Deep Brain Stimulation for Tinnitus

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Tinnitus – Auditory Phantoms

Auditory Percept Without an External Source

Pathophysiology
- Aberrant Activity Originates from Auditory System
- Hyperactivity, Synchronized Oscillations, and Reorganized Maps

Neural Signal Interpreted as a Realistic Auditory Object

Key Concepts
- Phantom Qualia Uncorrelated with Tinnitus Suffering
- Limbic System (Emotion, Reinforcement, Memory, Behavior)
- Non-Auditory Modulators (Eye, Facial, Cervical Movements)

Tinnitus Overview

- Common Condition with Graded Outcomes
- 10-15% - Prevalence in Adults
- 3% - Interferes with Work, Sleep, Concentration, and Interactions.
- 0.5% - Tinnitus Severely Disrupts “Normal” Life.
  - Chronic Auditory Pain
- 13 Million in US and Europe Seek Care
- Compensable Disability to Veterans
  - $0.5 B 2008
  - $1.0 B 2011
  - $2.0 B 2020

Tinnitus Therapeutics

- Reduce Contrast Mask Phantom Percept
- Suppress Hyperactivity
  - Examples
    - Maskers
    - Hearing Aids
    - Cochlear Implants
    - Cortical Stimulation
    - Vagal N Stimulation
- Reclassify Phantom Percept
- Reduce Salience
- Mitigate Emotional Distress
  - Examples
    - Tinnitus Retraining
    - Neuromonics
    - Fractal tones
    - Antidepressants
    - Cognitive-behavioral therapy

Disrupt Information Conveyance
  - Examples
    - Striatal Neuromodulation
Inspiration from a Case Report

63 year old otolaryngologist with 40 year history of mostly constant, high-pitched tinnitus. Tinnitus was mostly louder in the left ear, with episodic increases in loudness. Audiogram showed right moderate and left moderate-to-severe sensorineural hearing losses.

Left hemispheric stroke involving ‘the more dorsal part of the corona radiata. In addition there is involvement of the neostriatum, including the body of the caudate and the caudodorsal aspect of the putamen. As such it most likely involves thalamocortical radiations and corticothalamic projection in addition to corticocortical fibers running in the superior longitudinal fasciculus.’

Clinical Outcomes
- Tinnitus Disappeared Completely
- Hearing Remained Unchanged


What is DBS?

Deep Brain Stimulation
- Electrical stimulation delivered through an implanted probe alters brain function
- “Pacemaker” for the brain
- Over 50,000 implanted worldwide
- Five components to the DBS system

The Basal Ganglia Subcortical Network

Essential Functions
- Gating
- Acting
- Attending
- Evaluating
- Critiquing
- Reinforcing

Probe delivers stimulation to deep brain nuclei
Anchor secures probe to the skull
Connector establishes link to the controller
Programmer communicates with the controller to customize therapy
Controller determines parameters for brain stimulation and houses the power source

Xavier Studio
http://www.xavierstudio.com
Basal Ganglia – Reinforcement Learning

How Habitual Behavior is Organized in Response to Rewards or Enforcers

Actor-Critic Model

Actor selects actions → Critic criticizes actions

critique is transformed to a reinforcement learning signal

Striatal (Area LC) Neuromodulation in Tinnitus:
Lesion Observations and Electrical Stimulation Experiments in Humans undergoing DBS Surgery

Tinnitus Percept Modulation

- Loudness
- Sound Quality

Interpretation


‘Natural History’ of New Onset Tinnitus

- Initially, unfamiliar phantom percepts relatively loud, commanding attention and annoyingly intrusive.
- Typical Course - Over the next 6 to 12 months, most patients will generally report their phantom percepts are much softer and more familiar, no longer commanding attention and by and large easy to ignore. Tinnitus will have nearly or completely vanished from conscious awareness or has become non-bothersome.
- Atypical Course - In a select minority, patients suffer because phantom percepts remain as salient as they were at the onset. Despite auditory phantoms having become familiar, they continue to drive attentional, emotional, motivational and behavioral distress.

Key Features

- Instruction on details of phantom percepts are represented in the central auditory system.
- Permission to gate candidate phantom percepts for conscious awareness is controlled by the dorsal striatum.
- Action to attend, reject or accept phantom percepts, and form perceptual habits is decided by the ventral striatum.
- Determination of tinnitus distress severity is mediated through the limbic and paralimbic system-nucleus accumbens-ventral striatum loop.

Next Steps

- Funding from NIH for R01 Phase I Trial.
- IDE for 8 Subjects using the Medtronic Device.
- Target Date for Subject Enrollment is Jan 2013.