Tinnitus suppression using translingual neurostimulation (TLNS): case study
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Purpose: To apply and evaluate the new original method of mild and moderate tinnitus suppression, using non-invasive translingual neurostimulation (TLNS) and targeted auditory training program.

METHODS:
Training Procedure: Subject perform auditory tasks during electrotactile stimulation of the tongue lasted 20 min, twice a day, during 180 days, with several 1-3 week brakes. Auditory training therapy included a monaural and a binaural sound stimulation by narrow-band noise. The noise spectrum corresponded to tinnitus spectrum. The noise intensity was varied every session to measure thresholds for tinnitus suppression.
Auditory stimulation: Auditory masking paradigm was applied to suppress the tinnitus. Masker stimuli consist of two successively presented BPNs with duration 5s each separated by silence interval of 5s in duration. All stimuli used in the experiment are prepared digitally in Matlab and saved as 96-kHz sampling rate, 32-bit PCM wave files. Stimuli consisted of two sets of band-pass noise (BPN) with center frequencies ranging from 0.5 to 16.0 kHz and varied in center frequencies and bandwidth. Sounds were delivered to the ears by headphones.

Translingual stimulation: A non-invasive neuromodulation of brain stem was conducted by electrotactile tongue stimulation, using portable neuromodulation stimulator (PoNS), Figure 1A. The pattern of electrical impulses was delivered through heart-shaped matrix of 143 electrodes arranged in hexagonal patterns. The overall result of this stimulation is the comfortable and convenient presentation of almost 26.7 million stimulation pulses to the tongue during a typical 20-minute therapy session.

RESULTS:

Tinnitus suppression using PoNS device: Noise presented to L(T) ear only, 0 dB to 105 dB SPL.

Figure 2. Masking noise thresholds for A-LOW (0.1-2.1 kHz), B-MEDIUM (2-4 kHz) and C-HIGH (4-6 kHz) frequencies at monaural (RED) and binaural (BLUE) signal presentation.

Figure 3. Masking noise thresholds at monaural (A) and binaural (B) signal presentation for LOW (0.1-2.1 kHz), RED dots; MEDIUM (2-4 kHz), BLUE dots; and HIGH (4-6 kHz), GREEN dots, frequencies.

Figure 4. Masking noise thresholds for different stimulation frequencies (columns) at two different conditions (rows), presented in calendar time scale, that reveals brakes in training process.

• Tinnitus suppression becomes more effective from session to session during all training period, Figure 2,3,4.
• After 20 sessions, subject start to report episodes of complete disappearance of tinnitus.
• Total drop of tinnitus intensity in 30-35 dB was observed. Binaural stimulation was more effective in suppression of tinnitus perception than the monaural presentation on the affected ear.
• Achieved tinnitus suppression did not reverse during 1-3 weeks brakes or six months of follow-up observation, Figure 5.

CONCLUSIONS:
The significant clinical effect of tinnitus compensation was reached through exposure individualized auditory training in combination with non-invasive neuromodulation of brainstem structures. We revealed the central level was generating tinnitus, despite initially peripheral (cochlear) origin. These insights have prompted the development of innovative brain-based treatment approaches to directly target the neuronal correlates of tinnitus.

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