interference, if enhanced emotional processing occurs early on or as a long-term consequence of tinnitus, and which brain regions control this response. We examined patients with long-term tinnitus and patients with new cases of tinnitus as well as control subjects without tinnitus. The three groups of volunteers were matched by age with equal numbers of men and women.

Procedure

In the first of three sessions, the participants' brain activity was recorded with an electroencephalogram (EEG) while they watched 90 pictures with varying emotional content to trigger emotional processing. Heart rate and startle responses were measured. Also, functional magnetic resonance imaging (fMRI) was applied while the participants viewed a similar set of pictures. During both the EEG and the fMRI sessions, the participants were asked to mentally involve themselves in the situations illustrated in the pictures.

Results

Psychometric testing revealed no significant differences between acute and chronic tinnitus sufferers except for two variables: A significant number of chronic tinnitus sufferers had tried acupuncture as an alternative treatment, whereas the recent-onset tinnitus patients had not tried this treatment at all. This potentially shows that as tinnitus continues, patients will expand their search for relief by trying alternative treatments. Furthermore, those with long-term tinnitus felt significantly more nervous or depressed than patients with recent-onset tinnitus.

Conclusion and Outlook

In general, we found no altered emotional processing in tinnitus patients, as Jastreboff had proposed. However, the fMRI data did show significant differences not only in limbic brain structures but also in brain areas involved in auditory processing.

People with tinnitus showed more brain activity than did non-tinnitus control subjects especially when processing negative pictures. Additionally, patients with recent-onset tinnitus had increased brain activity in the limbic and auditory processing structures as compared to patients with long-term tinnitus. Unless caused by daily stress or by a negative appraisal of the ear sound itself, negative emotions might therefore be a risk factor for tinnitus patients.

Potential Involvement of Pain Receptors and Substance P in Tinnitus Relief

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Subjective tinnitus refers to the perception of sound in the absence of an outside sound source. Many different mechanisms have been suggested to explain subjective tinnitus. Some data suggests that tinnitus originates from aberrant neural activity in regions of the central auditory brain, while other findings indicate that tinnitus originates in the inner ear. Inner ear models of tinnitus generally assume that tinnitus arises from an "irritative lesion" in the cochlea that causes some neurons in the auditory nerve to respond at abnormally high discharge rates in the absence of sound. The high rate of neural activity is transmitted from the inner ear to the brain where it is supposedly perceived as a real sound. Indeed, several studies have found evidence of abnormally high rates of spontaneous activity in the auditory nerve following conditions that normally cause tinnitus (e.g., noise exposure, high doses of aspirin).

What mechanisms cause the increase in spontaneous neural activity in the auditory nerve? Recent studies from our laboratory have suggested that substance P and its receptor, neurokinin, might play an important role in regulating the level of activity in the auditory nerve. Substance P is a brain chemical that is thought to play an important role in chronic pain, a condition likened to subjective tinnitus. Moreover, some researchers have suggested that substance P might play an important role in tinnitus that is associated with migraine headaches. Substance P has been observed in the inner ear, but its function is largely unknown.

The goal of our ATA-funded research grant was to determine if substance P could modulate the activity of neurons in the auditory nerve of the inner ear and if so, to learn the cellular basis for these effects.

To determine if substance P has an effect on the activity of auditory nerve fibers, we monitored the electrical response of individual auditory neurons by giving an electrical stimulus or putting chemicals on the neuron while observing the cells under a microscope. When substance P was applied to the neurons, it suppressed the flow of electrical current and altered the pattern of neural activity in the auditory neurons. Substance P also seemed to increase neural activity induced by glutamate, a chemical in the inner ear hair cells.

Our results clearly show that substance P can modify the activity of neurons in the inner ear. This suggests the possibility that drugs that modify the release of substance P, or other drugs that block the substance P receptor, might be used to treat certain forms of tinnitus. ▩