

# Listening to tailor-made notched music reduces tinnitus loudness and tinnitus-related auditory cortex activity

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## Abstract

Maladaptive auditory cortex reorganization may contribute to the generation and maintenance of tinnitus. Because cortical organization can be modified by behavioral training, we attempted to reduce tinnitus loudness by exposing chronic tinnitus patients to self-chosen, enjoyable music, which was modified (“notched”) to contain no energy in the frequency range surrounding the individual tinnitus frequency. After 12 months of regular listening, the target patient group ( $n = 8$ ) showed significantly reduced subjective tinnitus loudness and concomitantly exhibited reduced evoked activity in auditory cortex areas corresponding to the tinnitus frequency compared to patients who had received an analogous placebo notched music treatment ( $n = 8$ ). These findings indicate that tinnitus loudness can be significantly diminished by an enjoyable, low-cost, custom-tailored notched music treatment, potentially via reversing maladaptive auditory cortex reorganization.

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## Supporting Information: Okamoto et al. 10.1073/pnas.0911268107

### SI Methods

**Subjects.** Twenty healthy, normal hearing subjects (five females) between 21 and 43 years of age (mean, 29.6 years) participated in a behavioral study that investigated whether the probands could reliably perceive a phantom “auditory afterimage” sensation known as “Zwicker tone (1)” after the cessation of notched music.

**Stimuli and Experimental Design.** We presented auditory stimuli of 10-s duration diotically. The participants were supposed to report whether they could perceive a Zwicker tone right after the cessation of these stimuli or not (two-forced choice). We presented four different types of sound stimuli: white noise, notched noise, normal music, and notched music. Notched noise and notched music were prepared from white noise (sampling rate: 44,100 Hz) or normal music (sampling rate: 44,100 Hz) by eliminating the one octave wide frequency band centered at 4 kHz. We used eight different pieces of normal music and eight corresponding pieces of notched music for this study. The sound stimuli were adjusted to have identical overall root-mean-square power. We randomly presented each sound stimulus type eight times with intensity of 40 dB SPL.

**SI Results.** The means and standard deviations of the rates that the participants reported the phantom auditory sensation to be present were  $34.4\% \pm 34.1\%$  (white noise),  $64.4\% \pm 36.8\%$  (notched noise),  $21.3\% \pm 15.2\%$  (normal music),  $20.0\% \pm 16.9\%$  (notched music). Paired  $t$  tests revealed a significant difference between the white noise and the notched noise conditions ( $t_{19} = 4.445$ ,  $P < 0.001$ ); however, there was no significant difference between the normal music and the notched music conditions ( $t_{19} = 0.295$ ,  $P = 0.772$ ). Therefore, it seems that the notched noise could cause the Zwicker tone, whereas the notched music could not.

1. Zwicker E (1964) Negative afterimage in hearing. *J Acoust Soc Am* 36:2413–2415.