

Food insecurity has lasting impacts on the brains and behavior of mice

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Credit: martha sexton/public domain

While food insecurity is a problem for a growing segment of the U.S. population—made even worse by the coronavirus pandemic—few

studies have looked at the effect that feast or famine has on the developing brain in isolation from other factors that contribute to adversity.

A new study by neuroscientists at the University of California, Berkeley, simulated the effects of [food](#) insecurity in juvenile [mice](#) and found lasting changes later in life.

"We show that irregular access to food in the late juvenile and early adolescent period affects learning, decision-making and [dopamine neurons](#) in adulthood," said Linda Wilbrecht, UC Berkeley professor of psychology and member of the Helen Wills Neuroscience Institute.

One key difference in behavior involved cognitive flexibility: the ability to generate new solutions when the world changes.

"Mice searching for rewards might be inflexible, sticking to only one strategy even when it no longer yields a reward, or they might be flexible and quickly try out new strategies. We found that the stability of the food supply mice had when they were young governed how flexible they were under different conditions when they were grown up," she said.

Epidemiological studies have linked food insecurity in children and adolescents with weight gain in later life, as well as learning problems and lower scores in mathematics, reading and vocabulary. But these studies are confounded by other poverty-related issues, such as maternal depression and environmental stressors. The new study was designed to look at the developmental and behavioral impacts of food insecurity in a controlled setting not possible using [human subjects](#).

The study has implications for humans. Policymakers acknowledge the importance of good nutrition in [early childhood](#) through [high school](#), with federally-funded free or reduced-price breakfast and lunch

programs available in schools throughout the United States. The federal Supplemental Nutrition Assistance Program (SNAP) also provides benefits to supplement the food budget of needy families. For families living paycheck to paycheck, these food programs have demonstrated effects—in particular, boosted performance in school and rates of graduation.

But there may be times when kids cannot access food programs, such as during summer vacation. Programs may also inadvertently create a feast and famine cycle when benefits are distributed with weeks between payments, potentially leaving impoverished families unable to afford food at the end of each payment cycle. According to a recent report from the U.S. Department of Agriculture, 6.2% of households with children—2.3 million households total—were food insecure in 2021.

"I think that we have to understand that even transient food insecurity matters, the brain doesn't just catch up later. Food insecurity can have long-term impacts on how someone's brain functions," Wilbrecht said. "The ability to learn and make decisions is something that's developing during childhood and adolescence, and we are seeing how these critical skills are impacted by access to food. Access to food is something that we can address in this county. Feeding and benefits programs exist, and we can make them better by making access to benefits or food more reliable and consistent. Supporting [brain development](#) is a good reason to support food programs."

The research, conducted with UC Berkeley faculty members Helen Bateup, Stephan Lammel and their lab colleagues, will appear in an upcoming print edition of the journal *Current Biology*. It was posted online July 20.

Flexibility under changing rules

Wilbrecht and her colleagues, including Robert Wood Johnson Foundation Health and Society Scholar Ezequiel Galarce, mimicked human food insecurity in mice by delivering food on an irregular schedule while still allowing enough food to maintain safe body weight. This food regimen began a week before puberty onset in mice, equivalent to late childhood in humans, and continued for 20 days through the equivalent of late teen ages in mice. Another group of mice was offered food whenever they wanted it.

They then tested cognition in adulthood using foraging tasks where mice searched a changing environment for rewards. For example, a behavior—in this case, learning which odor led to the Honey Nut Cheerios—might be successful for a short time, but not forever. A second odor now predicted where the reward was hidden.

The well-fed and food-insecure mice were tested as adults in both certain and uncertain settings, with noticeable differences in cognitive flexibility. Food-insecure mice were more flexible in uncertain situations than were well-fed mice, while well-fed mice were more flexible in more stable situations.

"You would have to test in the field to see how these different flexibility profiles affect survival," she said. "The findings are nuanced, but hopeful, because we identify both gain and loss of function in learning and decision-making that are wrought by experience of scarcity."

While the effect of food insecurity on cognition in male mice was robust, female mice showed no effect on cognition.

"This is one of the most robust behavioral effects we've ever seen when we've been modeling adversity," Wilbrecht said.

Food insecurity had other decidedly negative effects in female mice,

however. Those females who were food insecure when growing up tended to become overweight when given unrestricted food in adulthood, something mirrored in humans who've grown up with [food insecurity](#). Male mice showed no such effect.

Doctoral student Wan Chen Lin and researchers in the Bateup and Lammel labs also looked at the brain's reward network, which is governed by the [neurotransmitter dopamine](#), and found changes there, as well, in male mice.

"We found that the neurons in the dopamine system, which is critical for learning, decision-making and reward-related behaviors, like addiction, were significantly altered in both their inputs and their outputs," Wilbrecht said. "It suggests there are more broadscale changes in the learning and decision-making systems in the brain."

For example, the researchers saw changes in the synapses of dopamine neurons that project to the nucleus accumbens and also found changes in dopamine release in the dorsal striatum. These dopamine neurons have been shown to play a role in learning and [decision-making](#) in numerous other studies.

The researchers are continuing their studies of food-insecure mice to determine if they are more susceptible as adults to addictive behaviors, which are associated with the dopamine network.

More information: Wan Chen Lin et al, Transient food insecurity during the juvenile-adolescent period affects adult weight, cognitive flexibility, and dopamine neurobiology, *Current Biology* (2022). [DOI: 10.1016/j.cub.2022.06.089](https://doi.org/10.1016/j.cub.2022.06.089)

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