

Thanks for the Memories



Researchers explore the failings and fortitude of working-memory capacity.

by JANE M. SANDERS

Under stress or with a lack of sleep, people with a high working-memory capacity (WMC) can look like those with a low WMC.

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If you've ever driven straight home when you intended to do an errand on the way, you've experienced the kind of habitual behavior that can result in everyday forgetfulness or, in the worst case, tragedy, when circumstances require you to depart from routine to complete a task.

Studies of such memory lapses have revealed similar brain mechanisms at work, whether we forget to pick up milk at the grocery store, or fail to drop off sleeping children at daycare and inadvertently leave them to suffocate in a hot car.

"How do you act according to your goals when your habits run the show?" asks Professor Michael Kane, who collaborates on research with Georgia Institute of Technology Professor of Psychology Randy Engle. "We can get through a lot of our day on autopilot based on past experience. When we're forced to rely on a

non-habitual response, we can get ourselves into a lot of trouble when the habitual task captures our attention. There are important individual differences in the extent to which people can act according to their goals and not their habits.”

These individual differences occur, at least in part, in working-memory capacity (WMC). It is the ability to maintain information in a highly active, accessible state despite competition for one’s attention, and to then use the information in normal activities, Engle explains.

Engle and Kane have found that people with a greater WMC are generally more successful in overriding habitual behaviors when they must. It’s not entirely clear whether this ability is innate, Kane says. But the researchers have discovered a strong correlation between WMC and “fluid intelligence,” or inherited mental ability.

“We do know that working memory capacity is fairly stable,” Kane says. “But under certain conditions, people with a high working-memory capacity can look like those with a low WMC. Those conditions include having too much to do, being stressed out, being sleep-deprived or intoxicated.”

Such conditions may explain some cases of parents forgetting sleeping children in the back seat of their cars. In a California case last year, a young college professor’s son suffocated after the father forgot to drop off his child at daycare on his way to work. The father was fatigued from loss of sleep, and he was not the usual person who took the child to daycare. He drove down the road he normally took to work and drove past the daycare center. His behavior was guided by his habit, Engle says. Authorities did not charge him with a crime, but other parents have faced prosecution in similar cases. About 40 such incidents occur annually in the United States.

“Thinking of my own experiences as an active father of two children makes me sympathetic with this (California) father,” Engle says. “Being a father is the most important thing in my life, even though my children are grown now. But I also love my work, and I really get into it. I can’t tell you how many times I’ve gotten a call from the school to tell me to come pick up my children. I just got distracted.

“... We all forget things,” Engle adds. “They’re just usually not so important as a sleeping child in the back seat of the car.... This is a worst-case scenario of the loss of our immediate goal from working memory, and our behavior comes under habitual control.”

Engle and Kane have conducted numerous experiments to learn more about the brain mechanisms related to working-memory capacity. They



give study subjects a variety of tests to measure WMC. These tests strongly predict performance on cognitive tasks closely related to real-world activities, such as reading, writing, language comprehension, reasoning and problem-solving, Engle says. In the tests, subjects receive items to recall, while they must also perform another attention-demanding task that is interjected between receiving the items for recall.

To assess WMC, Engle’s lab frequently uses a reading-span task in which subjects read aloud a series of sentences, each followed by an unrelated word. Ultimately, subjects are scored on their ability to recall the list of unrelated words. In an operation-span task, subjects read aloud a series of equation-word strings such as “Is $(4 \times 2) + 3 = 6$? Yes or No? DOG.” Subjects answer whether the equation is correct and then read the capitalized word aloud. Again, researchers score subjects based on correct recall of the words.

College students with a low WMC typically succeed in correctly recalling two words, but not three. People with a high WMC remember four or more.

Engle and Kane also use an “antisaccade” task — which tracks rapid eye movements from one fixed point to another — to test the relationship between WMC and a person’s ability to avoid habitual responding. Subjects fixate in the middle of a computer screen, but must respond to target information briefly presented to one side or the other of the display. Just before the target appears on one side, an attention-attracting cue flickers on the other side. But subjects must try not to move their eyes toward the flickering cue. In the control condition of this test, the cue occurs on the same side of the display as the subsequent target.

Experiments show no difference between low- and high-WMC subjects in the control condition. In the antisaccade test, both groups make more errors by looking toward the flickering cue, but subjects with low WMC make many more habitual errors.

Forgetting to remove a sleeping child from the back seat of a car is a worst-case scenario of the loss of an immediate goal from working memory, researchers say.

Working-memory capacity is the ability to maintain information in a highly active, accessible state despite competition for one’s attention.



PHOTO BY GARY MEEK

Students in Professor Randy Engle's lab use an "antisaccade" task — which tracks rapid eye movements from one fixed point to another — to test the relationship between working-memory capacity and a person's ability to avoid habitual responding.

Lower Right: Georgia Institute of Technology Professor of Psychology Randy Engle leads research on working-memory capacity — the ability to maintain information in a highly active, accessible state despite competition for one's attention, and to then use the information in normal activities.

Below: An "antisaccade" task tracks rapid eye movements from one fixed point to another to test the relationship between working-memory capacity and a person's ability to avoid habitual responding.

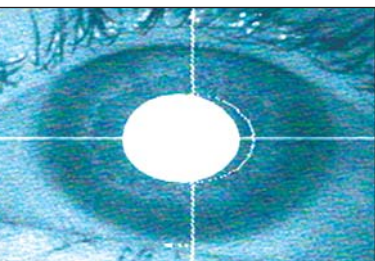


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Researchers note that age affects performance on these tests of WMC. Young children and older adults typically don't perform as well as young adults.

Engle and another collaborator have found that WMC is important under novel conditions and that expertise may reduce the effects of a limited WMC.

The researchers questioned men and women with varying levels of WMC, age and knowledge of baseball after the subjects listened to realistic, but simulated radio broadcasts of baseball games. Subjects followed the outcome of several players as they came to bat. For example, they had to explain that the first batter went to first base, and then the second batter hit a double. The third batter walked. So where is the second batter?

The researchers found a strong correlation between high WMC and good performance on the test.

"Also, there was a question about whether a high level of knowledge of baseball would insulate someone from the negative effects of age on performance," says Engle's collaborator Zach Hambrick, a Georgia Tech alumnus and assistant professor at Michigan State University. "We found this was not the case. The older adults benefited from their prior knowledge of baseball as much as the younger subjects, but that didn't make up the age difference in memory. So there's no way around it — aging causes a decline in memory."

In a recent follow-up study, Hambrick explored the acquisition of new knowledge in a naturalistic setting. He tracked people across an entire basketball season to determine what they learned about the game. Again, subjects had varying levels of WMC and knowledge of the sport.

"The main similarity (between the studies) was that the major predictor of the ability to acquire new information was what you already knew," Hambrick notes. "Having some knowledge of what you're trying to learn about gives you a scaffolding or framework. Knowledge begets knowledge."

But in the major difference between the two studies, WMC did not contribute to the amount of new knowledge a person acquired. "This was a different situation, though," Hambrick adds. "People were learning at their own pace; it was not a timed

task. They were learning over long period.... It may be that there are different types of learning situations. Some call upon working-memory capacity, and others don't."

As researchers continue to study working memory, they are quick to note that WMC is only one factor that can affect a person's success. For example, Engle and Kane found only a modest correlation between college students' grade point averages and their WMC.

"Working-memory capacity is raw intellectual power," Kane explains. "But all kinds of things — motivation, habits, knowledge and peers — affect a person's success in school and on the job."

Having a high WMC does make you better at doing certain things than others. "A high working-memory capacity is an advantage for reasoning the solution to novel problems, and that's a real benefit," Kane adds. "But how often in the course of a day is this required?"

For those who know or suspect they have a low WMC — or even busy, stressed-out people with a high WMC — the researchers suggest using a reminder system. For example, if you're breaking routine and taking your child to daycare, you might put your briefcase in the back seat so you have to look there before getting out of the car.

"Trigger a remembering of a goal," Kane adds. "Use external memory aids. Write it down. We are all limited in how much we can think about at any one time. We can often use the environment to support remembering what we need to think about." **RH**

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PHOTO BY GARY MEEK

Memory and attention research provides insight to real-world issues

Whether in school, on the job or on the front lines, a person's working-memory capacity (WMC) may affect their performance, according to researchers at Georgia Tech and elsewhere. So here are some real-world situations where research in this field may provide insight.

■ WMC studies are important to the U.S. Air Force – which funds research by Georgia Tech Professor of Psychology Randy Engle — as it evaluates individuals for various jobs. For example, a high WMC is typically associated with fast decision-making and an ability to track many different events, such as is required from pilots and air traffic controllers.

The military is also interested in the effects of fatigue on WMC. "The ability to maintain focus is exceedingly important," Engle says, "especially for completing complex tasks after a person has been awake for hours and hours." Bomber pilots, for example, were awake for 30 to 60 consecutive hours (with the help of caffeine) during the war in Iraq.

■ In the workplace, employers might want to predict a person's performance on the job. The employer would probably consider a person's prior experience and intelligence test scores. But the employer might also want to know a person's general information-processing capability, which is reflected in a WMC test score, the researchers note. Also, many stress-related events in the environment will lead to a reduction in WMC, which, in turn, will hurt complex cognition, Engle adds.

■ WMC research might also benefit engineers designing an aircraft cockpit that minimizes demands on working memory, suggests Michael Kane, a University of North Carolina at Greensboro professor who collaborates with Engle. Sound cues, for example, might signal when certain decisions need to be made.

■ Carmakers might incorporate technology to prevent parents from forgetting a sleeping child in the back seat. "They might use heat or movement detection devices," Kane says. "If the car is off and locked, an alarm might go off if a body is detected by heat or vibration."

■ WMC research offers hope of early detection of Alzheimer's disease, according to research by Engle's former graduate student Virginia Rosen. She tested two groups of middle-aged individuals — one consisting of carriers of the gene associated with early onset of Alzheimer's and the other, non-carriers. The carriers, who showed no symptoms of the disease, performed significantly worse on a WMC test than did the control group. This suggests that WMC measures are unusually sensitive to early changes in the ability to control attention associated with Alzheimer's, the researchers reported in 2002.

— Jane M. Sanders



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A high working-memory capacity is typically associated with fast decision-making and an ability to track many different events, such as is required from pilots and air traffic controllers.