Exploring how the human brain stores and preserves information

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Research into how the human brain stores information could lead to

treatments for people who struggle with everyday tasks.

Professor Jan Buitelaar, an expert in neurodevelopmental illnesses, is intrigued by a possible link between attention deficit hyperactivity disorder—or ADHD—and memory.

While genes play a big part in ADHD, Buitelaar thinks the recordkeeping part of the brain known as "working memory" does too. Working memory holds a limited amount of information such as a street address or phone number for a brief time while providing a fundamental base for higher mental processes like decision-making.

Storage test

"When a teacher explains something to a pupil, the child is expected to keep much of that information active in their mind and also to integrate it with facts and knowledge stored elsewhere in the brain," said Buitelaar, who conducts research at the Radboud University Medical Center in the Netherlands. "These functions are carried out by working memory."

Now, a new project is seeking to shed new light on links between mental illnesses such as ADHD and working memory.

While ADHD affects millions of people in Europe, it is far from being the only neurological condition associated with working-memory deficits.

"Working memory can be compromised in many disorders—from schizophrenia to Alzheimer's disease and Parkinson's—but also in healthy aging," said Dr. Bernhard Spitzer, a cognitive neuroscientist at the Max Planck Institute for Human Development in Germany. "So understanding it better is very important."

Spitzer leads the EU project, which is called DeepStore and runs for five years through 2026.

Although working memory has very limited capacity—at any given time, it can accommodate just four to seven pieces of information—it is essential for normal human functioning and represents what Spitzer calls a "superpower."

Nimble wonder

When working memory underperforms, people lose track of what they did moments after doing it—for instance, forgetting that they put a towel into a gym bag straight after zipping it up.

"If your attention skills are weak, you have constant lapses in what enters your working memory," said Buitelaar. "So these connections are much harder to make."

The DeepStore team aims to lay the ground for better treatments for people with troubles in this area by expanding understanding of where and how the brain stores these memories. Until recently, conventional wisdom held that the working-memory system resided entirely in the brain's prefrontal cortex. Now it's known, albeit with limited detail, that many other parts of the brain are also involved.

"How storage of working memory is distributed in the brain still needs explaining," said Spitzer. "Getting to the bottom of this puzzle will take us an important step towards understanding the superpower of working memory."

The team believes the importance of working memory lies in its nimbleness—its ability to transform and reformat information.

"We now know it's highly adaptive and dynamic," said Spitzer. "For example, if I hold up a pen, you can store the information before your eyes in your working memory in myriad formats: as a photographic image, as an abstract concept linked to what you know to be the function of a pen or as an object that's being held at a certain angle. And your brain will be able to change the format according to the task the information is needed for."

The DeepStore team is using eye-tracking, functional brain scans and other non-invasive techniques for measuring brain activity and magnetic fields in people.

In a subsequent step, the researchers will look at data from electrodes implanted into the brains of non-human primates to decipher the neural underpinnings of working memory down to the single-cell level.

"By the end of our research, we hope to have a better understanding of the dynamics of working memory and how it provides us with just the right information at just the right time for whatever task is at hand," said Spitzer.

Knowing about and how

While some people struggle to retain transient information, others have trouble storing, preserving and retrieving data absorbed in the past.

Long-term memory is the focus of another research project.

Called MemUnited, it runs for two and a half years through May 2025 and is a collaboration between Ghent University in Belgium and Columbia University in the US.

The researchers aim to expand knowledge about the neural processes

shared by the brain's two primary systems supporting long-term memory: the "declarative" and "procedural" ones.

Declarative memory processes allow the conscious recall of facts and past events—the "knowing about." This covers both general knowledge such as scientific concepts and personal experiences.

Procedural memory processes support the retention of skills, habits and "muscle memory." This is the "knowing how" function that includes things like riding a bike or preparing a mug of coffee.

"People typically use procedural knowledge to make a cup of coffee and automatically select the necessary actions in the right order," said Dr. Nina Dolfen, a Belgian psychologist who runs MemUnited.

Overlapping opportunities

Until recently, experts thought the procedural and declarative memory systems operated independently and involved different parts of the brain.

But human brain scans over the past decade have shown that some neural processes are shared, with both systems tapping into the hippocampus—a major part of the brain associated with memory.

Nonetheless, little is known about the overlap.

"If these two memory systems interact with each other, it's possible that an intact brain process can work like a scaffold, supporting learning in an area where there's a deficit," said Dolfen.

Examples exist where one long-term memory type is trained to compensate for the other after a brain injury—for instance, a stroke.

Dolfen referred to the example of the steps involved in making a cup of coffee to illustrate the possible impact on the brain of people who have endured a stroke.

"They may not remember the order of these steps while retaining the ability to execute the individual actions necessary to complete the task," she said.

Dolfen held out the eventual prospect of helping such people by tapping into their declarative memory through visual cues, with each step of the process represented by a different image.

Because the research is still at the fundamental rather than any applied stage, examining healthy volunteers is the best way to study the overlap between the declarative and procedural memory systems.

Dolfen is conducting memory tests on 35 young, healthy volunteers while monitoring their brain activity using functional magnetic resonance imaging, or fMRI. Ultimately, she hopes scientists will use her results to take advantage of the ways these two types of long-term memory overlap.

"If we can find creative ways to give people back their independence after an injury, that would be great," Dolfen said.

More information:

- DeepStore
- MemUnited
- EU brain research and innovation