Prenatal cannabis exposure and its lasting impact on memory

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Professors Miranda Reed from Auburn University and Vishnu Suppiramaniam from Kennesaw State University have studied how prenatal cannabis exposure affects brain development and cognitive functions, including memory

As cannabis prohibition diminishes globally, its use has become increasingly common and accepted. Researchers are now examining the effects on vulnerable groups, including pregnant women. Notably, cannabis is one of the most frequently used substances during pregnancy, prompting significant concerns about its impact on unborn children and potential long-term consequences. Professors Miranda Reed of Auburn University and Vishnu Suppiramaniam of Kennesaw State University have investigated how prenatal cannabis exposure can influence brain development and cognitive functions, such as memory.

The hippocampus, a small brain structure, is essential for memory storage and formation. It plays a key role in ‘spatial memory,’ which helps us remember and navigate our surroundings, and ‘contextual memory,’ which involves recalling specific details of past experiences. Memory formation and recall in the hippocampus rely on synaptic plasticity, the ability of synapses (connections between neurons) to strengthen or weaken based on usage. Strengthening synapses, known as long-term potentiation, is essential for creating new memories, while weakening synapses, called long-term depression, are involved in forgetting information.

Our research investigates the impact of prenatal cannabinoid exposure (PCE) on hippocampal synaptic plasticity and memory formation. To simulate the effects of human cannabis use during pregnancy, the research team exposed pregnant rats to cannabinoids. As the offspring matured into adolescents, the researchers evaluated their memory and learning abilities. These assessments included tests to see if the rats could remember an unpleasant stimulus, like a mild electric shock, to gauge contextual memory. Additionally, the rats performed a water maze task to evaluate spatial memory.

Deficits in hippocampal-dependent memory

Interestingly, adolescent rats exposed to cannabinoids before birth showed significant deficits in hippocampal-dependent memory. But how does this happen? Cannabinoids interact with the brain through structures called cannabinoid receptors, such as the CB1 receptor, which is present throughout the brain, including the hippocampus. When a pregnant woman uses cannabis, cannabinoids like THC can cross the placenta and reach the developing fetal brain, potentially affecting brain development.

A key discovery of the study centered on the neurotransmitter glutamate, which plays a crucial role in learning and memory. Neurotransmitters are chemicals released into synapses, facilitating communication between neurons in the brain. Glutamate is a prevalent excitatory neurotransmitter, meaning it typically enhances the activity of the neurons it interacts with. In the hippocampus, glutamate receptors, such as GluN2A and GluN2B, are integral to synaptic plasticity. Maintaining a proper balance between these receptors is essential for normal memory function.

The study revealed that prenatal cannabinoid exposure (PCE) in rats disrupted this delicate balance. Exposure to cannabinoids altered the activity of GluN2A and GluN2B receptors, which in turn affected synaptic transmission. Essentially, the brain's ability to strengthen synaptic activity – a critical process in learning and memory – was compromised. This disrupted glutamate signaling in adolescent rats exposed to cannabinoids before birth helped explain their memory impairments.

Structure of neurons altered

Moreover, PCE appeared to alter the structure of the affected neurons. The rats exposed to cannabinoids prenatally showed reduced levels of a protein called polysialylated-neural cell adhesion molecule (PSA-NCAM). This protein influences synaptic growth and structure and plays a significant role in hippocampal development during fetal growth. PSA, or polysialic acid, is a special component of NCAM proteins that significantly affects their function. With lower levels of PSA-NCAM in the brains of PCE rats, their synapses were less capable of reinforcing neural activity through synaptic plasticity, impairing their ability to form new memories.

Is it possible to treat PCE-induced memory deficits?

Encouragingly, the researchers found that it might be possible to treat PCE-induced memory deficits despite the neural changes likely beginning long before the rats reached adolescence. Treating the rats with PSA helped restore their memory function, suggesting that increasing PSA-NCAM levels in the hippocampus could be a viable treatment option for children exposed to cannabis in the womb. Assuming similar mechanisms apply to humans, such treatments might one day help these children regain some cognitive abilities. However, further research is needed to determine whether these processes are identical in humans and how these mechanisms can be safely targeted with drug treatments.

Regardless of whether PCE-induced cognitive impairment is ultimately treatable, this study serves as a cautionary tale for pregnant women considering cannabis use. Prenatal exposure can have significant and lasting effects on memory and learning. Like any intoxicating substance, cannabis carries risks that should be understood before making the choice to consume it.

Future of prenatal cannabis exposure research

We have demonstrated that cannabis exposure can profoundly impact the developing brain's ability to create and retain memories. By uncovering some of the complex molecular mechanisms behind these effects, the study also offers hope for future treatments. Notably, PSA-NCAM emerged as a key player in both PCE-induced memory impairment and the potential recovery of cognitive function as a treatment modality.

As cannabis use becomes more widespread globally, it is crucial that research continues to explore its effects on vulnerable populations. This will enable potential users to make informed decisions about their health and that of their children. Our work is a vital step in this ongoing journey.

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