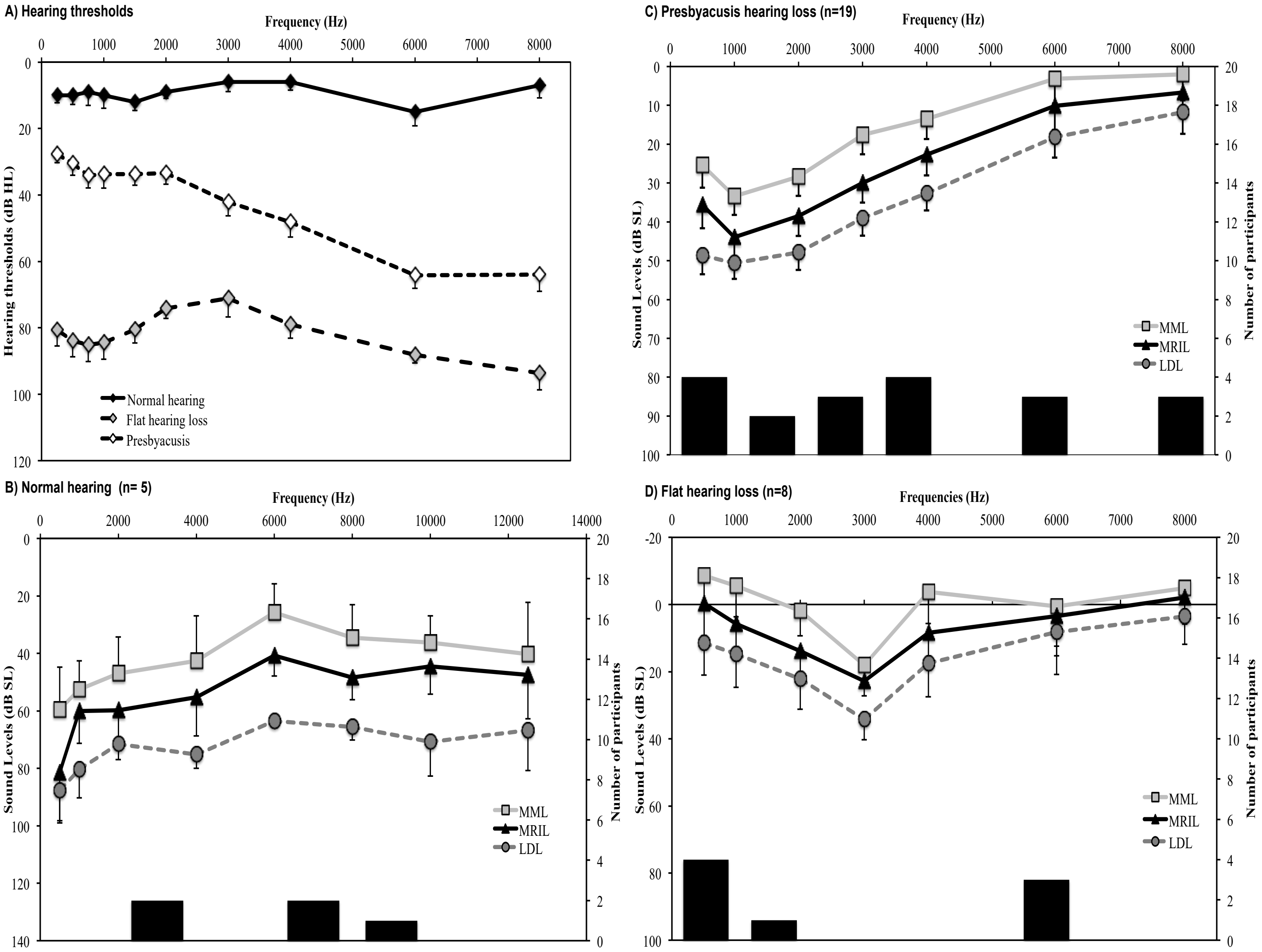
A) Hearing thresholds
Frequency (Hz)
Hearing thresholds (dB HL)
Normal hearing
Flat hearing loss
Presbyacusis
B) Normal hearing (n= 5)
Frequency (Hz)
Sound Levels (dB SL)
Number of participants
MML
MRIL
LDL
C) Presbyacusis hearing loss (n=19)
Frequency (Hz)
Sound Levels (dB SL)
Number of participants
MML
MRIL
LDL
D) Flat hearing loss (n=8)
Frequencies (Hz)
Sound Levels (dB SL)
Number of participants
MML
MRIL
LDL

Psychoacoustic measures of tinnitus: Key messages

Psychoacoustic measures of tinnitus: key messages

- **Dominant Frequency**
The main tinnitus frequency typically falls within the region of hearing loss.

- **Loudness**
Tinnitus loudness is usually low, ranging from 0 to 10 dB SL.

- **Masking**
Masking is more effective when the acoustic signal includes the tinnitus frequency and/or adjacent frequencies.

- **Suppression**
Temporary suppression of tinnitus is enhanced by acoustic stimulation that targets the tinnitus frequency and/or nearby frequencies.

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Psychoacoustic measures of tinnitus: Summary

Tinnitus Assessment Steps

1.Laterality
Determine whether the tinnitus is **unilateral or bilateral**. Is there **one or multiple tinnitus perceptions**?

2.Timbre
Identify the sound quality: **tonal**, **narrowband noise**, or **white noise**?

3.Frequency Matching
Match the perceived tinnitus frequency using pure tones or narrowband noise.

4.Loudness Matching
Estimate the tinnitus loudness in dB SL (sensation level).

5.Minimum Masking Level (MML)
Determine the lowest level of noise required to mask the tinnitus.

6.Residual Inhibition
Assess whether tinnitus is temporarily suppressed following acoustic stimulation.

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A tool for measuring hyperacusis

By Marsha Johnson

As the head audiologist of two busy tinnitus and hyperacusis clinics near Portland, OR, I am directly involved in observing and charting the progress of patients while they are enrolled in the treatment program.

Approximately 40% of patients who report to this clinic for treatment of tinnitus also display some degree of hyperacusis, which is an abnormally low tolerance for sound levels in persons who, in most cases, have essentially normal hearing. Hyperacusic patients will often display intolerance levels between 25 dB and 90 dB in response to both recorded and live voice stimuli and to tone presentations.

Hyperacusis is relatively uncommon, and currently there is very little in the way of research or clinical data regarding the condition. It is different from recruitment, which is the abnormal growth of loudness in a damaged ear with significant hearing loss. Most hyperacusic patients have hearing within normal limits.

ing treatment. Patients who perceive a worsening of their tinnitus as a result of acoustic stimulation will often develop phonophobia, or fear of sound.

CALCULATING THE JHQ

Based on extensive experience with hyperacusic patients at this clinic, I have developed a new measurement tool, the Johnson Hyperacusis Dynamic Range Quotient (JHQ), which is presented here in hopes that other audiologists and clinicians will find it useful.

To determine the JHQ, you need to obtain air-conducted thresholds. First, find the patient's uncomfortable loudness levels (UCLs) using recorded materials to increase the accuracy and the re-test reliability. UCLs will be used for general assessment purposes and to compare with other test results to assess the true degree of hyperacusis, although normative data for the relationship between UCLs and loudness discomfort levels (LDLs) have not been established at this time.

Table 1. *Sample derivation of the Johnson Hyperacusis Quotient*

Frequency	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	6000 Hz	8000 Hz
Air threshold (in dB)	10	15	10	5	10	15	20
LDL (in dB)	45	55	50	55	45	40	35
Subtract threshold from LDL =	35	40	40	50	35	25	15

Total Score = 240 divided by 7 frequencies tested = 34.3 Johnson Hyperacusis Quotient

Loudness discomfort levels (LDL)

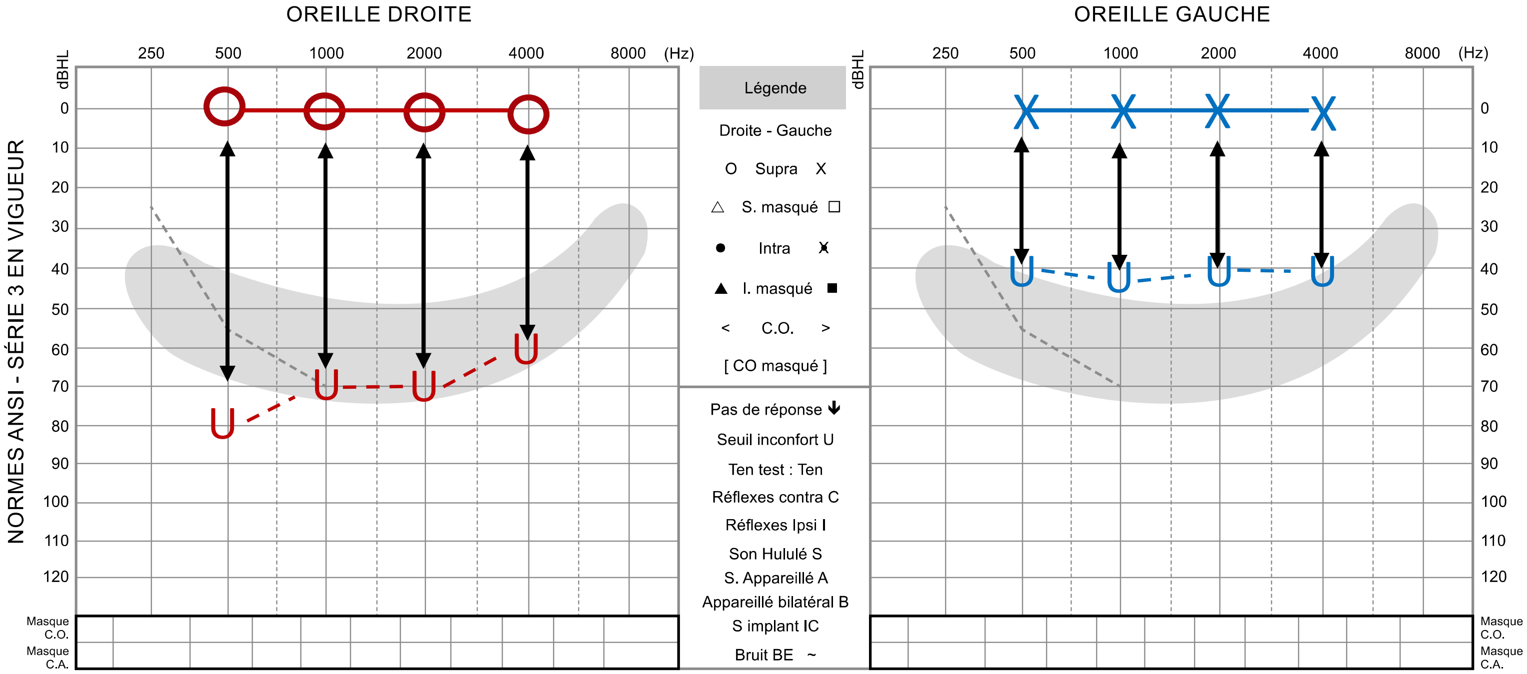

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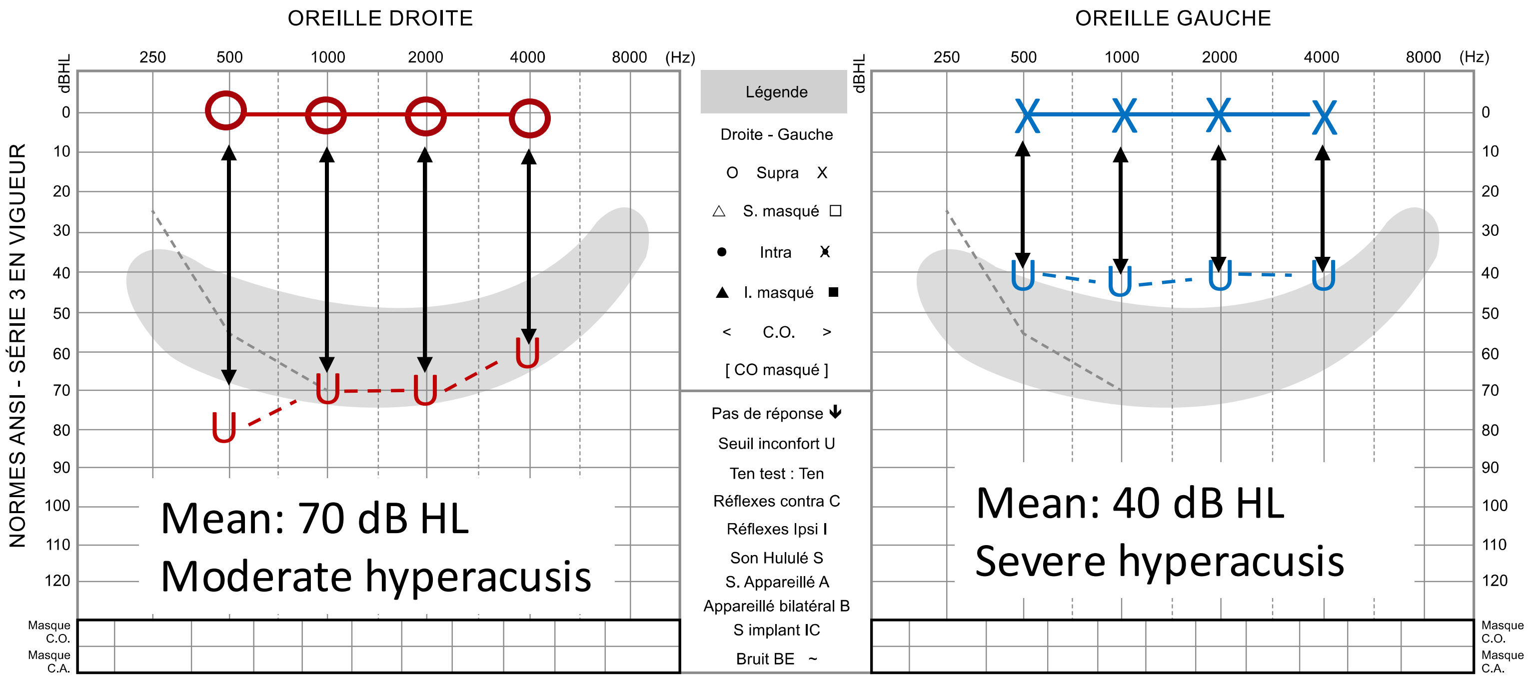
Table 2. *Hyperacusis rating scale*

Rating	Range of JHQ	Comments
Mild	75-90 dB	Nearly within normal limits
Moderate	50-74 dB	Use ascending approach
Severe	30-49 dB	Careful with tympanometry
Profound	0-29 dB	Careful with voice/equipment

Loudness discomfort levels (LDL)



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Loudness discomfort levels

ronmental sounds. ULLs for pure tones were tested at 500, 1000, 2000, 3000, and 4000 Hz. Tone pulses were started at 50 dB or 30 dB above hearing threshold, and raised in 5 dB steps until the patient reported discomfort. The authors then measured ULLs for everyday sounds such as a baby crying, a dog barking, a bird singing, and speech-weighted noise. Meaningful comparison of the different stimuli was achieved by measuring long-term sound spectra and short-term levels in narrow bands with center frequencies from 250 to 8000 Hz. They found that, far from being a consistent measure, ULLs of pure tones varied between

who socialized or worked in noisy environments were recruited directly from being in those environments, underwent ULL testing, and completed a multi-item questionnaire. The questionnaire involved participants rating the percentage of time in the environment they recalled the noise level being of a particular comfort level, using a 9-point scale from "very soft" to "painfully loud." Their results indicated large discrepancies in measures from which they concluded that ULLs may not accurately predict a patient's impression of uncomfortable loudness. They concluded the procedure may not provide a reliable basis for setting the

Fackrell, K., & Hoare, D. J. (2018). Scales and questionnaires for decreased sound tolerance. *Hyperacusis and disorders of sound intolerance*, 43-58.

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Problems with loudness discomfort levels

- Very uncomfortable for patients
- Biased by patients' fear
- Influenced by personality (Stoic, cautious, etc.)
- Highly dependent on instructions
- High false positive rate
- Poor reflection of the complaint (Does not complain about pure tones)

LDL and subjective complaints

- Little or no correlation between subjective complaint and discomfort thresholds

- A study by Zaugg, Thielman, Griest & Henry (2016) showed a weak correlation between these two elements (139 subjects)

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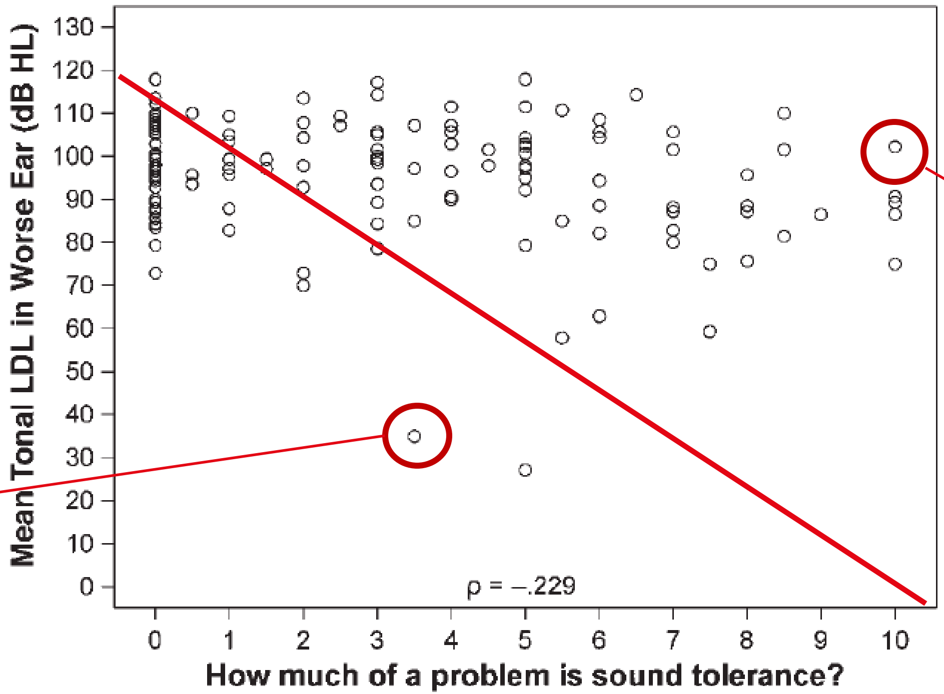
Figure 4. Scatterplot of mean tonal LDL for the worse ear at Run 2 by the self-reported sound tolerance (SRST) rating.



LDL at 30 dB HL Subjective complaint at 4/10

LDL at 110 dB HL Subjective complaint at 10/10

Zaugg et al. (2016)

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Seuils d'intolérances avec sons naturels

Discomfort thresholds are lower for natural sounds (e.g., dog barking, baby crying, etc.) than for pure tones

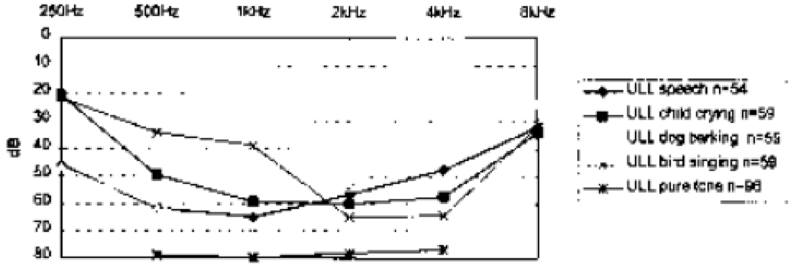

Fig. 3. Mean ULL pure tones for the right ear compared with the mean ULL for specific sounds divided into different frequencies.

Anari, Axelsson, Eliasson et Magnusson, 1999

USEFULNESS OF PSYCHOACOUSTIC MEASURES

Clinical utility of psychoacoustic measures of tinnitus

•**Counselling**
Validate subjective perception and transfer it to the real world. The sound have a frequency and an intensity, can be presented to a family member

•**Prognostic value?**
Conceivable than a patient with a tinnitus easily maskable will benefit from sound therapy

•**Subtyping tinnitus**
Maskable tinnitus vs. non maskable tinnitus
Positive RI vs No-RI, peripheral vs central tinnitus?

•**Personalized sound therapy**
Difficult to fit a patient for an amplification notch therapy without knowing the tinnitus pitch

•**Patients follow-up**
Increase, decrease, change in pitch, new tinnitus, etc.

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Clinical utility of psychoacoustic measures of tinnitus

"The biggest problem our patients often encounter is describing the noise they are hearing to us.

This new tool offers sufferers the opportunity to select the noise closest to what they're hearing and then goes onto explain some of the potential treatment options which might be able to help them or allow them to research this further themselves".

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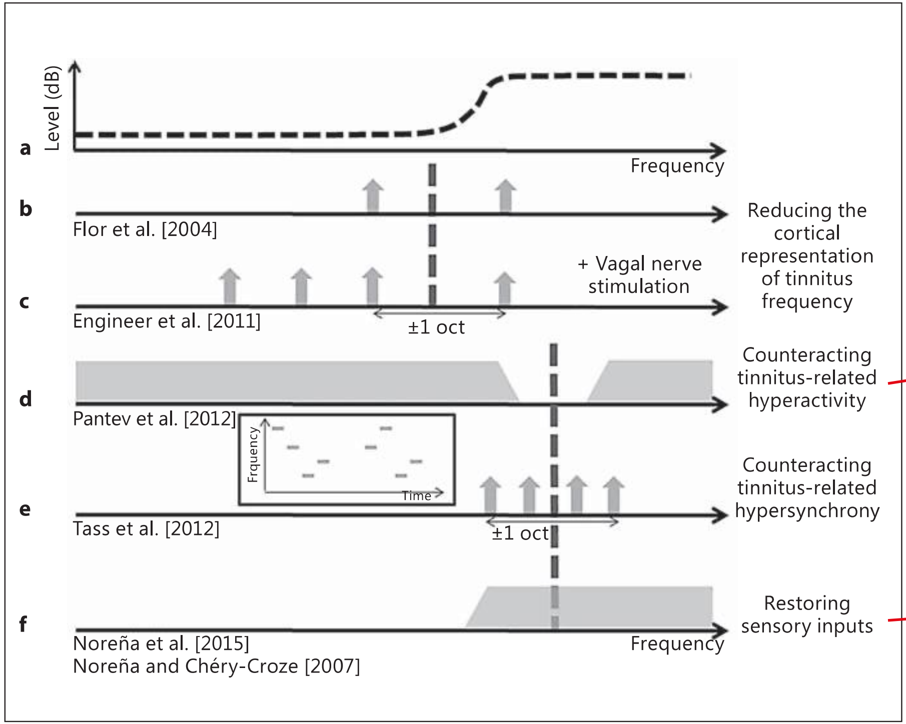
Clinical utility of psychoacoustic measures of tinnitus



Proceedings

Audiology & Neurotology

Published online: May 19, 2015

Audiol Neurotol 2015;20(suppl 1):53–59
DOI: 0.1159/00038074

Revisiting the Cochlear and Central Mechanisms of Tinnitus and Therapeutic Approaches

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joint disorders [Dauman and Bouscau-Faure, 2005; Ramirez et al., 2008; Westcott et al., 2013]. Tinnitus can result from many different aetiologies. A major challenge in tinnitus research is to identify the different causes of tinnitus in order to develop therapies specific for each tinnitus subtype [Noreña, 2011, 2012a; Noreña and Farley, 2013]. This article is aimed at providing a short review on putative mechanisms of tinnitus.

Notch Amplification

Conventionnal Amplification

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International Journal of Audiology 2012; 51: 914–919

Original Article

Tinnitus pitch, masking, and the effectiveness of hearing aids for tinnitus therapy

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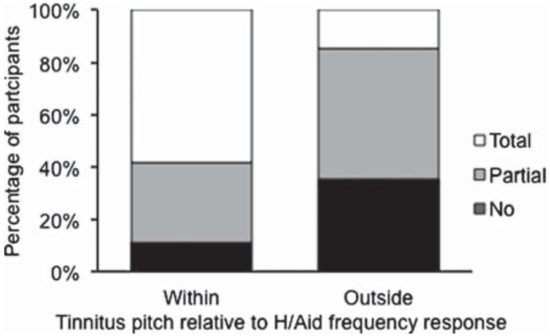

Figure 7. The percentage of participants with tinnitus pitch falling within and outside the frequency response of their hearing aids, for each group.

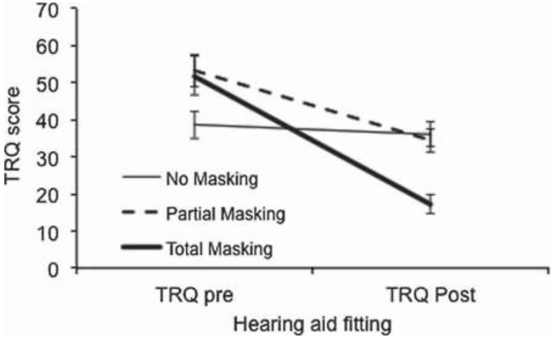

Figure 2. Mean TRQ scores (error bars represent ± 1 standard error of the mean [SE]) for each group prior to and three months post the fitting of hearing aids.

A State-of-the-Art Review: Personalization of Tinnitus Sound Therapy

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Background: There are several established, and an increasing number of putative, therapies using sound to treat tinnitus. There appear to be few guidelines for sound therapy selection and application.

Aim: To review current approaches to personalizing sound therapy for tinnitus.

Methods: A "state-of-the-art" review (Grant and Booth, 2009) was undertaken to answer the question: how do current sound-based therapies for tinnitus adjust for tinnitus heterogeneity? Scopus, Google Scholar, Embase and PubMed were searched for the 10-year period 2006–2016. The search strategy used the following key words: "tinnitus" AND "sound" AND "therapy" AND "guidelines" OR "personalized" OR "customized" OR "individual" OR "questionnaire" OR "selection." The results of the review were cataloged and organized into themes.

Results: In total 165 articles were reviewed in full, 83 contained sufficient details to contribute to answering the study question. The key themes identified were hearing compensation, pitched-match therapy, maskability, reaction to sound and psychosocial factors. Although many therapies mentioned customization, few could be classified as being personalized. Several psychoacoustic and questionnaire-based methods for assisting treatment selection were identified.

Conclusions: Assessment methods are available to assist clinicians to personalize sound-therapy and empower patients to be active in therapy decision-making. Most current therapies are modified using only one characteristic of the individual and/or their tinnitus.

Psychoacoustic Hands-on lab

- TEAM of 3 or 4
- One member will be the patient, will use the ''weird'' bone conduction (not really bone conduction) with the ear shape
- This individual will hear a tinnitus sound
- The other member of the TEAM will evaluate the tinnitus of the tinnitus simulated patient
- After one member has been tested you can switch

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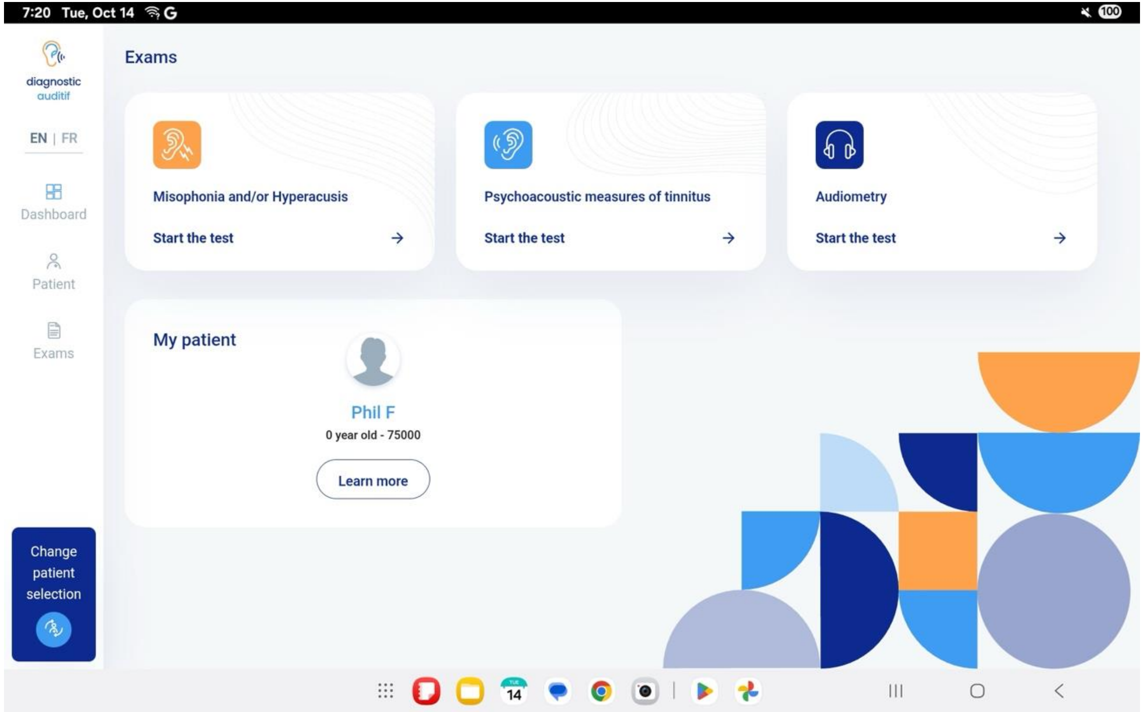
Psychoacoustic Hands-on lab

- The lab will be perform using an Androïd App



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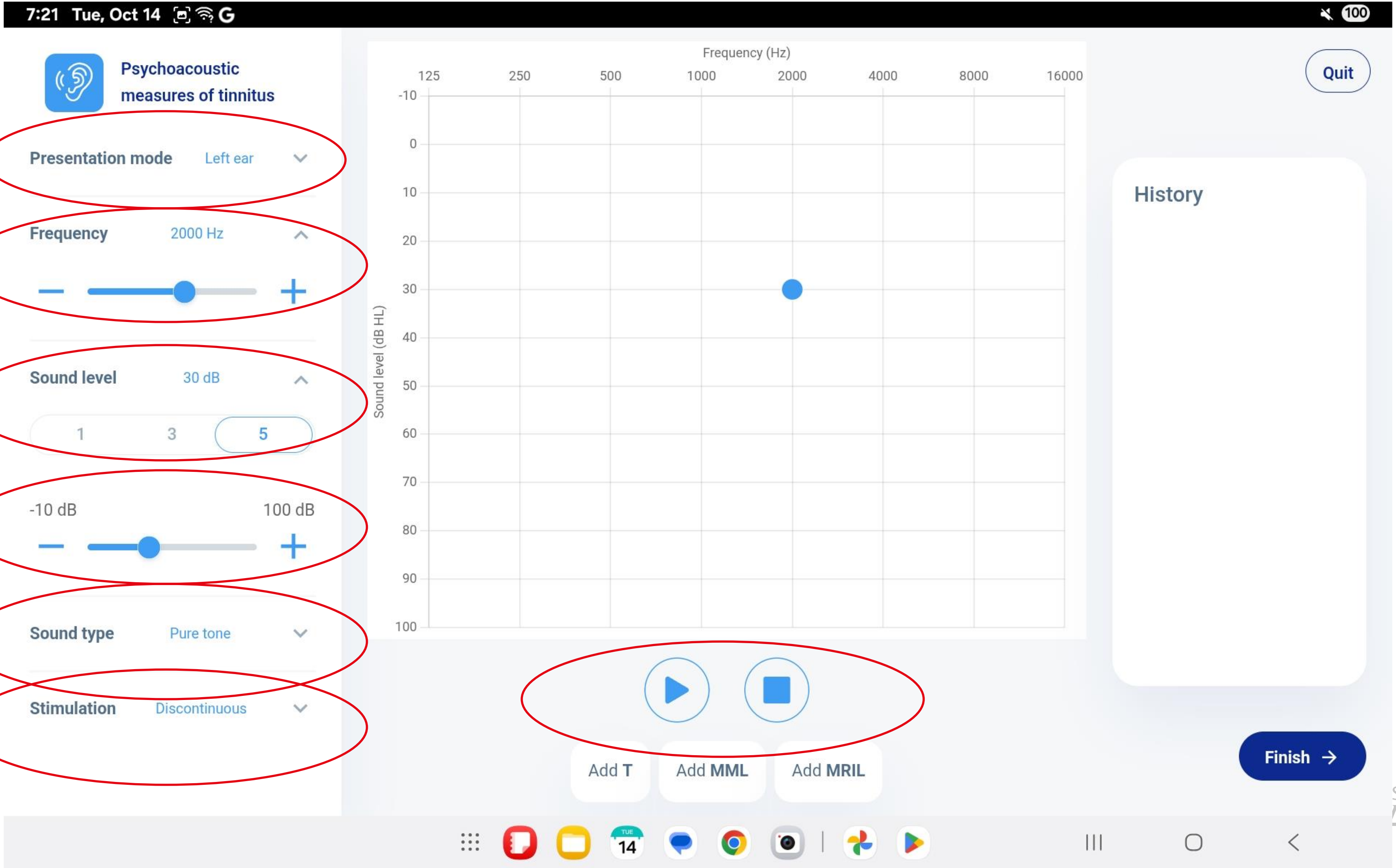
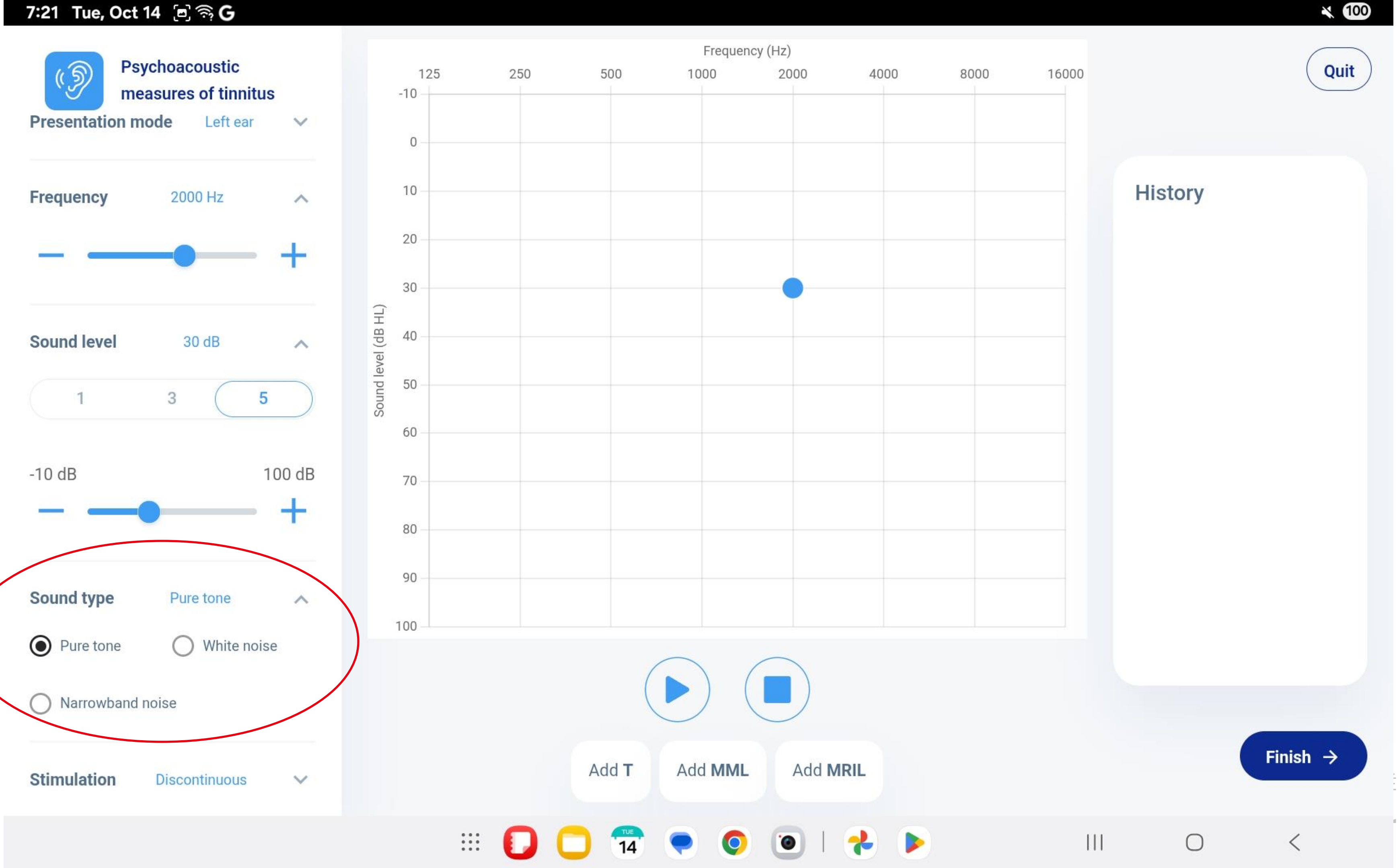
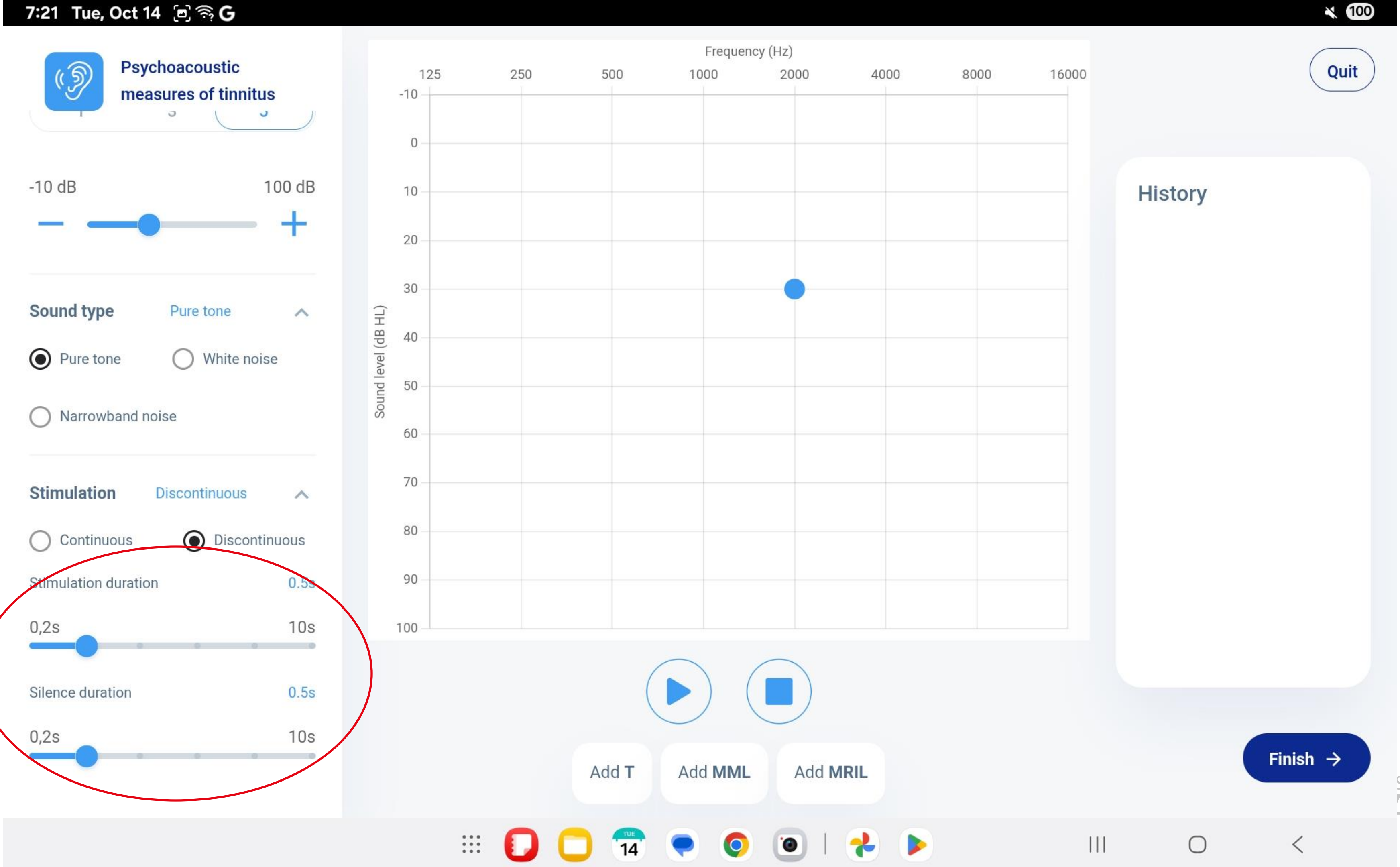

7:21 Tue, Oct 14
Psychoacoustic measures of tinnitus
Presentation mode Left ear
Frequency 2000 Hz
Sound level 30 dB
1 3 5
-10 dB 100 dB
Sound type Pure tone
Stimulation Discontinuous
Frequency (Hz)
125 250 500 1000 2000 4000 8000 16000
Sound level (dB HL)
-10 0 10 20 30 40 50 60 70 80 90 100
Add T
Add MML
Add MRIL
Quit
History
Finish
SITÉ
AL


7:21 Tue, Oct 14
Psychoacoustic measures of tinnitus
Presentation mode
Left ear
Frequency
2000 Hz
Sound level
30 dB
1
3
5
-10 dB
100 dB
Sound type
Pure tone
Pure tone
White noise
Narrowband noise
Stimulation
Discontinuous
Frequency (Hz)
125
250
500
1000
2000
4000
8000
16000
Sound level (dB HL)
-10
0
10
20
30
40
50
60
70
80
90
100
Add T
Add MML
Add MRIL
Quit
History
Finish



7:21 Tue, Oct 14
100
Psychoacoustic measures of tinnitus
Quit
-10 dB
100 dB
Sound type
Pure tone
Pure tone
White noise
Narrowband noise
Stimulation
Discontinuous
Continuous
Discontinuous
Stimulation duration
0.5s
0,2s
10s
Silence duration
0.5s
0,2s
10s
Frequency (Hz)
125
250
500
1000
2000
4000
8000
16000
Sound level (dB HL)
-10
0
10
20
30
40
50
60
70
80
90
100
History
Add T
Add MML
Add MRIL
Finish

Thank you!

Questions?