Structural and functional neuroplasticity of tinnitus-related distress and duration

Martin Meyer, Patrick Neff, Martin Schecklmann, Tobias Kleinjung, Steffi Weidt, Berthold Langguth

University of Zurich, Switzerland
University of Regensburg, Germany
Agenda

• **Background** - From the ear to the brain

• **Neuropsychological frameworks**

• **Tinnitus** - distress and duration

• Results of neurophysiological and neuroanatomical studies and discussion
Peripheral hearing loss and reorganization of the auditory cortex

(Eggermont & Roberts 2004)
Plasticity in the auditory cortex

III. late consequences of neural plasticity
The alliance of the tinnitus triad

d de Ridder et al. (2011) PNAS
The auditory „phantom pain“

“.. that phantom perception arises as the consequence of multiple parallel overlapping dynamic brain networks ..”

“.. we hypothesize that both tinnitus and phantom pain are perceptual states of continuous learning, where — in the absence of an external input — the phantom percept is reinforced and the connection with aversive emotional associations is continuously updated.”

“Through the involvement of learning mechanisms, the phantom percept becomes associated to distress, which in turn is reflected by a simultaneously coactivated nonspecific distress network consisting of the parahippocampal area, ACC, anterior insula, and amygdala.
Tinnitus and distress

Source density in alpha1 higher for high distress patients

Source density in alpha2 higher for high distress patients

Vanneste et al. (2010)
Subjective aspects of tinnitus

Data driven PCA identifies two main factors:
1. Tinnitus distress
2. Tinnitus duration/presence

<table>
<thead>
<tr>
<th></th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRISM</td>
<td>.907</td>
<td>-.247</td>
</tr>
<tr>
<td>TQ Total score</td>
<td>.865</td>
<td>-.206</td>
</tr>
<tr>
<td>VAS (eyes closed)</td>
<td>.744</td>
<td>.532</td>
</tr>
<tr>
<td>Tinnitus duration</td>
<td>-.216</td>
<td>.917</td>
</tr>
</tbody>
</table>
Subjective aspects of tinnitus

<table>
<thead>
<tr>
<th>Correlations between Components and Other Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tinnitus Presence</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td><strong>Tinnitus Distress</strong></td>
</tr>
<tr>
<td>(first component)</td>
</tr>
<tr>
<td><strong>Tinnitus Presence</strong></td>
</tr>
<tr>
<td>(second component)</td>
</tr>
<tr>
<td><strong>Hearing threshold</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Time of day</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Tinnitus severity</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Note. Correlations are Pearson Product-Moment Correlations. \( N = 24 \); except for Tinnitus disturbance, \( N = 17 \). \(^*\) / \(^**\) Significance correlation with \( p < .05 / .001 \) (two-sided testing).
Correlation with psychopathological data

Distress

Meyer et al. (2014), Neural Plasticity
Correlation with psychopathological data

Duration

Meyer et al. (2014), Neural Plasticity
Cortical Surface Area and Cortical Thickness Demonstrate Differential Structural Asymmetry in Auditory-Related Areas of the Human Cortex

Martin Meyer¹,², Franziskus Liem¹,³, Sarah Hirsiger², Lutz Jäncke²,³ and Jürgen Hänggi³

¹Neuroplasticity and Learning in the Healthy Aging Brain (HAB LAB), Institute of Psychology, ²International Normal Aging and Plasticity Imaging Center and ³Division of Neuropsychology, Institute of Psychology, University of Zurich, Zurich, Switzerland
Negative Correlation „Distress - Volume“
(n=256, corrected for multiple comparisons)

Reduced cortical volume in the bilateral auditory cortex and the right anterior insula

Meyer, Neff, Liem, Kleinjung, Weidt, Langguth, Schecklmann (in prep.)
Negative Correlation „Distress - Area“

(n=256, corrected for multiple comparisons)

Area contributes (not thickness) contributes to the finding of structural plasticity in bilateral auditory cortex.
Correlation "Distress – Thickness"

Meyer, Neff, Liem, Kleinjung, Weidt, Langguth, Schecklmann (in prep.)
Correlation „Duration – Thickness“

Anterior ACC/subcallosal area =>

Gateway in the serotonergic limbo-thalamocortical circuit

(Rauschecker et al. 2010, Neuron)
Summary

- Evidence that TI must not be considered a homogeneous group.
- Long duration since onset of tinnitus does not necessarily result in emotional distress.
- Non-distressed TI may have better noise cancelling system or top-down coping strategies.
- Cortical surface area and cortical surface may change specifically as function of tinnitus-related distress and duration.
- EEG- and MRI based brainprints may help to classify distinct tinnitus subtypes and may further development of neuromodulatory treatment.
Thanks for your attention!!

Before brain imaging always think of
Functional-structural Network Model
of Tinnitus Pathophysiology
(modified after De Ridder et al. (2013))

Red circles: results corrected for multiple comparisons
Blue circles: uncorrected results

DLPFC  VLPFC  auditory cortex  precuneus
frontopolar  dACC  insula  inferior parietal
OFC  sgACC  amygdala  hippocampus  parahippocampus
PCC

Tinnitus distress
Neuronal synchronicity

Cochlear damage results in partial deafferentiation and breakdown of lateral inhibition of frequency gradients in the auditory cortex.

When local inhibition is reduced the neighbouring modules “take over” the recent representation due to increased excitation.

Eventually, this leads to subjective abnormal sound sensations.

Thalamocortical (TRN) dysrhythmia contributes to the generation of this vicious circle.

The tinnitus triad: auditory, attentional and emotional circuits start to ally.
Resting-state EEG in tinnitus persons
Neuroanatomical alterations in tinnitus individuals

Adjamian et al. (2014)