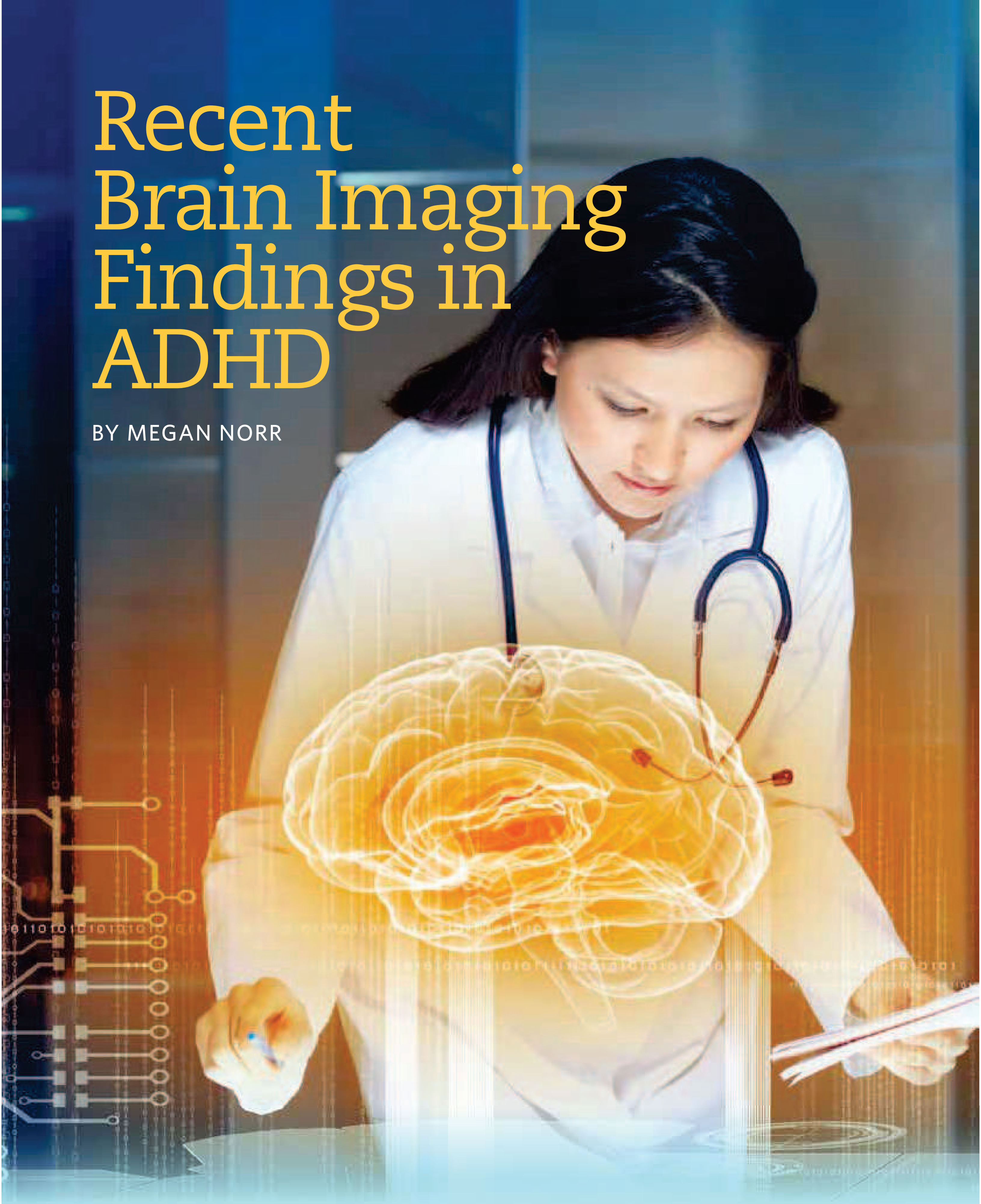
Recent Brain Imaging Findings in ADHD

BY MEGAN NORR



“Can you tell I have ADHD from looking at my brain?”

I sat with the young man in front of a computer screen looking at a picture of his brain. He had just participated in a one-hour brain scan, during which he did computer tasks while lying in the narrow, donut-shaped tube of an MRI machine. We took high-resolution pictures of his brain and did scans that would examine its activity and connections. Naturally, looking at the inside of his own head, he wanted to know if his brain was different in any way, and if so, how?

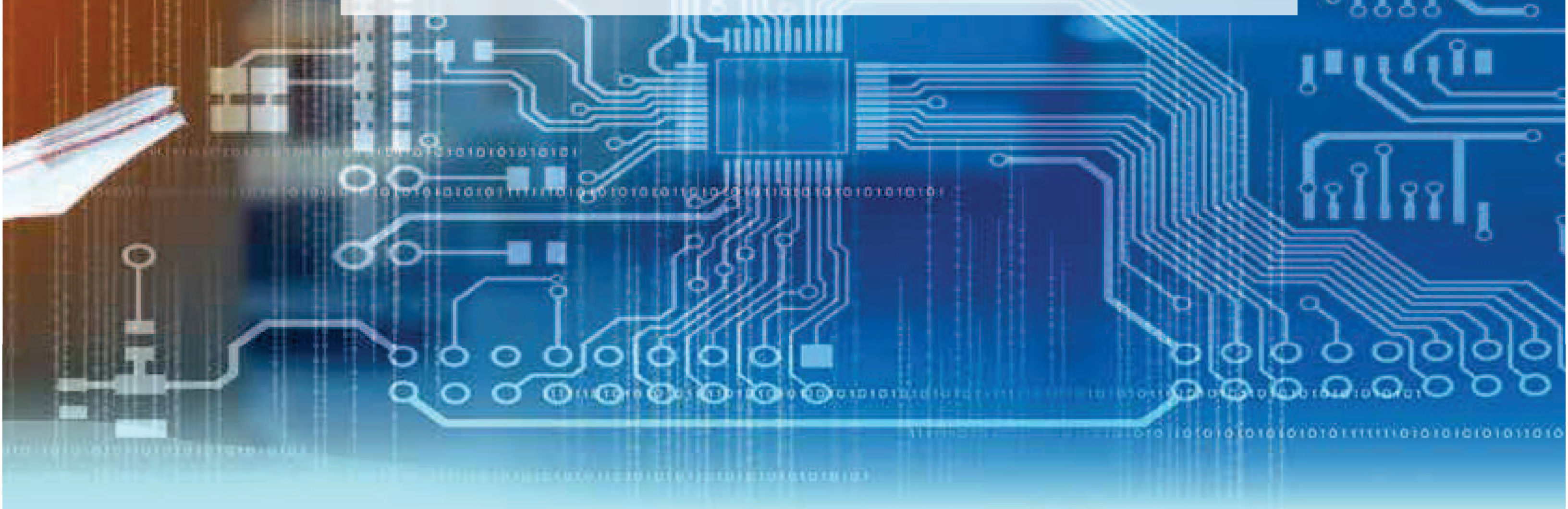
Over the past twenty years, brain imaging has identified several key brain regions that function differently for people with ADHD. Some of these regions, like areas in the frontal and cingulate cortices, are responsible for executive functions, such as working memory, managing attention, and planning. Other areas, such as the striatum (a subcortical structure), are responsible for feeling rewarded and managing motivation. These brain areas can act abnormally in a number of ways: They can be underactivated during a task, leading someone to be distractible and unfocused, or they can be overactivated, leading the person to work extra hard to do something that someone else might have little trouble doing, like remembering a phone number or finding the motivation to do homework.

But has knowing which brain regions differ in people with ADHD led to a brain scan or test that can tell if someone has ADHD? Not really. Or perhaps more accurately: Not yet.

Using big data to diagnose ADHD

One recent advance in brain imaging research isn’t so much a scientific discovery as a playground rule: share. Instead of studying small samples of people in their local area, researchers are now sharing data to create large, diverse collections of brain scans.

The ADHD-200 is one such collection, consisting of MRI scans of people with and without ADHD from eight international institutions. Of the 776 datasets in the collection, 285 belong to people diagnosed with ADHD. The organizers of the ADHD-200 held a contest to see who could develop the most accurate diagnostic test for ADHD. The winning group from Johns Hopkins earned the most points by correctly identifying 94 percent of the people



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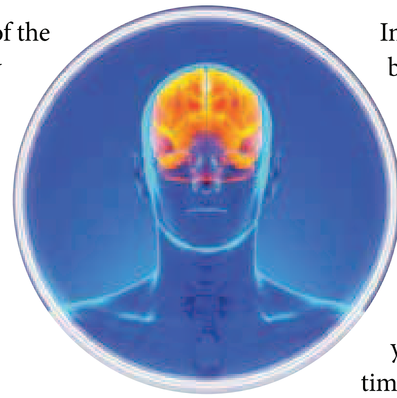
who *didn't have ADHD* and 21 percent of the people who did. While this wasn't a very sensitive test (that is, it didn't pick out the most cases of ADHD), it excelled by classifying the correct ADHD subtype in 89.5 percent of the cases it diagnosed.[1] The ADHD-200 results suggest that brain imaging could play a groundbreaking role in identifying individuals' unique presentation of ADHD.



Individual differences in ADHD: Gender, symptoms, and diagnosis

Until recently, a question that has been overlooked in ADHD research is whether the brains of males and females with ADHD differ from one another. Boys are more likely to struggle with hyperactivity and impulsivity (blowing out the birthday candles at someone else's birthday), while girls are more likely to show inattention and disorganization (less obvious behaviors like daydreaming, often mistaken for laziness). These differences in symptoms may arise from differences in the brains of boys and girls with ADHD.

A recent study of adults found that the severity of hyperactivity in men and inattention in women was related to brain regions affected by ADHD: Less activation in those regions meant more severe symptoms. Brain imaging could provide a much-needed way to assess historically hard-to-diagnose or underdiagnosed populations.[2]

Beyond brain areas: Brain networks

A relatively new line of research in brain imaging involves studying the complex ways brain areas communicate and interact. A *brain network* is a series of brain regions that activate together to perform a complex task. Several important networks have weaker connections in ADHD, including the cognitive control and salience networks, reward and motivation networks, and the "default mode" network. The default mode network (DMN) is active when you are not engaged in a task. When you are daydreaming or relaxing, your DMN is doing work.[3] Normally, there is a push-pull relationship between the DMN and networks that are activated by tasks. If you are doing your taxes, making lasagna, or even gardening, concentrating on something makes your default mode *deactivate*. It is suppressed in order to free up resources for the task at hand.

In ADHD the push-pull relationship between the default mode network and other networks isn't as strong, meaning the DMN isn't suppressed as completely or the task network isn't activated as much. If you have ADHD and you are in a meeting or lecture, you might suddenly start thinking about updating your Facebook status instead. That's your default mode activating at the wrong time. Perhaps your medial prefrontal cortex, a key part of the DMN responsible for self-related thinking, isn't sufficiently suppressed.

A better understanding of how these complex characteristics of the brain affect ADHD will be necessary for developing a diagnostic test. In the meantime, this research could help scientists and clinicians develop new treatments and give better recommendations (like cognitive training) that target larger brain networks.

Long-term effects of medication on the brain

A massive amount of data has accumulated in recent years examining the effects of stimulant medication use on children, adolescents, and adults. Reviews and meta-analyses, methods used to synthesize large numbers of research studies, have shown that stimulant medications keep the brain from showing ADHD-related differences like decreased brain tissue in executive function and reward processing areas. Similarly, medication use for ADHD is associated with less reduction in activation and better connectivity between brain networks. However, only a handful of studies have examined the effects of medication across time in the same group of subjects.[4] In the long term, it remains unclear whether stimulant medications have a lasting "normalizing" effect on the brain, because it is nearly impossible (and potentially unethical) to control someone's environment enough to determine the effect of medication alone.[5]

The field of brain imaging has made significant advances by studying bigger and more diverse samples of people with ADHD, going beyond finding individual brain areas affected by ADHD to examining how they interact, and synthesizing an ever-growing body of research to understand the bigger picture.

The story of the ADHD brain is getting more nuanced.

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A brain scan may one day provide crucial insight into how an individual's brain functions, but it will not be diagnostic alone. The gold standard in ADHD diagnosis—clinical testing, observation, and reports from multiple sources (parents, teachers, and peers)—will likely remain. And that is good: People with ADHD have unique difficulties and strengths, and diagnosis and treatment selection should be flexible enough to accommodate those differences.

A graduate student at the University of California, Berkeley, **Megan Norr** *is pursuing her PhD in clinical psychology. She conducts brain imaging research using MRI to study neurodevelopmental disorders across the lifespan. She also provides mental health services, including counseling and psychological evaluation, to children, teens, and families. Her research interests include executive and emotional functioning in teens and young adults with autism and ADHD, gender differences in ADHD, and female neurobiology, diagnosis and treatment, and health outcomes.*

NOTES

1 Interestingly, a group from the University of Alberta developed a more accurate diagnostic test without using the brain imaging data. This highlights the importance of integrating multiple types of data and illustrates that brain imaging is probably not, at this time, the best tool for diagnosing ADHD.

2 In recent years the prevalence of ADHD in African-American populations has grown to equal or even surpass ADHD in Caucasians. ADHD prevalence is apparently increasing in Hispanic populations, as well, reflecting better identification and diagnosis of ADHD generally. However, it is unlikely that ADHD affects the brain differently for different races.

3 It is a myth that we only use 10% of our brains. In reality, most of the brain is active almost all the time. Even when we are sleeping, nearly every part of the brain shows some level of activity. The brain is constantly switching between brain networks, activating in dynamic and complex patterns to think, feel, desire, decide, and so on. In truth, 100 percent of brain areas have some function (most have several!) and they activate and coactivate with each other depending on the stimulus or task.

4 One study found that children who were treated with medication for one year had less volume reduction in the cingulate cortex compared to children who were not treated with medication. In adults, the cingulate, which is not only smaller in ADHD but also underactive, was more active (in other words, it functioned more "normally") after six weeks of treatment with medication.

5 Often medication is not the sole factor leading to better outcomes, and some studies found that medication had no effect on the brain at all. In studies where medication use was associated with positive outcomes there could be other factors or combinations of factors that were responsible for improved brain function. Perhaps children who were medicated also received behavioral therapy, school accommodations, or parental support (or some combination thereof) that was responsible for helping their brain to develop more normally.

FURTHER READING

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