Short-term tinnitus adaptation effects to predictable and unpredictable sounds

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Mechanisms and models

- Attention
- Emotion
  - Limbic system
- Memory
- Stress
- Autonomic
- Somatosensory

**Figure 1:** Brain networks involved in tinnitus perception and distress. Alongside the auditory cortex, regions of subgenual (sgACC), dorsal anterior cingulate cortex (dACC), posterior cingulate cortex (PCC), precuneus, parietal cortex, hippocampus, frontal cortex, amygdala and anterior insula have also been identified. These regions overlap with memory, emotion, and attention networks. Reproduced with permission from (De Ridder et al., 2011), p.8077.
Tinnitus as Prediction Error

- Prediction of what is going to happen next is essential to human survival

- Bayesian brain predicts incoming sensory input by combining **prior knowledge with new sensory information** (Friston, 2010)
Tinnitus as Prediction Error

At each level of sensory processing, the difference between incoming sensory input and existing internal memory representation - the **prediction error** only - is passed onto the next level for processing.
Tinnitus as Prediction Error

A

1. multiple predictions

2. actively sample data in environment

3. information

4. uncertainty

Gibb's free energy
\[ S = k \log W \]

Shannon's free energy
\[ H = n \log s \]

5. select 1 percept

6. Bayesian updating
\[ P(A|B) = \frac{P(B|A)P(A)}{P(B)} \]

B

Predictions

Intentionality

Creative Spontaneous Undeterministic

Is determined / constrained by environment

Generation of alternative options

Deterministic Selection of option

Is determined / constrained by memory

Change Movement
Tinnitus as Prediction Error

De Ridder et al., 2014

- Peripheral lesion means **missing input** reaching the cortex for certain frequencies
- Topographically-restricted **prediction error** occurs
- Brain ‘focuses’ on this
- Subsequent central plasticity processes attempt to compensate for prediction error - **constant conscious awareness**
- Ultimately gives rise to the **sensation of tinnitus**
Our Study

• Compared the effect of short-term amplitude-modulated sound therapy stimuli on tinnitus, where tinnitus was audible at either predictable or unpredictable intervals

• Serves as a pilot study for a clinical trial being undertaken now

• Explored using the Ecological Model of tinnitus
Ecological framework for tinnitus

- Searchfield et al., 2014
Study Design

Part A. Short-term Adaptation Experiment

Part B. Two week Sound Trial
Study Design

Part A. Short-term Tinnitus Adaptation Experiment

**UNPREDICTABLE**
Random rise-fall times, amplitude maximal variation +/- 2-5 dB in relation to the minimum masking level of tinnitus

**PREDICTABLE**
Steady state surf, amplitude maximal variation +/- 2-5 dB in relation to the minimum masking level of tinnitus
Study Design

Part A. Short-term Tinnitus Adaptation Experiment

**Behavioural study**
- Audiometric screening
- Psychoacoustic matching for tinnitus

**Four experimental conditions**
- Baseline
- 30 minutes of Quiet
- 30 minutes of Predictable
- 30 minutes of Unpredictable

**At the end of each condition:**
- Tinnitus Loudness Rating (1-10)
- Tinnitus Distress Rating (1-10)
- Loudness Level Match (dB SL)
Study Design

- Predictable and unpredictable sound stimuli loaded onto **MP3 player**
- Participants took home player
- Listened to one stimuli (randomized) for one week - 5 day gap - Listened to other stimuli for one week
- Asked to keep **written notes** of sound track usage
- **Interviewed** at the end of the trial – recorded and transcribed

Part B. Two week Sound Trial
Part B. Two week Sound Trial

- **Framework qualitative method** (Gale et al., 2013) was used to analyze the interviews

- Data charted and **common themes** identified
Participants

- Inclusion criteria:
  - aged over 18
  - Have constant tinnitus
  - hearing in the normal to a moderate-severe loss range
  - normal middle ear function

23 participants (14 male, 9 female, mean age = 58.6 years, SD = 12.8) for Part A from the University of Auckland Tinnitus Research Volunteer Database

Subgroup of 7 participants (5 male, 2 female, mean age = 58.63 years, SD = 11.92) for Part B
Results

Part A. Short-term Tinnitus Adaptation Experiment

- Tinnitus loudness for the Unpredictable sound was significantly lower than Baseline ratings.
- No significant difference for loudness level matches between conditions.
Results

Part A. Short-term Tinnitus Adaptation Experiment

- Tinnitus annoyance ratings for the Unpredictable condition were significantly lower than Baseline.
- Tinnitus annoyance ratings for the Predictable condition were also significantly lower than Baseline.
Results

Part B. Two week Sound Trial

- **Environments** where sound therapy was used were common
  - Majority during the evening time or before bed

- **Divergence** of individuals: benefit (4) vs. no benefit (3) from sound therapy
  - External sound may trigger negative reactions
  - Among individuals with benefit: preference of unpredictable (3) over predictable (1) sounds
  - Dynamic nature
  - Found both sounds to be static however

- **MP3 device handling** a common issue - single button control
Part A. Short-term Tinnitus Adaptation Experiment

Discrepancy between loudness level match and subjective rating change across conditions

• Similar effects observed in long-term tinnitus treatments - significant subjective but negligible objective loudness changes of tinnitus (Penner, 1988; Jastreboff, 1994)

• May utilise different reference points (Searchfield et al., 2014)
  - Effect of higher-order psychosocial factors

Significantly lower tinnitus loudness and distress levels following presentation of Unpredictable sound compared to baseline

Significantly lower tinnitus loudness following presentation of Predictable sound compared to baseline
Part A. Short-term Tinnitus Adaptation Experiment

**PREDICTABLE**
- steady amplitude modulation

Memory trace matched – **prediction held**

**Habituation**

- Searchfield et al., 2014
Part A. Short-term Tinnitus Adaptation Experiment

- Searchfield et al., 2014

- Random amplitude modulation

- Novel deviants always present

**Prediction Error**

Attention processes diverted to processing of sound instead of tinnitus
Future Directions

• In the short-term, greater reduction in tinnitus outcomes for unpredictable sound

• Anticipated that perceptual changes can be sustained if presented for a long-term
  – Designing interventions incorporating these stimuli for long-term tinnitus relief

• Objective measures of assessing differences in predictable and unpredictable sound therapy stimuli
Future Directions

• Identification of subgroup of individuals for whom sound therapy is of no benefit

• Development of sound features
  – Unpredictable environmental sounds, pleasant and not static

• How to administer the sound effectively
  – User-friendly devices with manual volume control
Thank you

Please address any questions/comments to:

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