Do Concussions Leave a Lasting Imprint on the Hearing Brain?

By Nina Kraus, PhD, and Travis White-Schwoch

Concussions are something of a clinical conundrum. There has been growing concern that one or more blows to the head can cause lasting brain damage, even after symptoms appear to have resolved. The diagnosis of concussions relies on the evaluation of multiple organ symptoms, but it is important to note that patient reports of their symptoms are inherently subjective. Patients are said to have "recovered" from concussions once those symptoms subside. However, it can be difficult to guarantee that a patient has completely recovered because of the lack of a gold standard biological test for concussions.

Neuropathological studies offer compelling evidence that repeated blows to the head cause brain injuries. About a century ago, "punch drunk" boxers were found to have motor, cognitive, and speech problems (*JAMA.* 1928;91[15]:1103). Post-mortem examination of the boxers' brains revealed consistent neuropathology evocative of dementia, which aligned with their symptoms (*Psychol Med.* 1973;3[3]:270).

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CHRONIC TRAUMATIC ENCEPHALOPATHY

In the past decade, a similar pathology has been observed in brain autopsies of former professional football players. The term "chronic traumatic encephalopathy" was introduced to describe patterns of neurodegeneration often correlated with changes in mood, cognition, and behavior before death (*Brain.* 2016;136:e255). One of the key ideas behind chronic traumatic encephalopathy is that the condition does not only result from concussions but also from regular and repeated blows to the head. Imagine a lineman on a football team. His body and head are jostled on every single snap. The idea is that these repeated "subconcussive" blows accrue over time and contribute to brain damage.

The challenge is that this diagnosis can only be made after a post-mortem evaluation of the brain. From a theoretical standpoint, this raises the question of whether these neurodegeneration patterns can be attributed to blows to the head, noting that correlation does not mean causation. Even if we accept this hypothesis, the inability to detect this neural damage in living patients is a barrier to earlier and better clinical management.

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FREQUENCY-FOLLOWING RESPONSE

In the March 2017 issue *of The Hearing Journal*, we discussed how the frequency-following response (FFR) is a new, objective approach to identify concussions (*Hearing Journal.* 2017;70[3]:56). The FFR is a measure of sound-evoked synchronous neural activity and a sensitive test of brain health. The unique advantage of the FFR is that it requires no behavioral response from patients; patients cannot will their brains to respond in a certain way. Therefore, it can sidestep many of the challenges that current approaches to diagnose concussions face.

We showed that the neural coding of the fundamental frequency of speech (F0) is acutely disrupted in children who have sustained a concussion (*Sci Rep.* 2016;6:39009). We also showed that neural coding of the F0 improves as children recover and that the FFR could be statistically modeled to classify children into concussion or control groups with 90 percent accuracy.

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However, the question remains whether we can detect potential neural damage from a concussion after patients have recovered. To test this hypothesis, Kraus and colleagues measured FFRs in 50 collegiate football players (*Neurosci Lett.* 2017;646:21). Half of the football players never had a concussion; the other half had sustained a single concussion anywhere from one to six years prior. None of the football players showed any symptoms of a concussion.

Despite their apparent recovery, the football players who had a single concussion exhibited a distinct neural signature: Their responses to the F0 were weaker than that of their peers. However, it should be emphasized that this was a small effect and that it remains to be seen if this weak response has functional consequences for cognition and communication. Nevertheless, this observation suggests that even a single concussion can leave an imprint on the brain.

Another advantage of the FFR is that it is a standardized test of auditory processing with norms available across the lifespan (*Cereb Cortex.* 2015; 25[6]:1415). Kraus and colleagues, therefore, considered how the football players generally performed relative to norms. Those with a previous concussion performed at the 20th percentile, which meant that their FFR-F0s were smaller than 80 percent of the healthy population. The players without a single concussion performed slightly below the population mean. They were at the 40th percentile, indicating that their FFR-F0s were smaller than 60 percent of the population.

Could this be evidence for brain damage from repeated subconcussive hits? The only way to answer this question is through a longitudinal study that tracks athletes through one or more seasons. Such a prospective study could lend much-needed clarity to questions surrounding football and the brain. Ultimately, this knowledge could make sports safer by providing an objective look at the brain health of athletes.