The Emotional Impact of Mild Traumatic Brain Injuries and Tinnitus

By Fatima Husain, PhD

Mild TBI and Tinnitus

With better treatment and management of traumatic brain injury (TBI), attention has focused on symptoms associated with TBI, such as tinnitus. Apart from a higher incidence of tinnitus, patients with TBI report consequences ranging from loss of consciousness lasting a few seconds to seizures; from confusion and disorientation to memory dysfunction; and, in some cases, TBI results in coma or death. Thus, as with tinnitus and its related effects, the signs of TBI can range from mild to severe. In this article, I focus on tinnitus associated with mild TBI (mTBI). It should be noted that tinnitus can arise from both the injury causing mTBI as well as medications used to treat the problematic symptoms associated with TBI.

Medical organizations in the United States and around the world use somewhat different criteria in diagnosing mTBI and differentiating it from other more severe forms of TBI. Nevertheless, the emerging consensus is that persistent symptoms associated with mTBI include headaches, sleep disturbances, mental health disorders, cognitive difficulties, balance and vision dysfunction, and fatigue.

As individuals with tinnitus know, some of these symptoms associated with mTBI also occur with tinnitus, such as sleep disturbance, emotional problems, concentration difficulties, and fatigue. The rate of incidence of tinnitus in the mTBI population is between 38 and 53 percent, varying depending on the cause of injury. In a retrospective study of military personnel diagnosed with mTBI, about 67 percent of patients exposed to blasts and 58 percent of those not exposed to blasts developed tinnitus.

This brief report focuses on what happens in the brain when patients experience emotional problems associated with tinnitus and mTBI. The main processor of emotions is the amygdala, and the hippocampus is essential in forming new and, in particular, declarative memories. It’s not surprising that the amygdala has been ascribed a major role in theories of tinnitus generation. In these theories, the sound of tinnitus grabs our attention because it stands out from other sounds of daily life (such as people talking or passing cars, which are evaluated as neutral and familiar, and hence more easily “tuned out”). When one attaches negative meaning to the unwanted tinnitus sound, one attends to it even more, thus ensuring its persistence. This is not unlike the reaction to a mosquito bite; the more one thinks about it, the more it itches, and vice versa. Despite being unable to make the mosquito bite simply “go away,” the mind has the capability to amplify or dampen the strength of the
sensation, depending upon what our thoughts are focused on. Likewise, with tinnitus, shifting thoughts away from the unwanted sound and toward a positive goal or activity can lead to the ability to minimize the “itch” of tinnitus, thereby supporting habituation.

After the onset of tinnitus, managing the emotional response to it, possibly mediated by the limbic system, plays an important role in learning to habituate to chronic tinnitus sound(s). The 2018 Spring issue of Tinnitus Today magazine was devoted to the topic of habituation and serves as a useful resource on the process of habituation and how a tinnitus patient can work to achieve it.

In our own studies, we have shown that if one has bothersome or severe tinnitus, a likely contributor is a hyperresponsive amygdala, that is, one that comes online quicker and with great effect when hearing speech or environmental sounds. In cases of mild tinnitus, the patient may be habituated to tinnitus, and therefore suppressing the powerful response from the amygdala with emotionally relevant external sounds.

**What Does This Mean When One Has Both mTBI and Tinnitus?**

Individuals who develop mTBI may report tinnitus, but both they and their healthcare providers may not pay attention to tinnitus, compared with other more acutely debilitating symptoms of mTBI, until after the symptoms have stabilized and tinnitus has become chronic. Further, as noted earlier, medications used to treat mTBI symptoms may also facilitate the onset of tinnitus.

In mTBI, the size of the amygdala may be reduced and its connections with the rest of the brain altered. Recent studies of mTBI have reported on the diminished response of the amygdala as well as reduced size of this structure. This in turn has been linked to deficits in cognitive control or inhibitory control; the authors of this paper liken it to the cognitive deficits and trauma symptoms seen in cases of post-traumatic stress disorder (PTSD). In cases of PTSD, reduced function and size of the hippocampus are noted with an increased functioning of the amygdala. The co-occurrence of PTSD and mTBI has also been reported in epidemiological studies (which look at how different conditions interact and affect various populations) of U.S. military personnel. Although behavioral studies are beginning to investigate the impact of these conditions when they co-occur, few imaging studies of brain function have been published. In particular, the functioning of the amygdala when PTSD and mTBI co-occur with tinnitus has to be worked out.

As suggested earlier, patients with mTBI and tinnitus require unique treatment plans, involving diverse healthcare professionals, because the type of injury (blunt or blast-related) may affect the type of deficits seen in the patients. Further, the neuropsychological symptoms may vary from person to person. As a first step, given the commonality of symptoms between PTSD and mTBI and that their mechanisms overlap, tinnitus management in mTBI cases may require individualized and multidisciplinary approaches.

**PTSD and Tinnitus**

Events causing PTSD often include loud sounds that can result in damage to hearing, such as explosions or gunshots. As a result, PTSD is often accompanied by tinnitus. Although the actual etiology of tinnitus is often unknown, it likely has several factors that interact with PTSD, heightening the perception of tinnitus.

Perception of tinnitus is affected by how individuals direct their thoughts, and the thoughts of people with PTSD are influenced by the event that led to their PTSD. This event is often the same trauma that initiated their tinnitus. Consequently, PTSD and tinnitus may serve to amplify each other’s effects. A thought about PTSD may trigger thoughts about tinnitus, and vice versa. PTSD results in a condition called “hypervigilance,” in which the brain becomes acutely aware of incoming stimuli and sensations. In terms of neural networks, there is evidence to suggest that the equilibrium between the salience network and the default mode network is altered in PTSD, and this is noted even at rest (see the accompanying box); the association between activity in these networks and hypervigilance remains speculative but of great interest to researchers.
Hypervigilance associated with PTSD may influence tinnitus by heightening awareness of incoming sounds, a defensive mechanism intended to protect individuals from further traumatic events. Unfortunately, as a result, tinnitus can receive increased attention, or increase in loudness, particularly in the presence of startling sounds that exacerbate the perceived tinnitus handicap.

Avoiding situations that can trigger tinnitus (such as social outings to restaurants, movies, or parties) can result in the individual becoming isolated. Increased isolation increases time spent focusing and ruminating on negative thoughts and emotions linked to PTSD and tinnitus. This further exacerbates the discomfort from tinnitus.

Decreasing anxiety and rumination associated with PTSD can lessen tinnitus, leading to improved quality of life. Cognitive behavioral therapy (CBT) is one approach that can help individuals feel more at ease with their thoughts and, in fact, is the only treatment to show improvements in tinnitus-related measures in randomized controlled trials. The goal of CBT is for individuals to take note of what thoughts they are thinking, assess the validity and usefulness of the thoughts, and then challenge and change the thoughts as needed. This can be an effective way to develop a mind-set geared toward positive coping skills and decreased negative ruminations about the discomfort caused by tinnitus and PTSD.

Although CBT and other interventions may not necessarily “cure” either condition, they can be helpful in managing tinnitus and PTSD effects. CBT can improve self-efficacy beliefs, which have been shown to improve treatment outcomes. This same concept can be applied to patients with mTBI and tinnitus. Changing thoughts cannot change the past — the mTBI remains part of the patient’s history — but such intervention can help the patient cope with the consequences of traumatic exposures in the present and the future, thereby reducing the negative impact exerted by the mTBI and associated tinnitus.

Fatima Husain, PhD, is a cognitive and computational neuroscientist by training, with a special interest in speech and hearing. For the past 12 years, the major focus of her lab has been the study of tinnitus. Her lab at the University of Illinois at Urbana-Champaign has studied tinnitus using a variety of methods, from behavior and surveys to several types of brain imaging. Dr. Husain’s goal is to better understand the brain-based mechanisms of tinnitus with a view toward testing and improving existing treatment options and eventually developing customized treatment plans.


**Note:** Central executive function here may be considered to be the dorsal attention network. ACC, anterior cingulate cortex; DLPFC, dorsolateral prefrontal cortex; INS, insula; mPFC, medial prefrontal cortex; PCC, posterior cingulate cortex; PPC, posterior parietal cortex.
Neural Networks of Tinnitus

Apart from the auditory pathways or network, that is, the brain regions involved in sound perception and by extension implicated in generating tinnitus sounds, a number of neural networks may be involved in the psychological reaction to tinnitus. Prominent among these networks are the attention network, the emotional processing network, the default mode network, and the salience network.

The limbic system is the primary system for processing emotions (e.g., joy, fear, anger), memories, and arousal, or base rate of stimulation. It is composed of those regions that can be thought of as the older or more primitive brain, namely, the amygdala, hippocampus, thalamus, hypothalamus, basal ganglia, but also parts of the neocortex such as the insula, the orbitofrontal cortex, and the cingulate gyrus (see Figure 1, p. 40).

The attention network is engaged in focusing on important tasks and orienting to signals and can be further divided into dorsal and ventral attention networks. The default mode network, sometimes termed the task-negative network, is more engaged and responsive at “rest,” when the brain is not performing a goal-directed task. Regions of the default mode network include the posterior cingulate cortex and the medial prefrontal cortex.

The dorsal attention network and the default mode network exhibit a push-pull relation, with one gaining ascendance at rest (the default mode) and the other, when performing a task (the dorsal attention network). The salience network is a more recently termed network, and its connections and functionality are less well understood. Its major role appears to be in determining which stimuli to focus attention on, and coordinating the neural responses necessary to respond to such stimuli. Apart from other regions, the canonical regions of the salience network are the insula and the anterior cingulate cortex, which are also part of the limbic system. One way to think about the salience network is as a fulcrum between the default mode and dorsal attention networks, switching between attention and resting state (see Figure 2, p. 42).

fMRI Facts and Points of Speculation

- Tinnitus affects the neural bases of cognition, attention, and emotion processing.
- Functional MRI (fMRI) allows us to vividly see the brain regions that are engaged in a task; we can compare between patients and controls and locate possible networks, thus allowing us to infer neural mechanisms of tinnitus.
- Because of the individual differences within the patient population and several methods of acquiring data or performing analysis, findings from different labs may vary. But over numerous studies, as evidence accumulates, our understanding of the neural mechanisms of tinnitus will improve.
- Below are a few studies and their findings from our lab.
  - Husain et al. (2011):  
    - Elevated activation in auditory attention and short-memory networks in individuals with tinnitus.
    - Although no behavioral differences were found between patients and controls,
fMRI Facts and Points of Speculation (continued)

the alterations in the attention network point to different adaptations due to chronic tinnitus.

- Schmidt et al. (2013) and Schmidt et al. (2017).
  - Increased coupling between limbic regions and the auditory and dorsal attention resting-state networks.
  - Decreased coupling between precuneus and default mode resting-state network in people with long-term tinnitus, exaggerated by tinnitus severity.
  - Individuals with tinnitus are still using their attention network even when not doing a task; possibly they are paying attention to the tinnitus sound and are not completely at rest. This may explain some of the fatigue individuals with tinnitus often experience.

  - Heightened activation of limbic system (posterior cingulate and insula) in the initial emotional responses to tinnitus, after recent onset.
  - Heightened activation of frontal regions (e.g., middle frontal gyrus) but reduced activation of the amygdala for those with mild long-term tinnitus, indicating habitation.
  - Heightened response of the amygdala but reduced response of the frontal regions in those with bothersome long-term tinnitus, indicating unsuccessful habitation.

18 Moring et al. (2018).

What’s Functional Magnetic Resonance Imaging?

At any given moment, millions of electrical impulses whirl through your brain. Electricity is what drives this vast and complex network, with four key elements in neurological wiring: neurons, axons, dendrites, and synapses. At junctures between synapses, these impulses trigger neurotransmitters, which in turn modulate electrical activity in the next cell. Somehow these processes of neural communication underpin every thought, feeling, and action. By measuring changes in oxygenation, functional magnetic resonance imaging (fMRI) indirectly reveals the consequences of neural activity. (Active brain areas consume more oxygen, which increases blood flow to those areas.) The fMRI is the workhorse in cognitive neuroscience for studying brain function and is used regularly to study how tinnitus affects the brain. 😊