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Abstract: The article discusses the scientific research regarding artist Lonni Sue Johnson's amnesia and her apparent inability to create memories as of November 2013, focusing on scientists from Johns Hopkins and Princeton universities who are studying the extent of Johnson's brain damage, memory loss, and cognitive deficits. People with intellectual disabilities are addressed, along with viral encephalitis and traumatic brain injuries. Former medical research patient Henry Molaison is also mentioned.

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The Art of Memory

What scientists are learning from an artist who has lost her power of recall

When you first meet Lonni Sue Johnson, it takes a few moments to realize that something isn't quite right.

"Hello!" she says brightly, looking up in surprise, with an expression of pure delight on her face. "Would you like to see my drawings?" Her glee seems strangely childlike for a woman in her early 60s; she's just a little happier to see you than feels appropriate, given that you're a complete stranger. You might think for a moment that she suffers from an intellectual disability--what used to be called mental retardation.

But then she shows you the drawings. They're complex and finely executed, and they feature elaborate visual puns. She's obviously got a lively intelligence. The only odd note in the artwork--

stacks upon stacks of it--is that it tends to be richly decorated with letters of the alphabet and often includes lists of words, all beginning with the same letter or with letters in alphabetical order. You might be tempted to place her on the autism spectrum. But that makes no sense either, given the open joy she displays at connecting with people.

Leave the room for a moment and come back, however, and things become clear. "Hello!" she says brightly, as though she's never seen you before. "Would you like to see my drawings?" And if you leave again and return once more, she'll greet you the same way. Because as far as she knows, she never has seen you before.

Johnson is profoundly amnesiac. She's essentially unable to form new memories: some experiences are gone in seconds, others in minutes, but next to nothing endures. She can't bring up many old memories either. She recalls few episodes from her life and has little general knowledge about the world. She was in eighth grade when John F. Kennedy was shot, but if you show her a picture of him, all she knows is that he was a President.

Such cases of annihilated memory are very rare. Some are caused by traumatic brain injury; others, like Johnson's, are the result of viral encephalitis, which often kills its victims or leaves them comatose. But they're also extraordinarily valuable: by looking at how illness or injury robs people of memory, neuroscientists have an opportunity to gain insights into how it works when all is well.

For that reason, a team of scientists from Johns Hopkins and Princeton universities have been studying Johnson for the past four years, ramping up their efforts dramatically in the past two and recently submitting for publication the first of what will be many papers on her that will continue for the rest of her life. Once a month or so, the researchers show up at Johnson's mother's house in Princeton, N.J., or bring her to the brain-imaging center at the Princeton Neuroscience Institute for a battery of tests in an attempt to probe the extent of her brain damage and cognitive deficits and perhaps to contribute, albeit indirectly, to future treatments for Alzheimer's disease and other forms of memory loss.

Johnson is not the first person whose dramatically damaged brain has served as such a keyhole into the workings of memory. As long ago as the 1950s, a man named Henry Molaison, known in the medical literature only as H.M. until his death in 2008, received similar attention. Molaison's condition was a result of surgery to relieve severe epilepsy. After the operation, his seizures went away, but his memory did too--dooming him to spend the rest of his life in a perpetual now.

But Molaison was very different from Johnson. He had been an assembly-line worker with higher-than-average intelligence but no unusual talents. Johnson, by contrast, was a hugely successful commercial artist who drew covers for the New Yorker and supplied illustrations to TIME, the New York Times and dozens of other high-profile clients. She was an accomplished amateur violist and a private pilot, who bought a farm in upstate New York so she'd have her own landing strip.

Her musical ability is especially significant and serendipitous, gathering in multiple skills that rely on memory--the ability to practice and improve, to learn a composition by heart, to recognize musical

themes that recur from song to song. Music is the subject of the upcoming paper and is an area of Johnson's mind that investigators have only lately begun to address.

And Johnson has one other advantage over Molaison. She grew ill not in 1953--when Molaison had his surgery--but in 2007, the era of CT and PET scans and fMRIs, imaging technologies that allow scientists to observe the state and function of complex brain structures rather than just guessing at them from the outside.

With the help of the hardware and Johnson's willingness to sit still for so much study, science may be able to answer one other, more abstract question: What is it like to have lost so many memories about your life and the world? If who you are is an amalgamation, at least in part, of the things you've experienced--the people you've loved, the places you've lived, the tragedies you've endured--are you actually you at all when those things are wiped away? The self is ineffable, but it's also material, the product of neurochemicals sparking their way through living tissue. How we draw the line between those two dimensions--the biological and the experiential, the brain and the far less knowable mind--has kept philosophers awake for millennia. Johnson, with her profound damage to the material self, may help us better understand the immaterial one.

Fever in the Dark

Johnson's plunge through the memory rabbit hole began on New Year's Eve 2007, when her mother Maggi, now 95, and her sister Aline, 59, received an early-morning phone call telling them she had been rushed to the hospital and was at the brink of death. Aline and Maggi jumped in the car and drove more than 200 miles (320 km) just as a major snowstorm was winding down.

By the time they reached her, Johnson, then 57, had drifted off to sleep. When she awoke, her mother and sister were in the room. Says Maggi: "She looked around, her mouth gaping, as if she were wondering, 'What am I looking at?'" It was a week before they could be sure Johnson recognized her mother and another few days before she spoke her sister's name.

For the next six months or so, the pair followed Johnson from hospital to acute rehabilitation facility to subacute nursing unit, working alongside therapists to teach her how to walk again, talk again, feed herself. Over those long months, they also pushed her to resume drawing, one step at a time. "She could barely draw a line on her own for the first few months," says Aline. "So my mother invented games, such as drawing a shape and having Lonni Sue copy it."

It was no wonder Johnson was struggling so much. Brain scans revealed that her encephalitis had effectively destroyed her hippocampi, a pair of sea-horse-shaped structures deep in the brain's basement. It also did extensive damage to structures surrounding the hippocampus, including areas known as the perirhinal cortex and the parahippocampal cortex. That was very bad news since the job of the hippocampus is to consolidate short-term memories into permanent, long-term ones. If the hippocampus isn't there to do that work, everything starts over every few minutes.

The reason, explains Larry Squire, a professor of psychiatry at the University of California at San Diego, is that what seems like a single memory is actually many memories in different parts of the brain. The recollections you have of last year's Thanksgiving dinner, for example, consist of sights

and sounds and smells and tastes and deeper links to the people who were there, all of which are processed in different parts of the brain. It's the job of the hippocampus to act like the attentive host at a party making introductions among all those parts. "It's a common mistake to think that memories are initially in the hippocampus and then get shipped somewhere," says Squire. "They're never shipped. They're always somewhere else."

Given how small and tightly packed the brain's multiple structures are, a tiny bit of greater or lesser damage in any direction around a central lesion can have a powerful impact. Molaison had trouble retrieving memories of things he did leading up to his surgery, but he could easily call up cold facts--so-called declarative information--from his childhood, such as what town he came from and where he went to high school and who President Roosevelt was. For Johnson, these kinds of details have been lost. She recalls the layout of her childhood home and the name of her street and the fact that she used to fly a small plane--and little else. The difference may have to do with the damage to her perirhinal and parahippocampal cortices. Molaison suffered only partial loss of the former; Johnson has almost certainly lost significant parts of both.

The Long Crawl Back

The slow recovery Johnson has made offers other clues about how memory works. Months after she started painstakingly copying lines, Johnson began sketching without help. Eventually, says Aline, "the little people came back." Tiny human figures had been a hallmark of Johnson's pre-amnesia art. "It was one of the first indications that those images were still inside her head. If it weren't for the art, how would we know they were there?" But exactly where they'd been hiding or how they were flushed out remain unclear.

Equally mysterious is why Johnson can identify her pre-encephalitis drawings as her own, despite the fact that she can't identify even the world's most famous paintings except the Mona Lisa. "Whatever it is that allows her to recognize her own style is incredibly complex," says Johns Hopkins cognitive neuroscientist Barbara Landau, who works with Johnson. "I don't think we know how to characterize it."

They also can't explain why Johnson is so fixated on the alphabet. Nearly a year after the encephalitis struck, an acquaintance of Aline's wondered whether Johnson might enjoy doing word-search puzzles, in which hidden words are embedded in random grids of letters. As soon as Johnson got her hands on the books, she devoured them.

"All these pages, hundreds of pages," Aline recalls, "and when she got to the end, she asked with great urgency, 'What should I do?'" So she began creating her own puzzles, then incorporated the letters and wordplay into her art. Eventually, she had created a portfolio so large and oddly compelling that her artwork, both pre- and post-illness, was featured in exhibitions at Baltimore's Walters Art Museum and at the Morven Museum in Princeton.

Aline is convinced that the alphabet's familiar and immutable sequence has given her sister's life meaning in a world that must otherwise seem completely disjointed. "It makes sense," says Michael

McCloskey, another Johns Hopkins neuroscientist on the research team. "It structures her day and gives her something to hang on to."

Music, with its alphabetic and semimathematical structure, might have the same kind of ordering effect the letters do. Johnson retained her ability to play the viola and to read music, both of which involve unconscious memory--sometimes known as procedural or muscle memory. It was unclear, however, whether she could learn a new piece and improve over time. So Emma Gregory, a Johns Hopkins postdoctoral fellow on the research team, recruited a Johns Hopkins undergrad to compose something for Johnson. Then they put one sheet of music after another in front of her, some containing the entire piece, some with just passages. Time after time, Johnson would read the title, "Caprice," aloud and say, "Oh, that's made of cap and rice," solving a mini-word-search puzzle on the fly. Then, inevitably: "What language is that?"

But, says Gregory, "she absolutely did seem to learn the piece." Now the scientists are curious about whether she has retained other skills like driving a car or piloting a plane. Nobody is going to put her in a cockpit and send her flying. "You can go," said Landau, laughing, when the idea came up at a team meeting. "I'll watch from down below." But getting her into a flight simulator is not out of the question.

Ghost in the Machine

Johnson's sessions in the MRI scanner are as informal as the scientists and her family can make them. Princeton's Nicholas Turk-Browne and his colleague Sabine Kastner, an M.D. and a neuroscientist, supervise the work. They spend a few minutes chatting with Aline and Maggi as they make sure Johnson doesn't have anything metal in her pockets; then they use an airport-type security wand to double-check. As the tests progress, the scientists sit in a control room, explaining what they want her to do--and explaining again, with complete patience, when she forgets.

Many of the tests involve neural adaptation, in which Johnson is shown images in quick succession. In normal people, the brain grows familiar with the images, reacting less strongly to pictures that are repeated. That shows up as reduced activity in the visual cortex. In Johnson's case, the scientists expected that without a working hippocampus, learning of this kind would not happen if the repetitions occurred after a significant delay. But confounding expectations, it did, which means she is learning some other way. "That's a riddle we have to solve," says Kastner.

Ultimately, neuroscientists hope their memory research will lead to treatments for people with dementia or traumatic brain injury. At Toronto's Baycrest research hospital, for example, neuropsychologist Eva Svoboda is part of a team that uses smartphones and other technology to create a sort of artificial memory.

The program, known as Memory Link, takes advantage of the fact that many people with amnesia still have an intact procedural-memory system so they can learn the gestures and icons that let them navigate through a phone. "It's a huge, huge leap for patients," says Svoboda. "They can store virtually unlimited information, take pictures, write memos, set alerts to go off for medications or appointments."

As a result, studies by Svoboda and her colleagues have shown, many patients go from being utterly dependent on families and caretakers to taking some control of their own lives. "In some cases," she says, "spouses have been able to return to work, and patients have avoided moving into nursing homes." The advent of wearable technologies could bring even greater benefits, says Svoboda. A device called SenseCam, for example, developed by Microsoft Research and worn on a strap around the neck, takes photos automatically throughout the day. "Your spouse comes home and asks, 'What did you do today?'" says Svoboda, "and this camera has captured that."

Face-recognition software on a device like Google Glass could be even more useful. "Most of our patients," says Svoboda, "are unable to recognize people they've met since their injury." She imagines a scenario in which Glass figures out who someone is, searches Facebook and the patient's calendar and discreetly supplies all the information the patient needs to avoid an awkward situation. Using a smartphone or some other technology is not the same as restoring a person's memory, of course; it's comparable to providing glasses to someone who's nearsighted. Restoring memory function is more like LASIK--a true repair--but for the brain, that is years away, if it's even possible.

What's not possible is answering the inevitable question of what Johnson's life feels like. What sort of awareness does she have? "She's obviously aware of her own existence," says Kastner. "She's conscious. But we do not know exactly what that self-perception is. That would be a very interesting question to get at if one could."

But one can't--at least not by asking. Early in her illness, Johnson seemed aware of the gravity of her impairment, and it seemed to upset her greatly. Even now, she clearly knows something is missing. "I miss the life I had," she says, sometimes adding poignantly, "Do you know how much I miss flying?" But if you ask her about her memory problem, she responds emphatically, "There's nothing wrong with my memory."

Even if she could address her deficit, it's not clear how useful her perceptions would be, since words can go only so far in conveying mental state. The reassuring thing, Turk-Browne says, is that "Lonni Sue does seem happy. She's motivated, she's driven to do things that give her pleasure. She has an incredibly supportive family." Those are things much to be desired. Johnson has clearly lost an incalculable amount. But joy--even unremembered joy--is at least some compensation.

BEFORE

Johnson's artwork was playful, colorful and highly sought after; it was published in TIME and the New York Times as well as the New Yorker. Tiny human figures were one of her recurring motifs.

AFTER

Word puzzles aided Johnson's recovery, the alphabet's immutable form seeming to structure her world. Alphabetic wordplay is a big part of her current work; the tiny people are too.

PHOTO (COLOR)