Medical Xpress

Study reveals how the brain overcomes its own limitations

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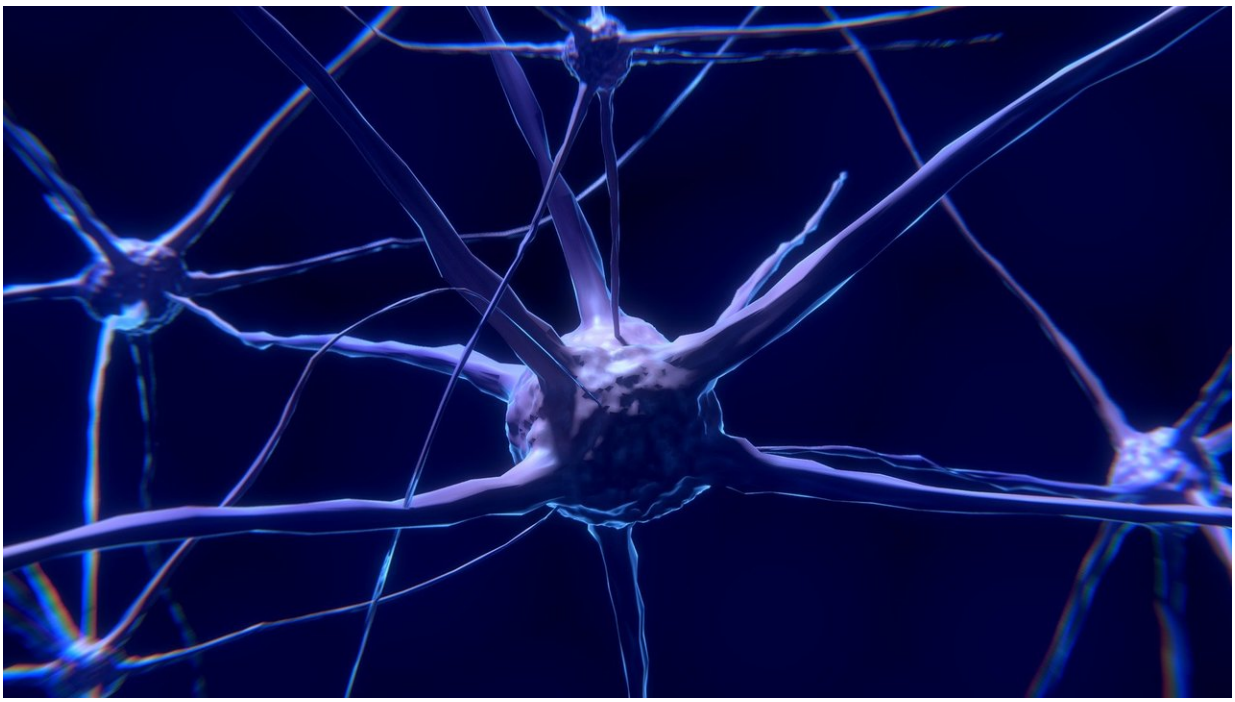

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Imagine trying to write your name so that it can be read in a mirror. Your brain has all of the visual information you need, and you're a pro at writing your own name. Still, this task is very difficult for most people. That's because it requires the brain to perform a mental transformation that it's not familiar with: using what it sees in the mirror to accurately guide your hand to write backward.

MIT neuroscientists have now discovered how the brain tries to compensate for its poor performance in tasks that require this kind of complicated transformation. As it also does in other types of situations where it has little confidence in its own judgments, the brain attempts to overcome its difficulties by relying on previous experiences.

"If you're doing something that requires a harder mental transformation, and therefore creates more uncertainty and more variability, you rely on your prior beliefs and bias yourself toward what you know how to do well, in order to compensate for that variability," says Mehrdad Jazayeri, the Robert A. Swanson Career Development Professor of Life Sciences, a member of MIT's McGovern Institute for Brain Research, and the senior author of the study.

This strategy actually improves overall performance, the researchers report in their study, which appears in the Oct. 24 issue of the journal *Nature Communications*. Evan Remington, a McGovern Institute postdoc, is the paper's lead author, and technical assistant Tiffany Parks is also an author on the paper.

Noisy computations

Neuroscientists have known for many decades that the brain does not faithfully reproduce exactly what the eyes see or what the ears hear. Instead, there is a great deal of "noise"—random fluctuations of electrical activity in the brain, which can come from uncertainty or ambiguity about what we are seeing or hearing. This uncertainty also comes into play in social interactions, as we try to interpret the motivations of other people, or when recalling memories of past events.

Previous research has revealed many strategies that help the brain to compensate for this uncertainty. Using a framework known as Bayesian integration, the brain combines multiple, potentially conflicting pieces of

information and values them according to their reliability. For example, if given information by two sources, we'll rely more on the one that we believe to be more credible.

In other cases, such as making movements when we're uncertain exactly how to proceed, the brain will rely on an average of its past experiences. For example, when reaching for a light switch in a dark, unfamiliar room, we'll move our hand toward a certain height and close to the doorframe, where past experience suggests a light switch might be located.

All of these strategies have been previously shown to work together to increase bias toward a particular outcome, which makes our overall performance better because it reduces variability, Jazayeri says.

Noise can also occur in the mental conversion of sensory information into a motor plan. In many cases, this is a straightforward task in which noise plays a minimal role—for example, reaching for a mug that you can see on your desk. However, for other tasks, such as the mirror-writing exercise, this conversion is much more complicated.

"Your performance will be variable, and it's not because you don't know where your hand is, and it's not because you don't know where the image is," Jazayeri says. "It involves an entirely different form of uncertainty, which has to do with processing information. The act of performing mental transformations of information clearly induces variability."

That type of mental conversion is what the researchers set out to explore in the new study. To do that, they asked subjects to perform three different tasks. For each one, they compared subjects' performance in a version of the task where mapping sensory information to motor commands was easy, and a version where an extra mental transformation was required.

In one example, the researchers first asked participants to draw a line the same length as a line they were shown, which was always between 5 and 10 centimeters. In the more difficult version, they were asked to draw a line 1.5 times longer than the original line.

The results from this set of experiments, as well as the other two tasks, showed that in the version that required difficult mental transformations, people altered their performance using the same strategies that they use to overcome noise in sensory perception and other realms. For example, in the line-drawing task, in which the participants had to draw lines ranging from 7.5 to 15 centimeters, depending on the length of the original line, they tended to draw lines that were closer to the average length of all the lines they had previously drawn. This made their responses overall less variable and also more accurate.

"This regression to the mean is a very common strategy for making performance better when there is uncertainty," Jazayeri says.

Noise reduction

The new findings led the researchers to hypothesize that when people get very good at a task that requires complex computation, the noise will become smaller and less detrimental to overall performance. That is, people will trust their computations more and stop relying on averages.

"As it gets easier, our prediction is the bias will go away, because that computation is no longer a noisy computation," Jazayeri says. "You believe in the computation; you know the computation is working well."

The researchers now plan to further study whether people's biases decrease as they learn to perform a complicated task better. In the experiments they performed for the *Nature Communications* study, they found some preliminary evidence that trained musicians performed

better in a task that involved producing time intervals of a specific duration.

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