

Tinnitus: Babylonia to Bimodal

Marc Fagelson, PhD; CCC-A

East TN State University

Mountain Home VAMC

Fagelson@etsu.edu

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The contents of this presentation do not represent the views of the Department of Veterans Affairs nor the United States Government.

Agenda

- 8:00-8:45 – History of the diagnosis, taxonomy, and epidemiology
- 8:45-9:45 – audiologic and non-audiologic mechanisms (w/ special attention paid to the “normal” audiogram and its shortcomings)
- 9:45-10:15 – Break
- 10:15-10:45 – Veterans and Musicians: what we learn from special populations
- 10:45-11:15 – audiologic management (sound therapy, hearing aids, apps, novel sound, bimodal)
- 11:15-11:45 – non-audiologic management (CBT, lessons from trauma counseling)
- 11:45-12:00 – Q & A (15 minutes)

Historical Perspective

- First mentions of tinnitus are as old as the earliest medical records that we know about
 - Babylonian records go back to at least 700 BC
 - Translations of clay tablets include at least 22 mentions of “singing in the ears” or the ears “speaking”
 - Of the “singing” variety, the suspected cause of the tinnitus was a “ghost seizing on a man”
 - Spirit intrusion in Babylonian times was considered a primary cause of disease, and so this description is fairly typical

Historical Perspective

- Graeco-Roman Medicine
 - They believed the body was composed of four elements: cold, dry, moist, and hot
 - Good Health was achieved through their balance (if you were too hot, with fever, for example, you would be cooled off with water)
 - Tinnitus appeared to be “air trapped within the ear” and it needed to be removed
 - Remedies throughout this period were very “folksy” often involving gargling, exercise, ear drops of a variety of herbal remedies

Historical Perspective

- Islamic and Medieval Medicine
 - Noises attributed to various “humors” or intangible objects that acted upon the ear
 - Paul of Aegina (625-690 AD) indicated that the tinnitus was often accompanied by “increased sensibility” – an early mention of problems with sound tolerance that affects many people with tinnitus
 - During this time the consensus among the medical community was that tinnitus was caused by wind or air circulating throughout the ear and/or skull

Historical Perspective: Jean Marie Gaspard Itard (1774-1838)

“It happens quite often that the most systematic treatment of tinnitus, whether of true or false tinnitus, even if it is neither long-standing nor complicated by deafness, fails against the obstinacy of this acoustical lesion. The only thing to do is to make it less unbearable, by removing its biggest inconvenience, that of sleep deprivation, or to interfere with it almost continuously; I recommend for that a simple technique which is rarely ineffective, that is by covering the internal noise, real or imaginary by an external noise, similar and equally continuous.” – 1821, translation from Stephens (2000)

Historical Perspective

- Jean Marie Gaspard Itard (1800s)
 - Tinnitus was thought to be the result of “depravation of the ear” (as caused by hearing loss)
 - Discussed tinnitus as being related to depression because it seemed to cause sadness in the sufferers
 - Recognized that sleep disturbance was the most significant symptom, and that it was necessary to mask out the tinnitus in those cases where it interfered with ability to sleep/relax
 - Encouraged patients to use fires (roaring) or mechanical organs in their bedrooms; otherwise he recommended moving to a noisier location

Historical Perspective

- Jean Marie Gaspard Itard
 - The masking components and his acknowledgement that nothing really worked permanently were departures from previous medical literature
 - Prioritized addressing the disturbance caused by the tinnitus rather than the tinnitus sound itself
- Also in the 19th Century
 - Several disciplines in the medical and scientific fields used electricity for a wide range of applications; consider the common report that patients who receive CIs with tinnitus pre-implantation report remission (up to 78%) or reduction (up to 93%) of tinnitus across 28 studies analyzed by Baguley & Atlas (2007)

Tinnitus: Definitions and taxonomy

- “Obstinate...acoustical lesion” Itard, 1821
- ‘The conscious expression of a sound that originates in an involuntary manner in the head of its owner, or may appear...to do so’. McFadden et al., 1982
- “The perception of a sound which results exclusively from the activity within the nervous system without any corresponding mechanical, vibratory activity within the cochlea.” Jastreboff, 1995
- “Tinnitus is the conscious awareness of a tonal or composite noise for which there is no identifiable corresponding external acoustic source,” which becomes Tinnitus Disorder “when associated with emotional distress, cognitive dysfunction, and/or autonomic arousal, leading to behavioural changes and functional disability.” DeRidder et al., Prog. in brain res., 2020
- Further:
 - Minimum time criterion: The tinnitus lasts for minimum 5 min per day and occurs on the majority of days.
 - Acute tinnitus: tinnitus with a duration of less than 3 months. Chronic tinnitus: tinnitus with a duration of at least 3 months; still some controversy re: delineation between 3-6 months

Reaction to real sounds

Reaction to environmental nuisance sound

Phonophobia

Misophonia

Hyperacusis

Loudness recruitment

Phantom sound perceptions

Low frequency noise complaint

Pulsatile tinnitus

Auditory hallucinations of mental illness

Persistent spontaneous tinnitus

Sound evoked tinnitus

Musical hallucination

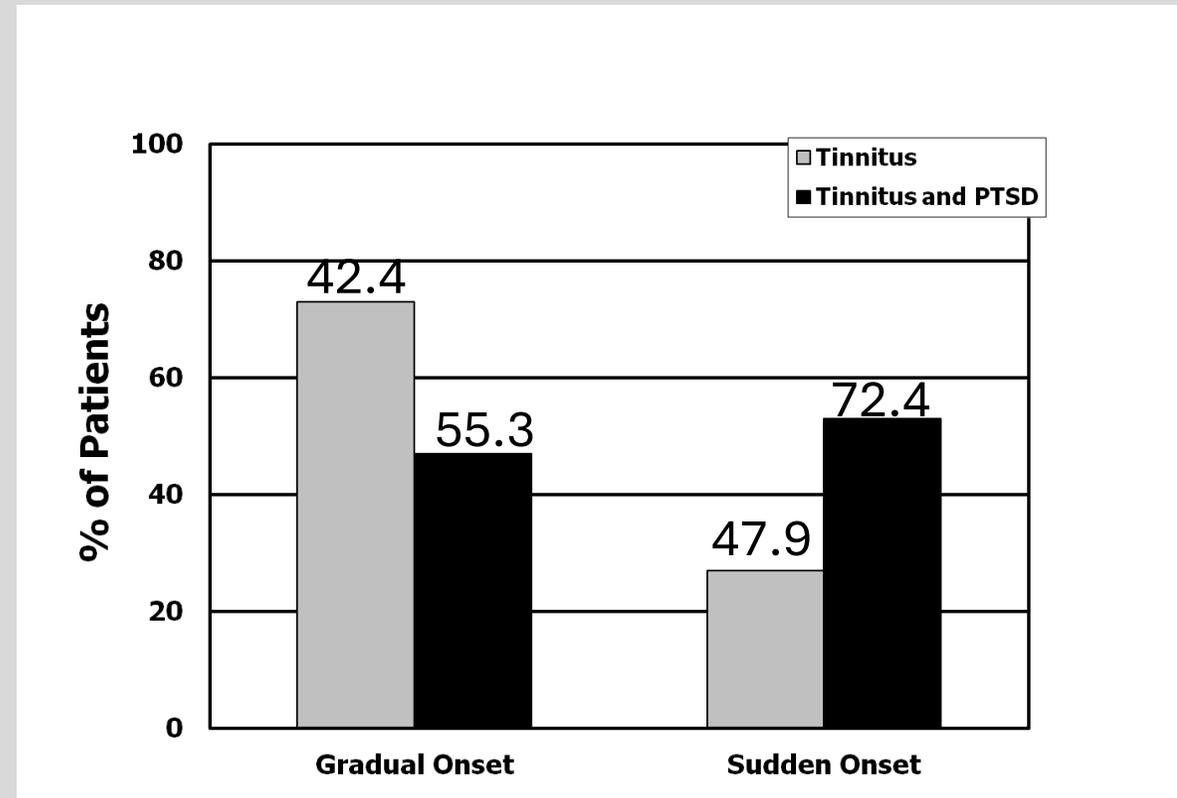
Somatosensory tinnitus

Syndromic tinnitus

Exploding head syndrome

Additional considerations

- Tinnitus disorder is more than merely a sensory event; if a sound does not provoke an emotional response, then it should be easier for a perceiver to ignore
- Problems with terminology such as “Ringing in the ears”
- Should we call it a “phantom” perception? “Spirit intrusion” and “Soul loss” have been specified by patients over the years
- Complications that demand attention from the clinician (potential exacerbators of items specified on McFerran et al slide):
 - Co-occurring psychological injury/disorder
 - Sudden-onset, traumatic onset



Tinnitus: Definitions and endpoints on various continua; interpret with caution

- No simple definition addresses the experience of the listener – The emotional response, at times overwhelming, the patient’s sense they have little or no control
- Constant vs. intermittent (temporary vs. permanent)
- Intrusive vs. nonintrusive; bothersome vs. nonbothersome
- Tinnitus vs. Tinnitus disorder
- Patient reports/ratings; may to some extent be borne out during psychoacoustic measurement (ie., loudness matching, pitch matching, minimum masking level)
 - Loud vs. soft; tonal vs. noisy; unidentifiable sound vs. identifiable sound
- Functional effects determine severity to a greater extent than psychoacoustic properties; distinguishing the sound from the response is essential
- Generally, the puretone audiogram will not be an adequate predictor of tinnitus severity; how well does the puretone audiogram capture “hearing loss”? Consider the Snellen eye chart

DISTANCE VISUAL ACUITY TEST
FOR TESTING AT 20 FEET

Actual Size
20 Foot

T Z

20
100

P T O C

20
60

Z L P E D

20
50

E T O D C F

20
40

D P C Z L F T

20
30

C F D T E O P L

20
25

L D C Z O T E P

20
20

P F C D T Z L E

20
16

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FELU-FR0690R CONTRAST SENSITIVITY CHART

————— Darker to **HS** —————

V R S K D R

N H C S O K

S C N O Z V

C N H Z O K

N O D V H R

C D N Z S V

K C H O D K

R E Z N V R

Definitions: Objective tinnitus, somatosounds

- Sound produced in the head and neck area audible to the patient as well as to external listeners
 - Vascular in origin - constriction or vascular abnormality (sometimes termed a bruit) – **Pulsatile tinnitus locked in time with the heartbeat**
 - Involuntary muscular contraction (ie., a tic or spasm), cervical vertebra and associated joints may also produce noise in certain postures
 - Specific to middle ear muscles: Tonic Tensor Tympani Syndrome (TTTS) associated with pain, sound intolerance, fullness
 - TMJ dysfunction, malocclusion may produce audible energy during chewing, talking, yawning
 - Clinician may use a (hearing aid) stethoscope or OAE equipment to hear or record the signal and case history may indicate that others have heard the sound reported by the patient

Definitions: Subjective tinnitus (AKA Primary Tinnitus)

- Neural activity, and corresponding “sound event” produced along the auditory pathway and audible only to the patient
 - The signal and its effect cannot be reasonably (or accurately?) quantified by any external measure (although it can be qualified, or its effects described)
 - Matching the signal to an external sound reveals that the auditory component of the sound is poorly correlated with the severity, or amount of suffering reported
 - In severe cases, a psychological contribution to the signal’s impact must be recognized and addressed for the intervention to proceed successfully

Definitions: Subjective tinnitus caused or exacerbated by pathology/disorder (AKA Secondary Tinnitus)

- The “sound event” may be subjective or objective (in which case it may also be categorized as a somatosound)
 - Meniere’s Disease or auto-immune/auto-inflammatory disorder
 - Ototoxic reaction
 - Somatosounds usually have an identifiable source (tonic tensor tympani syndrome, TMJ disorders, etc)

Tinnitus Classification Schemes (Dauman & Tyler, 1992)

- Distinction between ‘normal’ and ‘pathological’ tinnitus
- ‘Normal’ tinnitus (a sudden burst of unilateral, transient (or ‘tapering’ tinnitus; Oron et al, 2011))
 - Most normal auditory systems produce tinnitus on occasion
 - This tinnitus is idiosyncratic, appears unexpectedly, lasts less than five minutes
 - Occurs less than once/week (perhaps once/day)
 - Source unknown
 - Not too disturbing, probably because it goes away, predictably
 - May be superimposed on a person’s “regular” tinnitus
 - Some patients suggest the presence of this tinnitus “shuts off the ears”

Tinnitus Classification Schemes (Dauman & Tyler, 1992)

- ‘Pathological’ tinnitus
 - The dogma: tinnitus is experienced by individuals with thresholds outside the normal range more commonly than those with normal puretone thresholds
 - If a patient has thresholds in the normal range and bothersome tinnitus that reduces quality of life, do they have normal hearing?
 - Patient may report a trigger associated with toxins (noise, solvents, fuels, drugs, combinations)
 - Does not predictably go away
 - Etiology (and/or site of lesion); will influence intervention choices
 - Auditory source: Meniere’s, acute noise damage
 - Non-auditory triggers/exacerbators: events associated by the patient with PTSD, anxiety, depression
 - Idiosyncratic (of unknown source)

Tinnitus Classification Schemes (DeRidder et al., 2021: Tinnitus vs. Tinnitus Disorder)

- Affirms tinnitus as a somatic symptom disorder akin to chronic pain, suggests a set of criteria consistent w/ other entries in the Diagnostic and Statistical Manual of the American Psychiatric Association (DSM-V; APA)
- Both consist of a sensory component and an “affective component, reflecting its unpleasantness” (p. 6)
- The authors offer criteria for somatic symptom disorder specified as a patient who presents “with predominant tinnitus” consistent w/ the DSM terminology and structure
 - Criterion A: Tinnitus that is distressing or results in significant disruption of daily life.

Tinnitus Classification Schemes (DeRidder et al., 2021: Tinnitus vs. Tinnitus Disorder; cont.)

- Criterion B: Excessive thoughts, feelings, or behaviors related to tinnitus or associated health concerns as manifested by at least one of the following:
 - a. disproportionate and persistent thoughts about the seriousness of one's tinnitus,
 - b. persistently high level of anxiety about tinnitus.
 - c. excessive time and energy devoted to tinnitus.
- Criterion C: Although the tinnitus sound may not be continuously present, the state of being symptomatic is persistent (typically more than 3 months).
 - Persistent: A persistent course is characterized by severe symptoms, marked impairment, and long duration (more than 3 months).
 - Mild: Only one of the symptoms specified in Criterion B is fulfilled.
 - Moderate: Two symptoms specified in Criterion B are fulfilled.
 - Severe: Two or more of the symptoms specified in Criterion B are fulfilled, plus there are multiple somatic complaints (or one very severe somatic symptom).

Tinnitus Classification Schemes (McFerran et al., 2019)

- Other terms for sound experiences uncorrelated with external events
 - Auditory hallucinations of mental illness – schizophrenia, hearing voices
 - Musical hallucinations – the image of music playing as an external event; a vivid experience, as though the music is being played somewhere within range
 - Or as described by Sacks: “hallucinations in the sane”
 - Exploding head syndrome – the sensation of a very loud and brief crashing sound or explosion, often accompanied by sudden motion, usually occurring when beginning to fall asleep or when waking during the night (Cleveland Clinic)

Reaction to real sounds

Reaction to environmental nuisance sound

Phonophobia

Misophonia

Hyperacusis

Loudness recruitment

Phantom sound perceptions

Low frequency noise complaint

Pulsatile tinnitus

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Musical hallucination

Somatosensory tinnitus

Syndromic tinnitus

Exploding head syndrome

Tinnitus Prevalence and Characteristics: National Health Interview Survey (2014) (n=36,697//4,514 reported tinnitus) (Batts & Stankovic, 2024)

- US population sampled
- Prevalence of 11.2%; constant in 41.2% of those respondents; rates higher among men (12.8% vs. 9.8%)
- Severe tinnitus more common among women; 9.1% of women, 6.7% of men (overall 7.8% of tinnitus reporters)
- 28.3% indicated duration \geq 15 years (32.7% men vs. 22.8% women)
- 39.0% of respondents with tinnitus + hearing loss attributed HL to noise exp.
- 33.3% pts with hearing loss and no tinnitus attributed HL to aging
- 18.6% pts with tinnitus rated hearing as excellent vs. 54.5% in pts w/out tinnitus
- By a substantial margin, relative risk ratios for tinnitus were highest among those with hearing loss (4.08), Dizziness/imbalance (3.04), and hyperacusis (2.68)
- Significantly lower rates of all minority groups discussed tinnitus with a doctor compared to non-Hispanic whites

Severity, Exposures, Treatment Patterns in the US (Bhatt et al., 2016)

- Prevalence of 9.6% reported tinnitus w/in the year preceding interviews; constant in 41.2% of those respondents; rates higher among men (12.8% vs. 9.8%)
- Tinnitus reported in 19.2% of noise-exposed individuals, 6.8% non-exposed
- 7.2% indicated tinnitus a “big” or “very big” problem; 41.6% indicated tinnitus was a small problem; authors assert that for at least half the respondents, the symptom is tolerable and does not require intervention
- 27% indicated duration \geq 15 years; 36% indicating constant tinnitus
- 49.4% discussed tinnitus w/ a physician; medications were the most-frequently discussed intervention
- Hearing aids (9.2%), nutritional supplements (7.8%), wearable maskers (2.6%) and CBT (0.2%) were discussed much less often
- The survey responses indicated 2014 AAO-HNSF practice guidelines were rarely followed

Global Tinnitus Prevalence and Characteristics: Jarach et al., 2022

- Systematic review of 113 articles (culled from 767 pubs); majority from Europe
- Pooled prevalence among adults of 14.4% with no sex difference
- Pooled prevalence of 13.6% among children and adolescents
 - If the word “tinnitus” did not appear in questions to the children, then prevalence was 20.4%; when “tinnitus” was specified in questions, 5.6% prevalence was observed(!)
- Increased prevalence with age (9.7% \leq 44 yrs; 13.7% 45-64 yrs; 23.6% \geq 65 yrs)
- Pooled prevalence of severe tinnitus was 2.3%
- Authors stress the need for standardized intake forms, greater consensus on definitions/taxonomy, particularly important for studies examining pediatric populations; currently great variability in questions re: severity, chronicity
- “...global burden of tinnitus is large, similar to migraine and pain...”

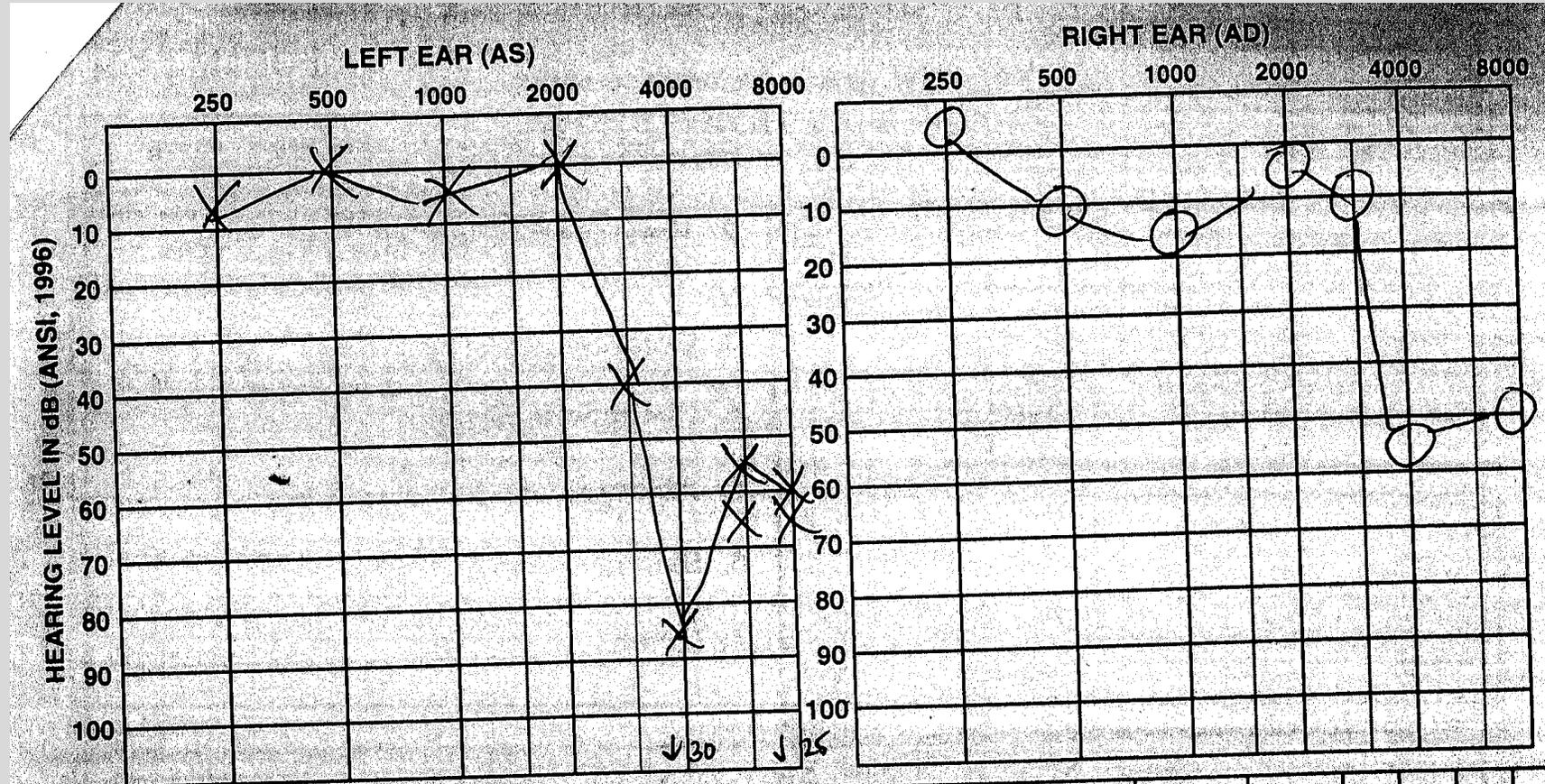
Mechanisms and effects: Auditory and non-auditory

1. Hearing loss vs. threshold loss
2. Otocentric model vs. Psychological model
3. Plasticity: purposeful, not always beneficial
4. Auditory system mechanisms of tinnitus

For calibration: Things to remember about the hearing pathway

1. The pathway exhibits spontaneous neural activity regardless of sound in the environment, or health of the system
2. Conductive system filters, mechanically amplifies, and delivers mechanical signal to a fluid-filled cochlea
3. The cochlea transforms mechanical waves into nerve signals
4. The nerve impulses pass through the VIIIth nerve and stimulate a complicated neural pathway
5. The neural pathway stimulates specific areas in the brain that evoke the sensation of sound, hearing, and can trigger emotional responses
6. Changes to pathway integrity (anatomy and/or physiology/ connectivity; from hair cell to synapse w/ VIIIth nerve, to subcortical pathway to cortex) can contribute to tinnitus generation and maintenance, sound tolerance disorders, and other unusual auditory consequences, without showing up on an audiogram

Patient #1



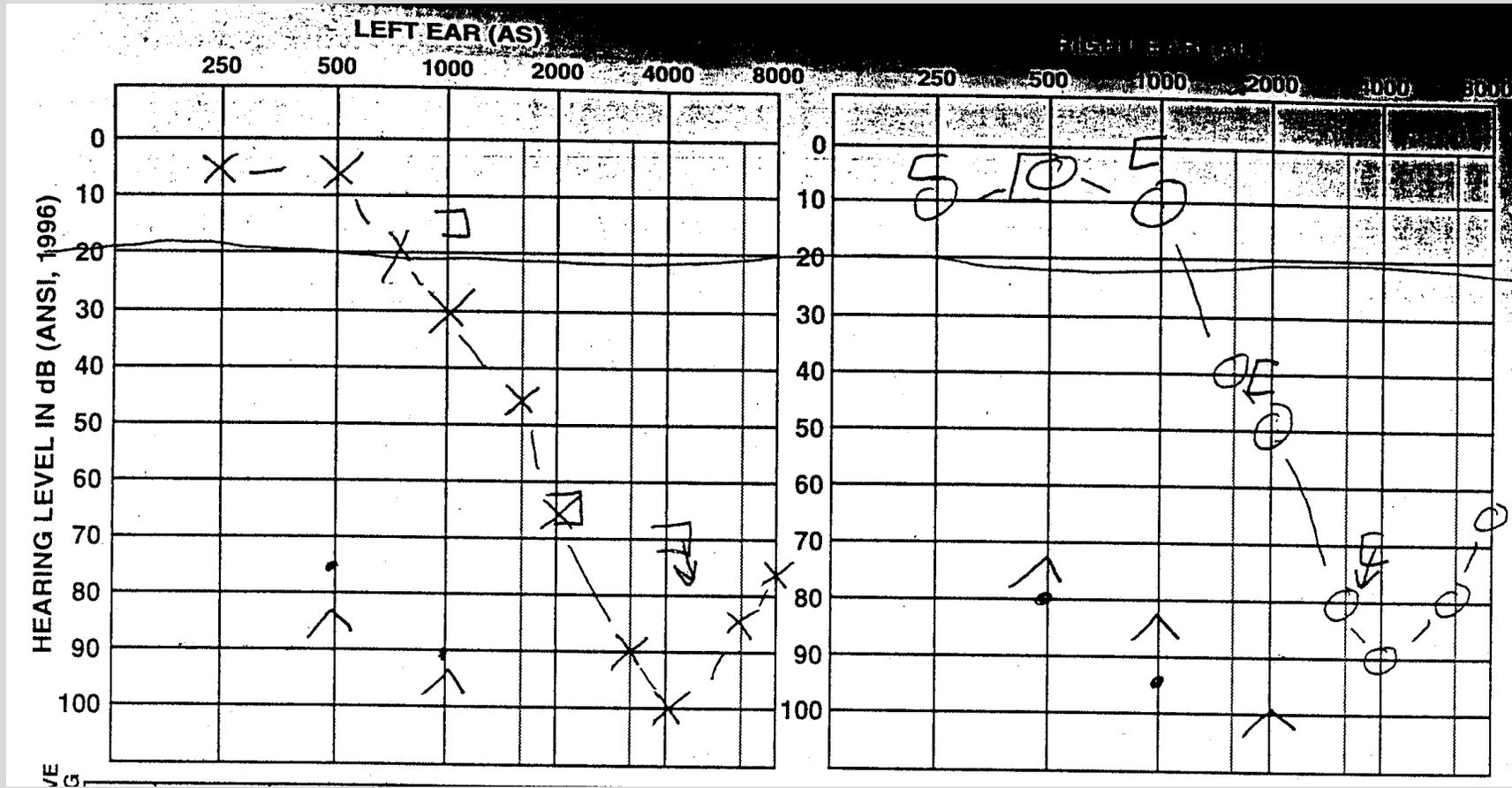
Patient #1: Severe Tinnitus

DIRECTIONS: The purpose of the questionnaire is to identify difficulties that you may be experiencing because of tinnitus. Please answer YES, SOMETIMES OR NO, to each question. Please Do Not Skip Any Questions.

- | | | | | |
|------|---|--------------------------------------|--|-------------------------------------|
| | Because of your tinnitus, is it difficult for you to concentrate? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-2 | Does the loudness of your tinnitus make it difficult for you to hear people? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-3 | Does your tinnitus make you angry? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-4 | Does your tinnitus make you feel confused? | <input type="radio"/> Yes | <input checked="" type="radio"/> Sometimes | <input type="radio"/> No |
| C-5 | Because of your tinnitus, do you feel desperate? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-6 | Do you complain a great deal about your tinnitus? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-7 | Because of your tinnitus, do you have trouble falling to sleep at night? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| C-8 | Do you feel as though you can not escape your tinnitus? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-9 | Does your tinnitus interfere with your ability to enjoy your social activities (such as going out to dinner, to the movies, etc..)? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-10 | Because of your tinnitus, do you feel frustrated? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| C-11 | Because of your tinnitus, do you feel that you have a terrible disease? | <input type="radio"/> Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-12 | Does your tinnitus make it difficult for you to enjoy life? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-13 | Does your tinnitus interfere with your job or household responsibilities? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-14 | Because of your tinnitus do you find that you are often irritable? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-15 | Because of your tinnitus, is it difficult for you to read? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-16 | Does your tinnitus make you upset? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-17 | Do you feel that your tinnitus problem has placed stress on your relationships with members of your family and friends? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-18 | Do you find it difficult to focus your attention away from your tinnitus and on other things? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| C-19 | Do you feel that you have no control over your tinnitus? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-20 | Because of your tinnitus, do you often feel tired? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-21 | Because of your tinnitus, do you often feel depressed? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| E-22 | Does your tinnitus make you feel anxious? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-23 | Do you feel that you can no longer cope with your Tinnitus? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-24 | Does your tinnitus get worse when you are under stress? | <input type="radio"/> Yes | <input checked="" type="radio"/> Sometimes | <input type="radio"/> No |
| E-25 | Does your tinnitus make you feel insecure? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |

F 40 C 16 E 36 T 92

Patient #2: Mild tinnitus



Patient #2: Mild tinnitus

INSTRUCTIONS: The purpose of the questionnaire is to identify difficulties that you may be experiencing because of your tinnitus. Please answer YES, SOMETIMES OR NO, to each question. Please Do Not Skip Any Questions.

| | | | | |
|------|--|--------------------------------------|--|-------------------------------------|
| F-1 | Because of your tinnitus, is it difficult for you to concentrate? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-2 | Does the loudness of your tinnitus make it difficult for you to hear people? | Yes | <input checked="" type="radio"/> Sometimes | <input type="radio"/> No |
| E-3 | Does your tinnitus make you angry? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-4 | Does your tinnitus make you feel confused? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| C-5 | Because of your tinnitus, do you feel desperate? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-6 | Do you complain a great deal about your tinnitus? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-7 | Because of your tinnitus, do you have trouble falling to sleep at night? | Yes | <input checked="" type="radio"/> Sometimes | <input type="radio"/> No |
| C-8 | Do you feel as though you can not escape your tinnitus? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-9 | Does your tinnitus interfere with your ability to enjoy your social activities (such as going out to dinner, to the movies, etc.)? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-10 | Because of your tinnitus, do you feel frustrated? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| C-11 | Because of your tinnitus, do you feel that you have a terrible disease? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-12 | Does your tinnitus make it difficult for you to enjoy life? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-13 | Does your tinnitus interfere with your job or household responsibilities? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-14 | Because of your tinnitus do you find that you are often irritable? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-15 | Because of your tinnitus, is it difficult for you to read? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-16 | Does your tinnitus make you upset? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-17 | Do you feel that your tinnitus problem has placed stress on your relationships with members of your family and friends? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-18 | Do you find it difficult to focus your attention away from your tinnitus and on other things? | Yes | <input checked="" type="radio"/> Sometimes | <input type="radio"/> No |
| C-19 | Do you feel that you have no control over your tinnitus? | <input checked="" type="radio"/> Yes | <input type="radio"/> Sometimes | <input type="radio"/> No |
| F-20 | Because of your tinnitus, do you often feel tired? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-21 | Because of your tinnitus, do you often feel depressed? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-22 | Does your tinnitus make you feel anxious? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| C-23 | Do you feel that you can no longer cope with your Tinnitus? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| F-24 | Does your tinnitus get worse when you are under stress? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |
| E-25 | Does your tinnitus make you feel insecure? | Yes | <input type="radio"/> Sometimes | <input checked="" type="radio"/> No |

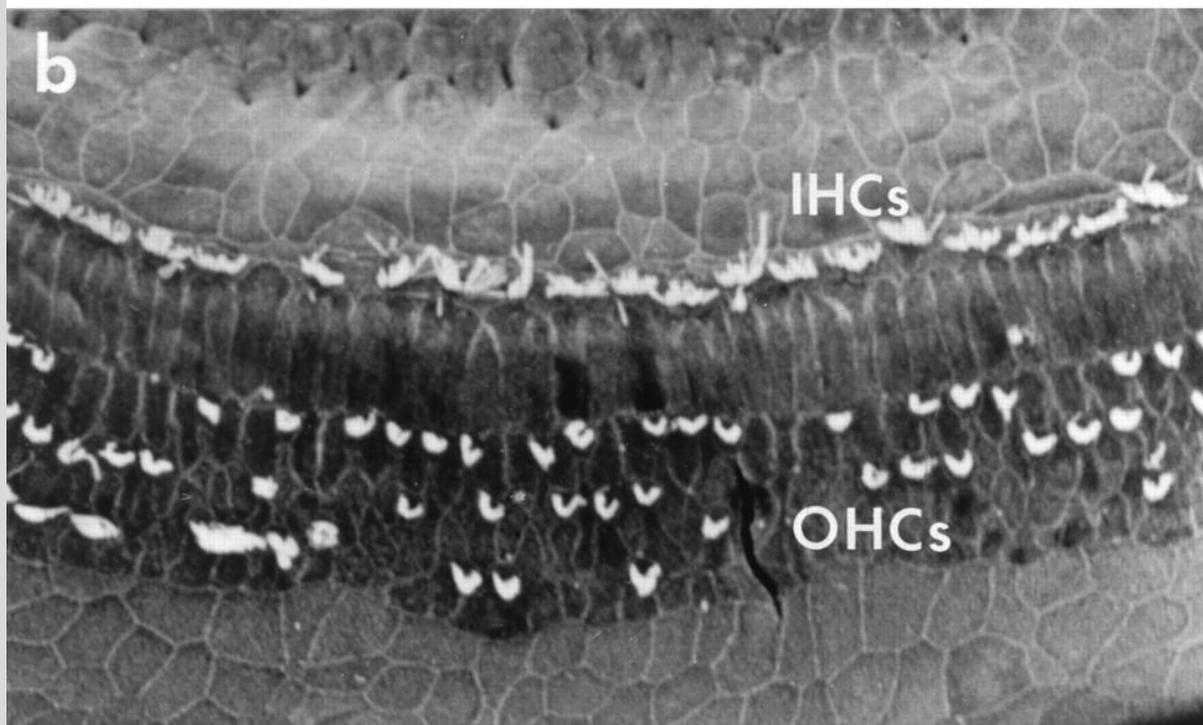
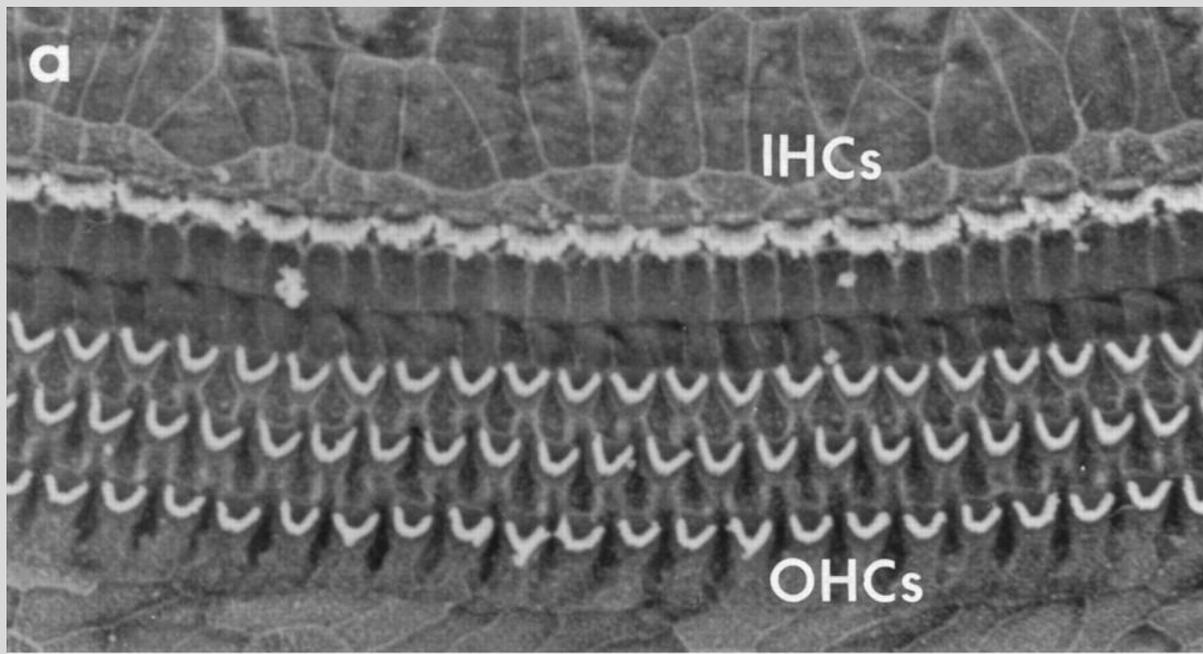
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Triggers: Auditory-Related

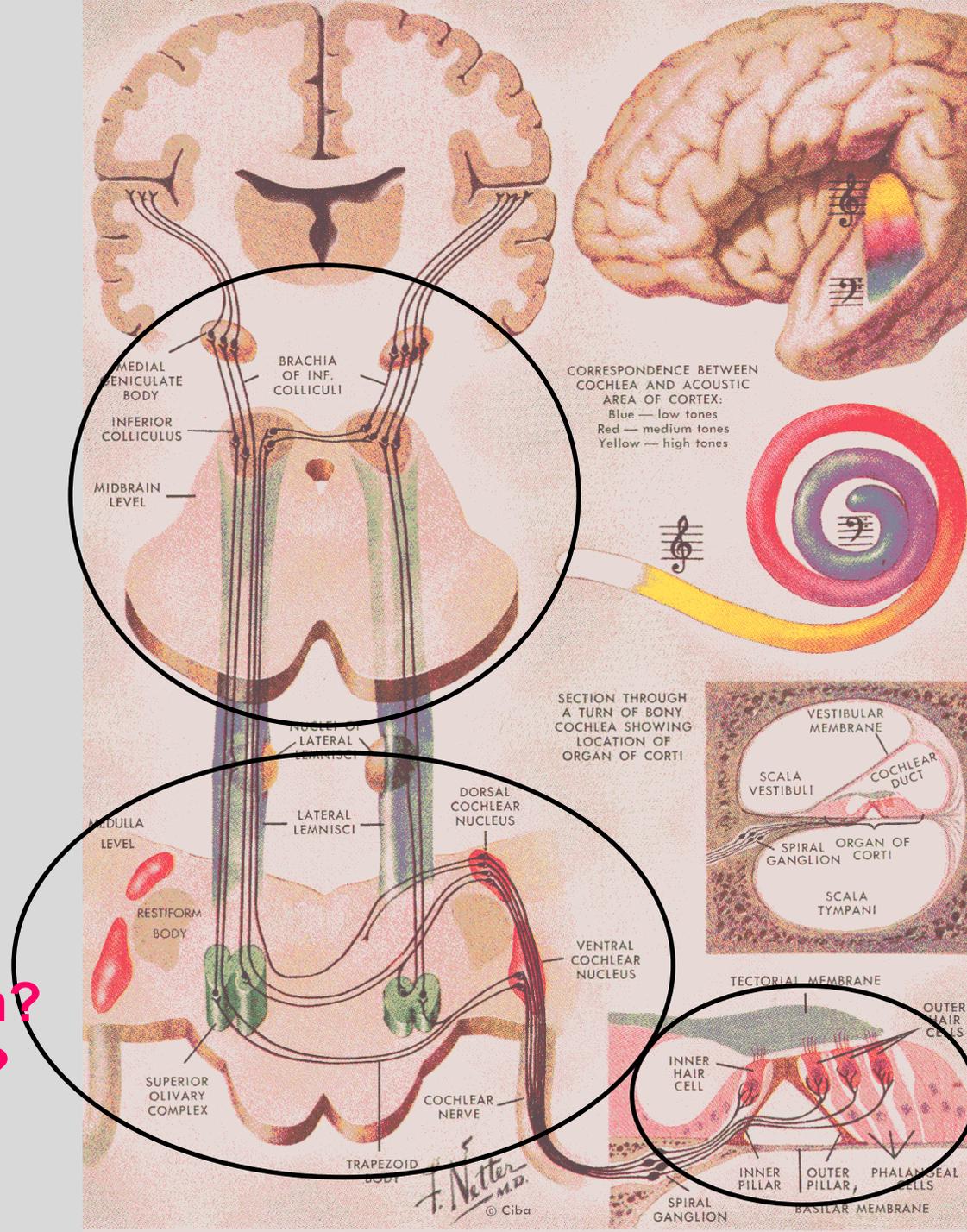
- Conductive hearing loss
 - May increase the detectability of spontaneous activity
 - May make a pre-existing tinnitus signal more detectable
 - Loudness/Disturbance produced by tinnitus may fluctuate if the loss is temporary or fluctuating
 - Fluctuations may influence effectiveness of maskers or hearing aids
 - May be correctable with surgery or other medical intervention (Kleinjung: when tinnitus is accompanied by hearing loss, manage the hearing loss first)

Triggers: Cochlear Damage and Acute vs. Chronic Tinnitus

- Acute
 - Immediately follows damaging exposure
 - Broadband exposure (i.e., music or explosion) leads to broadband, or noisy tinnitus
 - May last for a few days but should stop when sensory cells have either repaired or died off
- Chronic
 - Persists after damaging exposure and continues regardless of hair cell status
 - Persistence and annoyance related to its evaluation, reactivity, dynamic nature, associated memories
 - Cut-off between chronic and acute placed at 3 months post-onset (DeRidder et al, 2021), a somewhat controversial change from the long-reported 6 month timeframe



**Sub-Cortex:
Filtering &
Amplification:
should be
proportional to
perceived value**



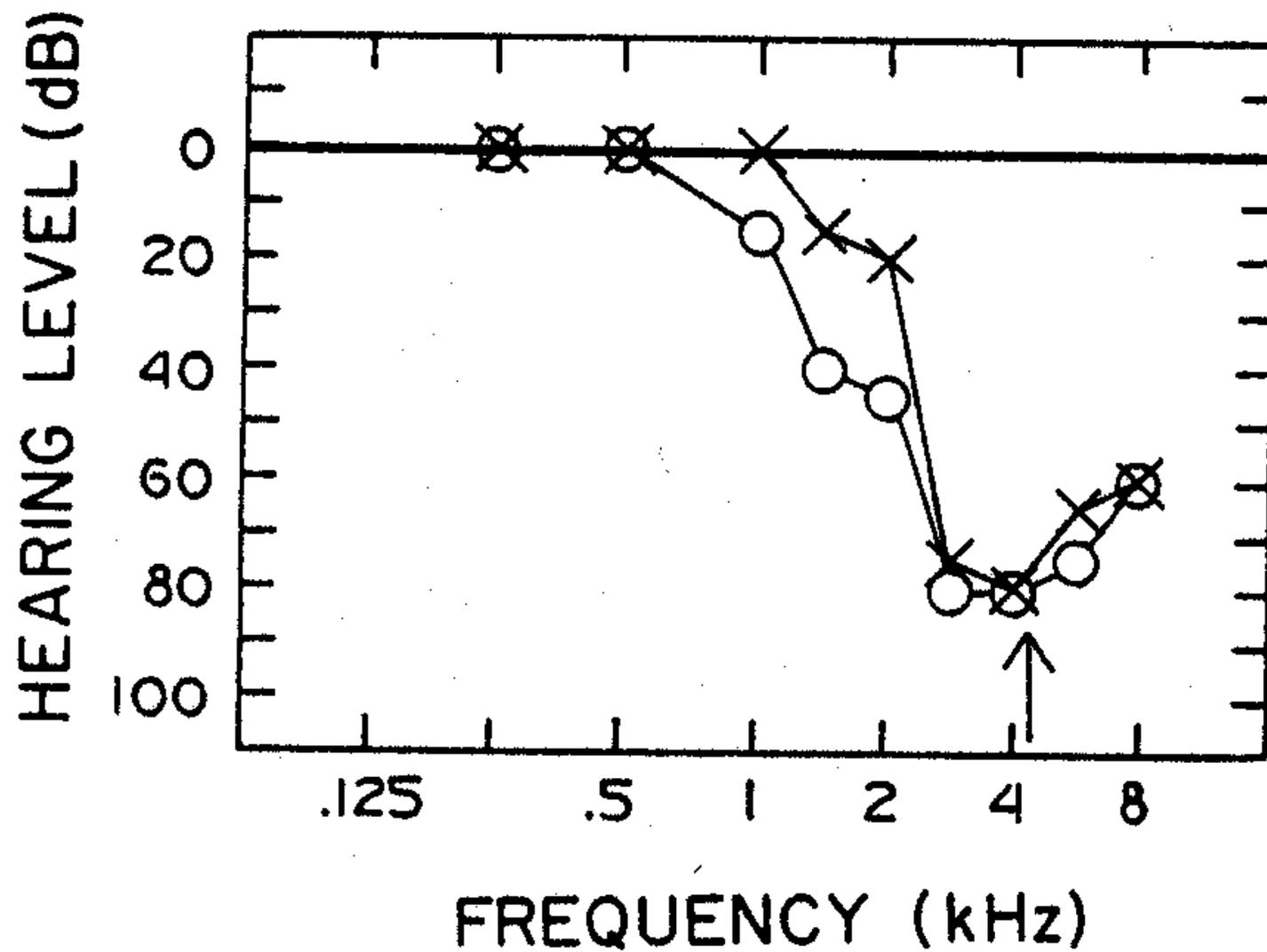
**Auditory Brainstem:
Compensation; Gain?
Disinhibition? Both?**

**Outer/Middle/Inner Ear
damage (OM, NIHL,
ototoxicity, damage
to sensory cells/
synapses, etc)**

Triggers: detectable change to pre-existing (spontaneous) neural activity

- Spontaneous activity – Eggermont, 2000
 - Spontaneous activity as baseline or background level of neural activity; damage along the pathway may alter afferent signal strength, synchrony or balance
 - Synchrony: Modifies spontaneous activity to form signal with periodicity or familiarity; a sound experience that the patient can label
 - Balance: Overall output from OHCs changes more substantially than output from IHCs; may contribute to modifications in auditory CNS processing that compels perceiver to focus on the affected frequency region
 - Strength: Reduced activation due to peripheral dysfunction may trigger gain and/or disinhibition
 - Consequences of damage often, but not always, most evident in areas w/ greatest hair cell loss (Schecklmann et al., 2012)

Penner, 1984



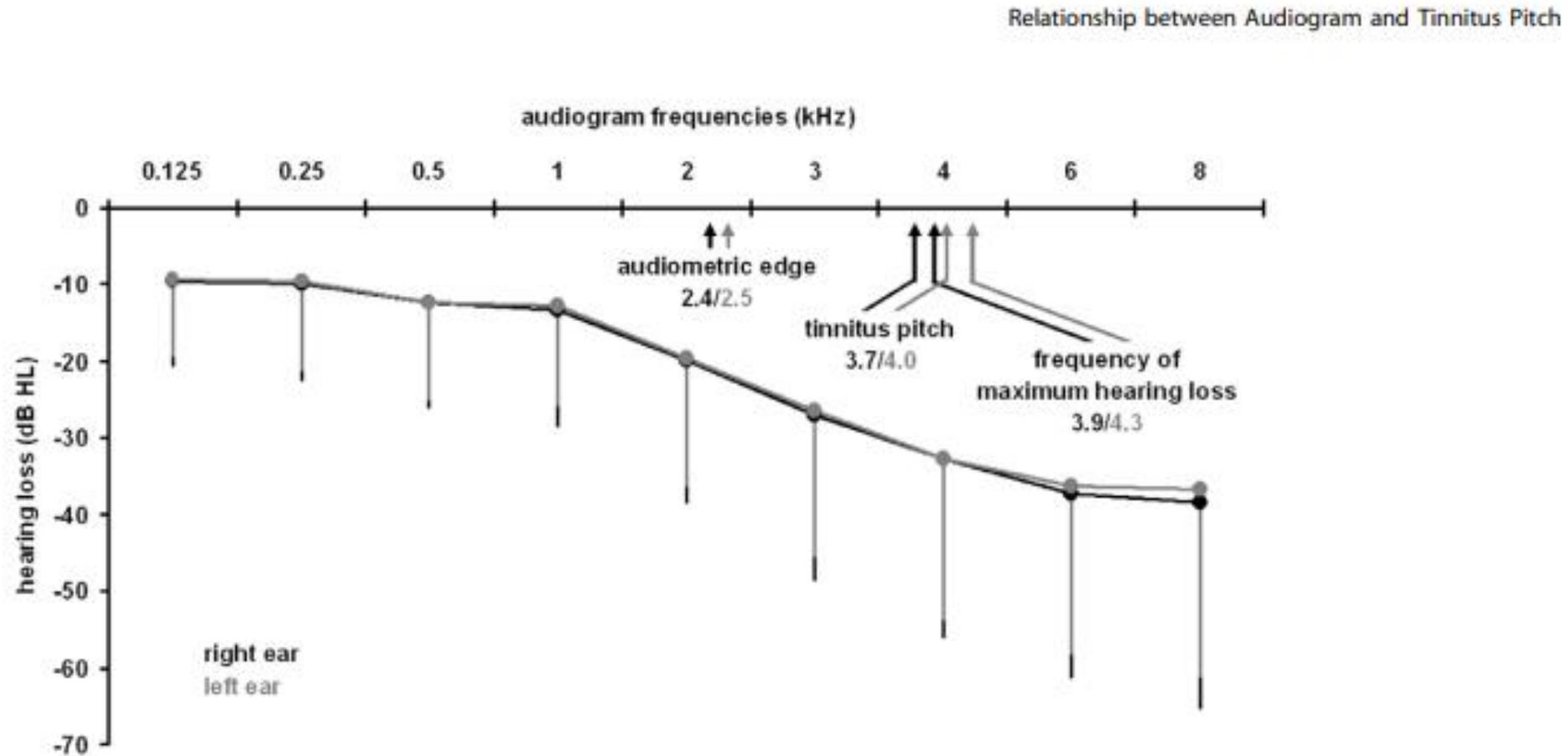


Figure 2. Relationship of audiogram and tinnitus pitch averaged for the whole sample, for the right and left ear. Please note that the averaged frequency of maximum hearing loss and the hearing loss as indicated by averaged audiogram data do not necessary result in the same values.

doi:10.1371/journal.pone.0034878.g002

Tinnitus in the Central Nervous System (CNS)

Activity in the CNS resembles a sequence of ‘clicks’ or bursts of electrical impulses. These impulses, if detected, are decoded by the brain and are assigned an identity, or meaning that should be proportional to the sound’s value.

Spikes below intended to represent spontaneous, ongoing, background neural activity in the central auditory pathway



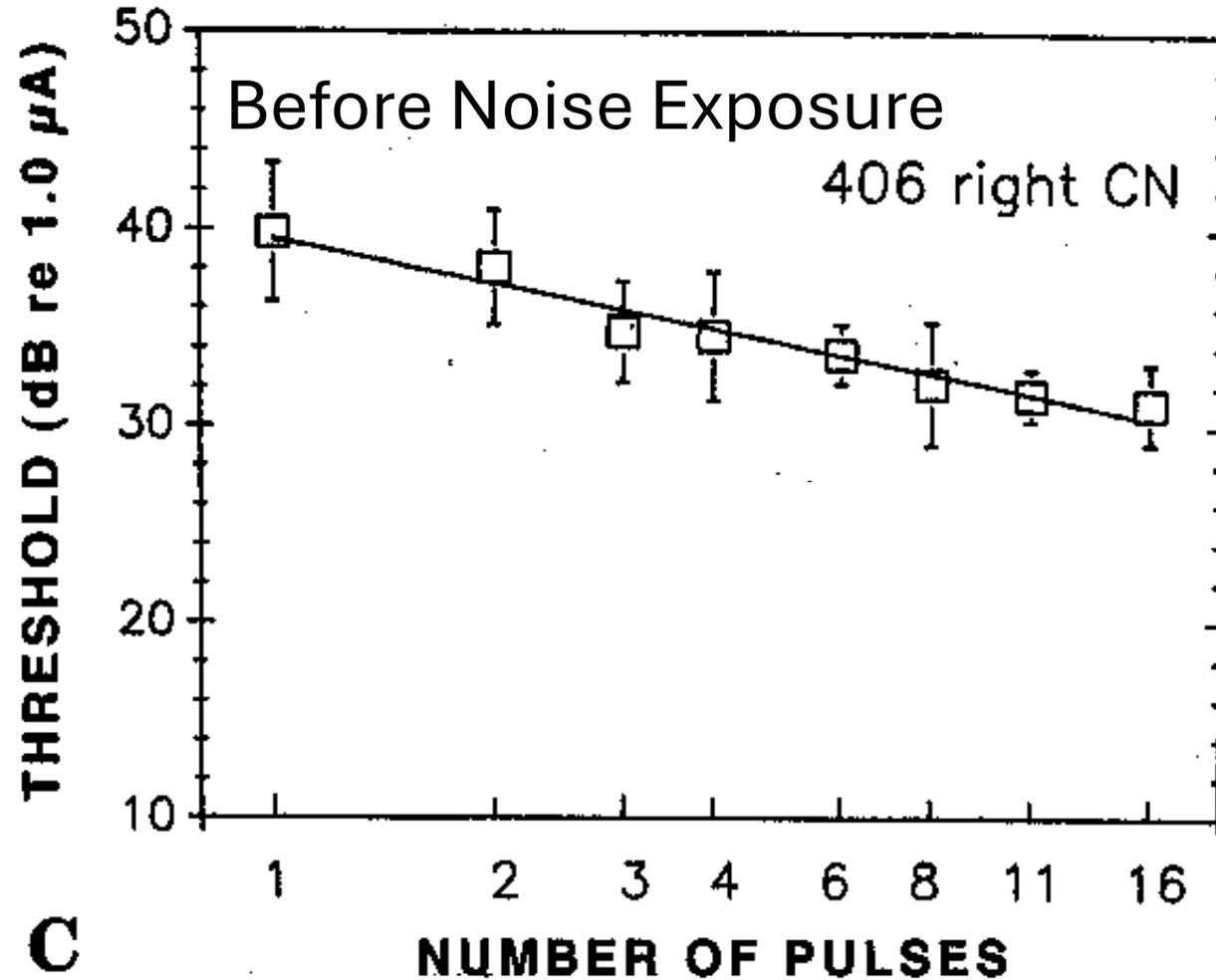
If the pattern of activity changes (for example, increased periodicity or synchrony), the “new” spontaneous activity may compel re-assessment and result in an auditory event demanding an increased share of attention/resources



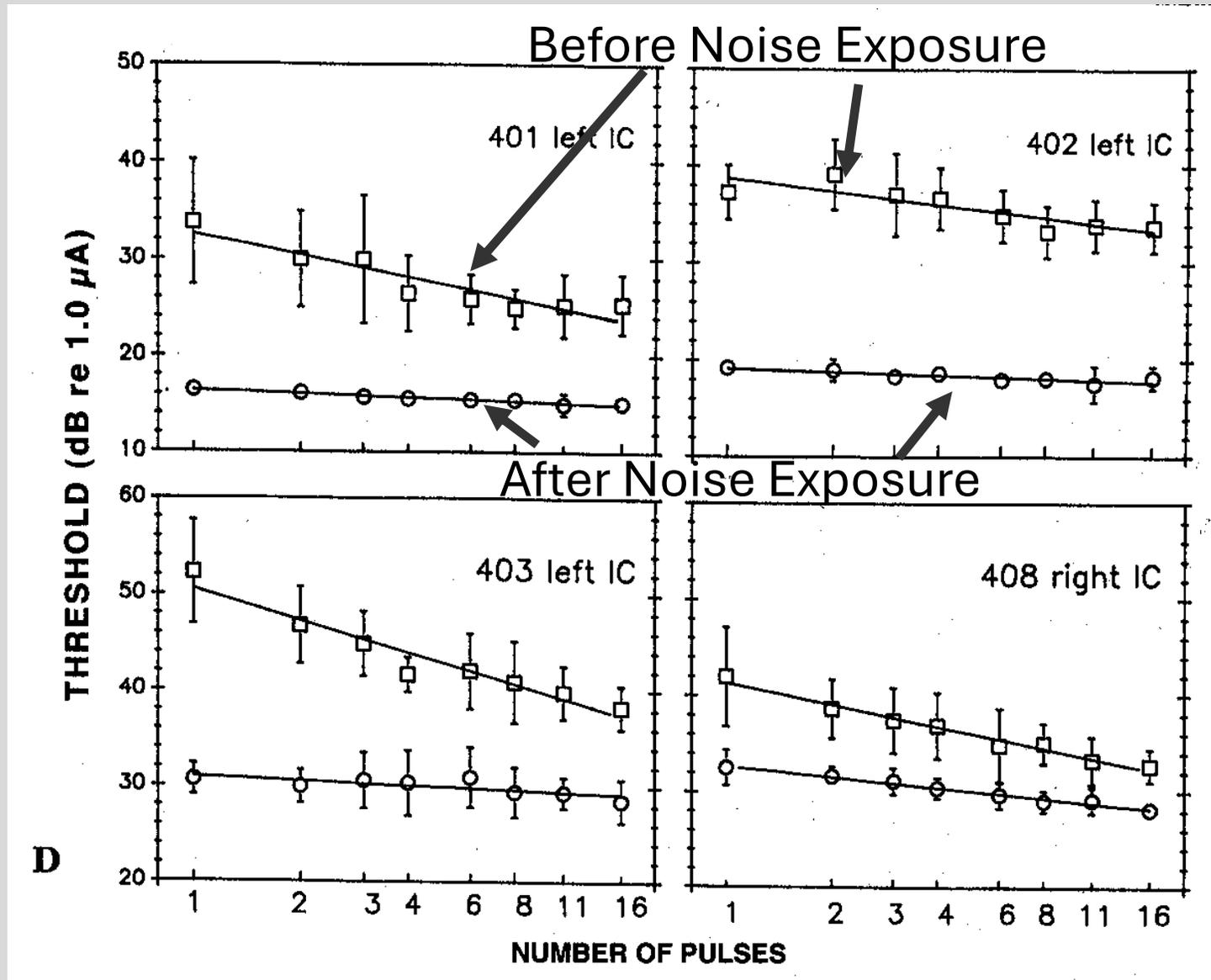
Tinnitus: Effects of damaging noise

- Brainstem and spontaneous activity
 - Noise damaged animals display increased spontaneous activity in dorsal cochlear nucleus (DCN) and inferior colliculus (IC) (Kaltenbach, 2000)
 - When stimulated electrically (i.e., not by sound), DCN and IC neurons reveal modified growth functions
 - Gamma-aminobutyric acid (GABA), an inhibitory neurotransmitter, reduces this effect when provided to an experimental animal

Change in cochlear nucleus neuron activity following noise

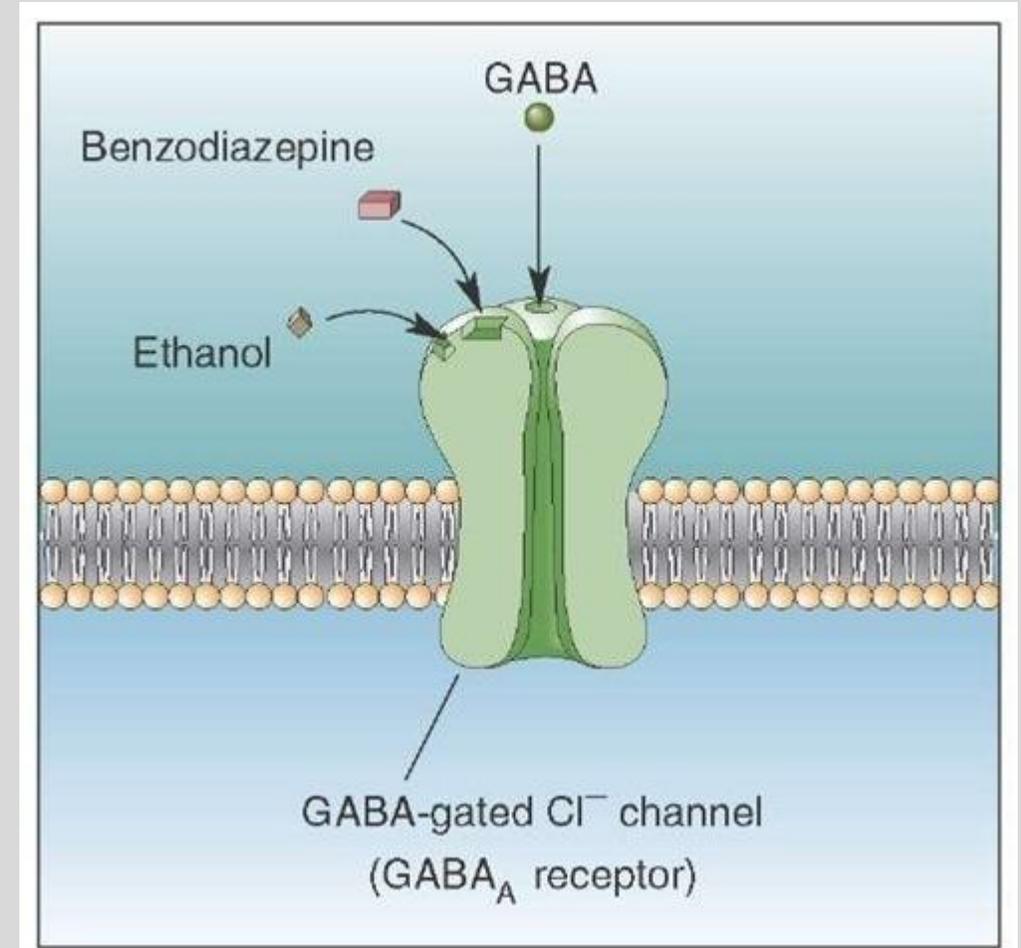


CNS reorganization: change in IC neurons



Tinnitus: Role of GABA

- GABA is an inhibitory neurotransmitter
- Neurons that produce GABA have inhibitory roles in CNS activity; GABA hyperpolarizes cells
- Drugs mimic, or amplify, GABA's effects
 - Benzodiazepines, barbiturates, ethanol
- Damage from noise reduces GABA-related inhibition; may result in disinhibition
- Therefore, the mechanisms underlying tinnitus appearance and maintenance may be related to increased gain (would also explain changes in loudness perception) as well as decreased inhibition (would also explain speech in noise challenges, esp. in pts with normal thresholds)



Brainstem changes following cochlear damage

Damage to the pathway decreases the amount of neural activity produced by sound. The ascending pathway modifies its own behavior to compensate for the change in stimulation, or the “lost” afferent signal (auditory gain? disinhibition? both?)

| Compensation | Some Potential Consequences |
|---------------------|--|
| Auditory Gain | Disorders of sound tolerance, exaggerated startle, absent wave I with normal wave V |
| Disinhibition | Speech in noise problems, disorders of sound tolerance, concentration/focus challenges |

Non-Auditory Triggers: The neurophysiological model

- Assumptions of the Neurophysiological Model
 - Perception occurs in the brain's primary sensory areas (the movie screen analogy)
 - The brain's recognition of the environment is learned on stimuli that originate outside the body
 - Tinnitus is generated internally and does not follow the same perceptual rules as external sounds; consider masking in cases of unilateral tinnitus

MINIMUM MASKING LEVELS: (white noise)

Presented in R ear, tinnitus suppressed @ _____ dBHL in the R ear
44 dBHL in the L ear
_____ dBHL AU

Presented in L ear, tinnitus suppressed @ _____ dBHL in the R ear
36 dBHL in the L ear
_____ dBHL AU

Presented AU, tinnitus suppressed @ _____ dBHL in the R ear
46 dBHL in the L ear
_____ dBHL AU

Assumptions of the Neurophysiological Model

Tinnitus is present in ears with normal puretone thresholds

- Heller and Bergman (1953) demonstrate that almost all NH individuals report tinnitus if they are placed in a quiet enough environment for 5 minutes or less
- Del Bo et al (2008) replicate the findings
 - Therefore, the tinnitus signal may be a by-product of normal auditory system function (implications for “cure” as tinnitus is arguably part of all of us)

Assumptions of the Neurophysiological Model

Non-Auditory trigger (Hazell, 1995)

- Hearing loss is not a consistent trigger and shouldn't be viewed as a prerequisite for the generation of a troubling tinnitus signal
- Psychological trauma and physical trauma were triggers for people with no hearing loss about 10% of the time
- Hazell (1995) with 100 patients reported only 26% could identify a specific auditory triggering event

Tinnitus and Non-auditory Triggers

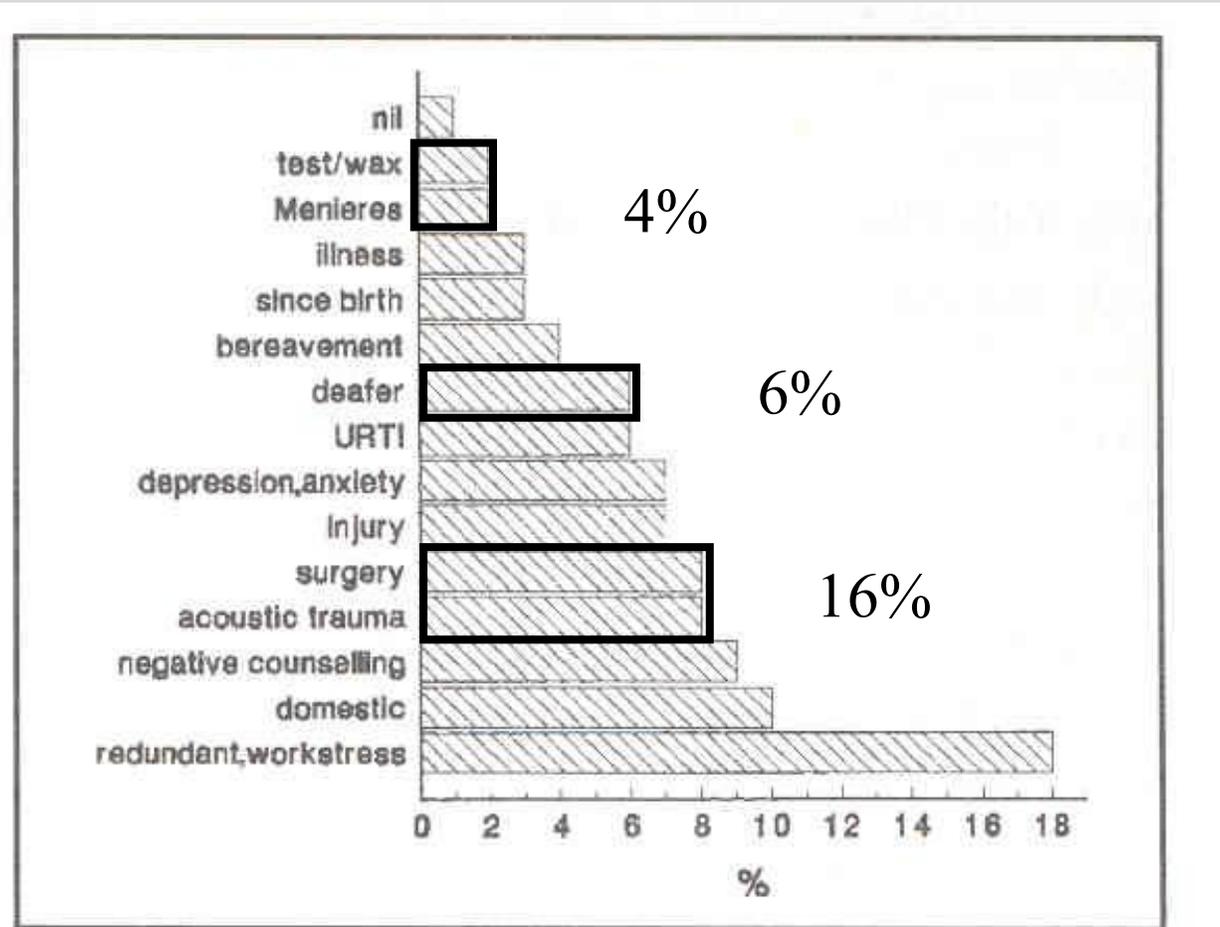
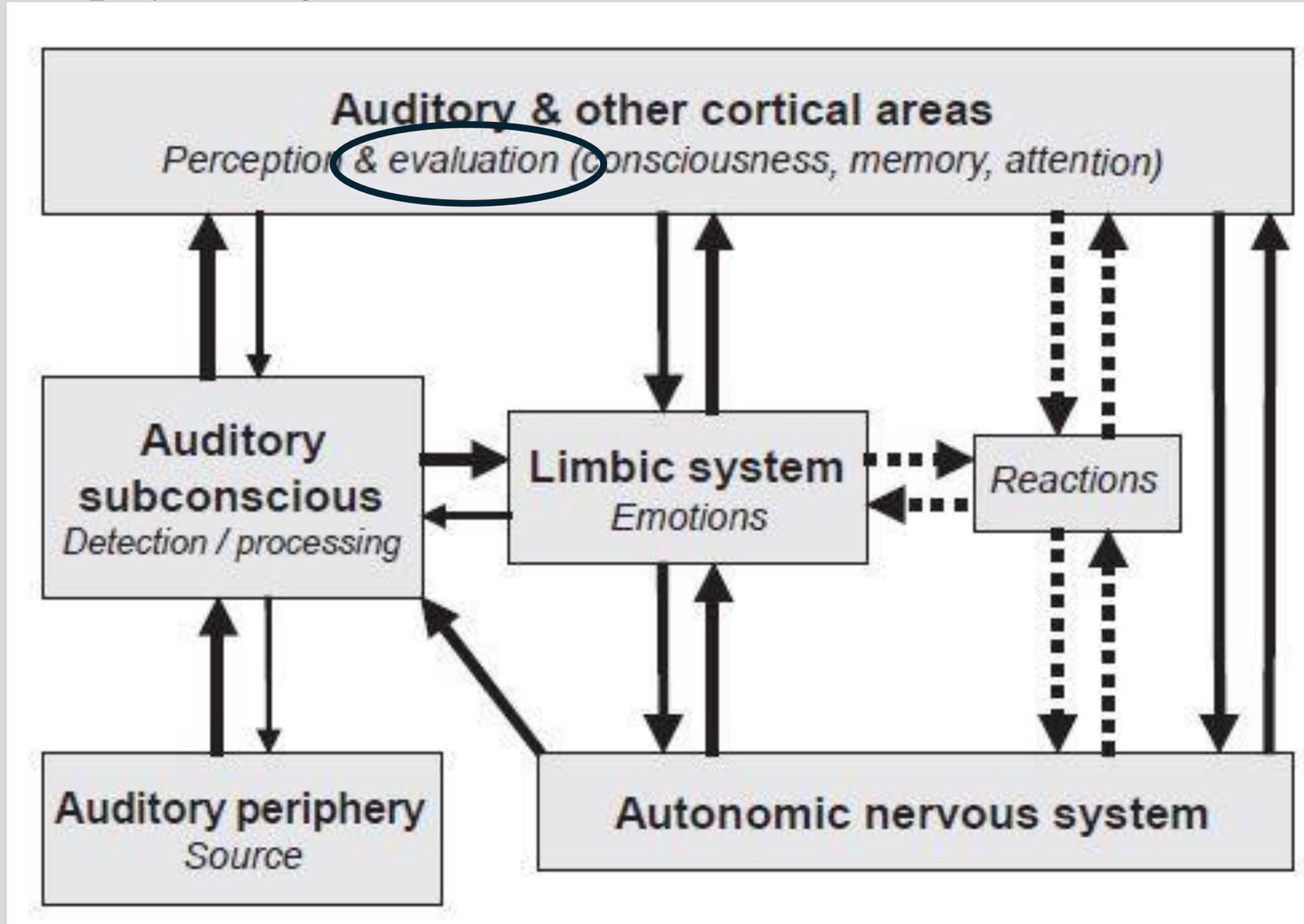


Figure 3: Factors which trigger the onset of tinnitus. (URTI=upper respiratory tract infection).

Neurophysiological Model

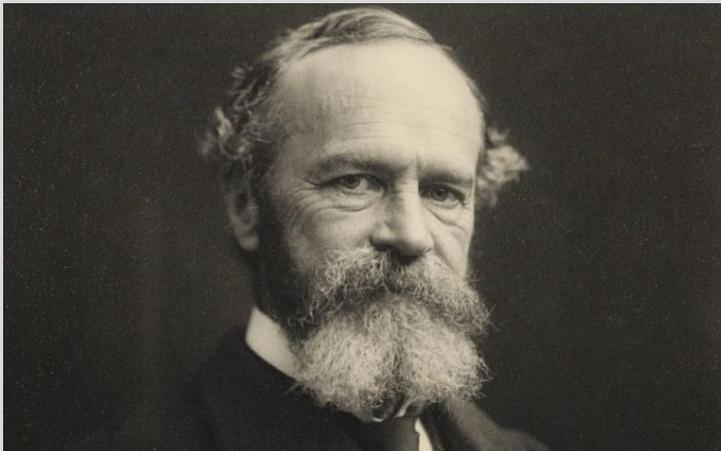


Adapted from Jastreboff, 1999

Special Populations: Veterans, Music-exposed Individuals, Traumatic Onset

Experience: Durability of Trauma effects

Trauma's effects on brain structures and connectivity is linked to occurrence of depression, PTSD, anxiety, and other MH injury. It appears the triggering event influences/increases tinnitus salience, hones/prioritizes its appraisal, and heightens the potential to trigger and/or be triggered by memories of the event long after the event occurred.



- William James (1890): “An impression may be so exciting emotionally as almost to leave a scar upon the cerebral tissues.”

Experience, Neural Plasticity, and DST

- Aage Møller (2010): “Activation of neural plasticity can be purposeful and beneficial, or it can be purposeful, but not beneficial.”
- By what means can providers assess patients’ challenges in order to maximize the probability that we foster beneficial neuroplastic changes?
- William James (1890): “An impression may be so exciting emotionally as almost to leave a scar upon the cerebral tissues.”
- Is there evidence that a patient’s experiences (ie., related to tinnitus onset or quality) influence tinnitus disorder/severity?

Links between tinnitus and PTSD: Survivors of the Khmer Rouge in Cambodia (J. of traumatic stress, 2006; Transcultural Psychiatry, 2008)

- 50% of 104 patients had current tinnitus (“at least one episode in the last month”) “Tinnitus triggered flashbacks and gave rise to catastrophic cognitions, and those trauma associations and catastrophic cognitions had a major role in generating PTSD.” Tinnitus thought of as a form of “soul loss” (Hinton et al 2006)

Experimenters developed a Tinnitus Flashback Presence Questionnaire and a Tinnitus Flashback Scale

| Events related to presence and distress | Events related also to specific sounds |
|--|---|
| Blows to the head (w/ traumatic recollection) | Gunfire, ordinance (whistling of projectiles) |
| Malaria | Submersion of head underwater (drowning or torture) |
| Starvation, Exhaustion | Buzzing of insects (1.7 of 7.9 Cambodians died between 1975-1979) |

NCPTSD Data (PTSD.va.gov)

Conditions under which patients may experience tinnitus onset (2005-2012).

| Combat Stressors | | Seeing dead bodies | Being shot at | Being attacked/ ambushed | Receiving rocket or mortar fire | Know someone killed/ seriously injured |
|-------------------------|---------|--------------------|---------------|--------------------------|---------------------------------|--|
| Iraq | Army | 95% | 93% | 89% | 86% | 86% |
| Iraq | Marines | 94% | 97% | 95% | 92% | 87% |
| Afghanistan | Army | 39% | 66% | 58% | 84% | 43% |

Consider these environments in the context of traumatic memory and tinnitus salience when onset approximated the moment of the event

Why Consider Traumatic Associations in the audiology clinic?

- Tinnitus accompanied by psychological injury more burdensome(?)
 - Greater handicap as indicated on questionnaire responses
 - Patients have lower levels of confidence in ability to manage condition, poorer coping ability and lower self-efficacy, than patients whose tinnitus is not complicated by psychological injury
- Tinnitus-related symptoms that distinguish patients with trauma history/PTSD:
 - 2x more likely to report sudden-onset
 - 3x more likely to report reactive tinnitus
 - Patients with PTSD nearly 4x as likely as those w/ tinnitus alone to state that hyperacusis is a bigger challenge than tinnitus

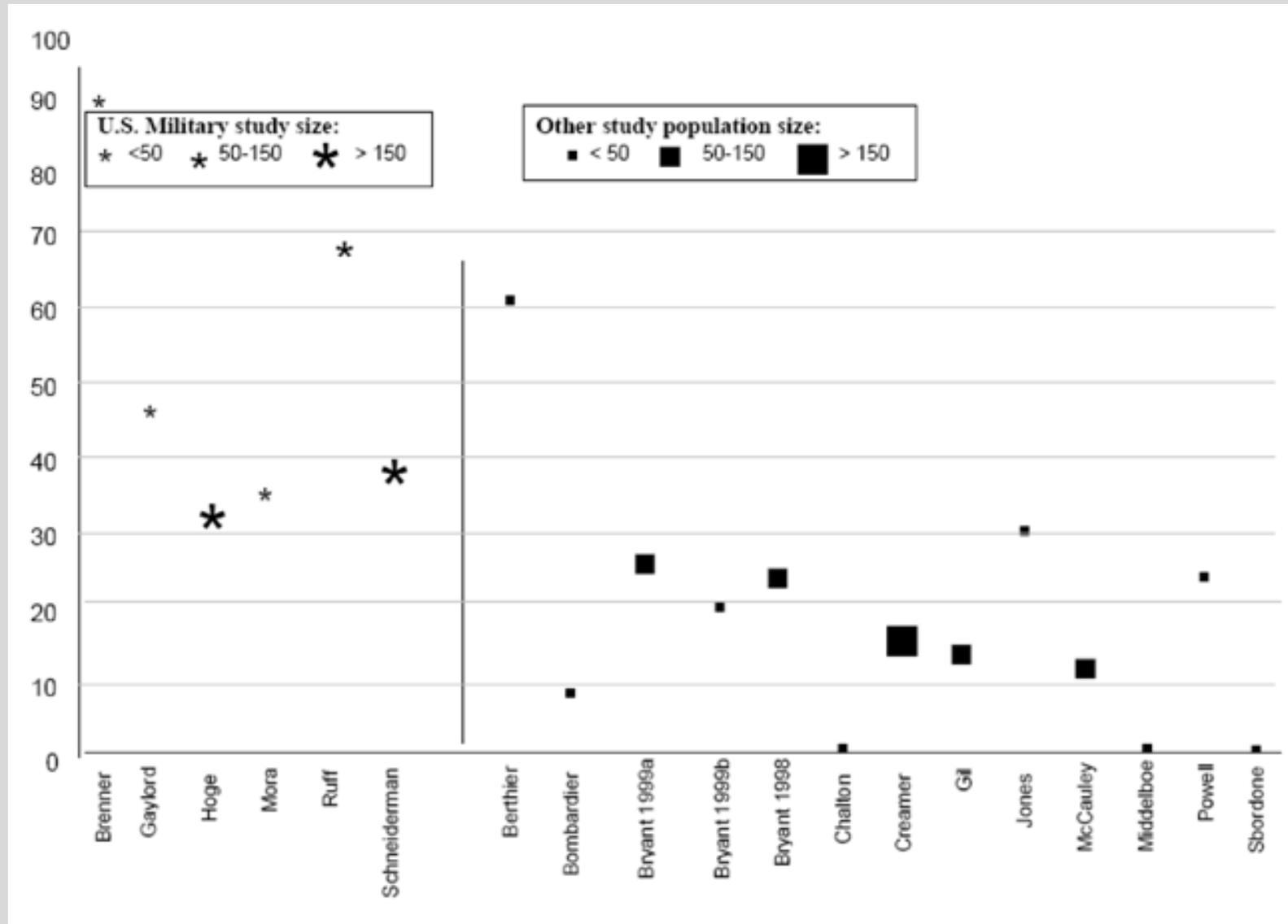
Special Populations: Veterans and Musicians

1. Risk factors including but not limited to hazardous exposures
2. Trauma (physical, psychological, acoustic) and its reminders may influence (and include) tinnitus
3. Functional impacts require unique considerations and may complicate use of hearing protection
 - Veterans experiencing intrusive memories, hyperarousal
 - Soldiers needing environmental awareness and monitoring orders
 - Occupational concerns for musicians, engineers, road crews

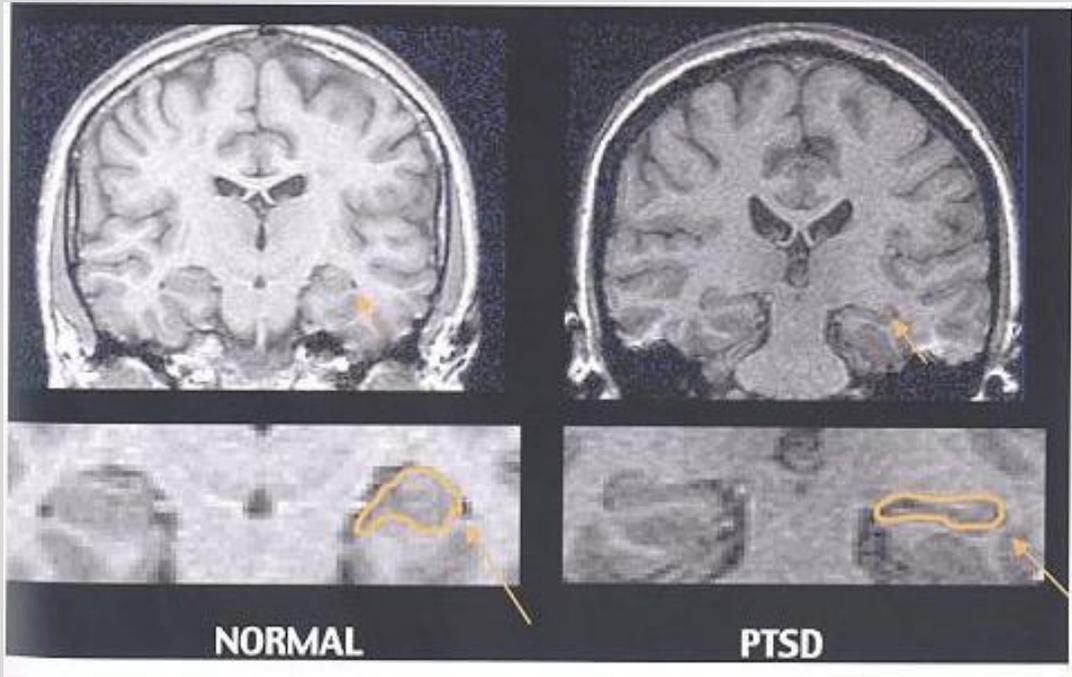
“Invisible” injuries and what we learn from veterans

- Jones and Wessely (2005): Review military psychiatry from Boer War through 1st Gulf War
 - Expresses historic difficulty of addressing incapacitating injury unaccompanied by physical wounds
 - The “organic versus psychological” controversy for explaining (and driving administrative responses to) soldiers thus affected continues today
 - VHA in US changing policy re: tinnitus and audiogram
- Two views from the early 1900s:
 - WWI physician reported it, “a great misfortune that each soldier had to be certified as suffering from a definite disorder as this lent a spurious air of scientific certainty at a time when the disorder was far from understood.” (p. 118)
 - Freud: “The physicians had to play a role somewhat like that of a machine gun behind the front line, that of driving back those who fled.”

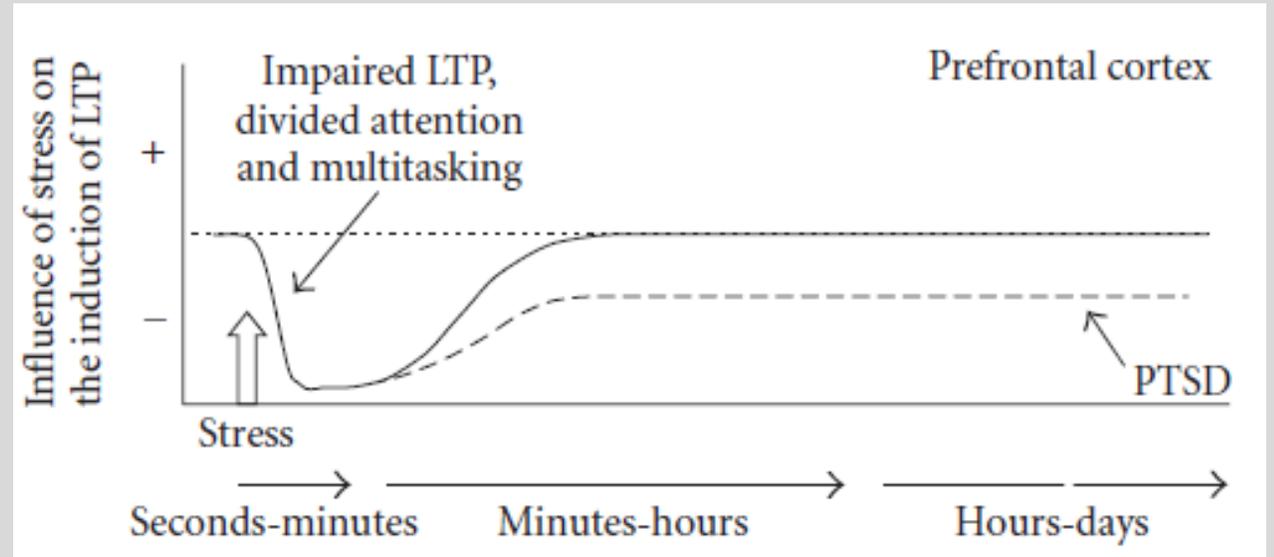
mTBI and PTSD Co-occur in military and civilian populations (Carlson, 2009; VA HSR&D analysis)



Hippocampus: reduced volume Bremner, 2002



Reduced Activity in Pre-Frontal Cortex: (Temporal Dynamics Model of Emotional Memory Processing (Diamond et al., 2007))



Poe et al (2020) and others: Locus Coeruleus-NA system “amplifies neural gain” but does so as it limits attention and encoding resources to “prioritized mental representations under arousal”

- “strong inputs are further enhanced, while weaker inputs are further inhibited” or “winner take more, loser take less” processing (Poe et al., 2020)
- Increases the conditions for hyperarousal, as well as reduced resources devoted to monitoring “less important” elements in the environment

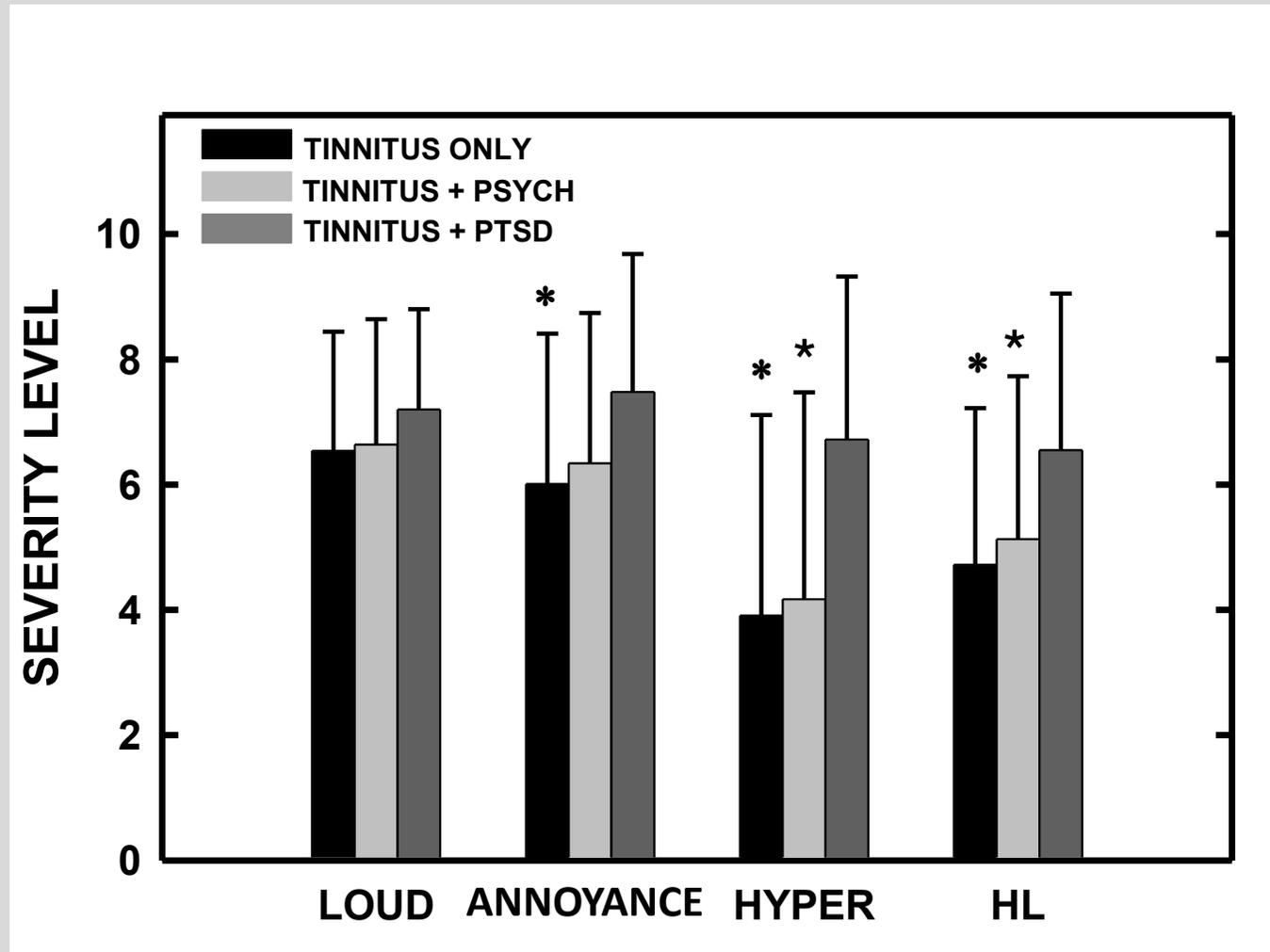
Service Connection Statistics for Veterans (2024 Data; fr. VA Benefits Report)

| Body System | Disability | N of Veterans | % of Total |
|-----------------|--------------------------------|---------------|------------|
| Auditory | Tinnitus | 3,255,323 | 7.8% |
| Musculoskeletal | Imp. of the knee, general | 2,069,942 | 5.0% |
| Neurological | Paralysis of Sciatic Nerve | 1,745,314 | 4.2% |
| Musculoskeletal | Lumbosacral or cervical strain | 1,611,188 | 3.9% |
| Auditory | Hearing loss | 1,594,271 | 3.8% |
| Mental | PTSD | 1,589,833 | 3.8% |
| Musculoskeletal | Imp. of the arm | 1,200,103 | 2.9% |
| Skin | Scars, general | 1,125,720 | 2.7% |
| Neurological | Migraine | 1,109,254 | 2.7% |

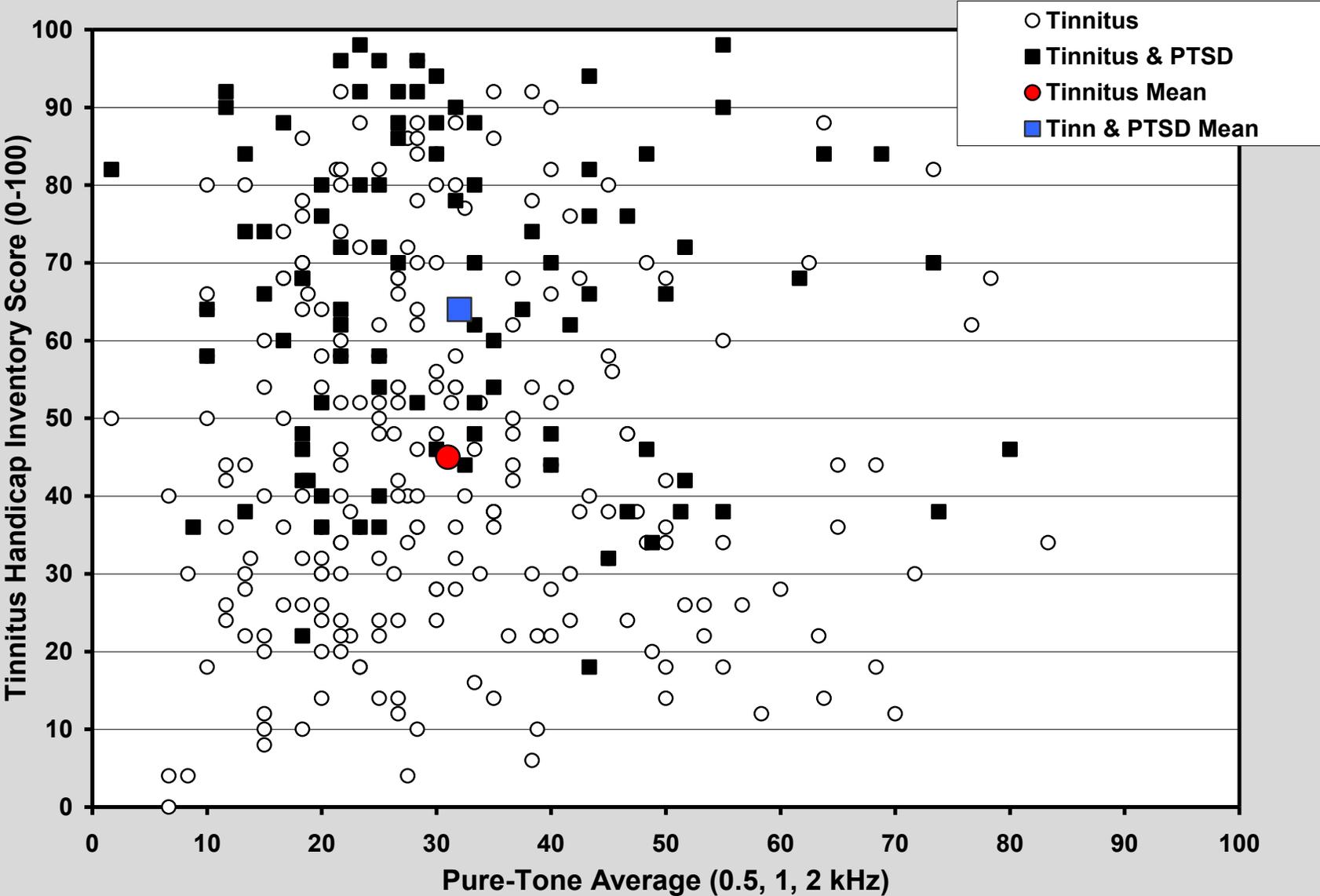
PTSD (and any stressor, really) as potential tinnitus exacerbator – Perception and Mislabeling

- Symptom Perception
 - Tinnitus rated as more handicapping when compared to unaffected individuals
 - Exaggerated Startle
 - More frequent complaints of sound tolerance problems than in pts with tinnitus but no trauma history
- Sensory Mislabeling
 - Linked to survival/threat memories that distort or challenge accurate evaluation of the environment
 - Exacerbated by the initial “misperceiving” of the stimulus; suggestion that hyperarousal should be considered a defense mechanism
- Biological Function – stress hormones
 - Chronic hyperarousal associated with elevated noradrenaline levels
 - Increased cortisol levels modify immune system function, modify arousal patterns, many other physiological changes

Patient Ratings of Tinnitus/Hearing Symptoms



Perceived Tinnitus Handicap, and Relation to Auditory Sensitivity



Musician-Reported music-induced hearing disorders (MIHDs): AAA Clinical Consensus Document (Santucci et al., 2020)

- All forms of music may be implicated (not just amplified rocknroll)
 - Royster et al (1991) reporting more than half of classical musicians sampled presented w/ notched audios. Violinists and violists showed asymmetric hearing loss ($AS > AD$) attributed to their posture that ensures AS exposure
- Music-exposed individuals particularly challenged by auditory symptoms that co-occur with psychological components exacerbated by career-related stress:
 - Tinnitus: “perhaps the most reported form of MIHD among musicians.”
 - Reports of tinnitus interfering with tuning and performing (“a distraction during performances” and “it reduces music listening enjoyment”)
 - Loudness/Pain/Fear hyperacusis
 - Decreased tolerance independent of puretone threshold,
 - Pitch disparities
 - Diplacusis binauralis

Additional intake forms (note that many providers working with musicians develop and use their own materials – Malyuk; personal comm.)

- Listening Activity Questionnaire (Sandridge & Newman, 2006)
 - Items re: communication in crowded settings, small groups, one-on-one; also questions patients re: situations in which they would like to improve abilities (ie., motivation for wearing hearing aids)
- Motives for Listening to Music Questionnaire (Kuntsche et al., 2016)
 - Adolescent population; questions listening habits and preferences
 - Also probes musical preferences with regard to emotional reactions
 - 4 motives: enhancement of personal growth, coping with daily stress, improving social relationships, conforming with peers

Additional intake forms (note that many providers working with musicians develop and use their own materials – Malyuk; personal comm.)

- Noise Exposure Questionnaire (Johnson et al., 2017)
 - Focused on “annual” exposure levels/rates; occupational and recreational
 - Offered screening assessments, essentially for the general population
- Sound Preference and Hearing Habits Questionnaire (Meis et al., 2018)
 - Identify sound (quality) preferences with respect to hearing aids and other devices
 - Descriptors such as “warm” “full” “bombastic” – participants indicated their musical preferences
 - Authors found great variance across listeners re: preference and habits, as well as with regard to the money they would spend on listening platforms and hardware; music as a profoundly personal event
 - Counseling with consideration of the humanities may reconcile elements of hearing loss that are at once isolating, yet ubiquitous; perhaps akin to “a desire for collective experience in a music world obsessed with individualized experiences” (Petridis; The Guardian, 2025)

MusiCares Survey Data

- August, 2022-July, 2025
- 1,139 participants (although not all responded to all items); additional questions
 - Years exposed – 59% indicated 20+ yrs; 78% indicated 10+ yrs
 - Hearing protection use: 53% indicated less than 10 years
 - Ear(s) exposed – 78% indicated both; 12% left; 10% right
 - Ever experienced acoustic trauma? – 57% indicated ‘yes’

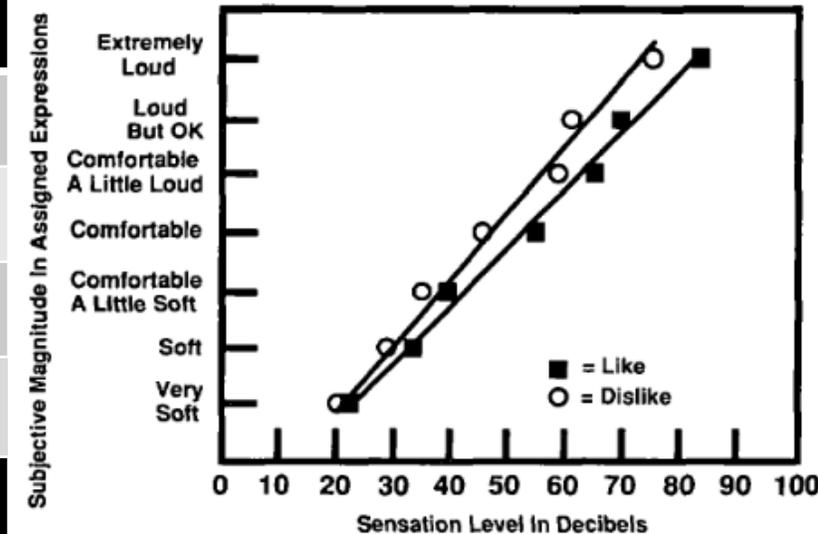
MusiCares Survey Data

- Is your work environment too loud? NOTE: 34% of respondents indicated studio work such as engineering and producing

| N=1119 | # of Responses | % |
|-----------------|-----------------------|----------|
| Just Right | 586 | 52% |
| Too Loud | 507 | 45% |
| Not Loud Enough | 26 | 3% |

- How loud is your playing?

| N=1077 | # of Responses | % |
|-----------------|-----------------------|----------|
| Just Right | 826 | 76% |
| Too Loud | 169 | 16% |
| Not Loud Enough | 63 | 6% |
| Unsure | 19 | 2% |



Musician reports of hearing difficulties

More than 2/3 of participants in MusiCares reported more than one of the forms of music-induced hearing disorder

| Music-induced Hearing Disorder | MusiCares (2022-2025); One Problem (N) | MusiCares; One Problem (%) | Multiple Problems (N) | Multiple Problems (%) |
|---------------------------------------|---|-----------------------------------|------------------------------|------------------------------|
| | N= 361 | 32% | N=754 | 68% |
| Speech Recog | 62 SPIN; 3 in quiet | 17%; 1% | 312 SPIN; 86 qt. | 31%; 11% |
| Tinnitus | 253 | 70% | 526 | 70% |
| Loudness DST | 34 | 9% | 245 | 33% |
| Diplacusis/ Dysacusis | 9 | 3% | 114 | 15% |

Comparison to large musician-centered surveys

Total mentions by music-exposed individuals sampled across dozens of studies
(DiStadio et al, 2018)

| MIHD | MusiCares (2022-2025) | DiStadio et al. 2018 (N=4618; 42 studies) | |
|-----------------------------------|------------------------------|--|--|
| | N= 1135 | Pop/Rock (N=973) | Classical (N=3645) |
| Hearing loss (from audios) | | 63.5%; mainly 4-8 kHz, No loss below 2kHz | 32.8%; mainly 3-8 kHz, 3.5% w/ loss at 250 & 5 |
| Asymmetric HL | | 32% | 46.0% |
| Speech Recog | 33% SPIN; 8% in quiet | | |
| Tinnitus | 70% | 26% | 27% |
| Loudness DST | 26% | 27% | 19% |
| Diplacusis | 11% | 3%: 4/139 sampled | 8%: 19/241 sampled |

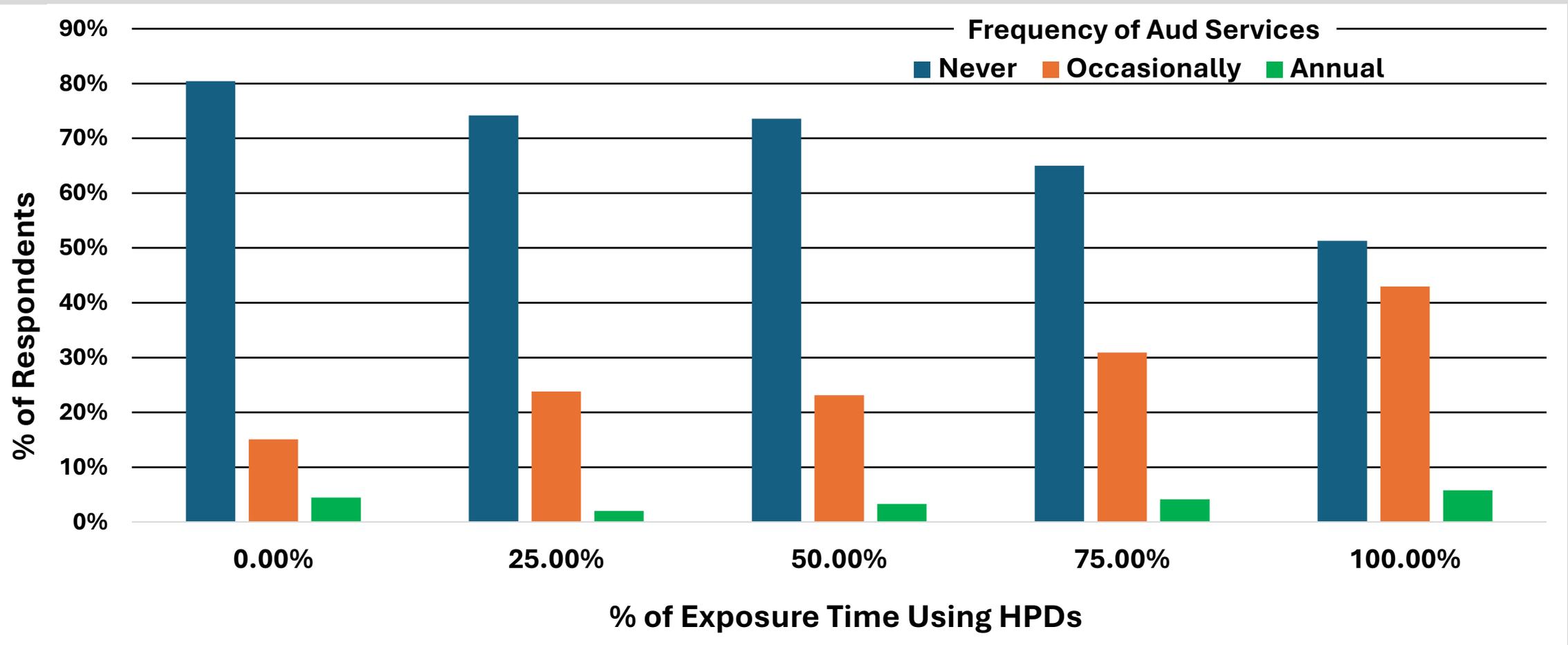
Challenges for musicians accessing services may be similar to those experienced by veterans

- Wartinger et al (2024)
 - Accessibility issues and frequent episodes receiving negative counseling
 - Difficulty admitting presence/severity due to compromise of occupational position; “There is a job to do” balanced against, “others need to be able to trust me”
 - Onset of tinnitus may influence its perceived value (trauma, regret, guilt)
 - Negative counseling (ie., “you should quit playing”), MH burden
 - Sense of being judged based on appearance when seeking clinical services
 - Additionally for music-exposed individuals:
 - Effortful listening (demand and motivation both very high)
 - Schedule problems affecting access and compliance w/ clinical interventions
 - Poor diet and few opportunities to practice positive health-related activities

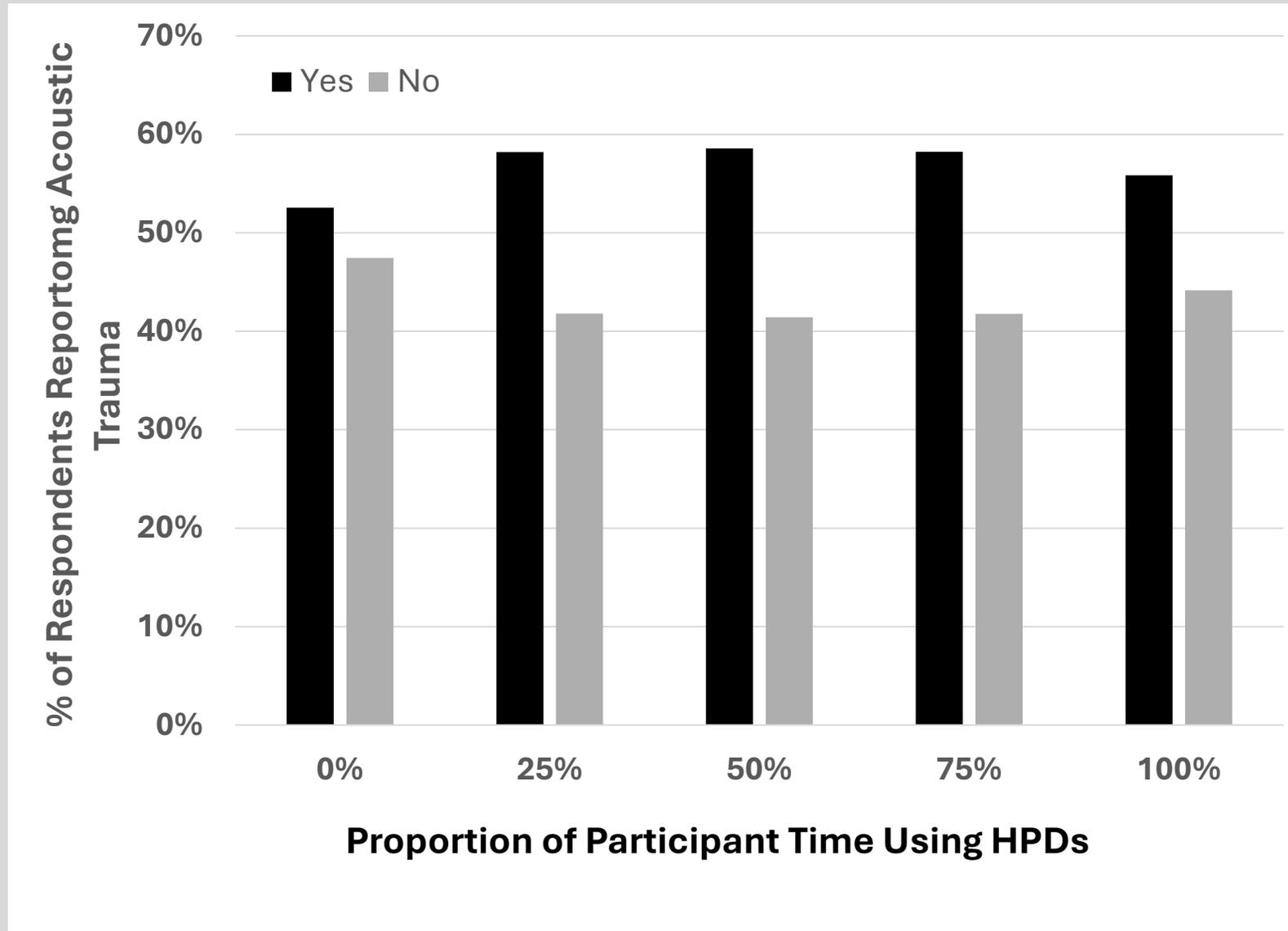
Hearing protection and audiology visits

How often accessing Audiology services?

Never: 69.2%; Occasionally: 27.0%; Annually: 3.8%



Hearing protection and reported acoustic trauma



Music Audiology

Considerations for the practitioner:

- Appreciate the musician's situation, perhaps in the context of the deeply personal relationship many non-musicians (and clinicians) have with music
- The musician's estimate of loudness may be influenced by personal taste; the music-exposed individual may not be the best judge of the exposure level/dose
- Management must balance value of desensitization with potential for setbacks; however both loudness and pitch are amenable to training
- More work required to determine efficacy of using in-ear monitors in environments other than music venues

Emerging practice opportunities and considerations

1. Management vs. Cure
2. Review of current practice guidelines and reviews of practice
3. Sound-based and bimodal interventions
4. Using tenets of CBT in the Audiology clinic to support associated counseling elements is not CBT, and its not new

Treatment (ie., cure) vs. Management

| Treatment Approaches | Management Approaches |
|--|--|
| <p data-bbox="236 379 963 644">OBJECTIVE: Eliminate or reduce the tinnitus sound by treating underlying pathology</p> <ul data-bbox="236 796 894 1061" style="list-style-type: none"><li data-bbox="236 796 894 925">• Surgery (ie., middle ear problems, Meniere's)<li data-bbox="236 939 805 996">• Deep-brain implant<li data-bbox="236 1011 886 1061">• Bimodal stimulation(?) | <p data-bbox="988 379 2311 636">OBJECTIVE: Alter the patient's response to the tinnitus in a way that facilitates coping with, and managing, the sound's emotional and psychological effects.</p> <ul data-bbox="988 729 1803 1196" style="list-style-type: none"><li data-bbox="988 729 1803 786">• Cognitive-Behavioral Therapy<li data-bbox="988 801 1595 858">• Self-Efficacy Training<li data-bbox="988 872 1620 929">• Hearing Aids/masking<li data-bbox="988 943 1717 1001">• Psychological Counseling<li data-bbox="988 1015 1411 1072">• Neuromonics<li data-bbox="988 1086 1640 1143">• Bimodal stimulation(?)<li data-bbox="988 1158 1403 1196">• PTM, TAT, TRT |

Management Resources

- Clinic Practice Guideline for tinnitus:
- http://oto.sagepub.com/content/151/2_suppl/S1.full.pdf+html (AAO)
- <https://link.springer.com/article/10.1007/s00106-019-0633-7> (European)
- <https://www.healthquality.va.gov/guidelines/CD/tinnitus/> (VA/DOD)
- <https://www.nice.org.uk/guidance/ng155> (UK)
- Recommendations regarding intake, assessment, and management
- Guidelines particularly important given patient population heterogeneity, and the mutually-reinforcing effects of co-occurring conditions/injuries

Practice Guideline Summaries

- Management: Bothered must be distinguished from nonbothered tinnitus; when bothered:
 - Interventions may be medical (drugs, surgery), audiological (sound based), psychological (counseling based), and/or alternative (ie., acupuncture)
 - Guidelines concur in recommending against:
 - Drugs specifically for tinnitus
 - Transcranial Magnetic Stimulation
 - Dietary supplements (e.g., ginkgo, melatonin, zinc)
 - Routine imaging (should only be conducted if otherwise indicated, ie., following abnormal ABR)
 - Guidelines concur in recommending for:
 - Cognitive Behavioural Therapy (strong rec.)
 - Hearing Aids (weak rec.)
 - Guidelines make no recommendation for:
 - Sound therapy across different approaches
 - Acupuncture

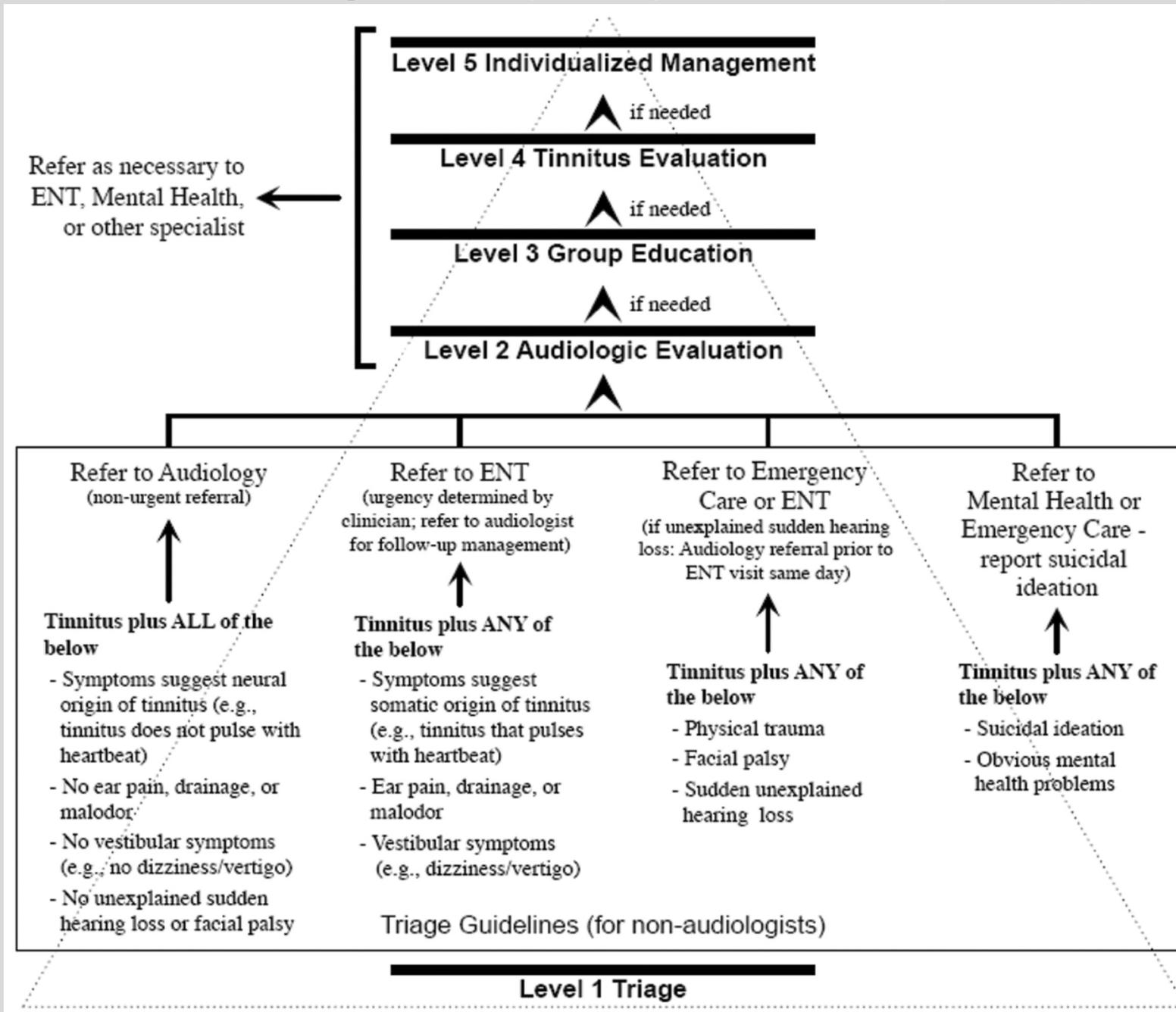
Practice Guideline Summaries

- Intake: prioritized items
 - Details re: onset, modulation, severity
 - Questionnaires assess specific activities and responses (choices can be made, seek out validated instruments)
 - European guideline specifies “at least one measure of tinnitus-related disability such as the Tinnitus Questionnaire or the Tinnitus Handicap Inventory” for patients expressing tinnitus that at least occasionally impairs routine function, changes emotional state, or worsens under stress
 - Medical and audiologic history
 - Fullness? Vestibular issues? Jaw problems? Mental health injury? Ototoxic medications?
 - Occupational/recreational noise history, exposure to toxins in the workplace, recreationally

What we ask patients can tell us about what we know, what we want to know, and what we want the patients to know we want to know

- Tinnitus Handicap Inventory (Newman et al., 1996)
 - Functional items (sleep, communication, concentration, quality of life)
 - Emotional items (anger, depression, anxiety, stress, frustration)
 - Catastrophizing items (fear, desperation, lack of control)
- Tinnitus Functional Index (Meikle et al., 2012)
 - 8 domains including: sleep, communication, concentration, quality of life, emotional response, relaxation, intrusiveness, and sense of control
- Tinnitus Primary Functions Questionnaire (Tyler et al., 2014)
 - 4 primary areas/activities including: emotions, hearing, sleep, concentration
- Focus on:
 - Sleep/relaxation
 - Communication/hearing
 - Concentration
 - Emotional effects/stress
 - Control
 - Intrusiveness

Progressive Tinnitus Management (Henry et al., 2008): Stepped Care



Practice Guideline Summaries

- Assessment: prioritized items
 - Determine need for medical/psychological referral
 - All guidelines stress importance of identifying cases of pulsatile tinnitus; AAO strongly recommends AGAINST imaging unless tinnitus is unilateral, pulsatile, or present with unilateral hearing loss; ask patient about phase locking with heart rate
 - The Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983) and the Generalized Anxiety Disorder Scale (GAD-7; Spitzer et al., 2006) often recommended to identify co-occurring psych issues
 - The intake forms target information re: sleep, communication, emotional response, concentration, quality of life, catastrophic thoughts regarding tinnitus, co-occurring conditions

Practice Guideline Summaries

- Assessment: prioritized items
 - Audiologic assessment
 - Basic evaluation (otoscopy, tones, immittance, word recognition); add speech in noise, EHF's (ie., test freq. >8kHz), loudness tolerance; less enthusiastic about tinnitus-related measures: residual inhibition, minimum masking level
 - Psychoacoustic tinnitus matching recommended in the European guideline, not recommended in AAO guideline.
 - Opinion here is that such measures require specific justification (ie., part of an intervention protocol); they are time consuming and not well correlated to functional/quality of life measures of severity

Tinnitus Clinical Practice Guideline (Tunkel et al., 2014; AAO)

1. **History and physical exam** - Clinicians should perform a targeted history and physical examination at the initial evaluation of a patient with presumed primary tinnitus to identify conditions that if promptly identified and managed may relieve tinnitus: **Recommended**

2A. **Prompt audiologic examination** - Clinicians should obtain a prompt, comprehensive audiologic examination in patients with tinnitus that is unilateral, persistent (≥ 6 months), or associated with hearing difficulties: **Recommended**

2B. **Routine audiologic examination** - Clinicians may obtain an initial comprehensive audiologic examination in patients who present with tinnitus (regardless of laterality, duration, or perceived hearing status): **Option**

3. **Imaging studies** - Clinicians should not obtain imaging studies of the head and neck in patients with tinnitus, specifically to evaluate the tinnitus, unless they have 1 or more of the following: tinnitus that localizes to 1 ear, pulsatile tinnitus, focal neurological abnormalities, or asymmetric hearing loss. **Strong recommendation against**

4. **Bothersome tinnitus** - Clinicians must distinguish patients with bothersome tinnitus from patients with nonbothersome tinnitus: **Strong recommendation**

Tinnitus Clinical Practice Guideline (Tunkel et al., 2014; AAO)

5. **Persistent tinnitus** - Clinicians should distinguish patients with bothersome tinnitus of recent onset from those with persistent symptoms (≥ 6 months) to prioritize intervention and facilitate discussions about natural history and follow-up care: **Recommended**
6. **Education and counseling** - Clinicians should educate patients with persistent, bothersome tinnitus about management strategies: **Recommended**
7. **Hearing aid evaluation** - Clinicians should recommend a hearing aid evaluation for patients with hearing loss and persistent, bothersome tinnitus: **Recommended**
8. **Sound therapy** - Clinicians may recommend sound therapy to patients with persistent, bothersome tinnitus: **Option**
9. **Cognitive behavioral therapy** - Clinicians should recommend cognitive behavioral therapy to patients with persistent, bothersome tinnitus: **Recommended**

Tinnitus Clinical Practice Guideline (Tunkel et al., 2014; AAO)

10. **Medical therapy** - Clinicians should not routinely recommend antidepressants, anticonvulsants, anxiolytics, or intratympanic medications for a primary indication of treating persistent, bothersome tinnitus: **Recommendation against**

11. **Dietary supplements** - Clinicians should not recommend Ginkgo biloba, melatonin, zinc, or other dietary supplements for treating patients with persistent, bothersome tinnitus: **Recommendation against**

12. **Acupuncture** - No recommendation can be made regarding the effect of acupuncture in patients with persistent bothersome tinnitus. **No recommendation**

13. **Transcranial magnetic stimulation** - Clinicians should not recommend transcranial magnetic stimulation for the routine treatment of patients with persistent, bothersome tinnitus: **Recommendation against**

Complications re: treatment vs. management

- Surgery in cases w/out middle ear involvement – typically would be VIII N. section (ie., House and Brackmann, 1981)
 - Surprisingly (at least at that time) inconsistent benefit, as:
 - 414 patients w/ VIIIth nerve section for tumor w/ assoc. vertigo and tinnitus; 45% reported improvement in tinnitus
 - 55% reported no change or exacerbation of tinnitus
 - “Surgical management of tinnitus, although successful in some cases, does not provide a valid and reliable mode of treatment for subjective tinnitus.”
 - Not conducted routinely because of these poor odds, invasiveness, and loss of hearing following procedure
 - Failure generally attributed to the observation that the ear is not the source of the tinnitus

Surgical Approaches: Kleinjung, 2013

- Middle ear: procedures associated with tinnitus change
 - Myringotomy and tubal insertion
 - May address tinnitus in addition to sensation of fullness
 - Tympanoplasty – surgical repair of perforation

| Study | N | Complete Remission | Partial Remission | No Change | Tinnitus Worse |
|-------------------|----------|---------------------------|--------------------------|------------------|-----------------------|
| Baba et al (2004) | 151 | 24.5% | 41.7% | 25.9% | 7.9% |
| Helms (1981) | 59 | 33.3% | | 33.3% | 33.3% |
| Lima et al (2007) | 23 | 34.8% | 47.8% | 13.0% | 4.3% |

Surgical Approaches: Kleinjung, 2013

- Middle ear surgery: Stapes surgery (otosclerosis)
 - Hearing improved in approx. 90% of patients, tinnitus as below:

| Study | N | Complete Remission | Partial Remission | No Change | Tinnitus Worse |
|----------------------------|----------|---------------------------|--------------------------|------------------|-----------------------|
| Ayache et al (2003) | 48 | 56.3% | 27.1% | 12.5% | 4.2% |
| Da Silva Lima et al (2005) | 23 | 39.1 % | 56.5% | 4.4% | 0 |
| Gersdorff et al (2000) | 50 | 64.0% | 16.0% | 14.0% | 6.0% |
| Oliveira (2007) | 19 | 52.6% | 37.0% | 10.4% | 0 |
| Ramsay et al (1997) | 268 | 48.2% | 33.2% | 7.8% | 10.8% |
| Sakai et al (1995) | 22 | 27.0% | 41.0% | 27.0% | 5.0% |
| Sparano et al (2004) | 40 | 52.5% | 32.5% | 12.5% | 2.5% |
| Szymanski et al (2003) | 149 | 73.0% | 17.0% | 10.0% | 0 |

Background: Cochrane Review re: Hearing aids for tinnitus

- Cochrane review (Hoare et al., 2014)
 - Objective: “To assess the effects of hearing aids specifically in terms of tinnitus benefit in patients with tinnitus and co-existing hearing loss.”
 - 330 studies addressed hearing aids and tinnitus
 - 115 failed to meet criteria for Abstract review
 - Of the 215 abstracts reviewed, 69 full text papers qualified
 - 39 of these did not address the research question (i.e., 19 were review articles)
 - All but one of the remaining studies failed to provide evidence commensurate with a randomized controlled trial
 - Finding “not definitive” for benefit with small differences and minimal effect sizes between TRT, hearing aids, and other sound generating devices
 - Subjects did not suffer from loudness tolerance problems (i.e., they were all category I or II according to the TRT scheme)

Background: Review of studies w/ less control/ weaker evidence support hearing aid use

- Scoping Review (Shekhawat et al., 2013)
 - Scoping reviews consider studies whose level of potential bias and evidence do not meet those for a Cochrane Review or other systematic review
 - Ideal for identifying trends and opportunities for targeting research areas
 - “Although the quality of evidence for hearing aids' effect on tinnitus is not strong, the weight of evidence (17 research studies for, 1 against) suggests merit in using hearing aids for tinnitus management.”

Additional Consideration: Mild/Minimal Hearing Loss

- Sereda et al., 2015 Delphi Review
 - Questions directed at providers (N=29) rather than patients; assesses consensus among professionals
 - Determined that in cases of mild hearing loss, a patient-centered approach prioritizing patient complaints and reported needs was more strongly considered by practitioners than audiometric findings
 - Considered patient reports of hearing difficulties, motivation to use hearing aids, and the impact of hearing loss quality of life

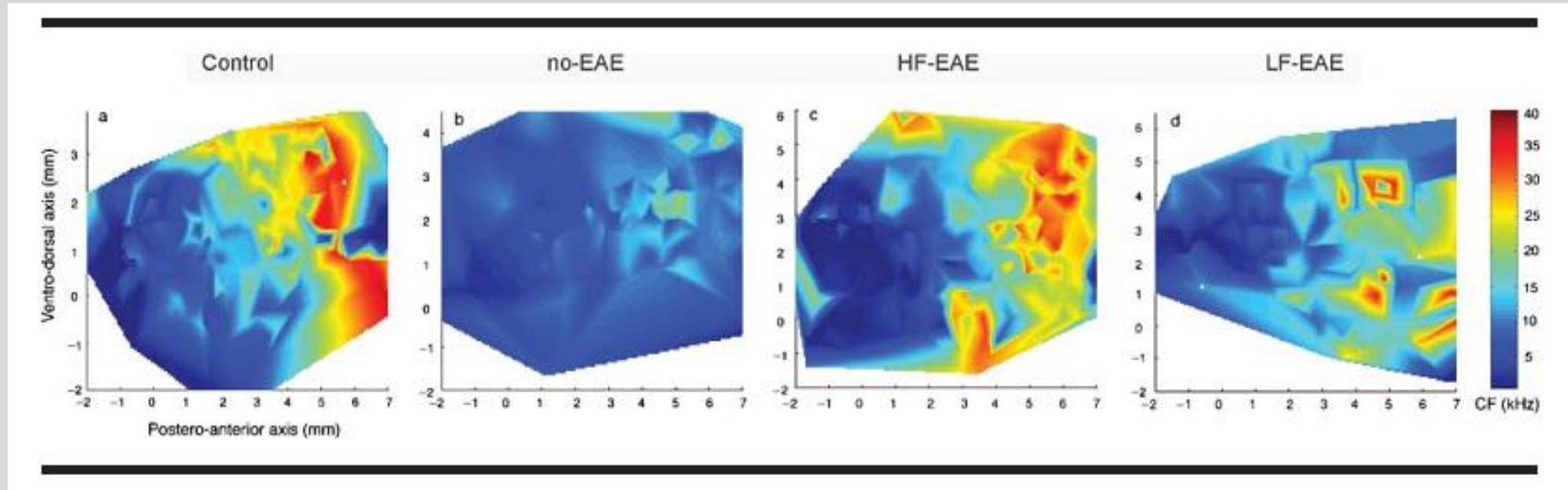
Additional Consideration: Mild/Minimal Hearing Loss

- Sereda et al., 2015 Delphi Review
 - Panelists questioned were in strongest agreement that hearing aids:
 - Provided environmental sound enrichment for tinnitus
 - Served to recalibrate auditory/central gain
 - Reduced concentration/listening effort needed to hear
 - Reduced stress caused by hearing difficulties
 - Provided distraction from tinnitus
 - Helped habituate to tinnitus
 - These items similar to what patients with PTSD tell us about their hearing aids as well; additional benefits from the sense that the patient may monitor the environment accurately

Sound Therapy Objectives

- Tinnitus masking through reduced audibility of the tinnitus (Vernon, 1977)
- Tinnitus masking to induce a sense of relief (Vernon & Meikle, 2000)
- Foster habituation (Jastreboff and Hazell, 1993) or relaxation (Sweetow & Sabes, 2010)
- Reversing or modifying abnormal cortical activity (Tass et al., 2012)
- Reversing or modifying abnormal cortical reorganization (Norena & Eggermont, 2005)

From Eggermont, 2008

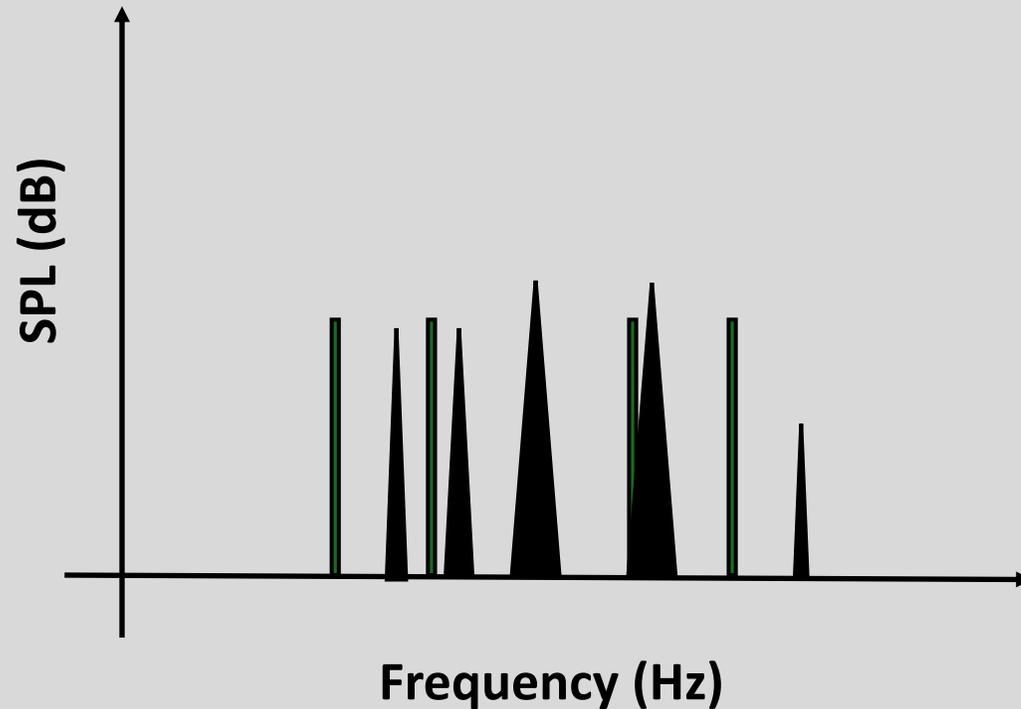


Even after traumatizing exposure, use it or lose (more of) it:
Effect of an enriched acoustic environment on noise-exposed cats; as cortical reorganization is often linked to tinnitus generation and persistence, the use of sound post-exposure may minimize the pre-disposing conditions that contribute to both tinnitus and auditory pathway reorganization

Acoustic Coordinated Reset (Tass et al, 2012)

- Reductions reported in tinnitus loudness and annoyance
- Reduced severity as measured on the TQ
- Tinnitus pitch decreased
- Elements of the EEG associated w/ tinnitus reduced in magnitude
- Effects related to complex tinnitus (ie., multi-tone, noisy, insect-like) less clear
- Systematic review (Wegger et al., 2017) indicated the level of evidence supporting ACR was low, primary benefits included noninvasiveness, well-tolerated by patients, and patient-reported tinnitus reductions

**4-tone coordinated reset (CR)
neuromodulation stimulus (Tass
et al., 2012)**



**Goal is to modify auditory
CNS activity (ie., promote
desynchronization) in the
tinnitus region by acoustically
evoking changes in EEG
activity**

Sound Therapy: Neuromonics

- Developed by Paul Davis – a long-time proponent of using music instead of BBN
 - Similar in many ways to auditory integrative training (AIT)
 - A processing algorithm used to control spectrum of music and account for:
 - Threshold
 - Loudness Discomfort
 - Stimulus is processed music presented in a two-stage protocol (Hanley et al., 2008)

Sound Therapy: Neuromonics

- Protocol
 - Stage 2: after 2 months, background noise is reduced or eliminated
 - The ‘music’
 - New age
 - ‘Baroque’
 - Not intended as the center of attention, supposed to act as a background sound
 - Contraindicated for musicians, who have a hard time NOT listening closely to the music

Sound Therapy: Neuromonics

- Some early results (Hanley et al, 2007, 2008)
- After 6 mos. w/ device
 - More than 2/3 of the pts. demonstrate 40% or greater reduction in TRQ scores
 - On the rating scales, loudness and annoyance drop significantly
 - % of time aware of tinnitus also decreased
 - After 6 mos. pts utilize a “maintenance regimen”
- Problems
 - \$5,000. and in general, the marketing
 - If the “canned” music cannot be tolerated, the device produces more aggravation than relaxation
 - Could the same thing be done w/ a \$50 MP3 player and some good tunes?
 - Cleveland clinic (Newman and Sandridge, 2011, 2012) reported that cost/benefit far greater w/ MP3 player than Neuromonics

Tinnitus Treatments: Electrical

- Electrical stimulation/Cochlear Implants
 - McKinney et al, 2003
 - 82% (46/56) implant patients reported tinnitus at the time of assessment
 - Mean duration of deafness (13 yrs.)
 - Post-operatively:
 - Pts had better hearing (thresholds, word recognition) than pre-operatively
 - Significant reduction in perceived handicap from tinnitus, improvement continued through the first 12 mos post-op
 - (30-40% on the TQ)
 - Tinnitus perception did not seem to affect word recognition or other measures of implant performance

Tinnitus Treatment: Electrical

- Electrical stimulation/Cochlear Implants
 - In the population of cochlear implantation candidates, the prevalence of tinnitus is high, and has been reported to range from 52% to 100% (Baguley & Atlas, 2007)
 - CIs investigated re: tinnitus effects since 1990
 - 28 studies since that time (1990-2015) indicate that, of 1593 patients implanted (1558 with tinnitus prior to surgery):
 - Tinnitus completely remitted in 367 pts (as many as 78% in one study; 3 studies indicated >50%)
 - Tinnitus reduced but still present in 643 (as many as 93% in one study; 13 studies indicated >50%)
 - Tinnitus unchanged in 498 pts
 - Tinnitus exacerbation in 50 pts from 9 studies
 - Tinnitus onset occurred in 35 pts from 5 studies

Sound Therapy: Levo

- Some early results (Theodoroff et al; 2017)
- Compared the Levo sound program to broadband noise and bedside sound generators
 - Levo specified determining the patient's tinnitus "sound print" (the patient's unique tinnitus sound) for subsequent device use
 - Patients in the experimental (Levo) group were asked to listen to their "sound print" sound at night, at a volume matched by the patient to their tinnitus loudness
 - The "noise" group and the "bedside generator" group employed their choice of broadband masking sounds rather than the Levo stimulus
 - All three sound conditions reduced TFI scores, reduced the stimulus level that produced a loudness match, and reduced loudness rating measures; the tinnitus-matched sound's effect was slightly larger than the other sounds

Sound Therapy: Bimodal stimulation (Lenire system)

- Conlon et al., 2020, 2022
- Sound combined with electrical stimulation with the goal of fostering beneficial plasticity
 - Shore and colleagues (2000-2008) demonstrated a variety of excitatory and inhibitory responses in CN produced by acoustic coupled with somatosensory input
 - Rationale: “One feature unique to multisensory neurons is their propensity for receiving cross-modal compensation following sensory deprivation or deafferentation.” Shore et al., 2008

Sound Therapy: Bimodal stimulation

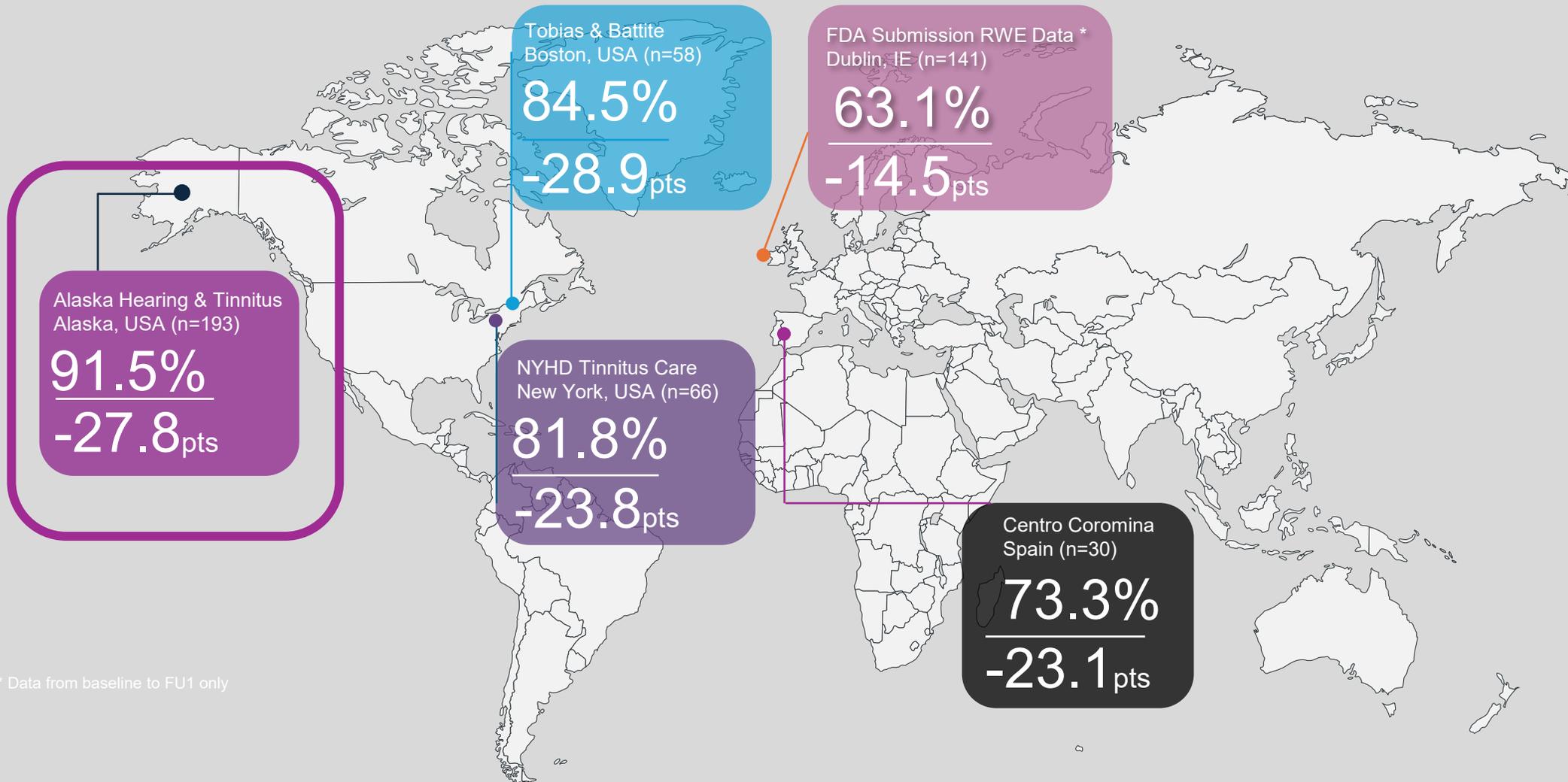
- Conlon et al., 2022: Study arms
 - Arm 1: tones and tongue stimulation with background noise
 - Arm 2: tones and tongue stim w/out background noise, no difference in results suggesting background noise not necessary
 - Arms 3 & 4: different strategies varying the time at which tongue stimulation was added to sound presentation, and varying tone presentation parameters
 - Benefits across all arms similar and maintained over 12 months
 - Benefit increased over the 2nd 6-week period as well as the 1st 6 wks

Sound Therapy: Bimodal stimulation

- Conlon et al., 2022: findings
 - 88% would recommend device to other patients
 - Some complaints regarding invasiveness, discomfort on tongue, burns or sores, increased tinnitus
 - Sound without electrical stimulation not as effective as the two paired
 - Benefits maintained for 12 months in about half the patients who started the study
- Concerns/limitations re: device and reporting
 - Studies not well-controlled (no true sham condition)
 - Cut-off values for claiming benefit debatable (the THI's MCID)
 - Exclusion criteria ensure large proportion of overall tinnitus population may not benefit
 - Unhelpful in cases of severe/profound hearing loss

Globally Consistent Independent Real-World Evidence

Percent of responders and mean change in THI from Baseline to FU2 (THI \geq 38)

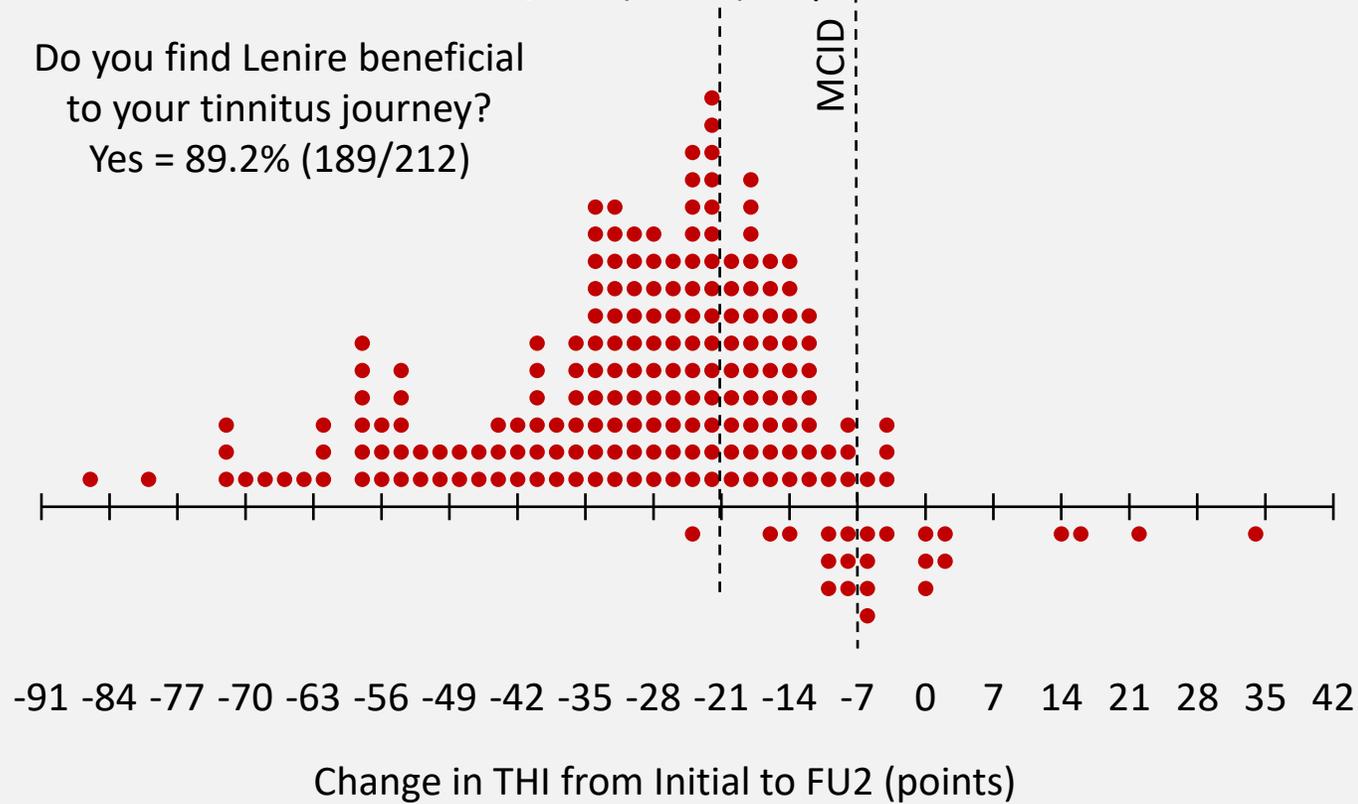


* Data from baseline to FU1 only

High Self-Reported Benefit Rate that Aligns with MCID of Seven Points

Newman et al 1998
132/212 (62.3%) resp.

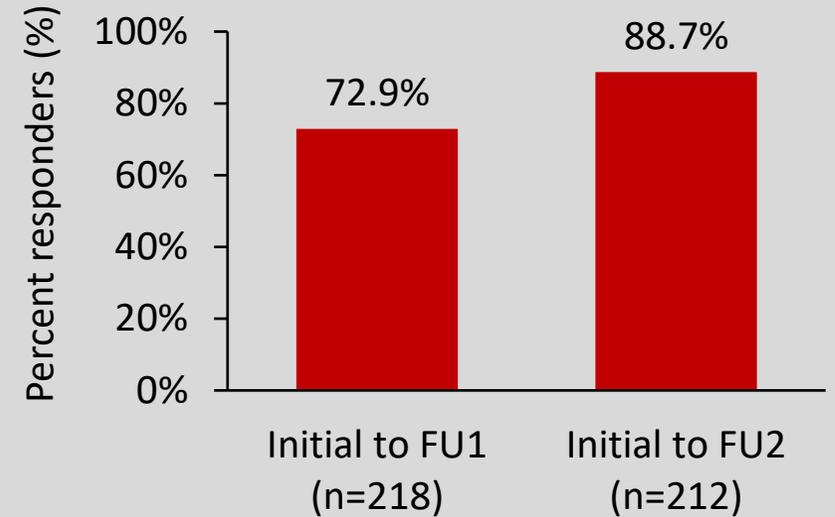
Do you find Lenire beneficial
to your tinnitus journey?
Yes = 89.2% (189/212)



MCID of 7 points inconsistent with the original
THI cut-off values

(Recommendation here is to employ 20 pt.
criterion; note 10-point criterion at this facility)

MCID improvement in THI \geq 10 points



Relevance for Management: Counseling and sound

- Many sources to affirm the value of tinnitus counseling as a stand-alone intervention, or as a component of one that is sound-based
 - Counseling and psychological approaches to management have stronger evidence base, and stronger recommendations, than sound therapy options
 - Most device manufacturers specify the need for counseling (device-specific and/or tinnitus-specific) in order to achieve the best outcomes
 - McKenna and Irwin (2008) reviewed sound therapy approaches, some that included counseling, some that did not
 - Sound therapy without counseling not as beneficial as sound with counseling
 - Counseling alone more effective than sound therapy alone
 - Even when sound is effective, addressing patients' psychological factors influence sounds' value
 - Reminds the audiologist that managing tinnitus, as with fitting hearing aids, must address realistic expectations reiterated/supported by counseling

Medical Humanities and Counseling: “Lifeworld of Tinnitus” (Pryce and Shaw, 2019)

- Considerations for items with the potential to improve patients’ tinnitus coping by fostering accurate and thorough components of a tinnitus narrative
 - Authors set out to answer the question: “what is it like to live with tinnitus?”
 - Focus intervention on “building coping mechanisms” not “symptom eradication” and acknowledge ambiguity surrounding use of word “cure”
 - Authors also indicated that some patients “manage” the symptom by avoiding interactions and situations; many patients lacked the “medical script with which to expound their symptom.”
 - Patients bothered by tinnitus feel “let down” by many medical disciplines and their experiences may produce sensations of “frustration, inadequacy, and powerlessness in clinicians” (Woivalin et al., 2011)

“Lifeworld of Tinnitus” (Pryce and Shaw, 2019)

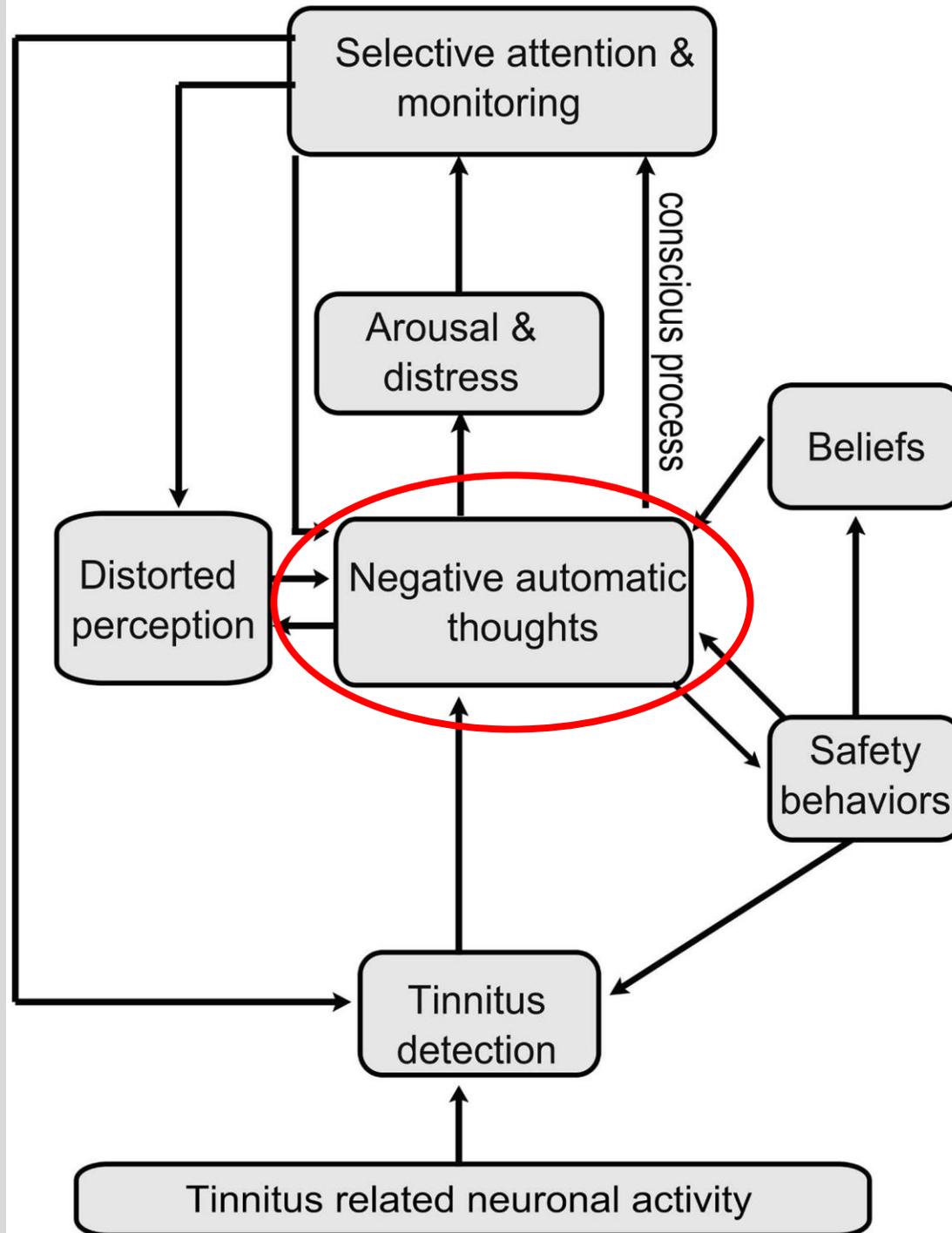
- “Experience is regarded as unique, and constructed based on individual learning, cultural and psychological perspectives. The perception is inseparable from the perceiver.” (p. 429)
- Consideration of a patient’s “lifeworld” requires accepting subjective and unique patient attributes; we do this with current intake forms, but not particularly well
 - The “lifeworld of tinnitus” would be “infused with important meanings and clues about what matters to the [patient]” in addition to what the patient already understands about tinnitus
 - Such items could include tinnitus psychoacoustic characteristics, but more importantly would need to address intrusiveness and functional effects, as well as supporting the “medical script”
 - Further, the authors highlight the value of identifying tinnitus features related to traumatic exposures, negative memories, occupational challenges, music enjoyment and aptitude, in addition to items specified on intake forms such as sleep, attention, communication, etc.

Patients with Tinnitus and Occurring Psychological Injury/Disorder

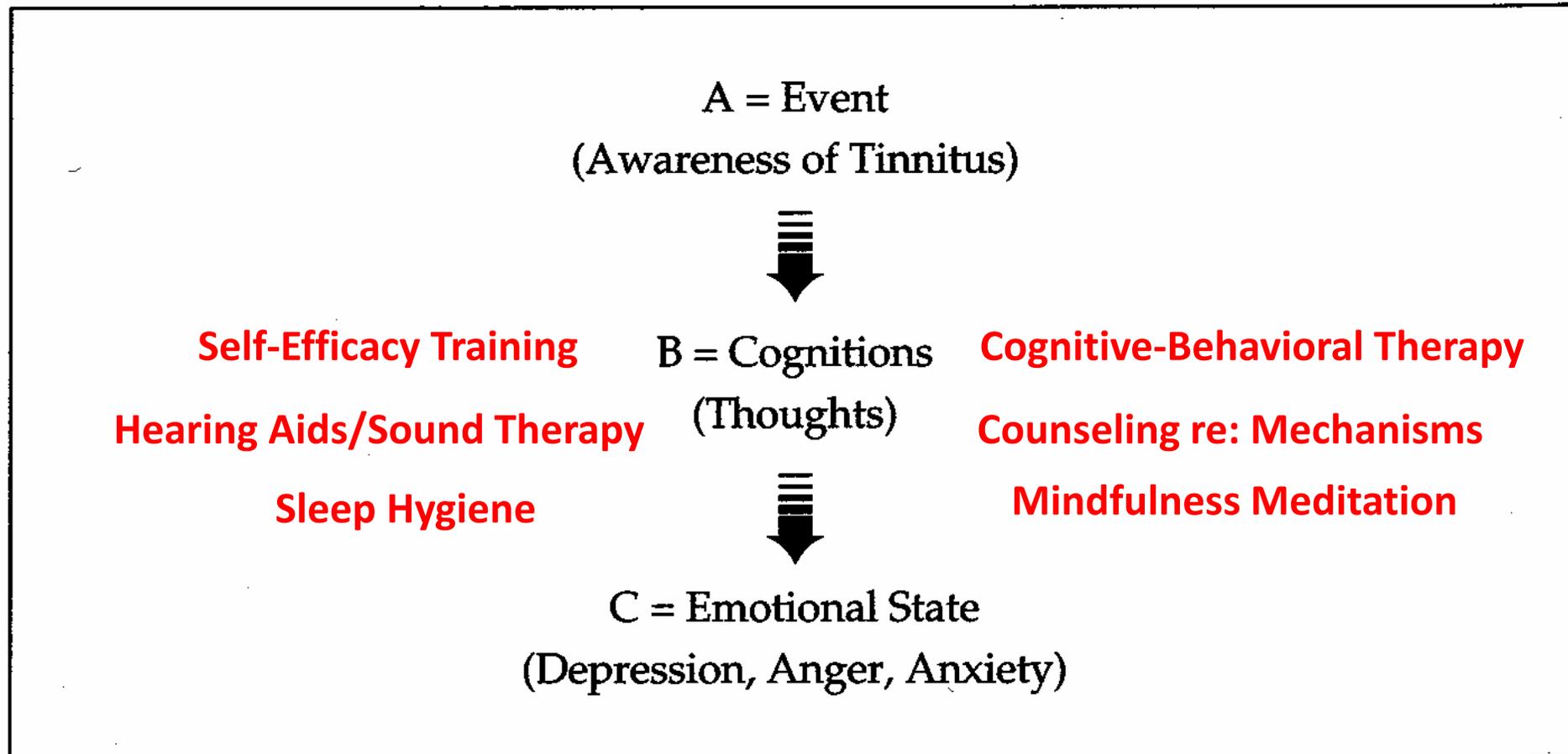
- Clinical findings support mutual reinforcement:
 - McKenna (2004), Coles (1995), Baguley (2011), not to mention centuries-old medical literature
 - Of our first 1200 patients, 421 (or 35%) were enrolled concurrently in one or more PTSD clinics (many have PTSD in addition to other psych-specific service connections)
 - An additional 354 patients seen in mental health clinics for anxiety/depression/panic disorders w/out PTSD
 - Symptoms that indicated need for psych referral relate to onset of tinnitus, reactive tinnitus, presence of hyperacusis, and exacerbating conditions (also nightmares, hypervigilance, exaggerated startle response)

McKenna et al., 2014: CBT model. Front. Neuro; Oct. 2014

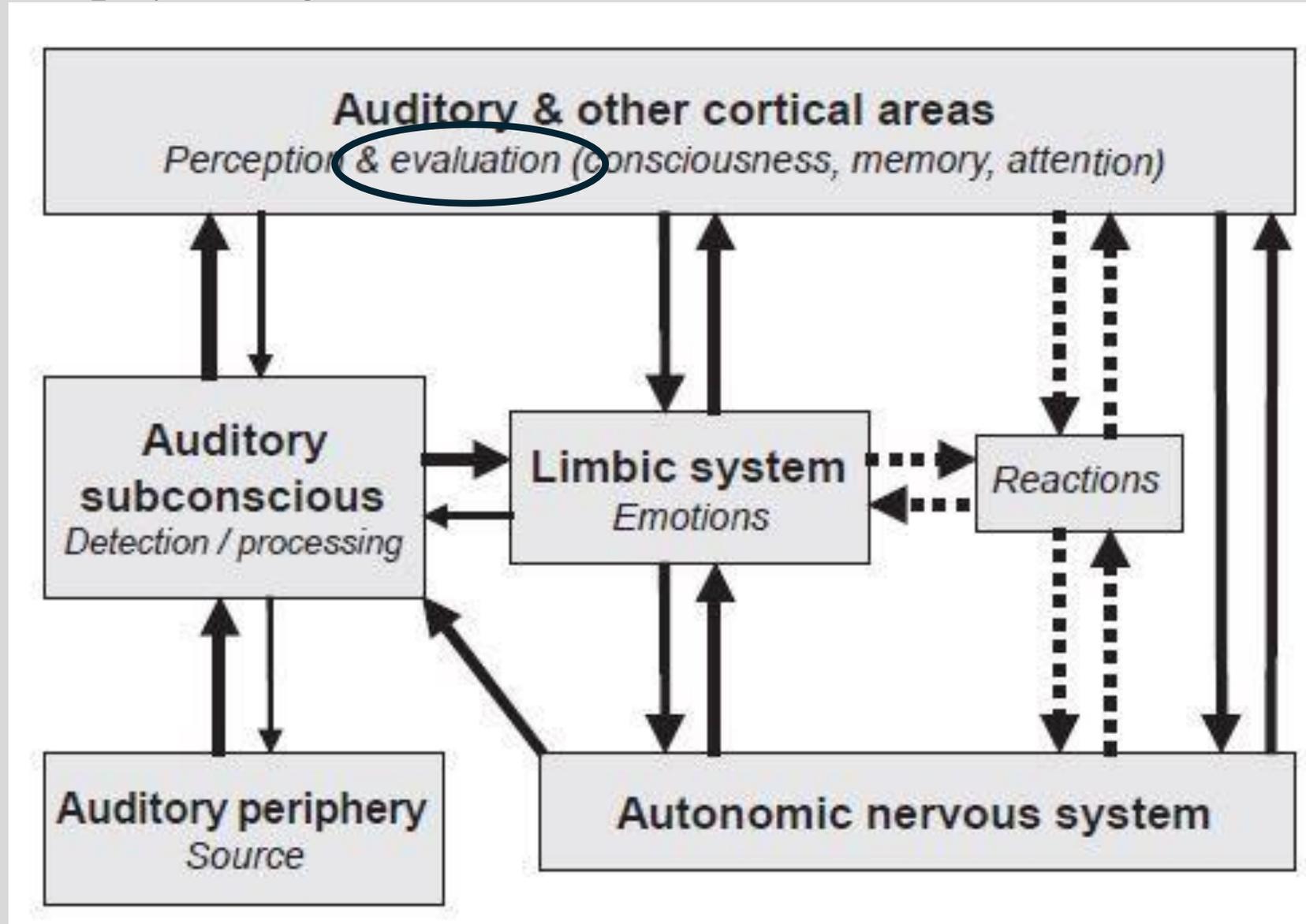
Consider the effects of trauma-related sudden onset tinnitus, or tinnitus linked to regret (ie., music overexposure). Tinnitus onset associations influence detection and may exert an outsized influence on subsequent sound processing and attentional resources



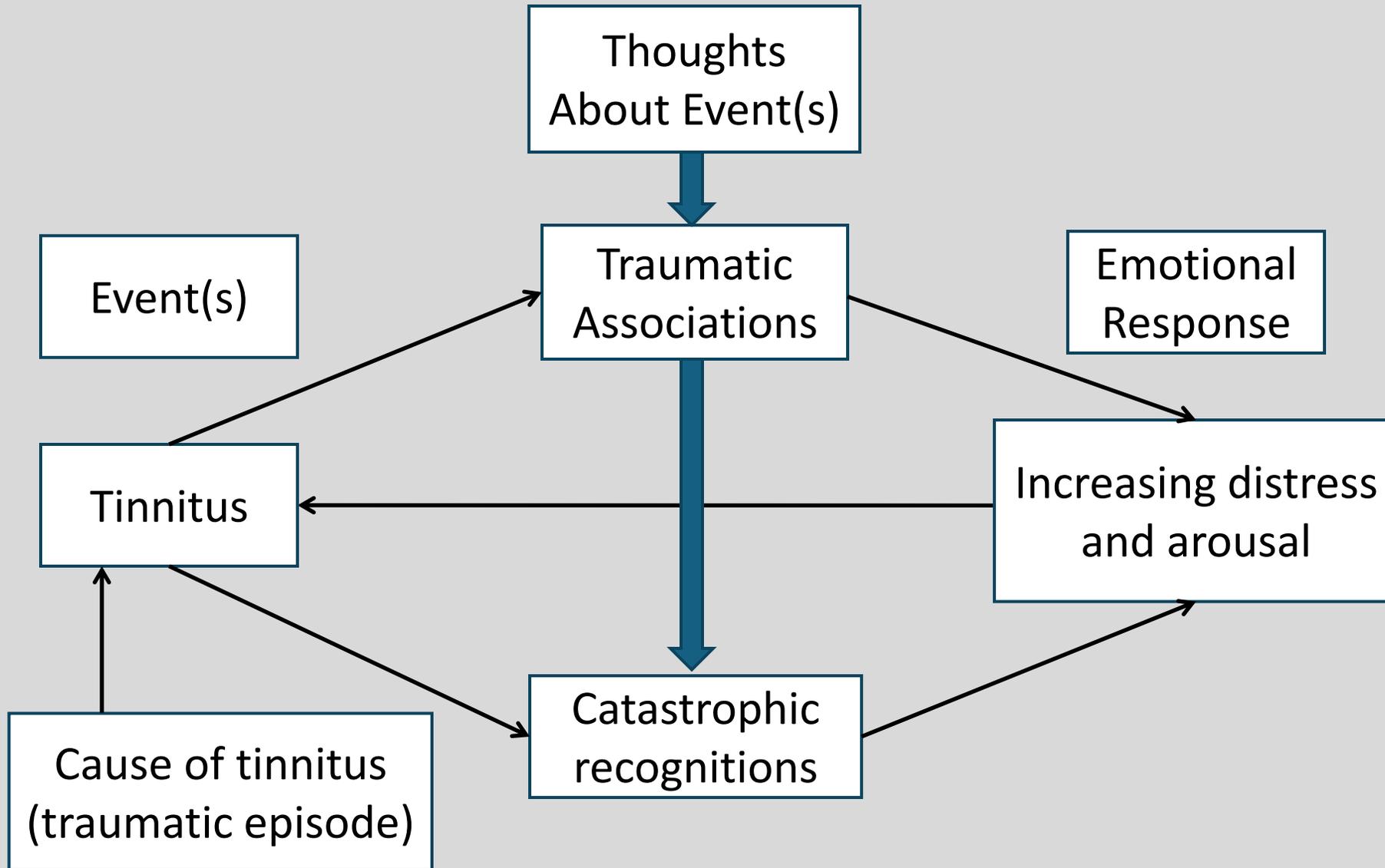
Using the ABC model for tinnitus interventions/counseling



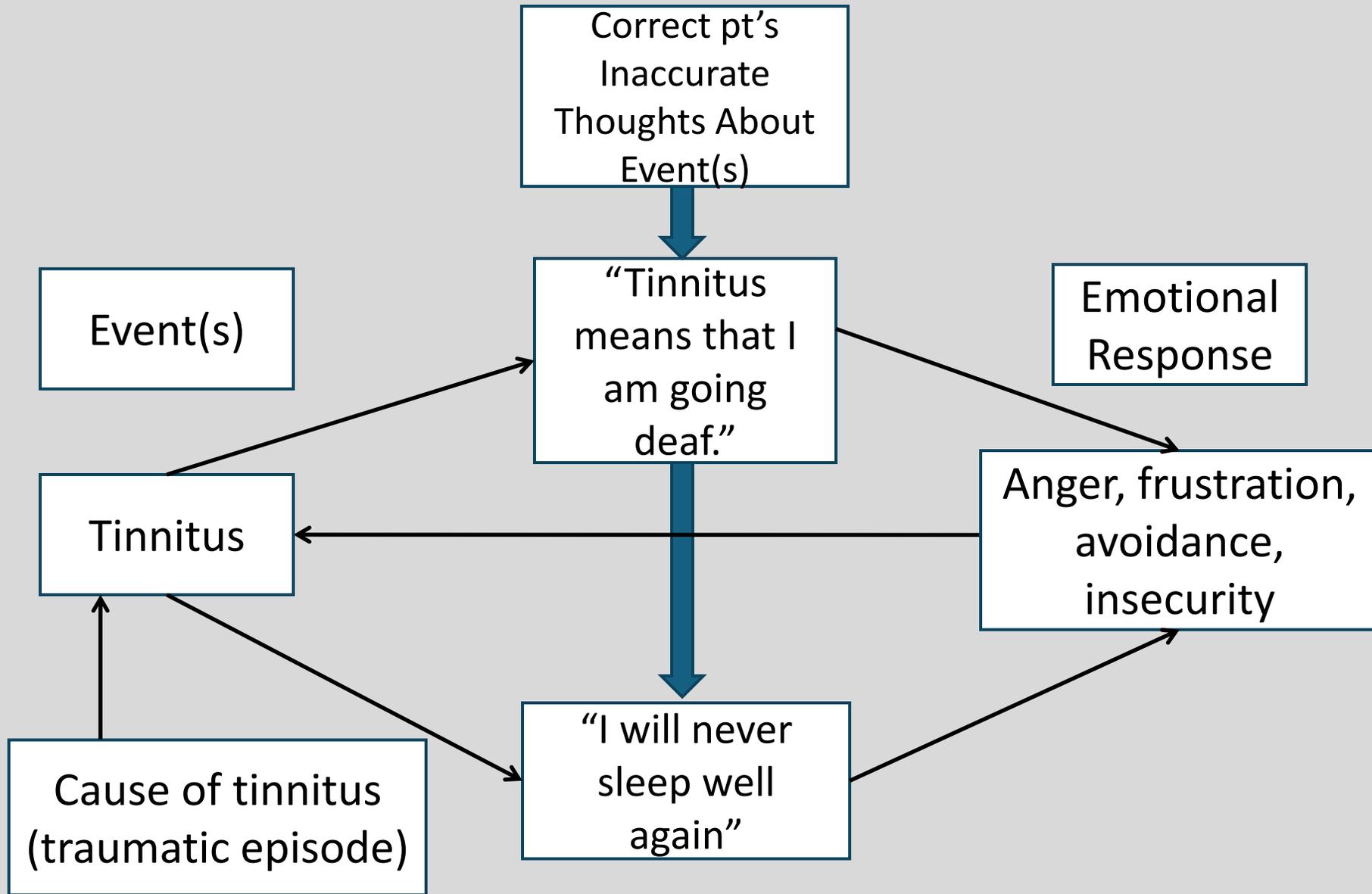
Neurophysiological Model



Adapted from Jastreboff, 1999



Adapted from Hinton et al., 2006 (J. of Traumatic Stress)



Adapted from Hinton et al., 2006 (J. of Traumatic Stress)

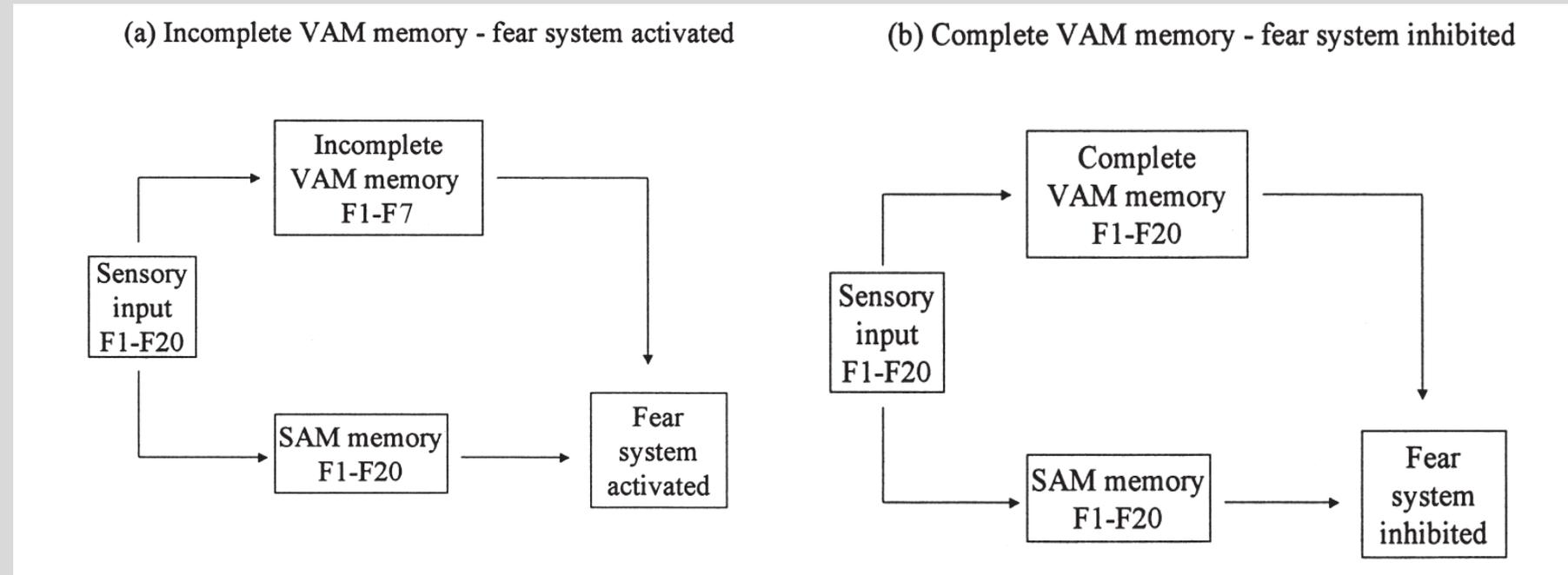
Panter-Brick (2014) Eur. J of Psychotraumatology

“To my mind, resilience is a process to harness resources to sustain well-being” (Panter-Brick & Leckman, 2013). She goes on to say:

“I like the word “process” because it implies that resilience is not just an attribute or even a capacity. I like the phrase “to harness resources” because it asks us to identify what are the most relevant resources to people in places like Afghanistan, Niger, or the United States [or what would be most relevant for a patient with bothersome tinnitus]. And I like the expression “sustained well-being” because resilience involves more than just a narrow definition of health or the absence of pathology.”

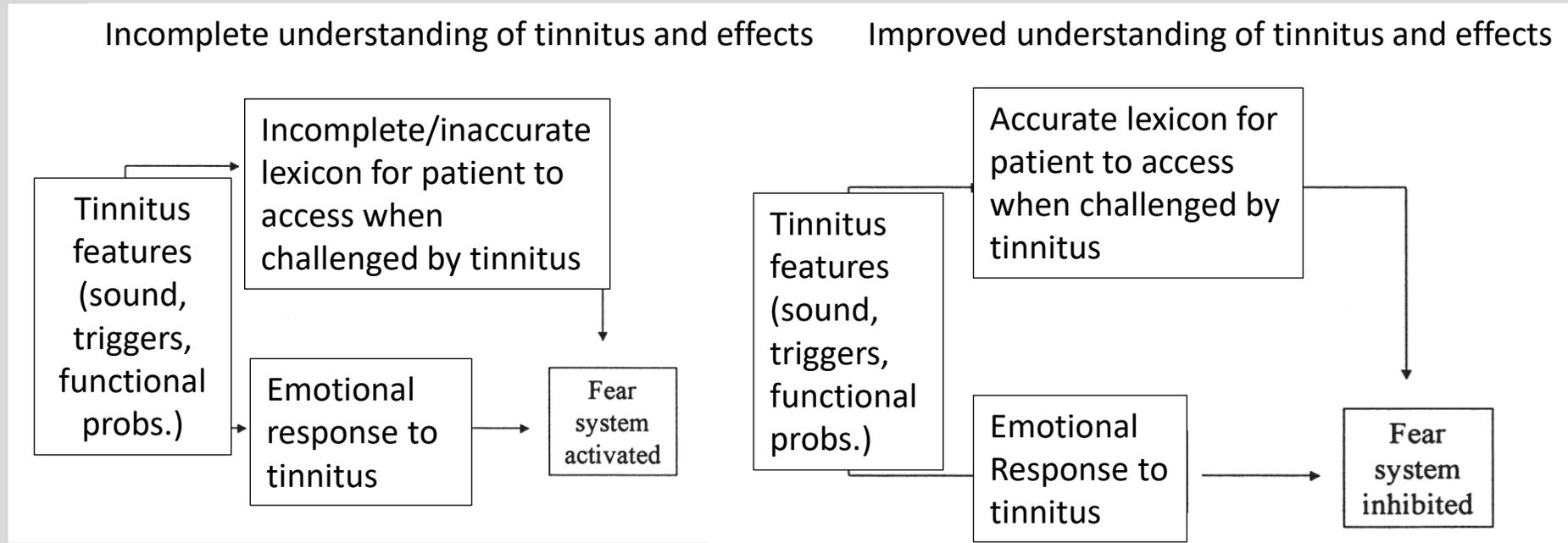
The trauma literature provides ample evidence of the resilience “process” being supported when patients can access and employ accurate narratives (ie., medical script) re: their condition, and challenging or triggering situations.

Brewin, 2001; the value of supporting/enriching patient recall and associated narratives



“As the VAM (ie., declarative memory) representation grows, fewer trauma [tinnitus] reminders are able to activate the body’s defensive reactions.” (p. 382); Exchange “fewer elements of tinnitus distress” for “fewer trauma reminders”

Brewin, 2001 (adapted); the value of supporting patient understanding of mechanisms and tinnitus facts



Consider “tinnitus features” as being associated with tinnitus onset, sound, exacerbators, triggers, understanding of mechanisms, sleep problems, concentration problems, emotional distress, understanding of effects on hearing, etc. “Demystifying” tinnitus, in this schema, could have a similar effect to the counseling targeting the verbally-accessible (narrative) memory that benefits trauma victims.

Summary

- Approaches based on sound therapy will remain, but to maximize benefit, effective counseling must be included in the intervention program
 - High prevalence of hearing loss among tinnitus pts; do not underestimate the importance of addressing hearing loss prior to employing tinnitus management strategies
 - Goals centered on supporting beneficial plasticity in order to reverse the changes that generate and perpetuate the tinnitus sensation
 - Heterogeneity of the tinnitus patient population ensures that nearly anything will work for some patients, but that nothing will work for all – reinforces importance of effective counseling and interprofessional consultations
 - Worth asking: how well, as a profession, have we met patient needs?

Summary

Atul Gawande in “Being Mortal” (2014)

Speaking as a physician, he states, “I am in a profession that has succeeded because of its ability to fix. If your problem is fixable, we know just what to do. But if it’s not? The fact that we have had no adequate answers to this question is troubling and has caused callousness, inhumanity, and extraordinary suffering.”
(p. 9)

