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Sounds, Seizures, and the Brain

Short communication
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Abstract

This brief review examines the effect of noise on the brain. While it is fairly well established that excessive noise can cause hearing damage, there has been evidence that sound can also trigger seizures and cause traumatic brain injury. Animals exposed to loud sounds develop different behavioural characteristics. Audiogenic and music genic seizures, traumatic brain injury from loud noises, such as fire alarms, and elevation in biomarkers for traumatic brain injury, as a result of exposure to sound have been documented. These observations show that sound and noise have can have a substantive impact on the brain and more research done in this area would be helpful in understanding hearing deficits, seizure disorder, as well as traumatic brain injury.

Keywords: seizure, audiogenic, epilepsy, sound, traumatic brain injury

Short Communication

Hearing, like most other senses involves transmutation of environmental stimuli into electrical potentials. Those electrical potentials that are picked up by environmental receptor organs being coded in some meaningful manner as it is sent to the brain via a pathway that integrates with other sensory stimuli to end up having an effect on the cortex when meaning making occurs. Hearing involves two different kinds of stimuli; loudness (dB) and pitch (Hz). These are based upon the amplitude and frequency of sound waves as they hit the tympanic membrane. This causes the sound waves to be amplified by the three inner bones of the ear, which then cause hair cells in the cochlea attached to the stapes to move back in forth with greater intensity. In the cochlea, the more hair cells that fire the louder the sound will be; and there is tonotopic representation of the pitch in the cochlea as well, such that lower frequency noises are closer to the round window (stapes) and higher pitches are closer to the oval window (output). The hair cell on the cochlea that get stimulated move back and forth causes an influx of sodium and an action potential that is transmitted along the auditory nerve to the olivary nucleus which then sends connections to the inferior colliculae, which enables localization of sound. From there, as with all sensory stimuli it sends its messages up through the latter geniculate nucleaus of the thalamus, and then on to the auditory nucleus.

The fact that exposure to loud (dB) or certain frequency (Hz) noises can damage hearing is widely accepted. However, such sounds may also cause many other less routinely thought of problems [1]. Animals and people exposed to such noises can develop seizures, subsequent loud noise exposure can lower seizure threshold and/or initiate seizures [2]. For example, there are different strains of mice that either, due to genetic disposition or exposure over generations to certain noises, have different behavioral phenotypes, seizure thresholds, and exhibit different responses to noise exposure [3,4]. There are differences between people and mice in terms of what they hear. People perceive sounds between 18-18000 hz, with 40-4800 being most relevant for speech. Rodents perceive sounds inaudible to us, up to 80,000 hz [5,6]. They communicate in an ultrasonic range. Noise exposure (95 db at 500-5000 hx twice a day for 5 min, for 28 weeks) produced aggressiveness, seizures, cortical, and subcortical lesions [7]. Wistar rats are one model species that is genetically sensitive to audiogenic seizures and have been extensively studied to examine epilepsy and comorbidities including traumatic brain injury, which is the leading cause of morbidity and mortality among young people in the US [8]. We have experienced similar effects on mice in our animal facility, when fire alarms went off in response to changes in air pressure over a four year period. Mice that were exposed to this developed high stress and aggression for multiple generations. Btbr mice (a mouse model of autism) that were exposed to these fire alarms for generations showed increased ultrasonic vocalizations on post-natal day 12 when with the dams and litter or if socially isolated and were more active (more peripheral and central entries) compared to litter controls. People with autism are often sensitive to noise as well.

Although fatigue, stress, withdrawal from anti-epileptic drugs and steroids (catamenial epilepsy) are accepted precipitants to ictal events, only 5% of seizures are believed to be triggered by environmental factors [9]. Most evidence about environment factors triggering epilepsy have come from case studies. An intriguing case involved a patient who had seizures when she heard a specific TV personality come on the air for four years. The only time the patient experienced a seizure was when this specific TV personality spoke. However, after many years she began to have seizures independent of this event [10]. There are also people who have been diagnosed with musicogenic seizures. These people have a seizure only when they hear a certain song or piece of music [11]. For example, there was a 19-year old Japanese woman who had seizures every time she heard "Dreamlover" by Mariah Carey [12]. There has been a case of an infant that had seizures from loud music-The Beatles in particular [13]. It is notable that the infant had no emotional connection to the Beatles and had hypofunction in the left hemisphere of the brain and there was some suggestion that the rhythmic pattern of Beatles music contributed to the epileptiform response [13]. However, in the woman with consistent ictal responses to Mariah Carey, there was an emotional component and the epileptogenic activity was in the right hemisphere [12]. There is also a case of a Canadian woman who had intractable epilepsy to a hip hop song Temperature by Sean Paul, which was resolved by brain surgery [14]. Why brain surgery for a song? Because seizures cause damage to a very important part of the brain the hippocampus, which control cognition, memory and affect.

The evidence that noise can cause direct effects on the brain and produce damage including traumatic brain injury is emerging but is largely anecdotal. One of these cases involved a Professional Firefighter/Paramedic. His coworker set off a fire siren (~200db, 1-3kHZ) the equivalent of a blast injury, while he was standing within a few feet of the siren. The Firefighter/Paramedic was able to remain standing but suffered a profound traumatic brain injury. The sound caused such sheering that he had cerebellar herniation and spent years recovering [15]. Despite being exposed to a potentially lethal noise, which could have killed him, and surely would have if he did not remain standing when he was exposed, he has undergone considerable rehabilitation and is now an advocate for people with traumatic brain injury.

A different case involved a researcher (CAF) working in a highly secured animal facility that was intermittently exposed to 120 db fire alarms in their secured work area over the course of 4 years. She began to develop depression, anxiety, PTSD first (dx'd 2 years after exposure) it then progressed to more cognitive symptoms and finally she began having changes in consciousness upon awaking (after 4 years). A few years later she began having seizures in response to noise. At first these were deemed pseudoseudoseizures, until a few years later EEGs verified irregular activity in the same region as a mass found earlier at the junction of occipitoparietal cortex and seizures increased with discontinuation of anti-epileptic drugs. This accounted for her low vision, neuropathy of fine motor skills, perilymph fistula and neuropsychological evaluation indicating she had a traumatic brain injury. The sequence of progression of these symptoms is not insignificant. To this day she has seizures if she hears sounds of a certain frequency. Her EEG progressed from normal to abnormal as the seizure disorder solidified, which continued on after fire alarms ceased.

Another interesting occurrence of sound induced brain injury was found when studying a group of diplomats working in Cuba. The diplomats were exposed to a strange auditory phenomenon and experienced symptoms similar to those with concussions or brain injury. When evaluated they were found to have traumatic brain injury even though they did not experience head trauma [16]. Although there is debate as to whether audiogenic stimuli in this case was being used as a warfare agent; it is available and sonic weapons have been used [17]. Initially the Havana incident was considered mass hysteria or a psychogenic event; however this was debunked when other reports came in from China, Europe, Russia and the Middle East and some cites in the US. The overlay of the physiological symptoms the individuals' experienced and the changes in their brain are very similar to what has been reported traumatic brain injury. This condition is now called "Havana syndrome". The symptoms of Havana syndrome include, hearing a loud sound; ear pain; tinnitus; vertigo; visual problems; nausea, cognitive difficulties, fatigue and sleep difficulties; dizziness, and pressure or vibrations in the head. Neuroimaging differences can also be seen in these individuals.

Biomarkers of traumatic brain injury increase with exposure to loud noise. Glial fibrillary acidic protein (GFAP) increases in certain brain regions of rats as a result of sound exposure. This would suggest that loud sounds have inflammatory effects on the brain [18,19]. Exposure to loud sounds can damage more than hearing and balance and needs to be taken seriously. Seizures and Traumatic brain injury are serious issues that can develop with noise exposure and medical providers should be aware of these possible effects. More research on sound and brain function is needed to elucidate the mechanisms of these problems and possible treatment options for patients dealing with auditory seizures and traumatic brain injury as a result of noise exposure.

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