Chronic tinnitus is a symptom with high prevalence. There is evidence that the tinnitus perception is related to unfavorable cortical plastic changes. In our recent study we have developed and evaluated a customized music training strategy that appears capable of both reducing cortical tinnitus related neuronal activity and alleviating subjective tinnitus perception. We hypothesize that the regular and enjoyable music training reverses unprofitable cortical reorganization to a certain degree by means of the focused strengthening of auditory inhibitory neuronal networks.

Subjective tinnitus is one of the most prevalent symptoms of hearing disorders in industrialized countries. Chronic tinnitus can severely worsen a patient’s quality of life. The tinnitus perception arises in auditory cortex, and tinnitus generation and maintenance have been associated with maladaptive auditory cortex reorganization. Maladaptive cortical plasticity has been shown to be reversible by behavioral training.

In our recent study, we developed and evaluated a customized music training procedure that aims at the reduction of subjective tinnitus loudness in normal-hearing humans suffering from chronic tonal tinnitus. The training was intended to reverse maladaptive plastic processes in auditory cortex supposedly contributing to the tinnitus perception. For the training, the patients selected their favorite music. The frequency spectrum of the music was modified for each patient individually by means of digitally filtering out the frequency band of one octave width centered at the individual tinnitus frequency (i.e., the frequency that sounds like the tinnitus). The patients were instructed to listen to their customized music regularly with pleasure.

The results of our training evaluation study demonstrated that those patients who had listened to their pleasant customized music (target group, N = 8) daily for approximately 2 hours over the course of 12 months experienced significantly reduced subjective tinnitus loudness [F(1,7) = 26.1, p = 0.001]. Moreover, subjective tinnitus annoyance [F(1,7) = 13.0, p = 0.009] as well as experienced handicapping by the tinnitus [F(1,7) = 15.1, p = 0.006] decreased significantly. In contrast, matched patients who had instead listened to pleasant placebo music (placebo group, N = 8) did not experience any significant changes in these variables over time (loudness: F(1,7) = 0.4, p = 0.54; annoyance: F(1,7) = 0.19, p = 0.68; handicapping: F(1,7) = 0.17, p = 0.69). The same holds true for matched patients who did not perform any tinnitus treatment (loudness: F(1,6) = 0.9, p = 0.38; annoyance: F(1,6) = 0.14, p = 0.72; handicapping: F(1,6) = 0, p = 0.85) throughout this time period (monitoring group, N = 7) (Fig. 1).

In order to complement and corroborate the subjective change measurements with neurophysiological data, we additionally measured tinnitus related evoked neuronal activity change by means of magnetoencephalography (MEG). We used auditory stimuli corresponding to the individual tinnitus frequency to target neuronal populations in both primary and non-primary auditory cortices that would contribute to the tinnitus perception. After 12 months of training, tinnitus related neuronal activity was significantly modified.
the other hand at the individual level: patients in whom the tinnitus became less loud exhibited reduced tinnitus related primary auditory cortex activity, and patients in whom the loudness had not changed or had increased exhibited the corresponding change in tinnitus related primary auditory cortex activity.

Reduced in the target group [ASSR: F(1,7) = 5.9, p = 0.045; N1m: F(1,7) = 24.6, p = 0.002]], but did not significantly change in the placebo [(ASSR: F(1,7) = 0.3, p = 0.48; N1m: F(1,7) = 2.2, p = 0.18] and monitoring groups [ASSR: F(1,6) = 0.0, p = 0.95; N1m: F(1,6) = 0.0, p = 0.85] (Fig. 3). Source modeling revealed that the activity measured was indeed generated in auditory cortical structures (Fig. 3).

Interestingly, there was a significant linear relationship (r = 0.69, p = 0.003) between tinnitus loudness change on the one hand and evoked neuronal activity change in primary auditory cortex on the other hand.
The future challenge will be to provide a similar training approach for tinnitus patients with hearing loss, and to identify and consider variables that would further increase the effectivity of the training.

Acknowledgements

We are grateful to Andreas Wollbrink, Karin Berning, Ute Trompeter and Hildegard Deitermann for technical assistance. This work was supported by the Deutsche Forschungsgemeinschaft (Pa 392/13-1, Pa 392/10-3).

References

1. Heller AJ. Classification and epidemiology of tinnitus. Otolaryngol Clin North Am 2003; 36:3-5.
2. Lockwood AH, Salvi RJ, Burkard RF. Tinnitus. N Engl J Med 2002; 347:904-10.
3. Eggermont JJ, Roberts LE. The neuroscience of tinnitus. Trends Neurosci 2004; 27:676-82.
4. Saunders JC. The role of central nervous system plasticity in tinnitus. J Commun Disord 2007; 40:313-34.
5. Eggermont JJ. Cortical tonotopic map reorganization and its implications for treatment of tinnitus. Acta Otolaryngol Suppl 2006; 556:9-12.
6. Elbert T, Rockstroh B. Reorganization of human cerebral cortex: The range of changes following use and injury. Neuroscientist 2004; 10:129-41.
7. Taub E, Us元件e G, Elbert T. New treatments in neurorehabilitation founded on basic research. Nat Rev Neurosci 2002; 3:228-36.
8. Okamoto H, Stracke H, Stoll W, Pante C. Listening to tailor-made notched music reduces tinnitus loudness and tinnitus-related auditory cortex activity. Proc Natl Acad Sci USA 2010; 107:1207-10.
9. Hämäläinen M, Hari R, Ilmoniemi RJ, Knuutila J, Lounasmaa OV. Magnetoencephalography: theory, instrumentation and applications to noninvasive studies of the working human brain. Rev Mod Phys 1993; 65:413-97.

10. Mühlnickel W, Elbert T, Taub E, Flor H. Reorganization of auditory cortex in tinnitus. Proc Natl Acad Sci USA 1998; 95:10340-3.

11. Diesch E, Struve M, Rupp A, Ritter S, Hülse M, Flor H. Enhancement of steady-state auditory evoked magnetic fields in tinnitus. Eur J Neurosci 2004; 19:1093-104.

12. Weisz N, Moratti S, Meinzer M, Dohrmann K, Elbert T. Tinnitus perception and distress is related to abnormal spontaneous brain activity as measured by magnetoencephalography. PLoS Med 2005; 2:155.

13. Diesch E, Andermann M, Flor H, Rupp A. Interaction among the components of multiple auditory steady-state responses: enhancement in tinnitus patients, inhibition in controls. Neuroscience 2010; In press.

14. Polley DB, Steinberg EE, Merzenich MM. Perceptual learning directs auditory cortical map reorganization through top-down influences. J Neurosci 2006; 26:4970-82.

15. Zatorre RJ, McGill J. Music, the food of neuroscience? Nature 2005; 434;312-5.

16. Blood AJ, Zatorre RJ. Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotions. Proc Natl Acad Sci USA 2001; 98:11818-23.

17. Bao SW, Chan VT, Merzenich MM. Cortical remodeling induced by activity of ventral tegmental dopamine neurons. Nature 2001; 412:79-83.