AP®

AP Seminar Performance Task: Individual Research-Based Essay and Presentation

Directions and Sources Packet

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Contents

Introduction

This performance task, highlighted in bold below, is one of three parts of the overall assessment for AP Seminar and one of two performance tasks. The assessment for this course is comprised of:

Team Project and Presentation

- Component 1: Individual Research Report
- Component 2: Written Team Report
- Component 3: Team Multimedia Presentation and Oral Defense

Individual Research-Based Essay and Presentation

- **Component 1: Individual Written Argument**
- **Component 2: Individual Multimedia Presentation**
- **Component 3: Oral Defense**

End-of-Course Exam

- Section I, Part A: Three Short-Answer Questions (based on one source)
- Section I, Part B: One Essay Question (based on two sources)
- Section II: One Essay Question (based on four sources)

The attached pages include a high-level view of this performance task; information about the weighting of the task within the overall assessment and the timeline during which the task should be completed; and detailed information as to the expected quantity and quality of student work.

Also included are the stimulus materials for the task. These materials are theme-based and broadly span the academic curriculum. After reading the materials, develop a research question that suits your individual interest. Your research question must be rich enough to allow you to engage in meaningful exploration and write and present a substantive, defensible argument.

Directions

Student Version

Weight: 35% of the AP Seminar score

Task Overview

This packet includes stimulus materials for the AP Seminar Performance Assessment Task: Individual Research-Based Essay and Presentation. This essay should be in the form of an argument.

You must identify a research question prompted by the provided stimulus materials, gather additional information from outside sources, develop and refine an argument, write and revise your argument, and create a presentation that you will be expected to defend. Your teacher will give you a deadline for when you need to submit your written argument and presentation media. Your teacher will also give you a date on which you will give your presentation.

Task Components	Length	Date Due (fill in)
Individual Written Argument	Approximately 2000 words	
Individual Multimedia Presentation	6–8 minutes	
Oral Defense	Respond to 2 questions	

In all written work, you must:

- Acknowledge, attribute, and/or cite sources using in-text citations, endnotes, or footnotes, as well as a bibliography. You must avoid plagiarizing (see attached College Board policy on plagiarism).
- Adhere to established conventions of grammar, usage, style, and mechanics.

Task Directions

1. **Individual Written Argument** (approximately 2000 words)
   - Read, analyze, and discuss the provided stimulus materials to identify areas for inquiry.
   - Compose a research question of your own prompted by the stimulus materials.
   - Gather additional information from outside sources through research.
   - Analyze, evaluate, and select evidence to develop a well-reasoned and well-written argument that answers the research question and conveys your perspective.

- Your research question must be inspired by one or more of the stimulus materials. Your essay must refer to and incorporate at least one of these documents.
- As part of your research, you must find outside sources, including peer-reviewed academic work, that will supply the evidence for your argument. You must locate these sources independently.
- During your research process, revisit your original research question. Ensure that the evidence you gather addresses your original purpose and focus. Refine your research process, or your research question, as needed to make sure that your evidence aligns with your research question and supports your argument.
- Your written argument must identify opposing or alternate views and consider their implications and/or limitations as well as the consequences and implications of one or more resolutions, conclusions, or solutions that you suggest.

2. **Individual Multimedia Presentation** (6–8 minutes)

   Develop a presentation that conveys your key findings and deliver it to an audience of your peers. The presentation and the media used to enhance the presentation should consider audience, context, and purpose. The presentation should reflect the major components of your written argument. Engage your audience using appropriate strategies (e.g., eye contact, vocal variety, expressive gestures, movement).

   - Use effective visual design elements to engage your audience and illustrate your points.
   - Use appropriate communication strategies. Do not read directly from your paper, slides, or a script. Instead, interact with visuals or other supporting elements. Rehearse your commentary in advance and prepare notecards or an outline that you can quickly reference as you are speaking.
   - Make explicit connections between the evidence you choose and claims about your key findings.
   - Situate your perspective within a larger context.

3. **Individual Oral Defense** (two questions)

   Defend your research process, use of evidence, and conclusion(s), solution(s), or recommendation(s) through oral answers to two questions asked by your teacher. (See list of sample defense questions on the following page.)

Sample Oral Defense Questions

Here are some examples of the types of questions your teacher might ask you during your oral defense. These are *examples only*; your teacher may ask you different questions, but there will still be one question that relates to each of the two categories below.

1. **Source selection and use**
   - How did the stimulus materials inspire your original research? Which stimulus material(s) prompted your research question?
   - What information did you need before you began your research, and how did that information shape your research?
   - What evidence did you gather that you didn't use? Why did you choose not to use it?
   - How valid and reliable are the sources you used? How do you know? Which sources didn't work?
   - How did you select the strategies you used to gather information or conduct research? Were they effective?
   - How did your research question evolve as you moved through the research process? Did your research go in a different direction than you originally planned/hypothesized?
   - What information did you need that you weren't able to find or locate? How did you go about trying to find that information?
   - How did you handle differing perspectives in order to reach a conclusion?
2. **Extending argumentation through effective questioning and inquiry**
   - What additional questions emerged from your research? Why are these questions important?
   - What advice would you have for other researchers who consider this topic?
   - What might be the real-world implications or consequences (influence on others' behaviors or decision-making processes) of your findings? What are the implications to your community?
   - If you had more time, what additional research would you conduct related to this issue?
   - Explain the level of certainty you have about your conclusion, solution, or recommendation.
   - How does your conclusion respond to any of the other research or sources you examined?
   - How did you use the conclusions and questions of others to advance your own research?

AP Capstone Policy on Plagiarism

A student who fails to acknowledge (i.e., through citation, through attribution, by reference, and/or through acknowledgment in a bibliographic entry) the source or author of any and all information or evidence taken from the work of someone else will receive a score of zero on that particular component of the AP Seminar and/or AP Research Performance Assessment Task. In AP Seminar, a team of students that fails to properly acknowledge sources or authors on the Written Team Report will receive a group score of zero for that component of the Team Project and Presentation.

To the best of their ability, teachers will ensure that students understand ethical use and acknowledgment of the ideas and work of others, as well as the consequences of plagiarism. The student's individual voice should be clearly evident, and the ideas of others must be acknowledged, attributed, and/or cited.

Can You Make Yourself Smarter?

By DAN HURLEY
Published: *The NY Times Magazine*, April 18, 2012

Early on a drab afternoon in January, a dozen third graders from the working-class suburb of Chicago Heights, Ill., burst into the Mac Lab on the ground floor of Washington-McKinley School in a blur of blue pants, blue vests and white shirts. Minutes later, they were hunkered down in front of the Apple computers lining the room's perimeter, hoping to do what was, until recently, considered impossible: increase their intelligence through training.

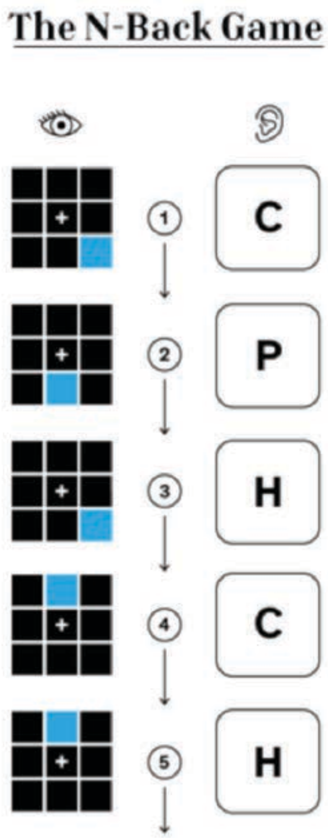
"Can somebody raise their hand," asked Kate Wulfson, the instructor, "and explain to me how you get points?"

On each of the children's monitors, there was a cartoon image of a haunted house, with bats and a crescent moon in a midnight blue sky. Every few seconds, a black cat appeared in one of the house's five windows, then vanished. The exercise was divided into levels. On Level 1, the children earned a point by remembering which window the cat was just in. Easy. But the game is progressive: the cats keep coming, and the kids have to keep watching and remembering.

"And here's where it gets confusing," Wulfson continued. "If you get to Level 2, you have to remember where the cat was two windows ago. The time before last. For Level 3, you have to remember where it was three times ago. Level 4 is four times ago. That's hard. You have to keep track. O.K., ready? Once we start, anyone who talks loses a star."

So began 10 minutes of a remarkably demanding concentration game. At Level 2, even adults find the task somewhat taxing. Almost no one gets past Level 3 without training. But most people who stick with the game do get better with practice. This isn't surprising: practice improves performance on almost every task humans engage in, whether it's learning to read or playing horseshoes.

What is surprising is what else it improved. In a 2008 study, Susanne Jaeggi and Martin Buschkuehl, now of the University of Maryland, found that young adults who practiced a stripped-down, less cartoonish version of the game also showed improvement in a fundamental cognitive ability known as "fluid" intelligence: the capacity to solve novel problems, to learn, to reason, to see connections and to get to the bottom of things. The implication was that playing the game literally makes people smarter.



Games based on N-back tests require players to remember the location of a symbol or the sound of a particular letter presented just before (1-back), the time before last (2-back), the time before that (3-back) and so on. Some researchers say that playing games like this may actually make us smarter.

Psychologists have long regarded intelligence as coming in two flavors: crystallized intelligence, the treasure trove of stored-up information and how-to knowledge (the sort of thing tested on "Jeopardy!" or put to use when you ride a bicycle); and fluid intelligence. Crystallized intelligence grows as you age; fluid intelligence has long been known to peak in early adulthood, around college age, and then to decline gradually. And unlike physical conditioning, which can transform 98-pound weaklings into hunks, fluid intelligence has always been considered impervious to training.

That, after all, is the premise of I.Q. tests, or at least the portion that measures fluid intelligence: we can test you now and predict all sorts of things in the future, because fluid intelligence supposedly sets in early and is fairly immutable. While parents, teachers and others play an essential role in establishing an environment in which a child's intellect can grow, even Tiger Mothers generally expect only higher grades will come from their children's diligence — not better brains.

How, then, could watching black cats in a haunted house possibly increase something as profound as fluid intelligence? Because the deceptively simple game, it turns out, targets the most elemental of cognitive skills: "working" memory. What long-term memory is to crystallized intelligence, working memory is to fluid intelligence. Working memory is more than just the ability to remember a telephone number long enough to dial it; it's the capacity to manipulate the information you're holding in your head — to add or subtract those numbers, place them in reverse order or sort them from high to low. Understanding a metaphor or an analogy is equally dependent on working memory; you can't follow even a simple statement like "See Jane run" if you can't put together how "see" and "Jane" connect with "run." Without it, you can't make sense of anything.

Over the past three decades, theorists and researchers alike have made significant headway in understanding how working memory functions. They have developed a variety of sensitive tests to measure it and determine its relationship to fluid intelligence. Then, in 2008, Jaeggi turned one of these tests of working memory into a training task for building it up, in the same way that push-ups can be used both as a measure of physical fitness and as a strength-building task. "We see attention and working memory as the cardiovascular function of the brain," Jaeggi says. "If you train your attention and working memory, you increase your basic cognitive skills that help you for many different complex tasks."

Jaeggi's study has been widely influential. Since its publication, others have achieved results similar to Jaeggi's not only in elementary-school children but also in preschoolers, college students and the elderly. The training tasks generally require only 15 to 25 minutes of work per day, five days a week, and have been found to improve scores on tests of fluid intelligence in as little as four weeks. Follow-up studies linking that improvement to real-world gains in schooling and job performance are just getting under way. But already, people with disorders including attention-deficit hyperactivity disorder (A.D.H.D.) and traumatic brain injury have seen benefits from training. Gains can persist for up to eight months after treatment.

In a town like Chicago Heights, where only 16 percent of high schoolers met the Illinois version of the No Child Left Behind standards in 2011, finding a clear way to increase cognitive abilities has obvious appeal. But it has other uses too, at all ages and aptitudes. Even high-level professionals have begun training their working memory in hopes of boosting their fluid intelligence — and, with it, their job performance. If the effect is real — if fluid intelligence can be raised in just a few minutes a day, even by a bit, and not just on a test but in real life — then it would seem to offer, as Jaeggi's 2008 study concluded with Spock-like understatement, "a wide range of applications."

Since the first reliable intelligence test was created just over a hundred years ago, researchers have searched for a way to increase scores meaningfully, with little success. The track record was so dismal that by 2002, when Jaeggi and her research partner (and now her husband), Martin Buschkuehl, came across a study claiming to have done so, they simply didn't believe it.

The study, by a Swedish neuroscientist named Torkel Klingberg, involved just 14 children, all with A.D.H.D. Half participated in computerized tasks designed to strengthen their working memory, while the other half played less challenging computer games. After just five weeks, Klingberg found that those who played the working-memory games fidgeted less and moved about less. More remarkable, they also scored higher on one of the single best measures of fluid intelligence, the Raven's Progressive Matrices. Improvement in working memory, in other words, transferred to improvement on a task the children weren't training for.

Even if the sample was small, the results were provocative (three years later Klingberg replicated most of the results in a group of 50 children), because matrices are considered the gold standard of fluid-intelligence tests. Anyone who has taken an intelligence test has seen matrices like those used in the Raven's: three rows, with three graphic items in each row, made up of squares, circles, dots or the like. Do the squares get larger as they move from left to right? Do the circles inside the squares fill in, changing from white to gray to black, as they go downward? One of the nine items is missing from the matrix, and the challenge is to find the underlying patterns — up, down and across — from six possible choices. Initially the solutions are readily apparent to most people, but they get progressively harder to discern. By the end of the test, most test takers are baffled.

If measuring intelligence through matrices seems arbitrary, consider how central pattern recognition is to success in life. If you're going to find buried treasure in baseball statistics to give your team an edge by signing players unappreciated by others, you'd better be good at matrices. If you want to exploit cycles in the stock market, or find a legal precedent in 10 cases, or for that matter, if you need to suss out a woolly mammoth's nature to trap, kill and eat it — you're essentially using the same cognitive skills tested by matrices.

When Klingberg's study came out, both Jaeggi and Buschkuehl were doctoral candidates in cognitive psychology at the University of Bern, Switzerland. Since his high-school days as a Swiss national-champion rower, Buschkuehl had been interested in the degree to which skills — physical and mental — could be trained. Intrigued by Klingberg's suggestion that training working memory could improve fluid intelligence, he showed the paper to Jaeggi, who was studying working memory with a test known as the N-back. "At that time there was pretty much no evidence whatsoever that you can train on one particular task and get transfer to another task that was totally different," Jaeggi says. That is, while most skills improve with practice, the improvement is generally domain-specific: you don't get better at Sudoku by doing crosswords. And fluid intelligence was not just another skill; it was the ultimate cognitive ability underlying all mental skills, and supposedly immune from the usual benefits of practice. To find that training on a working-memory task could result in an increase in fluid intelligence would be cognitive psychology's equivalent of discovering particles traveling faster than light.

Together, Jaeggi and Buschkuehl decided to see if they could replicate the Klingberg transfer effect. To do so, they used the N-back test as the basis of a training regimen. As seen in the game played by the children at Washington-McKinley, N-back challenges users to remember something — the location of a cat or the sound of a particular letter — that is presented immediately before (1-back), the time before last (2-back), the time before that (3-back), and so on. If you do well at 2-back, the computer moves you up to 3-back. Do well at that, and you'll jump to 4-back. On the other hand, if you do poorly at any level, you're nudged down a level. The point is to keep the game just challenging enough that you stay fully engaged.

To make it harder, Jaeggi and Buschkuehl used what's called the dual N-back task. As a random sequence of letters is heard over earphones, a square appears on a computer screen moving, apparently at random, among eight possible spots on a grid. Your mission is to keep track of both the letters and the squares. So, for example, at the 3-back level, you would press one button on the keyboard if you recall that a spoken letter is the same one that was spoken three times ago, while simultaneously pressing another key if the square on the screen is in the same place as it was three times ago.

The point of making the task more difficult is to overwhelm the usual task-specific strategies that people develop with games like chess and Scrabble. "We wanted to train underlying attention and working-memory skills," Jaeggi says.

Jaeggi and Buschkuehl gave progressive matrix tests to students at Bern and then asked them to practice the dual N-back for 20 to 25 minutes a day. When they retested them at the end of a few weeks, they were surprised and delighted to find significant improvement. Jaeggi and Buschkuehl later expanded the study as postdoctoral fellows at the University of Michigan, in the laboratory of John Jonides, professor of psychology and neuroscience.

"Those two things, working memory and cognitive control, I think, are at the heart of intellectual functioning," Jonides told me when I met with him, Jaeggi and Buschkuehl in their basement office. "They are part of what differentiates us from other species. They allow us to selectively process information from the environment, and to use that information to do all kinds of problem-solving and reasoning."

When they finally published their study, in a May 2008 issue of Proceedings of the National Academy of Sciences, the results were striking. Before training, participants were able to correctly answer between 9 and 10 of the matrix questions. Afterward, the 34 young adults who participated in dual N-back training for 12 weeks correctly answered approximately one extra matrix item, while those who trained for 17 weeks were able to answer about three more correctly. After 19 weeks, the improvement was 4.4 additional matrix questions.

"It's not just a little bit higher," Jaeggi says. "It's a large effect."

The study did have its shortcomings. "We used just one reasoning task to measure their performance," she says. "We showed improvements in this one fluid-reasoning task, which is usually highly correlated with other measures as well." Whether the improved scores on the Raven's would translate into school grades, job performance and real-world gains remained to be seen. Even so, accompanying the paper's publication in Proceedings was a commentary titled, "Increasing Fluid Intelligence Is Possible After All," in which the senior psychologist Robert J. Sternberg (now provost at Oklahoma State University) called Jaeggi's and Buschkuehl's research "pioneering." The study, he wrote, "seems, in some measure, to resolve the debate over whether fluid intelligence is, in at least some meaningful measure, trainable."

For some, the debate is far from settled. Randall Engle, a leading intelligence researcher at the Georgia Tech School of Psychology, views the proposition that I.Q. can be increased through training with a skepticism verging on disdain. "May I remind you of 'cold fusion'?" he says, referring to the infamous claim, long since discredited, that nuclear fusion could be achieved at room temperature in a desktop device. "People were like, 'Oh, my God, we've solved our energy crisis.' People were rushing to throw money at that science. Well, not so fast. The military is now preparing to spend millions trying to make soldiers smarter, based on working-memory training. What that one 2008 paper did was to send hundreds of people off on a wild-goose chase, in my opinion.

"Fluid intelligence is not culturally derived," he continues. "It is almost certainly the biologically driven part of intelligence. We have a real good idea of the parts of the brain that are important for it. The prefrontal cortex is especially important for the control of attention. Do I think you can change fluid intelligence? No, I don't think you can. There have been hundreds of other attempts to increase intelligence over the years, with little or no — just no — success."

At a meeting of cognitive scientists last August, and again in November, Engle presented a withering critique of Jaeggi and her colleagues' 2008 paper. He pointed to a variety of methodological weaknesses (many of which have been addressed in subsequent papers by Jaeggi and others) and then presented the results from his own attempt to replicate the study, which found no effect whatsoever. (Those results have yet to be published.)

The most prominent takedown of I.Q. training came in June 2010, when the neuroscientist Adrian Owen published the results of an experiment conducted in coordination with the BBC television show "Bang Goes the Theory." After inviting British viewers to participate, Owen recruited 11,430 of them to take a battery of I.Q. tests before and after a six-week online program designed to replicate commercially available "brain building" software. (The N-back was not among the tasks offered.) "Although improvements were observed in every one of the cognitive tasks that were trained," he concluded in the journal *Nature*, "no evidence was found for transfer effects to untrained tasks, even when those tasks were cognitively closely related."

But even Owen, reached by telephone, told me that he respects Jaeggi's studies and looks forward to seeing others like it. If before Jaeggi's study, scientists' attempts to raise I.Q. were largely unsuccessful, other lines of evidence have long supported the view that intelligence is far from immutable. While studies of twins suggest that intelligence has a fixed genetic component, at least 20 to 50 percent of the variation in I.Q. is due to other factors, whether social, school or family-based. Even more telling, average I.Q.'s have been rising steadily for a century as access to schooling and technology expands, a phenomenon known as the Flynn Effect. As Jaeggi and others see it, the genetic component of intelligence is undeniable, but it functions less like the genes that control for eye color and more like the complex of interacting genes that affect weight and height (both of which have also been rising, on average, for decades). "We know that height is heavily genetically determined," Jonides told me during our meeting at the University of Michigan. "But we also know there are powerful environmental influences on height, like nutrition. So the fact that intelligence is partly heritable doesn't mean you can't modify it."

Harold Hawkins, a cognitive psychologist at the Office of Naval Research who oversees most of the U.S. military's studies in the area, expressed a common view. For him, the question now is not whether cognitive training works but how strongly and how best to achieve it. "Until about four or five years ago, we believed that fluid intelligence is immutable in adulthood," Hawkins told me. "No one believed that training could possibly achieve dramatic improvements in this very fundamental cognitive ability. Then Jaeggi's work came along. That's when I started to move my funding from some other areas into this area. I personally believe, and if I didn't believe it I wouldn't be making an investment of the taxpayers' money, that there's something here. It's potentially of extremely profound importance." A similar view was expressed by Jason Chein, assistant professor of psychology at Temple University in Philadelphia, who published a series of studies — using another method, not N-back, for training working memory — that showed an increase in cognitive abilities. "My findings support what they've done," he says, referring to the work of Jaeggi and her colleagues. "I've never replicated exactly what they do. But across a number of labs, using similar but different approaches to training, we have related successes. I think there's a great deal of work to be done, but on the whole we are seeing positive signs."

This past winter, I went to visit Jason Chein's lab in Philadelphia, where he has begun to train subjects with something called a complex working memory span task. "It's a terrible name," he said with a laugh. "And you could call it a gimmicky psychological task. But there are 20 years of research behind it." Chein invited me to try my hand at it. Once he clicked "start" on the computer program, the screen showed a checkerboard of 16 squares, with all of them white except 1; I was supposed to remember the red square's location. Then it showed a series of three checkerboard patterns; for each, I had to decide whether the pattern was symmetrical or not. This sequence — having to remember the one red square, and then having to decide on symmetry — was repeated three more times. At the end, I had to click, in order, on the location of those four red squares.

I got only three right.

“Everyone gets better with practice,” he said. “Some people get up to being able to remember a string of 11 or higher.”

Of course, the goal is not to get better at remembering the location of red squares on a checkerboard but to expand a subject’s underlying working memory. Doing so, Chein has found, translates into the kind of real-world improvements associated with increases in cognitive capabilities. “We’ve seen, in college kids who do it, improvements in their reading-comprehension scores,” Chein said. “And in a sample of adults, 65 and older, it appears to improve their ability to keep track of what they recently said, so they don’t repeat themselves.”

In addition to working memory, researchers are seeking to improve fluid intelligence by training other basic mental skills — perceptual speed (deciding, in a matter of seconds, whether a number is odd or even), visual tracking (on a shoot-’em-up computer game, for instance) or quickly switching between a variety of tasks. Ulman Lindenberger and colleagues at the Max Planck Institute for Human Development in Berlin used 12 different tasks to train 101 younger and 103 older adults. Compared with those who received no training, those who participated in 100 daily one-hour training sessions (both young and old) showed significant improvements on tests that measured reasoning, working memory, perceptual speed (in young adults only) and episodic memory (the ability to remember a short list, for example). A statistical measure of how those improvements correlated to one another suggested, Lindenberger concluded, systematic improvements “at the level of broad abilities.”

At the University of California, Berkeley, Silvia Bunge, director of a laboratory on the building blocks of cognition, takes what she calls “an everything-but-the-kitchen-sink approach.” Working with 28 children from low socioeconomic backgrounds, she assigned half of them to play games designed to boost the speed of response times, and the other half to play games that target reasoning skills. “Quirkle,” for instance, challenges children to align tiles on a grid to match shapes and colors. After eight weeks of training — 75 minutes per day, twice a week — Bunge found that the children in the reasoning group scored, on average, 10 points higher on a nonverbal I.Q. test than they had before the training. Four of the 17 children who played the reasoning games gained an average of more than 20 points. In another study, not yet published, Bunge found improvements in college students preparing to take the LSAT.

Torkel Klingberg, meanwhile, has continued studying the effects of training children with his own variety of working-memory tasks. In October 2010, a company he founded to offer those tasks as a package through psychologists and other training professionals was bought by Pearson Education, the world’s largest provider of educational assessment tools.

Despite continuing academic debates, other commercial enterprises are rushing in to offer an array of “brain building” games that make bold promises to improve all kinds of cognitive abilities. Within a block of each other in downtown San Francisco are two of the best known. Posit Science, among the oldest in the field, remains relatively small, giving special attention to those with cognitive disorders. Lumosity began in 2007 and is now by far the biggest of the services, with more than 20 million subscribers. Its games include a sleeker, more entertaining version of the N-back task.

In Chicago Heights, the magic was definitely not happening for one boy staring blankly at the black cats in the Mac Lab. Sipping from a juice box he held in one hand, jabbing at a computer key over and over with the other, he periodically sneaked a peak at his instructor, a look of abject boredom on his freckled face.

"That's the biggest challenge we have as researchers in this field," Jaeggi told me, "to get people engaged and motivated to play our working-memory game and to really stick with it. Some people say it's hard and really frustrating and really challenging and tiring."

In a follow-up to their 2008 study in young adults, Jaeggi, Buschkuehl and their colleagues published a paper last year that described the effects of N-back training in 76 elementary- and middle-school children from a broad range of social and economic backgrounds. Only those children who improved substantially on the N-back training had gains in fluid intelligence. But their improvement wasn't linked to how high they originally scored on Raven's; children at all levels of cognitive ability improved. And those gains persisted for three months after the training ended, a heartening sign of possible long-term benefits. Although it's unknown how much longer the improvement in fluid intelligence will last, Jaeggi doubts the effects will be permanent without continued practice. "Do we think they're now smarter for the rest of their lives by just four weeks of training?" she asks. "We probably don't think so. We think of it like physical training: if you go running for a month, you increase your fitness. But does it stay like that for the rest of your life? Probably not."

If future studies confirm the benefits of working-memory training on fluid intelligence, the implications could be enormous. Might children with A.D.H.D. receive working-memory training rather than stimulant drugs like Ritalin? Might students in high school and college do N-back training rather than cramming for their finals? Could a journalist like me write better articles?

Of course, in order to improve, you need to do the training. For some, whether brilliant or not so much, training may simply be too hard — or too boring.

To increase motivation, the study in Chicago Heights offers third graders a chance to win a $10 prepaid Visa card each week. In collaboration with researchers from the University of Chicago's Initiative on Chicago Price Theory (directed by Steven D. Levitt, of "Freakonomics" fame), the study pits the kids against one another, sometimes one on one, sometimes in groups, to see if competition will spur them to try harder. Each week, whichever group receives more points on the N-back is rewarded with the Visa cards. To isolate the motivating effects of the cash prizes, a group of fourth graders is undergoing N-back training with the same black-cats-in-haunted-house program, but with no Visa cards, only inexpensive prizes — plastic sunglasses, inflatable globes — as a reward for not talking and staying in their seats.

The boy tapping randomly at his computer without even paying attention to the game? He was in the fourth-grade class. Although the study is not yet complete, perhaps it will show that the opportunity to increase intelligence is not motivation enough. Just like physical exercise, cognitive exercises may prove to be up against something even more resistant to training than fluid intelligence: human nature.

From The Science of Genius

Dean Keith Simonton

Identifying genius is a dicey venture. Consider, for example, this ranking of "The Top 10 Geniuses" I recently stumbled across on Listverse.com. From first to last place, here are the honorees: Johann Wolfgang von Goethe, Leonardo da Vinci, Emanuel Swedenborg, Gottfried Wilhelm von Leibniz, John Stuart Mill, Blaise Pascal, Ludwig Wittgenstein, Bobby Fischer, Galileo Galilei and Madame De Staël.

What about Albert Einstein instead of Swedenborg? Some of the living might also deserve this appellation — Stephen Hawking comes to mind. A female genius or two might make the cut, perhaps Marie Curie or Toni Morrison. And if a chess champion, Fischer, is deemed worthy, other geniuses outside the arts and sciences ought to deserve consideration — Napoleon Bonaparte as a military genius, Nelson Mandela as a political genius or Bill Gates as an entrepreneurial genius, to name a few candidates.

All these questions and their potential answers can make for some lively cocktail party conversations. What they reveal is how little we understand about the origins of intellectual and creative eminence. Explorations of this age-old debate have long sought to tease out the common features of geniuses working in disparate domains. The existence of unifying threads including genetic factors, unusually broad interests and a link with psychopathy — suggests that the mind of a genius has a discernible shape and disposition.

Ultimately the goal is to explain how an eminent thinker arrives at his or her world-changing moment, or moments, of insight. Although such breakthroughs often seem to appear in a flash, the underlying mechanisms are likely to be much more orderly. According to one theory I helped to develop, a genius hunts widely — almost blindly — for a solution to a problem, exploring dead ends and backtracking repeatedly before arriving at the ideal answer. If this line of research bears out, we can start to investigate whether genius can be cultivated, unleashing a wealth of new ideas for the benefit of all.

The Meaning of Genius

The first hurdle in the study of genius is to settle on a working definition. The word itself harks back to ancient Roman mythology, according to which every male was born with a unique genius that served as a kind of guardian angel, and every female had a juno. Much later, after the Renaissance, the word became more exclusive in its application, with only a few people showing genius. Philosopher Immanuel Kant believed, for example, that a genius was someone who produced works that were both original and exemplary. The term did not acquire scientific meaning until the late 19th century, when psychologists came to define genius in two distinct ways.

The first approach was to identify genius with exceptional achievement, as Kant did. These accomplishments elicit admiration and emulation from other experts in that field and often the world at large. Unquestioned examples of such works include Newton's *Principia*, Shakespeare's *Hamlet*, Tolstoy's *War and Peace*, Michelangelo's Sistine Chapel frescoes and Beethoven's "Fifth Symphony." Even though this definition can be extended to encompass extraordinary leadership, such as military brilliance, and prodigious performance, including some chess grandmasters, most scientific research concentrates on outstanding creativity within the sciences or the arts, which will also be the focus here.

The second definition of genius coincided with the emergence of intelligence tests in the first half of the 20th century. A genius was someone who scored sufficiently high on a standard IQ test — usually landing in the top 1 percent, with a score above 140, as proposed by psychologist Lewis Terman, the formulator of one of the original intelligence tests. These two definitions have little in common. Many persons with superlative IQs do not produce original and exemplary accomplishments. One example is Marilyn vos Savant, who was once certified by the *Guinness Book of World Records* as having the highest recorded IQ of any living person. Her weekly "Ask Marilyn" column for a Sunday newspaper supplement did not inspire a new genre of science, art or even journalism. And many exceptional achievers do not attain genius-level IQs. William Shockley, for example, received a Nobel Prize in Physics for coinventing the transistor yet had an IQ score well below 140. Exceptional achievement, then, seems the more useful measure.

Too often in popular writing, genius is conceived as a discrete category — this person is a genius, but that person is not. Yet just as people can vary in IQ, they can also differ in the magnitude of their creative achievements, with either a single notable contribution or a lifetime of prolific work. One such "one-hit wonder" is Gregor Mendel, who attained lasting fame for a single paper that reported his classic experiments in genetics. Had Mendel never taken an interest in breeding peas, his name would be unknown today. Charles Darwin's fame, in contrast, rests on far more than *On the Origin of Species*. Nobel laureate Max Born once said that Einstein "would be one of the greatest theoretical physicists of all time even if he had not written a single line on relativity." Hence, Darwin and Einstein exhibited greater genius than did Mendel. Accordingly, much research is devoted to assessing relative degrees of genius — most often gauged by creative productivity.

Origins of Genius

Finding the sources of consummate creativity has occupied the minds of philosophers and scientists for centuries. In 1693 English poet John Dryden wrote, "Genius must be born, and never can be taught." Two and a half centuries later French author Simone de Beauvoir countered, "One is not born a genius, one becomes a genius." The first scientific investigation devoted exclusively to genius concerned this precise issue. In 1869 Francis Galton published *Hereditary Genius*, in which he argued that genius is innate, based on his observations that geniuses tend to emerge from lineages that included other brilliant individuals. In response to criticisms, Galton later introduced the well-known nature-nurture issue. He conducted a survey of famous English scientists to discover some of the environmental variables involved in nurturing brilliance, and he examined factors such as birth order and education.

By the second half of the 20th century psychologists had moved to an extreme nurture position, in which creative genius rested solely on the acquisition of domain expertise. This idea was frequently expressed as the "10-year rule." Nobody can expect to reach the heights of creativity without mastering the necessary knowledge and skill because only experts can create — or so the thinking went. Indeed, Einstein learned lots of physics before he commenced his creative career.

This explanation cannot account for all the details, however. First, geniuses often spend less time acquiring domain expertise than their less creative colleagues. Studies have linked accelerated acquisition with long, prolific and high-impact careers. The 10-year rule is an average with tremendous variation around the mean. Further, major breakthroughs often occur in areas where the genius must create the necessary expertise from scratch. Telescopic astronomy did not exist until Galileo pointed his new instrument toward the night sky to discover what had never been seen before nor even expected. The moon had mountains, Jupiter had moons and the sun had spots!

Second, geniuses are more likely to exhibit unusually wide interests and hobbies and to display exceptional versatility, often contributing to more than one domain of expertise. This tendency was true not only in the era of Renaissance men but is also evident today. According to a 2008 study, Nobel laureates in science are more involved in the arts than less eminent scientists. Given that geniuses likely do not sleep any less than the rest of us, these extraneous activities would seem to distract from a dogged focus on a narrow field of interest. Einstein slept even more hours than the norm, but he still took time off to play Bach, Mozart and Schubert on his violin. At times these avocational activities inspire major insights. Galileo was probably able to identify the lunar mountains because of his training in the visual arts, particularly in the use of chiaroscuro to depict light and shadow.

The expertise acquisition theory also undervalues the genetic components that underlie a large number of cognitive abilities and personality traits that correlate with genius. In a recent meta-analysis, I found that at least 20 percent of the variation in creativity could be attributed to nature. For example, creative achievement is strongly associated with the personality trait of openness to experience, a highly heritable characteristic. The broad interests in art and music of many geniuses are clear manifestations of this trait. Many other predictors of achievement also have high heritabilities, such as cognitive and behavioral flexibility, along with a tolerance of ambiguity and change.

Nurture may still account for the lion's share of genius, and mastering a domain remains central. At the same time, genetics contributes heavily to the rate at which someone acquires the necessary skills and knowledge. Those with more innate talent can improve faster, launch their careers earlier and be more productive. In addition, genetics may help explain the different trajectories of equally well-trained individuals. Einstein did not know as much physics as many of his contemporary theoretical physicists, but what he did know went a long way. He could honestly say, "Imagination is more important than knowledge."

These influences are just a few of the ways genetics shapes the potential for genius. Let it suffice to note that I have probably understated the impact of genes on genius.

Madness and Magnificence

Researchers have long been tantalized by the question of whether the biological endowment of a genius also confers great setbacks. Greek philosopher Aristotle is reputed to have said, "Those who have become eminent in philosophy, politics, poetry and the arts have all had tendencies toward melancholia." This idea received wide currency in the 19th and 20th centuries at the hands of psychiatrists and psychoanalysts. Among the great writers, Virginia Woolf, Anne Sexton and Sylvia Plath all committed suicide. Vincent van Gogh did as well, and earlier he had cut off part of his ear to give to a prostitute. Newton sometimes suffered from extreme paranoia, and Galileo, possibly an alcoholic, was often bedridden with depression. Nevertheless, many psychologists have argued that such cases are the exceptions, not the rule. Some positive psychologists today consider creative genius a human strength or virtue.

My 2005 review of the literature, which summarized studies with varied methodologies, indicates that the association between genius and mental illness has considerable strength. Very creative writers tend to obtain higher scores on the psychopathology-related parts of the Minnesota Multiphasic Personality Inventory, a widely accepted personality test. A study using another instrument, the Eysenck Personality Questionnaire, found that extremely creative artists — and high-impact psychologists, for that matter — tend to receive elevated scores on the test's psychoticism scale, meaning that they are, among other things, egocentric, cold, impulsive, aggressive and tough-minded. Last, highly eminent scientists score higher on sections of the Cattell 16 Personality Factor Questionnaire that signify they are withdrawn, solemn, internally preoccupied, precise and critical. All told, top performers are not a very normal bunch.

Psychiatric studies bolster these results. The rate and intensity of certain psychopathic symptoms, such as depression and alcoholism, are noticeably higher in very creative individuals than in the general population. Research also suggests that these divergent thinkers are more likely to come from family lines at higher risk for psychopathology. Even if an extraordinary innovator is "normal," his or her family members may not be.

In line with these findings, in 2009 psychiatrist Szabolcs Kéri of Semmelweis University in Hungary found a genetic basis for both creativity and psychosis in a variant of the Neuregulin 1 gene. In this study, Kéri recruited a group of highly creative individuals and found that the participants who had this specific gene variant, which is linked with an increased risk of developing a mental disorder, also scored higher on measures of creativity.

Out-and-out psychosis, however, can shut down creative genius. This tragic reality was dramatically illustrated in the 2001 film *A Beautiful Mind*, the biopic about Nobel laureate John Forbes Nash and his struggles with schizophrenia. The costs and burdens of psychological dysfunction are also immediately apparent in the art of the mentally ill, such as the works preserved in the Prinzhorn Collection in Heidelberg, done by psychiatric patients in the early 20th century. Few if any of these artworks show signs of genius. Quoting Dryden again, "wits are sure to madness near allied, and thin partitions do their bounds divide."

Recent research conducted by psychologist Shelley Carson of Harvard University and her colleagues has sought to identify these thin partitions. Creative achievement is positively associated both with cognitive disinhibition — openness to supposedly extraneous ideas, images or stimuli — and higher intelligence and greater working memory. These mental capacities can potentially ameliorate the negative effects of disinhibition and even channel them to more useful ends. This synergy may well constitute the cognitive basis for serendipity. Not everybody would be able to work out the profound implications of such humdrum events as water overflowing a bathtub or an apple falling from a tree. But Archimedes and Newton did.

Thinking Outside the Box

Archimedes and Newton both worked in scientific fields, raising the possibility that their brands of creativity may have been similar. A more revealing question might be to investigate how their route to original thought compares with that of a superlative writer or musician. A physicist's way of thinking has little, if anything, in common with that of a painter. For example, learning how to solve a differential equation has as much utility for a painter as learning linear perspective has for a physicist — zero in most cases. Yet the themes uniting geniuses, as discussed earlier, suggest that a common creative principle may exist. Domain expertise, such as the knowledge of advanced problem-solving strategies, supports thinking that is routine, even algorithmic — it does not inherently lead to the generation of novel, useful and surprising ideas. Something else must permit a person to go beyond tradition and training to reach the summit of genius.

According to a theory proposed in 1960 by psychologist Donald Campbell, creative thought emerges through a process or procedure he termed blind variation and selective retention (BVSR). In short, a creator must try out ideas that might fail before hitting on a breakthrough. Campbell did not precisely define what counts as a blind variation, nor did he discuss in any detail the psychological underpinnings of this process. As a result, his ideas were left open to criticism.

Using a mixture of historical analyses, laboratory experiments, computer simulations, mathematical models and case studies, I have devoted the past 25 years to developing BVSR into a comprehensive theory of creative genius in all domains. The blindness of BVSR merely means that ideas are produced without foresight into their eventual utility. The creator must engage in trial-and-error or generate-and-test procedures to determine the worth of an idea. Two common phenomena characterize BVSR thinking: superfluity and backtracking. Superfluity means that the creator generates a variety of ideas, one or more of which turn out to be useless. Backtracking signifies that the creator must often return to an earlier approach after blindly going off in the wrong direction. Superfluity and backtracking are often found together in the same creative episode. Exploring the wrong track obliges a return to options that had been originally cast aside.

The reflections of Hermann von Helmholtz, a prolific physicist with numerous creative breakthroughs to his name, capture this process of discovery:

> I had to compare myself with an Alpine climber, who, not knowing the way, ascends slowly and with toil, and is often compelled to retrace his steps because his progress is stopped; sometimes by reasoning, and sometimes by accident, he hits upon traces of a fresh path, which again leads him a little further; and finally, when he has reached the goal, he finds to his annoyance a royal road on which he might have ridden up if he had been clever enough to find the right starting point at the outset.

This account of venturing blindly into uncharted territory and retracing steps resonates with evidence from other eminent creators. As Einstein once said, "If we knew what we were doing, we wouldn't call it research."

To see superfluity and backtracking in practice, consider the sketches that Pablo Picasso produced in preparation for his 1937 Guernica painting. Among them are clearly "superfluous" sketches, which have a human head on a bull's body . . . Picasso soon discovered that this was a dead end and backtracked to an earlier bull's head drawing . . . before continuing to the final two sketches . . . [T]he artist went too far in one direction in the last sketch, from which he backtracked yet again. Even more telling, after that last sketch Picasso largely reversed himself to a much earlier formulation . . . which shares the most unique features with the final version: the widely separated eyes, the thin-lipped open mouth with tongue, the menacing rather than inert visage and the Cubist rather than neoclassic style. These sketches are typical of blind variations both in the arts and in the sciences.

Only further research can expand the theory into a comprehensive, predictive model whose claims can be thoroughly tested. Even so, BVSR can help us make sense of certain quirks of the creative genius, including their personality traits and developmental experiences. Although they devote considerable time to achieving expertise, they also pursue other hobbies. Their openness to new ideas and their breadth of interests infuse them with seemingly irrelevant stimulation that can enrich blind variations.

As 19th-century German philosopher Arthur Schopenhauer said, "Talent hits a target no one else can hit; genius hits a target no one else can see." Exceptional thinkers, it turns out, stand on common ground when they launch their arrows into the unknown.

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MEASURING GENIUS

In 1926 Catharine Cox estimated the IQs of 301 eminent individuals. Using biographical data on early intellectual development, she and her collaborators calculated IQ using the formula IQ = 100 x MA/ CA, where MA = mental age and CA = chronological age. Some representative results are shown here. (The actual scores are taken from a secondary analysis of her data that I recently published with Anna V. Song of the University of California, Merced.) These rankings illustrate the value of using achieved eminence, rather than intelligence test scores, as a measure of genius. Philosopher George Berkeley, for example, did not leave a greater mark on the world than Newton or da Vinci. Further, eight of these creative geniuses have IQs below the "genius threshold" of 140. — D.K.S.

IQs	Scientists	Philosophers	Writers	Artists	Composers
190s		Gottfried Wilhelm von Leibniz	Johann Wolfgang von Goethe		
180s	Blaise Pascal	John Stuart Mill	Voltaire		
170s	Pierre-Simon Laplace	George Berkeley	Samuel Taylor Coleridge		
160s	Isaac Newton	René Descartes	Charles Dickens	Michelangelo	
150s	Johannes Kepler	Baruch Spinoza	Michel de Montaigne	Leonardo da Vinci	Wolfgang Amadeus Mozart
140s	Charles Darwin	Emanuel Swedenborg	Molière	Peter Paul Rubens	Ludwig van Beethoven
130s	Nicolaus Copernicus	Jean-Jacques Rousseau	Robert Bums	Rembrandt van Rijn	Gioachino Rossini
120s			Miguel de Cervantes	Bartolomé Esteban Murillo	Cristoph Willibald Gluck

Why Is Dancing So Good for Your Brain?

by Christopher Bergland, October 1, 2013

Dancing improves brain function on a variety of levels. Two recent studies show how different types of practice allow dancers to achieve peak performance by blending cerebral and cognitive thought processes with muscle memory and "proprioception" held in the cerebellum. Through regular aerobic training that incorporates some type of dance at least once a week anyone can maximize his or her brain function.

When was the last time you went out dancing? I make a habit of going to my local dance club called the Atlantic House at least once a week. I have been dancing to DJ David LaSalle's music in the same spot in front of a huge speaker since 1988. Some of my friends make fun of me for "chasing butterflies" and acting like a fool on the dance floor. I don't care. I know that dancing and spontaneously trying to spin like Michael Jackson is good for my brain.

While researching this blog, I pulled up some old footage of Michael Jackson spinning. He was an incredible dancer. . . . practicing a dance move like "spinning" from childhood reshapes the cerebellum (down brain) and allows a dancer to create superfluidity and not get dizzy while rotating quickly.

Do you feel dizzy sometimes when you stand up? Does a fear of falling prevent you from exploring the world more? If you are prone to dizziness, a new study has found that dancing may help improve your balance and make you less dizzy. In September 2013, researchers from Imperial College London reported on specific differences in the brain structure of ballet dancers that may help them avoid feeling dizzy when they perform pirouettes. You don't have to train to become a professional ballet dancer to benefit from some type of dancing.

The article is titled "The Neuroanatomical Correlates of Training-Related Perceptuo-Reflex Uncoupling in Dancers." The research suggests that years of training can enable dancers to suppress signals from the balance organs in the inner ear linked to the cerebellum. The findings, published in the journal *Cerebral Cortex*, could help to improve treatment for patients with chronic dizziness. Around one in four people experience this condition at some time in their lives.

In a previous *Psychology Today* blog titled "Fear of Falling Creates a Downward Spiral," I talk about the risk of Traumatic Brain Injury (TBI) due to a fear of falling and impaired balance. Taking time throughout your life to improve the function of your cerebellum through aerobic activity and some type of dance is a fun and effective way to avoid the perils of dizziness.

For this study the researchers at Imperial College London recruited 29 female ballet dancers and, as a comparison group, 20 female rowers whose age and fitness levels matched the dancers. Interestingly, most rhythmic aerobic exercise is going to be a bi-pedal motion or very linear — like rowing. It is interesting to note the benefits to proprioception and balance based in the cerebellum that is enhanced through dance.

The study volunteers were spun around in a chair in a dark room. They were asked to turn a handle in time with how quickly they felt like they were still spinning after they had stopped. The researchers also measured eye reflexes triggered by input from the vestibular organs. Later, they examined the participants' brain structure with MRI scans.

Normally, the feeling of dizziness stems from the vestibular organs in the inner ear. These fluid-filled chambers sense rotation of the head through tiny hairs that sense the fluid moving. After turning around rapidly, the fluid continues to move, which can make you feel like you're still spinning.

In dancers, both the eye reflexes and their perception of spinning lasted a shorter time than in the rowers. Sensory input evokes low-order reflexes of the cerebellum and higher-order perceptual responses of the cerebrum. Vestibular stimulation elicits vestibular-ocular reflex (VOR) and self-motion perception (e.g., vertigo) whose response durations are normally equal.

I have a section in my book, *The Athlete's Way*, which explores the connection to VOR and muscle memory during REM sleep . . . I say, "It became clear to me that creating a dreamlike default state of flow through sport is linked to VOR, too. It is really like REM in reverse. This is my original hypothesis. My father thinks it makes sense, but other scientists have yet to explore this theory." The new research from London this month offers exciting new connections to VOR and peak performance.

Dr. Barry Seemungal, from the Department of Medicine at Imperial, said: "Dizziness, which is the feeling that we are moving when in fact we are still, is a common problem. I see a lot of patients who have suffered from dizziness for a long time. Ballet dancers seem to be able to train themselves not to get dizzy, so we wondered whether we could use the same principles to help our patients."

The brain scans revealed differences between the groups in two parts of the brain: an area in the cerebellum where sensory input from the vestibular organs is processed and in the cerebral cortex, which is responsible for the perception of dizziness.

"It's not useful for a ballet dancer to feel dizzy or off balance. Their brains adapt over years of training to suppress that input. Consequently, the signal going to the brain areas responsible for perception of dizziness in the cerebral cortex is reduced, making dancers resistant to feeling dizzy. If we can target that same brain area or monitor it in patients with chronic dizziness, we can begin to understand how to treat them better."

"This shows that the sensation of spinning is separate from the reflexes that make your eyes move back and forth," Dr. Seemungal said. "In many clinics, it's common to only measure the reflexes, meaning that when these tests come back normal the patient is told that there is nothing wrong. But that's only half the story. You need to look at tests that assess both reflex and sensation." In summary, dancers display vestibular perceptuo-reflex dissociation with the neuronatomical correlate localized to the vestibular cerebellum.

Visualizing Movements can Improve Muscle Memory

A July 2013 article titled "The Cognitive Benefits of Movement Reduction: Evidence From Dance Marking" found that dancers can improve the ability to do complex moves by walking through them slowly and encoding the movement with a cue through "marking." Researcher Edward Warburton, a former professional ballet dancer, and colleagues were interested in exploring the "thinking behind the doing of dance."

The findings, published in *Psychological Science*, a journal of the Association for Psychological Science, suggest that marking may alleviate the conflict between the cognitive and physical aspects of dance practice — allowing dancers to memorize and repeat steps more fluidly. This creates what I call "superfluidity," which is the highest tier of "flow."

Expert ballet dancers seem to glide effortlessly across the stage, but learning the steps is both physically and mentally demanding. New research suggests that dance marking — loosely practicing a routine by "going through the motions" — may improve the quality of dance performance by reducing the mental strain needed to perfect the movements.

"It is widely assumed that the purpose of marking is to conserve energy," explains Warburton, professor of dance at the University of California, Santa Cruz. "But elite-level dance is not only physically demanding, it's cognitively demanding as well. Learning and rehearsing a dance piece requires concentration on many aspects of the desired performance." Marking essentially involves a run-through of the dance routine, but with a focus on the routine itself, rather than making the perfect movements.

"When marking, the dancer often does not leave the floor, and may even substitute hand gestures for movements," Warburton explains. "One common example is using a finger rotation to represent a turn while not actually turning the whole body."

To investigate how marking influences performance, the researchers asked a group of talented dance students to learn two routines: they were asked to practice one routine at performance speed and to practice the other one by marking. Across many of the different techniques and steps, the dancers were judged more highly on the routine that they had practiced with marking — their movements on the marked routine appeared to be more seamless, their sequences more fluid.

Conclusion: Synchronizing the Cerebrum and Cerebellum Creates Superfluidity

The researchers conclude that practicing at performance speed didn't allow the dancers to memorize and consolidate the steps as a sequence, thus encumbering their performance. This type of visualization and marking could be used to maximize performance across many fields and areas of life.

"By reducing the demands on complex control of the body, marking may reduce the multi-layered cognitive load used when learning choreography," Warburton explains. "Marking could be strategically used by teachers and choreographers to enhance memory and integration of multiple aspects of a piece precisely at those times when dancers are working to master the most demanding material," says Warburton.

It's unclear whether these performance improvements would be seen for other types of dance, Warburton cautions, but it is possible that this area of research could extend to other kinds of activities, perhaps even language acquisition. He said, "Smaller scale movement systems with low energetic costs such as speech, sign language, and gestures may likewise accrue cognitive benefits, as might be the case in learning new multisyllabic vocabulary or working on one's accent in a foreign language."

From "Is Coding the New Literacy?"

By Tasneem Raja

In the winter of 2011, a handful of software engineers landed in Boston just ahead of a crippling snowstorm. They were there as part of Code for America, a program that places idealistic young coders and designers in city halls across the country for a year. They'd planned to spend it building a new website for Boston's public schools, but within days of their arrival, the city all but shut down and the coders were stuck fielding calls in the city's snow emergency center.

In such snowstorms, firefighters can waste precious minutes finding and digging out hydrants. A city employee told the CFA team that the planning department had a list of street addresses for Boston's 13,000 hydrants. "We figured, 'Surely someone on the block with a shovel would volunteer if they knew where to look,'" says Erik Michaels-Ober, one of the CFA coders. So they got out their laptops.

Screenshot from Adopt-a-Hydrant Code for America

Now, Boston has adoptahydrant.org, a simple website that lets residents "adopt" hydrants across the city. The site displays a map of little hydrant icons. Green ones have been claimed by someone willing to dig them out after a storm, red ones are still available — 500 hydrants were adopted last winter.

Maybe that doesn't seem like a lot, but consider what the city pays to keep it running: $9 a month in hosting costs. "I figured that even if it only led to a few fire hydrants being shoveled out, that could be the difference between life or death in a fire, so it was worth doing," Michaels-Ober says. And because the CFA team open-sourced the code, meaning they made it freely available for anyone to copy and modify, other cities can adapt it for practically pennies. It has been deployed in Providence, Anchorage, and Chicago. A Honolulu city employee heard about Adopt-a-Hydrant after cutbacks slashed his budget, and now Honolulu has Adopt-a-Siren, where volunteers can sign up to check for dead batteries in tsunami sirens across the city. In Oakland, it's Adopt-a-Drain.

Sounds great, right? These simple software solutions could save lives, and they were cheap and quick to build. Unfortunately, most cities will never get a CFA team, and most can't afford to keep a stable of sophisticated programmers in their employ, either. For that matter, neither can many software companies in Silicon Valley; the talent wars have gotten so bad that even brand-name tech firms have been forced to offer employees a bonus of upwards of $10,000 if they help recruit an engineer.

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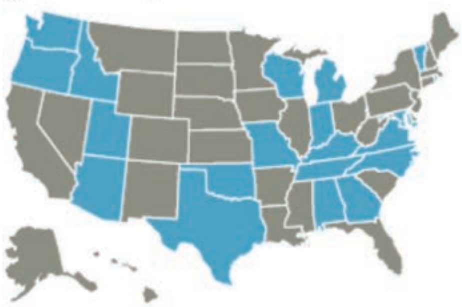
. . .[Y]ou might be forgiven for thinking that learning code is a short, breezy ride to a lush startup job with a foosball table and free kombucha, especially given all the hype about billion-dollar companies launched by self-taught wunderkinds (with nary a mention of the private tutors and coding camps that helped some of them get there). The truth is, code — if what we're talking about is the chops you'd need to qualify for a programmer job — is hard, and lots of people would find those jobs tedious and boring.

THE PIPELINE PROBLEM

Among AP courses taken last year, computer science is near the bottom.

English	862,000
Calculus	387,000
Spanish	154,000
Chemistry	140,000
European history	110,000
Computer science	31,000

Only 20 states count computer science toward graduation requirements in math or science.



Sources: College Board, Computer Science Teachers Association

But let's back up a step: What if learning to code weren't actually the most important thing? It turns out that rather than increasing the number of kids who can crank out thousands of lines of JavaScript, we first need to boost the number who understand what code can do. As the cities that have hosted Code for America teams will tell you, the greatest contribution the young programmers bring isn't the software they write. It's the way they *think*.…

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SO WHAT IS COMPUTATIONAL THINKING? If you've ever improvised dinner, pat yourself on the back: You've engaged in some light CT.

There are those who open the pantry to find a dusty bag of legumes and some sad-looking onions and think, “Lentil soup!” and those who think, “Chinese takeout.” A practiced home cook can mentally sketch the path from raw ingredients to a hot meal, imagining how to substitute, divide, merge, apply external processes (heat, stirring), and so on until she achieves her end. Where the rest of us see a dead end, she sees the potential for something new.

If seeing the culinary potential in raw ingredients is like computational thinking, you might think of a software algorithm as a kind of recipe: a step-by-step guide on how to take a bunch of random ingredients and start layering them together in certain quantities, for certain amounts of time, until they produce the outcome you had in mind.

Like a good algorithm, a good recipe follows some basic principles. Ingredients are listed first, so you can collect them before you start, and there’s some logic in the way they are listed: olive oil before cumin because it goes in the pan first. Steps are presented in order, not a random jumble, with staggered tasks so that you’re chopping veggies while waiting for water to boil. A good recipe spells out precisely what size of dice or temperature you’re aiming for. It tells you to look for signs that things are working correctly at each stage — the custard should coat the back of a spoon. Opportunities for customization are marked — use twice the milk for a creamier texture — but if any ingredients are absolutely crucial, the recipe makes sure you know it. If you need to do something over and over — add four eggs, one at a time, beating after each — those tasks are boiled down to one simple instruction.

Much like cooking, computational thinking begins with a feat of imagination, the ability to envision how digitized information — ticket sales, customer addresses, the temperature in your fridge, the sequence of events to start a car engine, anything that can be sorted, counted, or tracked — could be combined and changed into something new by applying various computational techniques. From there, it’s all about “decomposing” big tasks into a logical series of smaller steps, just like a recipe.

Those techniques include a lot of testing along the way to make sure things are working. The culinary principle of *mise en place* is akin to the computational principle of sorting: organize your data first, and you’ll cut down on search time later. Abstraction is like the concept of “mother sauces” in French cooking (béchamel, tomato, hollandaise), building blocks to develop and reuse in hundreds of dishes. There’s iteration: running a process over and over until you get a desired result. The principle of parallel processing makes use of all available downtime (think: making the salad while the roast is cooking). Like a good recipe, good software is really clear about what you can tweak and what you can’t. It’s explicit. Computers don’t get nuance; they need everything spelled out for them.

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. . .the building part is often not the hardest part: It’s figuring out what to build. “Unless you can think about the ways computers can solve problems, you can’t even know how to ask the questions that need to be answered,” says Annette Vee, a University of Pittsburgh professor who studies the spread of computer science literacy.

Indeed, some powerful computational solutions take just a few lines of code — or no code at all. Consider this lo-fi example: In 1854, a London physician named John Snow helped squelch a cholera outbreak that had killed 616 residents. Brushing aside the prevailing theory of the disease — deadly miasma — he surveyed relatives of the dead about their daily routines. A map he made connected the disease to drinking habits: tall stacks of black lines, each representing a death, grew around a water pump on Broad Street in Soho that happened to be near a leaking cesspool. His theory: The disease was in the water. Classic principles of computational thinking came into play here, including merging two datasets to reveal something new (locations of deaths plus locations of water pumps), running the same process over and over and testing the results, and pattern recognition. The pump was closed, and the outbreak subsided.

Detail from "On the Mode of Communication of Cholera," 1854

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. . .Jeannette Wing, a VP of research at Microsoft who popularized the term "computational thinking," says it's a shame to think CT is just for programmers. "Computational thinking involves solving problems, designing systems, and understanding human behavior," she writes in a publication of the Association for Computing Machinery. Those are handy skills for everybody, not just computer scientists.

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"CODE LITERATE." Sounds nice, but what does it mean? And where does literacy end and fluency begin? The best way to think about that is to look to the history of literacy itself.

Reading and writing have become what researchers have called "interiorized" or "infrastructural," a technology baked so deeply into everyday human life that we're never surprised to encounter it. It's the main medium through which we connect, via not only books and papers, but text messages and the voting booth, medical forms and shopping sites. If a child makes it to adulthood without being able to read or write, we call that a societal failure.

Yet for thousands of years writing was the preserve of the professional scribes employed by the elite. So what moved it to the masses? In Europe at least, writes literacy researcher Vee, the tipping point was the Domesday Book, an 11th-century survey of landowners that's been called the oldest public record in England.

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Commissioned by William the Conqueror to take stock of what his new subjects held in terms of acreage, tenants, and livestock so as to better tax them, royal scribes fanned across the countryside taking detailed notes during in-person interviews. It was like a hands-on demo on the efficiencies of writing, and it proved contagious. Despite skepticism — writing was hard, and maybe involved black magic — other institutions started putting it to use. Landowners and vendors required patrons and clients to sign deeds and receipts, with an "X" if nothing else. Written records became admissible in court. Especially once Johannes Gutenberg invented the printing press, writing seeped into more and more aspects of life, no longer a rarefied skill restricted to a cloistered class of aloof scribes but a function of everyday society.

Fast forward to 19th-century America, and it'd be impossible to walk down a street without being bombarded with written information, from newspapers to street signs to store displays; in the homes of everyday people, personal letters and account ledgers could be found. "The technology of writing became infrastructural," Vee writes in her paper "Understanding Computer Programming As a Literacy." "Those who could not read text began to be recast as 'illiterate' and power began to shift towards those who could." Teaching children how to read became a civic and moral imperative. . . .

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. . . "The spread of the texts from the central government to the provinces is echoed in the way that the programmers who cut their teeth on major government-funded software projects then circulated out into smaller industries, disseminating their knowledge of code writing further," Vee writes. Just as England had gone from oral tradition to written record after the Domesday Book, the United States in the 1960s and '70s shifted from written to computational record.

The 1980s made computers personal, and today it's impossible not to engage in conversations powered by code, albeit code that's hidden beneath the interfaces of our devices. But therein lies a new problem: The easy interface creates confusion around what it means to be "computer literate." Interacting with an app is very different from making or tweaking or understanding one, and opportunities to do the latter remain the province of a specialized elite. In many ways, we're still in the "scribal stage" of the computer age.

But the tricky thing about literacy, Vee says, is that it begets more literacy. It happened with writing: At first, laypeople could get by signing their names with an "X." But the more people used reading and writing, the more was required of them.

We can already see code leaking into seemingly far-removed fields. Hospital specialists collect data from the heartbeat monitors of day-old infants, and run algorithms to spot babies likely to have respiratory failure. Netflix is a gigantic experiment in statistical machine learning. Legislators are being challenged to understand encryption and relational databases during hearings on the NSA [National Security Administration].

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It may be hard to swallow the idea that coding could ever be an everyday activity on par with reading and writing in part because it looks so foreign (what's with all the semicolons and carets)? But remember that it took hundreds of years to settle on the writing conventions we take for granted today: Early spellings of words — *Whan that Aprille with his shoures soote* — can seem as foreign to modern readers as today's code snippets do to nonprogrammers. Compared to the thousands of years writing has had to go from notched sticks to glossy magazines, digital technology has, in 60 years, evolved exponentially faster.

Our elementary-school language arts teachers didn't drill the alphabet into our brains anticipating Facebook or WhatsApp or any of the new ways we now interact with written material. Similarly, exposing today's third-graders to a dose of code may mean that at 30 they retain enough to ask the right questions of a programmer, working in a language they've never seen on a project they could never have imagined.

To produce tech-savvy citizens "at scale," to borrow an industry term, the heavy lifting will happen in public school classrooms.

ONE DAY LAST YEAR, Neil Fraser, a young software engineer at Google, showed up unannounced at a primary school in the coastal Vietnamese city of Da Nang.

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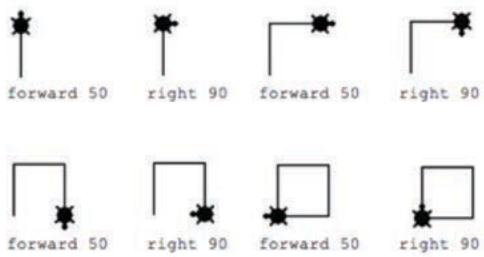
The fifth-graders in Da Nang were doing exercises in Logo, a simple program developed at MIT in the 1970s to introduce children to programming. A turtle-shaped avatar blinked on their screens and the kids fed it simple commands in Logo's language, making it move around, leaving a colored trail behind. Stars, hexagons, and ovals bloomed on the monitors.



Simple commands in Logo. MIT Media Lab

Fraser, who learned Logo when the program was briefly popular in American elementary schools, recognized the exercise. It was a lesson in loops, a bedrock programming concept in which you tell the machine to do the same thing over and over again, until you get a desired result.

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Early code education isn't just happening in Vietnamese schools. Estonia, the birthplace of Skype, rolled out a countrywide programming-centric curriculum for students as young as six in 2012. In September, the United Kingdom will launch a mandatory computing syllabus for all students ages 5 to 16.

Meanwhile, even as US enrollment in almost all other STEM (science, technology, engineering, and math) fields has grown over the last 20 years, computer science has actually *lost* students, dropping from 25 percent of high school students earning credits in computer science to only 19 percent by 2009, according to the National Center for Education Statistics.

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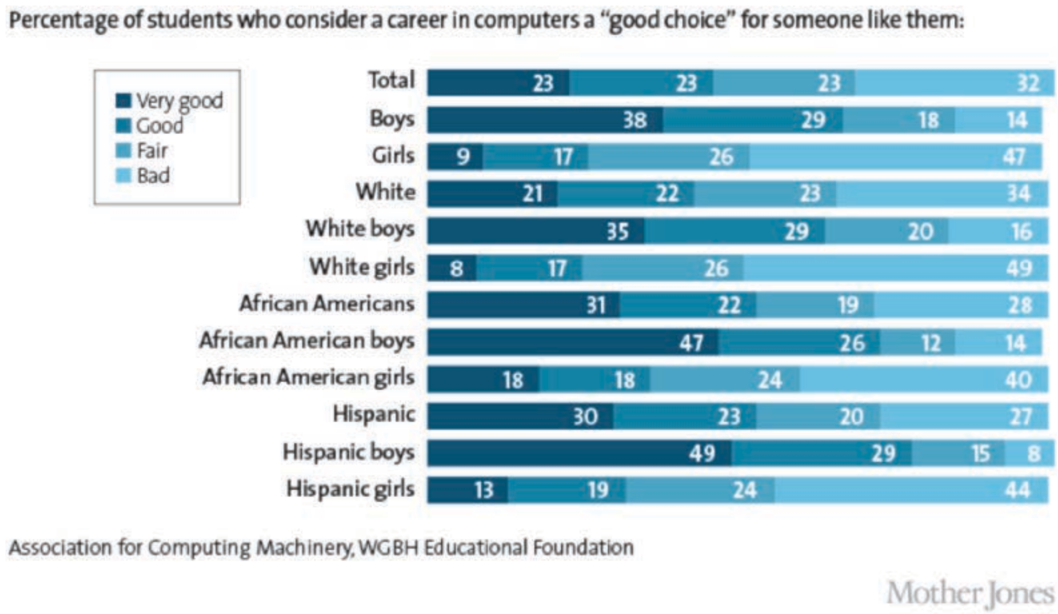

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IT WAS A LITTLE MORE THAN a century ago that literacy became universal in Western Europe and the United States. If computational skills are on the same trajectory, how much are we hurting our economy — and our democracy — by not moving faster to make them universal?

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We make kids learn about biology, literature, history, and geometry with the promise that navigating the wider world will be easier for their efforts. It'll be harder and harder not to include computing on that list. Decisions made by a narrow demographic of technocrat elites are already shaping their lives, from privacy and social currency, to career choices and how they spend their free time.

From Mapping the Bilingual Brain

Wednesday, December 12, 2012 - 01:00 PM
By Chris Berube

I was recently introduced to a friend's five-year-old daughter, and I'm already living in her shadow. She is being raised with not one, not two, but three languages. I began calculating how soon this child would know more total vocabulary than I do and realized it's probably already happened.

Nothing makes you feel intellectually insecure like finding out that a child might be smarter than you. But I found some small relief in talking with psychologist and noted researcher Ellen Bialystock, who studies the effects of language on the brain.

"Look, I will never say that bilingual kids are smarter," says Bialystock, from York University in Toronto, Canada, after I repeatedly peppered her with the question. "That's something you can never say."

Phew!

My relief, however, was cut short as Bialystock continued:

"What we can say is that some of the cognitive processes that are part of intelligence are more developed in bilinguals."

So what, exactly, does that mean?

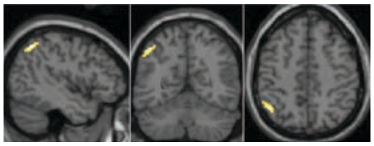
Brain Changer

A common view before the 1960s was that teaching a kid more than one language at a young age was confusing. Behavioral studies at the time posited that young minds weren't developed enough to handle so much information, and that bilingualism was disorienting for children. Since then, countless studies have shown that young brains are a lot more adaptable than old school social scientists gave them credit for being. Learning multiple languages won't confuse a child, or an adult learner: bilingualism actually *reshapes* the brain.

(A quick note here: when I refer to "bilingualism," I'm not talking about taking a couple of Spanish classes so you can order a *torta* with confidence; most of the cognitive benefits I'm about to point out only happen for people who are certifiably bilingual — people who pass fluency tests, things like that.)

In one study carried out by Cathy Price, a neuroimaging researcher at University College London, it was discovered that bilinguals had more gray matter in their *posterior supramarginal gyrus*, a long name for the ridged part of the brain that researchers have associated with vocabulary acquisition.

"When you learn more language, your *posterior supramarginal gyrus* will get a workout, and be stimulated to grow," says Price. "When you look at the images, there is more gray matter density with more than one language spoken." The image (on the following page) is just one of the brain scans Price's team took of a bilingual brain; it shows the same brain, from three different angles, with the yellow spot identifying the area of the brain where they've seen thickening:



Since gray matter makes up a good portion of the nerve cells within the brain, the more gray matter in that particular gyrus, the faster and more accurately your brain will perform certain tasks. For example, there is evidence that bilingual brains are better at doing tasks where conflicting information has to be processed. In one study, Ellen Bialystok subjected a group of 5 year olds — some bilingual, some monolingual — to something called "Simon Tests," which are used to determine how quickly people can respond to confusing stimulus. For example, you might be asked to push a button with your right hand that triggers a light on the left side of your field of view — things like that which feel unnatural. The bilinguals, on the whole, were much better at the tests, which suggests they are much better at sorting out conflicting information.

Since the bilingual brain is adept at suppressing the language that isn't being used in a given moment, it has experience inhibiting unhelpful information and promoting important stuff. There are lots of benefits to this — one study found that bilinguals were more able to filter out ambient noise. Speaking two languages means you feel less overwhelmed when trying to order in a busy restaurant, and makes you more capable of talking to someone on a crowded subway.

Price is quick to point out that, at best, any benefits are minimal. Bilinguals are only a few milliseconds faster at sorting information, but, hey, that adds up!

"Bilingualism is an experience," says Bialystock, and just like any other exercise (e.g., dancing, knitting, using sign language) it re-wires the brain, forming new neurons and new connections.

Preventative medicine

While many contemporary studies have linked bilingualism with a better-performing brain, more recently, a few researchers have begun exploring the question of whether language proficiency affects disease outcomes — does bilingualism, in other words, help stave off certain illnesses? Bialystok has studied people suffering from dementia and she believes that the healthier bilingual brain actually weathers the ravages of aging better than a monolingual one.

In one experiment published in 2012, Bialystock examined the brain scans of 40 patients diagnosed with probable Alzheimer's disease. "For our test subjects, we had people with the same level of disease, at exactly the same age," says Bialystok. They all showed approximately the same symptoms. Their brains, therefore, should look pretty much the same. But what Bialystok found was surprising.

Traditionally, the brain of a person with Alzheimer's atrophies as neurons die: the brain's outer layer begins to shrink, and the hippocampus withers. When Bialystok compared the brains of 40 patients, she found that the brains of the bilinguals in the study showed twice as much atrophy as the monolinguals. But despite having far more diseased brains, they had performed as well on cognitive tests as the monolinguals with less diseased brains.

What? With more atrophy, you'd expect the disease to be further along — you'd expect those patients to have more problems functioning day-to-day. But for the bilinguals, it wasn't, and they didn't. Bialystok has undertaken a couple of similar studies in the last few years, and every time, she's found the same result: language multiplicity appears to hold off the effects of dementia. In one examination of 211 probable Alzheimer's patients, the effect was so great, she found that the bilingual patients had reported the onset of symptoms 5.1 years later than the monolingual ones.

Bialystock is the first to say that, while her studies are promising, they aren't definitive. "There are lots of questions here," Bialystock says. "Like, why would bilingualism fight Alzheimer's anyway?" But she believes it has something to do with how language re-wires us.

Who's smarter?

That's all good news for that five year old, though I still wanted to know if she was smarter than me.

The closest I could come to an objective measurement was IQ scores . . . and well, I won't get into the caveats and thorniness of using IQ to measure anything, let alone how smart you are. Quite a few studies explicitly draw a parallel between bilingualism and a high IQ score, but researchers are quick to point out that such a relationship is not perfect.

"One of the IQ tests is a vocabulary test, and in general, we might expect bilinguals to do slightly worse on a [vocabulary] test in one language than if it was their only language," says Price.

The reason for this vocab disparity is that bilinguals learn and use each language "for different purposes, in different domains of life," according to a book by French linguist François Grosjean. A kid might learn and use different languages for home and school, which means that, because of context, they won't get the full vocabulary of either place. Kind of a "Jack of all trades, a master of none" scenario.

"Bilinguals have a larger vocabulary, since they speak two languages," says Price, "but they might know fewer words within a language."

It seems nit-picky to me to say that a bilingual individual might be at a disadvantage because they don't speak as many words in *each* of their languages, and I think it's fair to say that the cognitive benefits of bilingualism probably outweigh the slight disadvantage they face on a test that is often discredited. Which again is good news for the multilinguals, but not for me and my monolingual ego. And it's going to be hard to make up for lost time: researchers show that it's tougher to fluently learn a second or third or fourth language as you age, meaning that adult learners might have a hard time getting the sweet, sweet cognitive advantages that bilingual children enjoy. . . .

From Book II: Locke's Essay Concerning Human Understanding Of Ideas

Chapter I

Of Ideas in general, and their Original

1. *Idea is the object of thinking.* Every man being conscious to himself that he thinks; and that which his mind is applied about whilst thinking being the ideas that are there, it is past doubt that men have in their minds several ideas, such as are those expressed by the words whiteness, hardness, sweetness, thinking, motion, man, elephant, army, drunkenness, and others: it is in the first place then to be inquired, How he comes by them?

   I know it is a received doctrine, that men have native ideas, and original characters, stamped upon their minds in their very first being. This opinion I have at large examined already; and, I suppose what I have said in the foregoing Book [Book One "Of Innate Notions"] will be much more easily admitted, when I have shown whence the understanding may get all the ideas it has; and by what ways and degrees they may come into the mind; for which I shall appeal to every one's own observation and experience.

2. *All ideas come from sensation or reflection.* Let us then suppose the mind to be, as we say, white paper [a "blank slate"], void of all characters, without any ideas: How comes it to be furnished? Whence comes it by that vast store which the busy and boundless fancy of man has painted on it with an almost endless variety? Whence has it all the materials of reason and knowledge? To this I answer, in one word, from EXPERIENCE. In that all our knowledge is founded; and from that it ultimately derives itself. Our observation employed either, about external sensible objects, or about the internal operations of our minds perceived and reflected on by ourselves, is that which supplies our understandings with all the materials of thinking. These two are the fountains of knowledge, from whence all the ideas we have, or can naturally have, do spring.

3. *The objects of sensation one source of ideas.* First, our Senses, conversant about particular sensible objects, do convey into the mind several distinct perceptions of things, according to those various ways wherein those objects do affect them. And thus we come by those ideas we have of yellow, white, heat, cold, soft, hard, bitter, sweet, and all those which we call sensible qualities; which when I say the senses convey into the mind, I mean, they from external objects convey into the mind what produces there those perceptions. This great source of most of the ideas we have, depending wholly upon our senses, and derived by them to the understanding, I call SENSATION.

4. *The operations of our minds, the other source of them.* Secondly, the other fountain from which experience furnisheth the understanding with ideas is, the perception of the operations of our own mind within us, as it is employed about the ideas it has got; which operations, when the soul comes to reflect on and consider, do furnish the understanding with another set of ideas, which could not be had from things without. And such are perception, thinking, doubting, believing, reasoning, knowing, willing, and all the different actings of our own minds; which we being conscious of, and observing in ourselves, do from these receive into our understandings as distinct ideas as we do from bodies affecting our senses. This source of ideas every man has wholly in himself; and though it be not sense, as having nothing to do with external objects, yet it is very like it, and might properly enough be called internal sense. But as I call the other SENSATION, so I call this REFLECTION, the ideas it affords being such only as the mind gets by reflecting on its own operations within itself. By reflection then, in the following part of this discourse, I would be understood to mean, that notice which the mind takes of its own operations, and the manner of them, by reason whereof there come to be ideas of these operations in the understanding. These two, I say, viz. external material things, as the objects of SENSATION, and the operations of our own minds within, as the objects of REFLECTION, are to me the only originals from whence all our ideas take their beginnings. The term operations here I use in a large sense, as comprehending not barely the actions of the mind about its ideas, but some sort of passions arising sometimes from them, such as is the satisfaction or uneasiness arising from any thought.

5. *All our ideas are of the one or the other of these.* The understanding seems to me not to have the least glimmering of any ideas which it doth not receive from one of these two. External objects furnish the mind with the ideas of sensible qualities, which are all those different perceptions they produce in us; and the mind furnishes the understanding with ideas of its own operations.

   These, when we have taken a full survey of them, and their several modes, combinations, and relations, we shall find to contain all our whole stock of ideas; and that we have nothing in our minds which did not come in one of these two ways. Let any one examine his own thoughts, and thoroughly search into his understanding; and then let him tell me, whether all the original ideas he has there, are any other than of the objects of his senses, or of the operations of his mind, considered as objects of his reflection. And how great a mass of knowledge soever he imagines to be lodged there, he will, upon taking a strict view, see that he has not any idea in his mind but what one of these two have imprinted; though perhaps, with infinite variety compounded and enlarged by the understanding. . .

6. *Observable in children.* He that attentively considers the state of a child, at his first coming into the world, will have little reason to think him stored with plenty of ideas, that are to be the matter of his future knowledge. It is by degrees he comes to be furnished with them . . . . if a child were kept in a place where he never saw any other but black and white till he were a man, he would have no more ideas of scarlet or green, than he that from his childhood never tasted an oyster, or a pineapple, has of those particular relishes.

7. *Men are differently furnished with these, according to the different objects they converse with.* Men then come to be furnished with fewer or more simple ideas from without, according as the objects they converse with afford greater or less variety; and from the operations of their minds within, according as they more or less reflect on them. For, though he that contemplates the operations of his mind, cannot but have plain and clear ideas of them; yet, unless he turn his thoughts that way, and considers them attentively, he will no more have clear and distinct ideas of all the operations of his mind, and all that may be observed therein, than he will have all the particular ideas of any landscape, or of the parts and motions of a clock, who will not turn his eyes to it, and with attention heed all the parts of it. The picture, or clock, may be so placed, that they may come in his way every day; but yet he will have but a confused idea of all the parts they are made up of, till he applies himself with attention, to consider them each in particular.

Credits

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Page 29: "Mapping the Bilingual Brain" by Chris Berube, Radiolab.org, Dec. 12, 2012, http://www.radiolab.org.

Page 30: Brain scan images from "Neurolinguistics: Structural Plasticity in the Bilingual Brain" by Andrea Mechelli, Jenny T. Crinion, Uta Noppeney, John O'Doherty, John Ashburner et al., *Nature*, 2004 Oct. 14; 431(7010): 757, copyright © 2004, Rights Managed by Nature Publishing Group, as appeared in "Mapping the Bilingual Brain" by Chris Berube, Radiolab.org, Dec. 12, 2012.