EEG analysis may detect up to 99.5 percent of concussions

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Credit: AI-generated image (disclaimer)

A linebacker gets blindsided by a block, helmets colliding before the defender goes to ground. He rises before arousing suspicion, ignoring and playing through a cognitive haze.

A striker rises for a header off a free kick. An errant elbow reaches her

skull before the ball does. She shrugs it off, barely mentioning the mild headaches that follow.

A winger skates down the left flank, receiving a pass but also a hip check that sends him to the ice. His helmet blunts the glancing impact enough to delay the onset of symptoms for weeks.

Research has begun manifesting the specter of concussion that haunts contact sports. A 2020 survey from the National Center for Health Statistics found that 12 percent of Americans aged 12 to 17 have experienced concussion-like symptoms. But some estimates suggest that as many as one-third to one-half of sports-related concussions go unreported—whether because an athlete is unsure they experienced one, doesn't appreciate the dangers of ignoring it, or fears the possibility of missing action while recovering.

So the University of Nebraska–Lincoln's Khalid Sayood and Amirsalar Mansouri decided to apply their electrical engineering expertise to evolution's greatest feat of electrical engineering, the brain. Their goal: devise a way to regularly monitor brain activity for the sake of detecting the concussions that athletes, especially young ones, either don't know they have or don't want others to.

"Many high school kids get concussions but don't report them," said Mansouri, who earned his doctorate in electrical engineering a month ago. "And one of the main ways of initially diagnosing a concussion is a self-report from the athletes."

Unfortunately, studies have indicated that each subsequent concussion increases the odds of another. Experiencing two concussions in a short period can pose serious, potentially life-threatening risks, while multiple concussions over a longer period are linked with symptoms ranging from depression to dementia. With that in mind, the Nebraska researchers

have developed a method for analyzing readouts of electroencephalography, or EEG, that could ultimately help reduce the number of concussions that go overlooked or unreported.

Consisting of an electrode-covered cap and other equipment that generally fits in a briefcase, an EEG setup can go where it's needed. It also costs just a fraction of CT scanning, MRI and other more-sophisticated but immobile imaging techniques. And in a new pilot study, the researchers have shown that the modest EEG could help diagnose concussions with up to 99.5 percent accuracy, potentially identifying athletes in need of further diagnosis and treatment. A fully realized version of the approach, Mansouri said, would require no more than 20 minutes per athlete.

"My goal is to expand the application of EEG devices," Mansouri said, "because you can use them in developing countries or for high school kids who don't have access to the facilities that we have in Memorial Stadium."

On the brain

Mansouri's quest actually began with Memorial Stadium—specifically, Nebraska's Center for Brain, Biology and Behavior, which had previously collected EEG data from Husker football players under the guidance of Dennis Molfese, now professor emeritus of psychology. Those players had taken what's known as the 2-back task of working memory, which presents a sequence of single letters on a screen, then has a participant decide whether the current letter matches the letter that was presented two screens prior.

The Huskers first took the test in the preseason, when none had recently experienced a concussion, to establish a baseline of performance. Later, eight of those players—four of them still concussion-free, the other four

having experienced a concussion within the past week—took the test again. In both instances, the players wore EEG caps that recorded the electrical activity of their brains.

That electrical activity occurs in different frequency bandwidths—alpha, beta, theta, delta and others—that often indicate different cognitive states, such as wakefulness vs. sleep. Research has also found that those frequency bandwidths can offer insights into cognitive dysfunction, including epilepsy and, more recently, concussion-related issues.

So Mansouri and his colleagues analyzed the frequency bandwidths collected from each EEG electrode, comparing how closely the bandwidth readouts from any one electrode correlated with those of every other electrode on an athlete's scalp. That allowed them to identify location-based networks for each frequency bandwidth during the 2-back task.

The researchers took 350 samples of that data—essentially, the brain activity from seven of the eight Husker players when questioned about a letter during the 2-back task—and fed those samples into a machine-learning algorithm. They also told the machine which samples came from recently concussed vs. non-concussed players. From those samples, the machine analyzed how various frequency bandwidths, from various regions of the brain, either differed or remained the same in the concussed and non-concussed players.

Those differences and similarities formed the basis of multiple models for distinguishing between a recently concussed and non-concussed brain. One model might look at the theta bandwidth from the frontal region, for instance, with another comparing three collective bandwidths in the occipital region. The team then had the models attempt to classify the 50 samples of 2-back data from the one Husker player it had kept out of the machine-learning process, effectively asking each model: Did

these samples come from a concussed or non-concussed brain?

By repeating that process seven more times, with a different Husker player left out in each instance, every model was put to the test a total of 400 times. One of those models—which analyzes the collective theta-alpha bandwidth across all regions of the brain—correctly identified 398 of those 400 samples, or 99.5 percent, as coming from either a concussed or non-concussed player.

But the researchers were also curious about which region-specific models might yield reasonably accurate results. The fewer and smaller the regions, Mansouri said, the fewer EEG electrodes would need to be placed on a scalp, potentially reducing the costs of regular monitoring. Comparing the beta bandwidth in just the central region of the brain still led to 97.25 percent accuracy, while the theta-alpha bandwidth in the temporal region produced a 96.75 percent hit rate.

"So instead of having that big (electrode) cap, we could use smaller caps and, again, get good accuracy for reporting potential concussions," said Mansouri, who recently took a postdoctoral position with the Boys Town National Research Hospital.

Coming as it did from a pilot study, the team's approach needs to be further validated on multiple fronts before emerging as an actual method for concussion monitoring, Mansouri said. First up: applying it with a much larger sample of athletes, both without and with concussions.

The researchers detailed their findings in the journal *Neurotrauma Reports*.

Provided by University of Nebraska-Lincoln