

## **Tinnitus Research – Plugging the ear leads to the perception of phantom sounds**

Tinnitus is closely linked to hearing loss, and damage to structures of the inner ear and auditory nerve have been identified as major triggers for the development of the phantom auditory sensation. We could recently show that even tinnitus patients with a normal audiogram do in fact have cochlear damage that is not detected by conventional hearing tests. However, so far it has remained unclear whether the actual cochlear damage as such induces tinnitus, or if the tinnitus is a secondary effect of the resulting hearing loss. Our computer model of tinnitus suggests that a reaction of the brain to the hearing loss could induce tinnitus: After hearing loss, auditory nerve activity is reduced, and the auditory brain receives less input than normal. When the nerve cells in the auditory brain then try to compensate for this decrease in input signal by increasing their response gain, i.e. responding more vigorously to input signals, the neuronal circuits then also start amplifying neuronal noise, and generate tinnitus. Thus, our theory of tinnitus generation predicts that hearing loss should lead to the perception of phantom sounds, even without damage to the structures of the inner ear.

But how can you get hearing loss without cochlear damage? In fact, it's quite simple, you just need to plug the ear, as the sound attenuation provided by an ear plug increases the hearing thresholds. Standard ear plugs attenuate high-frequency sounds more strongly than low-frequency sounds (that's why everything sounds muffled when you have ear plugs in your ears), and our measurements showed that such an ear plug simulates a mild high-frequency hearing loss quite well.

To study the effects of “simulated hearing loss” on the auditory system, we teamed up with Prof. Kevin Munro and Charlotte Turtle from the University of Manchester. In our study, 18 volunteers with normal hearing and no tinnitus wore an earplug in one ear continuously for one week. At the end of the 7 days, 11 participants reported hearing phantom sounds, which they described as ringing, buzzing or humming. We then performed a more detailed characterisation of the phantom sounds with the ear plug still in place, using the same procedures that we also use for tinnitus pitch matching in our lab. The participants generally rated high-pitched sounds as most similar to the phantom sounds that they were hearing, and the results were similar to typical results obtained for tinnitus. As a next step, we “cured” the hearing loss in our participants by removing the earplug. In all participants, the phantom sounds then started to disappear. On the next day, only 4 people still heard phantom sounds, and on day 14 all phantom sounds were gone. The induction of phantom sounds through ear plugs was thus fully reversible.

These results establish a direct, causal link between a reduction of sound input and the occurrence of phantom sounds, and they also show that the whole process is fully reversible when hearing is restored to normal. Moreover, the results also demonstrate that cochlear damage is not necessary for the induction of phantom sounds. The whole process can also be recreated in our computer model, which shows the emergence of a neural correlate of tinnitus through adaptation after plugging the ear, and also the disappearance of the tinnitus-related neuronal activity when normal hearing is restored.

Interestingly, not all participants started hearing phantom sounds, similar to the fact that also not everyone with hearing loss gets tinnitus. In future studies, we thus plan to look for differences between participants who hear phantom sounds and those who don't. Maybe we'll be able to find the “off switch” for tinnitus that way.

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