Unexpectedly big wins improve two kinds of memory

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Researchers have discovered that instances in which outcomes are better than expected—finding an unexpectedly good parking spot, for example, or spotting a $20 bill on the sidewalk—improves memories of specific

events. This is in addition to the long-established role that unexpectedly good outcomes have in influencing what are called integrated memories.

Remembering where you parked your car this morning is an example of specific episodic memory, while remembering good places to park in general is an example of an integrated memory.

"Our new finding is that incidental, irrelevant details from specific events—whether the tree I parked beside was a spruce or a maple—are also strengthened by unexpectedly good outcomes," said Matt Nassar, an assistant professor of neuroscience at Brown University and the study's corresponding author. "This finding has potential ramifications for how people with depression remember things, which is a focus of our future research. We'd like to be able to develop potential therapies for patients, but we're not there yet."

Since reward-prediction error—the formal name for that instances in which outcomes are better than expected—involves the release of the neurotransmitter dopamine in a specific brain area, the findings unveil new implications for treating depression, which has been linked to imbalances in key neurotransmitters including serotonin, norepinephrine and dopamine.

This means that someone with depression may not encode positive memories as effectively as an individual without depression, said Nassar, who is affiliated with Brown's Carney Institute for Brain Science. And when someone with depression looks back on past events, they might remember the negative events better than the positive events, which has the potential to spur a negative feedback loop, he said.

For study co-author Daniel Dillon, a researcher at McLean Hospital and Harvard Medical School, exploring the clinical connection between depression and memory is the primary research focus. The findings were

published on Monday, May 6, in the journal *Nature Human Behaviour*.

The research team's experiment comprised both a learning phase and a memory phase. For each round during the learning task, participants were shown a point value between 1 and 100, shown an image of a living or inanimate object, given the option to gamble on whether they would win the "coin-flip" by playing or passing, and then informed if they won or lost. If the participants lost the round, they lost 10 points; if they won the round, they received the previously conveyed points for the round. At the end of 160 rounds, participants' point totals were converted into a small amount of money, typically less than $5, Nassar said.

After the learning phase, participants were tested on their memory for the specific images they saw. The researchers found that participants were much better at remembering the specific image from rounds where they had a high likelihood of winning compared to high-value rounds or rounds they chose not to play. They were not informed that the specific image would be important. They were only told that the general category of the object (living or inanimate) would determine the probability they would win.

The experiment, which was partly the senior thesis project of Anthony Jang, an undergraduate who earned his bachelor's degree from Brown in 2015, included more than 250 participants recruited through Amazon Mechanical Turk, a platform for crowdsourced work that serves as a convenient option for recruiting many participants for experiments.

While some of the participants paid close attention to the value of each round and the probability of winning for each category, the results of other participants were far more random, Nassar said. The people who paid more attention during the gambling rounds did better during the memory portion of the experiment, which he was able to incorporate into his computational model of the participants' memories.

The researchers also found that participants were equally good at remembering specific images from high value rounds they won when they were tested 5 minutes after the learning task as when they were tested 24 hours later, after a period of memory consolidation. That finding that surprised Nassar.

"There's a really nice study from 2010 by Ingrid Bethus and colleagues where they clearly show in rodents that dopamine doesn't help memory performance shortly after the learning experience, but it has a huge effect at 24 hours," Nassar said. "We spent quite a bit of time trying to rectify our results with that study because they don't line up. The tasks were quite different, given the two species involved. In the future, we hope to get a task that is more comparable to figure out the source of the timing differences."

In addition to attempting to determine the source of the memory consolidation differences, members of the research team are planning to rerun the experiment with participants with depression to see if they exhibit any memory differences.

Also, Nassar will continue his work determining the neural circuits involved in connecting reward-prediction error to episodic memories as well as untangling the interaction between the episodic memory system and integrated memory system.

More information: Positive reward prediction errors during decisionmaking strengthen memory encoding, *Nature Human Behaviour* (2019). DOI: 10.1038/s41562-019-0597-3 , www.nature.com/articles/s41562-019-0597-3

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