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Brain scans of 9- to 11-year-olds offer clues about aggressive, antisocial behavior

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The behavioral problems of a nine-year-old tend to look very different from those of a teenager. What if, before any severe delinquency and rule-breaking began, the young child's brain function and reward-seeking behaviors could provide clues about whether antisocial behavior, violence, and aggression might develop later?

Two papers from Rebecca Waller of the University of Pennsylvania, Samuel Hawes of Florida International University (FIU), and colleagues explored this question, specifically in regard to children who also display callous-unemotional (CU) traits, typically characterized by a lack of empathy, reduced sensitivity to others' emotions, and a lack of guilt around breaking rules.

"Early behavior problems really concern parents," says Waller, who runs the Emotion, Development, Environment, & Neurogenetics Lab at Penn. "The broad idea with this research was to see whether there are differences in the brain at an early age, before the more severe types of delinquency have started."

Using data from the National Institutes of Health's Adolescent Brain Cognitive Development (ABCD) Study, which started in 2015 and will follow about 12,000 9- to 11-year-olds for a decade, the researchers first looked at gray matter volume in the brain. They found that compared to typically developing children, those with disruptive behavior disorders had less gray matter in the amygdala and hippocampus, areas associated with processing emotion and forming memories.

The work, which Waller and Hawes published in *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, suggests that early behavior problems do show up in the brain, often regardless of the presence or absence of CU traits.

In a second paper, published in the *American Journal of Psychiatry*, the researchers focused on reward behavior, specifically brain function as ABCD Study participants anticipated and then received a reward. They found that relative to typically developing youth, those with behavioral disorders, including those with CU traits, had decreased activity in the brain's reward network while awaiting their prize but increased brain activity once they obtained it.

"A primary goal of this research," says Hawes, an FIU research assistant professor and co-investigator on the ABCD Study, "is to identify neural risk markers that can be used to inform personalized intervention and treatment efforts."

Analyzing gray matter

Waller has been using neuroimaging in her work for seven years. "The brain tells us something about what's going on with these kids that we couldn't learn just by observing their behavior, that we couldn't see from just watching them," she says.

In 2016, researchers at the University of Birmingham in the United Kingdom conducted a meta-analysis of 13 studies looking at how gray matter volume in the brain relates to conduct disorders. Waller and Hawes wanted to take a similar approach, this time using the larger sample size and younger age group in the ABCD Study and broadening the focus to include CU traits.

They took the 2016 meta-analysis as a starting point, selecting 11 regions in different parts of the brain whose functions relate to emotion processing, learning, and language. They also accounted for race and ethnicity, socioeconomic status, IQ, and sex, as well as anxiety and attention-deficit/hyperactivity disorder, the latter of which has been linked to more severe conduct disorders.

With study parameters in place, they analyzed the data to determine whether there were any differences in gray matter volume between typically developing children and those with early behavior problems, both with and without CU traits.

"We didn't find as many differences as we thought we would," Waller says. "But, relative to the healthiest kids, those with zero symptoms of

anything, kids with behavioral problems had relatively less gray matter in several important brain areas. But we didn't find differences specific to CU kids."

In particular, they noticed less gray matter in the amygdala, a small region in the brain's temporal lobe that processes environmental stimuli, as well as in the hippocampus, which is located next to the amygdala and plays a role in memory and learning. The researchers published the findings in *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*.

"We can cautiously infer that something atypical in the structural development of these two regions seems to be implicated in this type of pathology," Waller says. "Potentially, having this aberrant structure might contribute to deficits in emotional response, leading to the kids showing the behaviors that we see—but there are several steps of inference there."

Anticipation versus reward

Building on the gray matter work, Waller and Hawes turned to what's happening in the brain as children respond to reward. "There's a long history in behavioral research suggesting that youth with severe behavioral problems have increased reward drive," Hawes says. "These youth often continue to engage in reward-driven behaviors even when faced with serious punishment and other severe consequences." Yet previous fMRI results in this area were mixed.

Beyond that, little prior work with this population had parsed what happens during two distinct temporal phases of reward processing. "Anticipation and receipt of a reward are associated with different aspects of reward-related decision-making," Hawes says. "We were interested in looking at how brain activity in youth with behavior

problems differed from that of typically developing youth." So, they used a monetary-incentive task administered to youth taking part in the ABCD Study.

While lying in an MRI machine, participants were shown one of three colored shapes—a pink circle, yellow square, or blue triangle—signaling that they might win or lose money (20 cents or $5) or that nothing at all would happen. After a brief delay, they then saw a target, again one of the colored shapes. To win money or avoid losing it, they had to respond by pressing a button within a certain timeframe. Shortly thereafter, a message told participants their outcome. Each participant completed the process several times across multiple trials.

"At the beginning of each trial the participant sees how much money they could win. Once the target is presented and they press the button, there's a moment when they anticipate that they're going to be told they've won," Waller says. "Then they get feedback on the screen saying, 'You've won $5' or 'You've won nothing' or 'You've lost.' That's the moment of receipt, so there's separation in time between the feeling that they're going to win and when they're told they've actually won."

From these trials, the researchers garnered that relative to healthy children, those with behavioral disorders showed decreased brain activity when anticipating a reward and increased brain activity once they received it. This was particularly pronounced in the subset of youth with a behavioral disorder and CU traits. These findings they published in the *American Journal of Psychiatry*.

"This matters in terms of how we think about working with children in any number of settings," Hawes says. "Associations between environmental cues and rewards represent a key aspect of learning. Insight into how this process unfolds is essential, not only for understanding healthy development versus challenges to normal

socialization and development but also for shaping behaviors in more positive ways."

It also means that different children may require different interventions. "Not all kids with conduct problems are the same," Waller says. "There are some important subgroups with different things going on at the neural level who might need different treatment options."

Among other aspects, future work will analyze what's happening in the brain when losses occur—the yellow square in the monetary-incentive experiment. It's all with an eye toward understanding whether what's seen in the brain at age nine or 10 indicates the potential for risky behaviors down the line. Ultimately, the researchers say, it will help to develop novel treatments for conduct problems informed by what's known about brain function and structure in these disorders.

More information: Samuel W. Hawes et al. Reward Processing in Children With Disruptive Behavior Disorders and Callous-Unemotional Traits in the ABCD Study, *American Journal of Psychiatry* (2020). DOI: 10.1176/appi.ajp.2020.19101092

Rebecca Waller et al. Disruptive Behavior Problems, Callous-Unemotional Traits, and Regional Gray Matter Volume in the Adolescent Brain and Cognitive Development Study, *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging* (2020). DOI: 10.1016/j.bpsc.2020.01.002

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