The Cognitive Upside of Aging

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The view that we reach a kind of cognitive “peak” relatively early in life has been pervasive since the time of William James. In 1890, James wrote of the aging “dotard” as incapable of learning new information or even following a conversation. “So much for the permanence of the paths,” James wrote sarcastically in the first volume of *The Principles of Psychology*. According to a 2014 survey on perceptions of brain health and aging conducted by aging advocacy group AARP, people believed that the brain peaks at age 29 before beginning to deteriorate by age 53.

The world's population is aging rapidly. According to a 2015 demographic report produced by the Division of Behavioral and Social Research at the National Institute on Aging and the US Census Bureau, "the next 10 years will witness an increase of about 236 million people aged 65 and older throughout the world."

Although popular culture may perpetuate the notion that it's all downhill after 30, new research is painting a far more encouraging picture of the aging brain's capabilities: Rather than taking a nosedive, many cognitive skills continue to improve long after 30, with some skills peaking as late as our 60s and 70s.

In some respects, the poet Henry Wadsworth Longfellow may have been ahead of his time with his insights on how aging has its own advantages: "For age is opportunity no less / than youth itself, though in another dress, / and as the evening twilight fades away / the sky is filled with stars, invisible by day."

The Internet is now allowing researchers to study cognition across thousands — even hundreds of thousands — of participants of every age. The ability to leverage data collected from several thousand participants, rather than only the usual few dozen or few hundred, is enabling researchers to track the development of different cognitive skills across the lifespan with increasing accuracy. And the results of these massive new studies are bringing to light some surprising — and perhaps heartening — findings about the aging brain.

Although many cognitive skills do peak in the first few decades of life, people may be interested to learn that there are also many important abilities that hit their high points much later. Rather than a simple curve or U-shape, new research is showing that the cognitive landscape is filled with a shifting array of highs and lows.

Cognitive Peaks and Valleys

Although scientists have been studying the cognitive effects of aging for decades, methodological challenges have made it difficult for researchers to track and differentiate changes in cognitive skills over the lifespan. Two of the main methodological hurdles include obtaining insufficiently large data sets and a lack of statistically sound quantitative methods for comparing ages of peak performance.

Convincing hundreds, let alone thousands, of people to come into a lab in order to complete a battery of demanding cognitive tests is just one of the challenges for researchers who study older populations. Along with the normal difficulties of participant recruitment, adults in their 50s and 60s often are still working, while adults in their 70s and 80s may have mobility and transportation issues that make it difficult to get to the lab in the first place.

Joshua K. Hartshorne, an assistant professor of psychology at Boston College, and Laura Germine, an assistant professor of neuroscience at McLean Hospital and Harvard Medical School, were interested in looking at changes in different cognitive skills across the lifespan.

In an initial study, Hartshorne and Germine reanalyzed an old set of scores from Wechsler IQ and memory tests taken by a geographically diverse group of adults in the 1990s. Scores from 2,450 test-

takers were divided into 13 age categories representing individuals between the ages of 16 and 89. This allowed the researchers to chart peaks in various cognitive skills — ranging from memory to vocabulary — from adolescence through old age.

A comparison of the peaks for different cognitive tasks revealed that there was no single apex in overall cognitive skill; instead, there was huge variation in cognitive capabilities across the lifespan. The cognitive peaks were all over the place — and according to Hartshorne, this was the "smoking gun" that it's not all downhill for the aging brain.

Although the data were intriguing, this pool of participants was too small to make any solid conclusions. People in their late teens and early 20s are often the bread and butter of psychology research experiments, and getting large numbers of people in their 50s, 60s, and 70s into the lab was a major obstacle.

"Regular adults have been some of the hardest participants to get for this kind of research," Germine explained in an interview with the *Harvard Gazette*.

So Hartshorne and Germine turned to an unlikely new tool: viral Internet quizzes.

Along with APS Fellow Ken Nakayama of Harvard University, Germine founded TestMyBrain.org, a website that hosts a variety of short cognitive tests that users can complete within a few minutes. Since the site's foundation in 2008, researchers have collected data from more than 1.7 million volunteers all over the world. In a similar vein, Hartshorne has founded a website called GamesWithWords.org as a "Web-based research laboratory" for studying language.

Both Germine and Hartshorne felt that it was important for the tests on their website to be short and engaging, ensuring that participants enjoyed taking each one so much that they would be interested in taking a few more or even forwarding them to friends. Essentially, they wanted to make taking a cognitive battery just as easy and fun as taking one of the not-so-scientific personality tests people like to share on social media sites. In total, more than 3 million people have taken quizzes on the two websites.

In a second set of studies, Hartshorne and Germine enlisted TestMyBrain.org and GamesWithWords.org to collect large samples of data across five specific cognitive tasks. Three of these tasks — digit symbol coding, verbal working memory, and vocabulary — overlapped with the tasks from the Wechsler exam used in the previous study. The researchers also included a widely used test of emotional perception, which was not included in the original Wechsler tests.

Test data collected from online participants showed a very clear picture of cognitive peaks across the lifespan, one which largely matched the same pattern of results from the decades-old Wechsler tests. For example, information-processing speed crested early in life — around age 18 or 19. Short-term memory was another skill that seemed to hit its pinnacle fairly early in life, improving until age 25 before beginning to decline around age 35.

On the other hand, many cognitive proficiencies — vocabulary, math, general knowledge, and verbal comprehension — didn't peak until much later in life.

These types of skills serve as measures of crystallized intelligence — the kind of knowledge, familiarity with facts, and expertise that come from experience. As people age, they continue to learn new things and gather new experiences, so it makes sense that crystallized intelligence would continue to improve beyond the first few decades of life.

Germine and Hartshorne's analysis of the online data collected from thousands of participants showed that crystallized intelligence, as measured by vocabulary skills, essentially had no single high point — it continued to improve well into participants' late 60s and early 70s. In contrast, the Wechsler data showed vocabulary skills topping out mostly in the 40s.

To ensure that collecting data online hadn't somehow skewed the results, Germine and Hartshorne consulted another large dataset, the General Social Survey, which has been testing people's vocabularies for decades. Interestingly, this data confirmed that there really has been a steady shift in vocabulary performance over the last few decades: More recent generations peaked on this particular skill at later ages compared with previous generations. This would explain why the Wechsler data, which was collected decades before the online sample, showed a much earlier peak for vocabulary.

"With the increase in the proportion of adults engaged in cognitively demanding careers, it may be that ages of peak performance are later in the more recent Internet sample, particularly for vocabulary," Germine and Hartshorne write. "This could be related to the Flynn effect: IQ has increased steadily in modern times, possibly because of increasing amounts of time devoted to mental activity."

Another skill that improved with age was emotional perception. To test this ability, researchers asked participants to identify the mood of a person based only on a photograph of the individual's eyes. A menu provided a selection of potential options such as fearful, tentative, or playful for each photograph.

Again, the researchers found that adults in their 40s and 50s consistently outperformed younger adults. Interestingly, this ability also had a much longer plateau than any of the other cognitive skills that were tested.

"The peak in emotion-recognition ability was also much broader than the peaks for any of the other tasks, which reflects a long period of relative stability in performance between the ages of 40 and 60 years," Germine and Hartshorne write.

To ensure that their results were really accurate, the researchers recruited another large set of more than 18,000 online participants between the ages of 10 and 73 to confirm their visual and verbal working-memory findings. The replication showed the same pattern of cognitive peaks as the other experiments.

"At any given age, you're getting better at some things, you're getting worse at some other things, and you're at a plateau at some other things," Hartshorne says. "There's probably not one age at which you're peak on most things, much less all of them."

"It paints a different picture of the way we change over the lifespan than psychology and neuroscience have traditionally painted," Germine adds.

Finding Focus

A different large study conducted using data collected from TestMyBrain.org and published in *Psychological Science* found yet another unexpected boon for aging brains: Sustained attention tends to improve over time, ultimately peaking in the mid-40s.

Led by researchers Francesca C. Fortenbaugh, Joseph DeGutis, and Michael S. Esterman at the Boston Attention and Learning Laboratory at the VA Boston Healthcare System, this study tested sustained attention across 10,430 adults using a specialized task for identifying individual differences in people's ability to focus on a single task over 4 minutes.

"While younger adults may excel in the speed and flexibility of information processing, adults approaching their mid-years may have the greatest capacity to remain focused," DeGutis said in a statement. "One current hypothesis is that compared to younger adults, adults in their mid-years mind-wander less, leading to better sustained attention performance."

"This sample was larger than in all previous efforts to model changes in sustained-attention performance during development, aging, or across the life span combined, which allowed us to more precisely model transition periods in performance across the life span using segmented linear regression," the researchers explain.

Sustained attention, or the ability to concentrate on a task for an extended period of time, underlies several important cognitive processes, including learning, perception, and memory. Importantly, lapses in attention can lead to serious problems ranging from difficulty at work to an increased risk of car accidents. But measuring attention across individuals is itself a challenge; attention fluctuates, sometimes dramatically, from moment to moment.

To accurately measure an individual's overall concentration abilities, the team used a new tool they developed: the gradual-onset continuous performance task (gradCPT). Participants were shown a series of grayscale photographs of 10 city scenes and 10 mountain scenes. One photograph gradually transitioned into the next every 800 milliseconds, so that as one image slowly faded, a new image steadily took its place. The effect was similar to a crossfade transition from a movie, with one scene slowly dissolving into the next one.

A nearly equal ratio of male and female participants (5,027 males and 5,403 females) between 10 and 70 years old completed the gradCPT on the TestMyBrain.org website between March and September of 2014. Most participants found their way to the website through search engines or social media sites. The participants were told to press the space bar key whenever they saw a city scene, but to withhold a response when the image was a mountain scene.

The goal of the gradCPT was to create a task that required frequent responses from participants while having a relatively low cognitive demand. Identifying the difference between the two scenes was easy, but carefully attending to the transitions repeatedly became challenging over time.

By analyzing mean reaction time, reaction time variability, hits, misses, discrimination ability, and

criterion (a measure of strategy or willingness to respond in the case of uncertainty), the researchers were able to tease apart the changes in sustained attention across the lifespan. From ages 10 through 16, gains in both reaction times and discrimination ability were extremely large. After age 16, gains in these skills were much smaller until they peaked around age 43.

A factor analysis of the results suggests that people also begin to use different cognitive strategies as they age. Younger individuals demonstrated faster reaction times (due to either superior information-processing speed or more liberal response strategy), whereas older individuals showed a slower, more cautious strategy and evidence that they made more adjustments after a mistake.

In particular, Fortenbaugh and colleagues calculated the degree to which individuals slowed down their responses following an incorrect response. This phenomenon, referred to as "post-error slowing," is thought to reflect reactivity to making errors; essentially, it is the cognitive "Oops! Why did I do that?" after a wrong answer. Results of the study showed that post-error slowing consistently increased with age (3.5 ms per year), indicating that older adults engage in more self-monitoring after an error.

"While young adults may surpass people of other ages in the speed and flexibility of information processing, and older adults may possess the most stored knowledge regarding the world, we found that middle-aged adults have the greatest capacity to remain attentive," the researchers conclude.

The Happiness U-Curve

Despite the growing aches, pains, and other cons of aging, researchers consistently find a happiness paradox: As the body declines, happiness tends to increase. Across the lifespan, this "positivity effect" follows a U-shaped pattern — happiness starts out high in late adolescence, bottoms out in middle age, and reaches a second zenith in old age.

According to a 2011 Gallup analysis of more than 500,000 phone interviews, "a septuagenarian is far more likely than someone in their 30s to have high emotional health." The old-age happiness advantage held true even after controlling for myriad demographic factors, including gender, race, education, marital status, employment, and regional location.

This happiness U-shape appears in populations across the world. Economists Andrew Oswald (University of Warwick, United Kingdom) and David G. Blanchflower (Dartmouth College) documented this pattern in more than 500,000 people living in more than 70 different countries. Their analysis concluded that from Azerbaijan to Zimbabwe, people around the world tend to be happiest in their old age — regardless of their nationality.

"Only in their 50s do most people emerge from the low period. But encouragingly, by the time you are 70, if you are still physically fit then on average you are as happy and mentally healthy as a 20 year old," Oswald says. "Perhaps realizing that such feelings are completely normal in midlife might even help individuals survive this phase better."

The universality of the happiness U-curve implies that aging actually may play a positive role in the brain. One team of Australian researchers, led by Leanne Williams (now at Stanford University School

of Medicine), argues that a combination of neurological changes and life experiences account for this phenomenon. Using functional magnetic resonance imaging (fMRI) to monitor emotional processing as people of various ages viewed photographs of different facial expressions, Williams and colleagues found that older people were more emotionally stable and less reactive to negative emotional stimuli than younger people.

Contrary to pervasive negative stereotypes of declining memory and cognitive integrity, Williams and colleagues found that emotional well-being may increase with normal aging.

Their study included 242 individuals (122 males and 120 females) divided up into four major age categories: 12–19 years, 20–29 years, 30–49 years, and 50–79 years. In the scanner, participants were assessed for the neural activation evoked by emotions of threat and happiness depicted in facial expressions. After being shown a photograph of a face, participants had to select the best option for identifying the emotion being displayed in the photograph. They also were instructed to rate, using a 1-to-5 scale, the intensity of the emotion being displayed.

The results of the brain scans support a positive view of the aging brain: Rather than showing an inevitable decline across all functions, the images displayed a linear increase in emotional stability with age. This means that people in their 70s ultimately experience better emotional well-being than most people in their 20s.

The fMRI results suggest that as people age, the way their brains process emotional stimuli changes in ways that favor emotional stability. Brain scans indicated that the medial prefrontal cortex (mPFC), a brain area involved in the governance of emotional functions, processed stimuli differently across the lifespan, contributing to better emotional stability for older adults. As people aged, the mPFC areas became increasingly active while processing negative emotions compared with positive ones, suggesting that older people were comparatively better at controlling their reactions to negative emotions.

Ultimately, Williams and colleagues argue that as we age, this combination of neural processing, as well as an accumulation of life experience, provides older adults with the neural tools to take life in stride — a capability their younger counterparts will just have to wait for. œ

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