The Creative Brain

By Roger E. Beaty, Ph.D.

Our author's Cognitive Neuroscience of Creativity Lab at Penn State uses brain imaging and behavioral experiments to examine how creative thinking works in different contexts and domains, from the arts to the sciences to everyday life. His article examines the part of the brain that directs creative thought and asks the million-dollar question: Can creativity be enhanced?

When we think about creativity, the arts often come to mind. Most people would agree that writers, painters, and actors are all creative. This is what psychologists who study the subject refer to as Big-C creativity: publicly-recognizable, professional-level performance. But what about creativity on a smaller scale? This is what researchers refer to as little-c creativity, and it is something that we all possess and express in our daily lives, from inventing new recipes to performing a do-it-yourself project to thinking of clever jokes to entertain the kids.

One way psychologists measure creative thinking is by asking people to think of uncommon uses for common objects, such as a cup or a cardboard box. Their responses can be analyzed on different dimensions, such as fluency (the total number of ideas) and originality. Surprisingly, many people struggle with this seemingly simple task, only suggesting uses that closely resemble the typical uses for the object. The same happens in other tests that demand ideas that go beyond what we already know (i.e., “thinking outside the box”). Such innovation tasks assess just one aspect of creativity. Many new tests are being developed that tap into other creative skills, from visuospatial abilities essential for design (like drawing) to scientific abilities important for innovation and discovery.

But where do creative ideas come from, and what makes some people more creative than others? Contrary to romantic notions of a purely spontaneous process, increasing evidence from psychology and neuroscience experiments indicates that creativity requires cognitive effort—in part, to overcome the distraction and “stickiness” of prior knowledge (remember how people think of common uses when asked to devise of creative ones). In light of these findings, we can consider general creative thinking as a dynamic interplay between the brain’s memory and control systems. Without memory, our minds would be a blank slate—not conducive to creativity, which requires knowledge and expertise. But without mental control, we wouldn’t be able to push thinking in new directions and avoid getting stuck on what we already know.

Creativity By Default

Creative thinking is supported in part by our ability to imagine the future—our capacity to envision experiences that have not yet occurred. From planning dinner to envisioning an upcoming vacation, we routinely rely on our imaginations to picture what the future might look like. Interestingly, the same brain region that allows us to imagine a future is also involved in recalling the past: the hippocampus. A seahorse-shaped region embedded in the temporal lobe of the brain, the hippocampus plays an important role in piecing together details of experiences—people, places, objects, actions—both to accurately re-construct past events and to vividly construct possible future events. Early research with amnesiac patients provided clear evidence for the role of the hippocampus in remembering and imagining, finding that patients with damage to this area had trouble not only recalling the past but also imagining the future. Since then, researchers have used functional magnetic resonance imaging (fMRI) to study how the brain remembers and imagines.

Strikingly, some of the same brain regions activate when we recall past experiences and imagine future experiences. Important among them is a large set of cortical regions collectively known as called the *default network*. This network got its name from early brain imaging studies that found that the areas it connects—medial prefrontal cortex, posterior cingulate cortex, bilateral inferior parietal lobes, and medial temporal lobes—tend to activate "by default" when people are simply relaxing in a brain scanner without a cognitive task to do. When left to our own devices, we tend to engage in all sorts of spontaneous thinking—sometimes referred to as mind-wandering—much of which involves recalling recent experiences and imagining future ones. The engagement of the hippocampus and default network in memory and imagination is consistent with a popular theory of episodic memory known as the *constructive episodic simulation hypothesis*, which posits that both memory and imagination involve flexible recombination of episodic details, such as people, places, and events that we've encountered. On the one hand, remembering a past experience seems to require that we *reconstruct* that experience: piecing together the relevant people, places, and things that comprised the event—not simply pressing play like a video recorder. Likewise, imagining a future experience apparently requires that we *construct* that experience based on what has happened in the past. The flexible nature of the episodic system seems to be particularly beneficial for creative thinking, which also requires connecting information in new and meaningful ways.

In a recent study, we explored further whether the same brain regions support memory, imagination, and creative thinking. We presented research participants with a series of object cue words (e.g., cup) and asked them to use the cue words to either 1) remember a personal past experience, 2) imagine a possible future experience, or 3) think of creative uses for the object. This design allowed us to determine which brain regions were common and unique to episodic (remembering and imagining) and creative thinking. We found that memory, imagination, and creative thinking all activated the bilateral hippocampus.

This finding builds on other recent work on memory and creativity using episodic specificity induction, a procedure in which participants are trained to recall episodic memories in a high degree of detail. These studies found that episodic specificity induction (which strongly engages the default network) can improve creative divergent thinking: after the induction (they were instructed to recall in detail a recently-watched video), participants produced significantly more ideas, and these ideas were significantly more variable in their topics. A subsequent fMRI study found that the episodic induction process boosted activity in the left anterior hippocampus, linking creative performance to heightened activity in a brain region strongly associated with episodic memory. Together, these findings provide clear evidence that the hippocampus—as part of the medial temporal lobe subsystem of the default network—supports the generation of creative ideas: more proof that the same brain region that supports our ability to remember also supports our ability to imagine and create.

Directing Creative Thought

A controversial question in creativity research concerns the phenomenon of cognitive control: our capacity to regulate the contents of our minds. Does creative thinking happen spontaneously, or can we deliberately direct the process? On the one hand, relaxing the filter on our brains by letting our minds wander—a process governed by the hippocampus and default network—can allow new ideas to come to mind that might not have otherwise. On the other hand, serendipity and spontaneity alone do not guarantee either novelty or usefulness: we often need to redirect our thought processes away from what we already know and think hard about whether our ideas will actually work. This highlights two key elements of the creative thought process: idea generation and idea evaluation.

Cognitive neuroscience has begun to provide insight into these two sides of creativity. For example, one fMRI study asked visual artists to generate and evaluate ideas for a book cover based on short written descriptions. During idea generation, activation of the hippocampus and default network increased, presumably reflecting engagement of the episodic system. During idea evaluation, where artists were asked to critique their drawings, they again activated hippocampal and default regions, and also frontal brain regions associated with cognitive control, including the dorsolateral prefrontal cortex. Most interestingly, the analysis also showed increased communication (i.e., functional connectivity) between these regions during idea evaluation, suggesting cooperation between the spontaneous/generative aspects of the default network and the deliberate/evaluative aspects of the control network. These networks typically work in a complementary fashion: when one activates, the other tends to deactivate. When we let our minds wander, for example, we engage the default network, without needing to focus our attention through our control networks; conversely, when we try to focus our attention on a given task, we need our control network to work efficiently, without distraction from the mind-wandering default network. The study with visual artists, along with subsequent findings with poets and others, suggests that creative thinking involves increased communication between brain networks that usually work separately.

In a recent study, we explored whether this brain connectivity pattern may provide insight into individual differences in creative thinking, i.e., what makes some people more creative than others? One possibility is that creative people can more readily co-activate the default and control networks to solve creative problems. We recruited a large sample of participants, mostly undergraduate and graduate students and asked them to complete the creative uses task during fMRI. We recorded their ideas while they were in the scanner and later scored them for creative quality, allowing us to link each person's brain patterns to the quality of their ideas. We found that, as expected, people varied widely in their performance on this task. Some consistently came up with common uses for objects, such as saying a brick could be used for building something, while others devised decidedly more innovative responses, e.g. a brick could be ground up and used as a filtering substance. To analyze the data, we used a machine learning method called connectome-based predictive modeling (CPM). CPM allows researchers to characterize individual differences in such behavioral traits as personality and intelligence, by identifying functional connections in the brain that reliably predict these traits in new participants who were not used to build the models. In our study, CPM was used to estimate creative thinking ability based on brain connectivity patterns during the creative uses task.

Our analysis showed stronger functional connections between the default, control, and salience networks (a network involved in switching between the default and control networks) in highly creative people: the brain connectivity pattern reliably predicted the creativity score. Importantly, the association generalized to three other samples of participants: individuals with stronger functional connections between these networks tended to produce more original ideas.

Boosting Creativity

Psychology and neuroscience have made encouraging progress in our understanding of how the creative brain works. As summarized above, we now know that creative thinking involves the interplay of the brain's default and executive control networks, and that these connections allow us to spontaneously generate ideas and critically evaluate them, respectively. And we are learning about how our memory systems contribute: the same networks that we use to recall the past also allow us to imagine future experiences and think creatively.

Yet several important questions remain. One of the most important concerns whether creativity can be enhanced—and if so, how? Research findings thus far suggest that neuroscience tools can be used to predict the ability to think creatively, based on the strength of their brain network connections. But we do not yet know whether these connections can be strengthened to improve creative thinking. Longitudinal studies are needed. Just as the efficacy of cognitive or brain training programs in improving intelligence has been critically questioned, skepticism should be applied to interventions that claim to boost creativity.

While it remains unclear whether creativity can be improved in the long-term (i.e, trait creativity) some strategies may boost short-term (i.e. state) creativity. Given what we've learned about the neuroscience of creativity, it seems possible that harnessing the flexible and generative potential of the default network may provide a short-term boost. For example, when we are stuck on a problem—a phenomenon known as fixation or impasse—taking a break to let our minds wander may loosen things up and help us find a creative solution. Another potentially useful strategy involves priming the episodic system. The episodic induction process mentioned earlier—thinking about a past experience with as much detail as possible—has been shown to temporarily boost the number of ideas people generate on a creative thinking task.

Until rigorous science on creativity training has been conducted, there are a few things that may modestly boost creativity in a more sustained way. For one, we can pick up a creative hobby, like painting or learning a musical instrument. One study that trained students how to play music reported gains in their musical creativity over time. But whether such gains transfer to make people generally more creative is not yet known. (This is where cognitive "brain training" programs fall short: people tend to get better on specific training tasks, but this improvement doesn't generalize to other tasks.) Until research has clarified whether cognitive abilities can actually be improved through neuroscience-based intervention, old-fashioned arts education might be our best bet.

Bio

Roger E. Beaty, Ph.D., is an assistant professor of psychology at The Pennsylvania State University, where he directs the Cognitive Neuroscience of Creativity Lab. His lab studies the psychology and neuroscience of creativity, using brain imaging and behavioral experiments to examine how creative thinking works in different contexts and domains, from the arts, to the sciences, to everyday life. His research has been supported by grants from the John Templeton Foundation and the National Science Foundation. He received his Ph.D. at the University of North Carolina at Greensboro and completed postdoctoral training at Harvard University.