Everything our ears hear relates to brain activity. When a person speaks to us, the acoustic vibration of the air enters our ear through the ear canal. The vibration is then transduced (changed) into auditory nerve activity and transmitted to the auditory centers in the brain. This combined activity corresponds to our perception of sound.

Just like normal sound, tinnitus relates to some activity pattern in the brain. However, in the case of tinnitus, the activity is clearly abnormal. It may be that the abnormality is in fact very small in biological terms, but every tinnitus sufferer knows that it may be a penetrating, intense perception of sound.

One method used to study brain activity is functional magnetic resonance imaging (fMRI). Standard MRI has been used in hospitals for several decades for viewing images of anatomical structures in the body. The MRI scanner notices different magnetic properties in various tissues and constructs a picture, using shades of grayness to represent these differences. In contrast, fMRI, using the same principles, measures brain activity rather than brain anatomy. It turns out that if the brain is active at a particular location, blood flow in the area increases, slightly changing the local magnetic properties. This slight change can be detected by the fMRI scanner. Thus, by using fMRI, we can focus on brain areas that display brain activity.

Exploring Brain Activity

In the case of tinnitus it would seem to be straightforward to place a person in the fMRI scanner and see which brain areas display abnormal activity. This would be abnormal spontaneous activity, as there is no external stimulus that elicits it. However, an fMRI scanner is not very good at recording spontaneous activity. Instead, it is better suited to measuring changes in spontaneous activity. In particular, we can use fMRI to measure a change of activity induced by some external stimulus. Therefore, our research team, like some others, has taken an alternative approach. We performed two types of measurements: (1) we measured the response to sound in tinnitus patients and compared this to normal hearing subjects, and (2) we investigated changes in brain activity as a result of jaw motion, a maneuver that changes tinnitus in many patients.

Brain Function Differs Between People with Tinnitus and Those with Normal Hearing

In the first study, we compared patients with tinnitus to normal hearing individuals without tinnitus. The most significant finding was that in all hearing centers of the brain, the distribution between left and right ear activation was abnormal. This could be explained by assuming that neural inhibition (a mechanism by which a nerve cell communicates with other cells) was abnormal in the tinnitus subjects. In fact, one proposed cause of abnormal tinnitus-related brain activity is a lack of inhibition.

Although this explanation provides insight into tinnitus mechanisms, the finding that brain function was different in tinnitus subjects compared to normal hearing subjects is in itself significant. It seems to provide an objective measure that indicates that the function of auditory centers in the tinnitus group was different from that of normal hearing subjects.

Jaw Motion Can Actually Change Tinnitus

The second study relates to a phenomenon that at first sounds very exotic, but is actually quite common. Thirty percent of the patients in our tinnitus consultation report that jaw motion changes their tinnitus. We think that this is caused by the trigeminal nerve, the main sensory nerve of the face that connects to the jaw. In animal studies, other researchers have shown that this nerve has branches that connect to hearing brain centers in a part of the brain called the brainstem. Thus, jaw motion is expected to stimulate brainstem auditory regions. Our fMRI studies showed that jaw protrusion extensively activated the neural activity in the auditory center in the brainstem. A remarkable finding was that this

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Tinnitus Suppression

addition to AM and FM tones, we are also investigating pure tones, band-pass noise (limited to a specific frequency range) and white noise, totaling five different sound therapy approaches, delivered acoustically via headphones. In our electric-hearing population, we are working with cochlear-implant recipients who suffer from tinnitus. We are investigating the effects of electrode location, stimulation rate and intensity to find an effective stimulus that would suppress tinnitus.

Results With Our Research Participants

To date, we have enrolled 66 subjects in our tinnitus suppression study. Eighteen subjects have completed the acoustic stimulation experiment and 11 have completed the electric stimulation experiment. AM tones were the most effective in achieving a 30 percent reduction in perceived tinnitus – 10 out of the 18 subjects experiencing partial suppression through acoustic stimulation. Pure tones and FM tones were effective at partially suppressing the tinnitus for seven of 18 subjects; band-pass noise was effective in five subjects. Additionally, seven of 18 subjects experienced total (100 percent) suppression of their tinnitus with an AM tone and four subjects experienced total suppression of their tinnitus with an FM tone. Often, effective tones were high-frequency and near the frequency region of the matched tinnitus. No subject experienced total or partial suppression with white noise, a traditional sound therapy approach. Within the electrical experiment, seven out of 11 cochlear implant users had some degree of suppression, defined as experiencing complete, or near 100 percent, suppression during the experiment.

Benefits for Tinnitus Sufferers

The ability to drastically reduce the perception of tinnitus with the presentation of an acoustic stimulus or a reprogramming of an individual’s cochlear implant would have a profound significance for individuals suffering from tinnitus. Currently, there are limited treatment options, many of which are expensive or require years of therapy. If effective, our treatment would offer immediate benefits for those with tinnitus to dramatically improve their quality of life. If successful, this treatment method could form the basis of a rapid, effective and low-cost individualized tinnitus treatment.

Functional Magnetic Resonance Imaging of Tinnitus

change was true for both tinnitus sufferers and normal hearing controls. Apparently, the modulation of auditory activity in the brain is very normal. However, it was not actively perceived by normal hearing subjects and only by 30 percent of those with tinnitus.

An ATA Grant Supports Further Research Findings

These previous studies led to further questions, so we pursued further funding to try and answer them. The American Tinnitus Association is supporting one of the two extensive studies we are currently conducting in our lab using fMRI. It investigates brain activity in subjects with hearing loss and tinnitus. We are comparing the results in tinnitus patients with hearing loss to those in subjects with matched hearing loss and no tinnitus. We hope to help answer a key question in tinnitus research: Why do some people with hearing loss hear tinnitus, while others don’t? By comparing brain activity between both groups of subjects, we expect to find differences in the way the brain is active.

Current Conclusions

In summary, a key result of our fMRI research is that there are differences between tinnitus sufferers and normal hearing controls in the way the brain processes sound. Many people with tinnitus have probably been frustrated by the suggestion expressed by some health care professionals that their tinnitus may be all in their head. In fact, fMRI research confirms that tinnitus may indeed have a home in a person’s head; we are performing measurements that help us better understand brain activity that underlies tinnitus.

Pim van Dijk, Ph.D., is a Professor of Audiology in the Department of Otorhinolaryngology at the University Medical Center, Groningen, the Netherlands. His research interests include cochlear implantation, neuroimaging in tinnitus patients, biophysics of the inner ear and experimental tinnitus treatments. For more information, visit www.rug.nl/staff/p.van.dijk.