Can You Make Yourself Smarter?

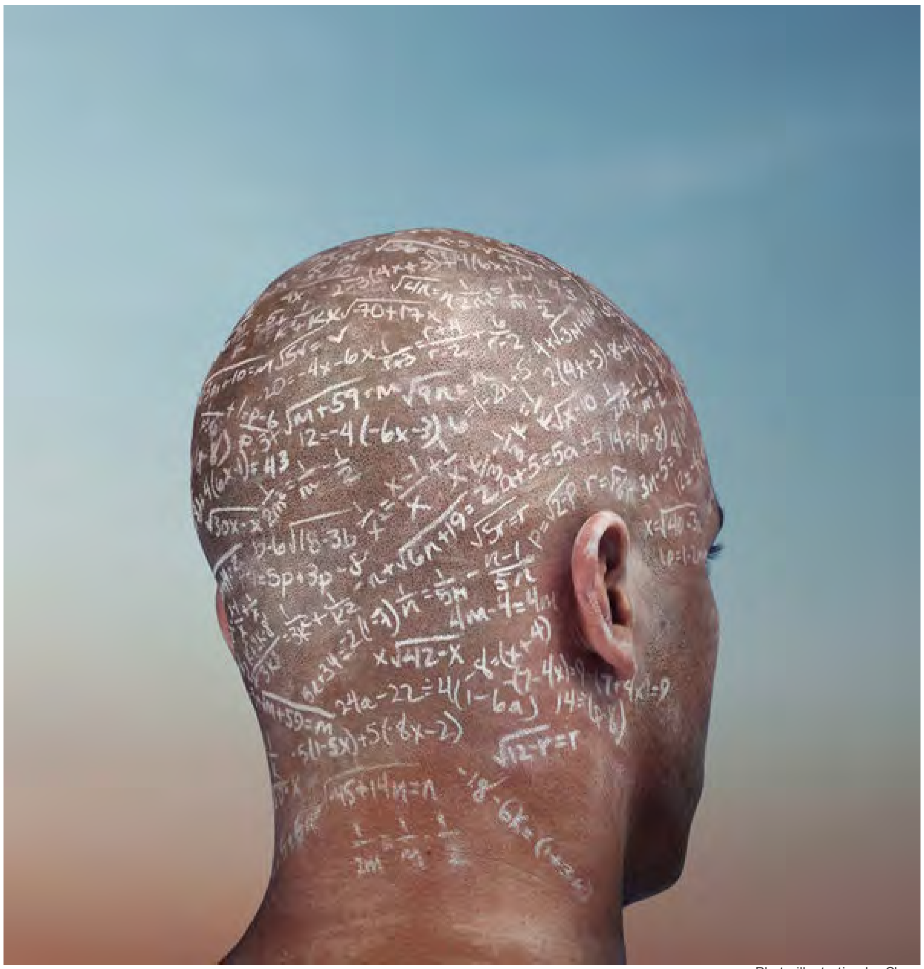

Photo illustration by Clang

By DAN HURLEY
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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.

What Your I.Q. Means

116+
17 percent of the world population; superior I.Q.; appropriate average for individuals in professional occupations.

"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

121+
10 percent; potentially gifted; average for college graduates

132+
2 percent; borderline genius; average I.Q. of most Ph.D. recipients

143+
1 percent; genius level; about average for Ph.D.'s in physics

158+
1 in 10,000; Nobel Prize winners

164+
1 in 30,000; Wolfgang Amadeus Mozart and the chess champion Bobby Fischer.

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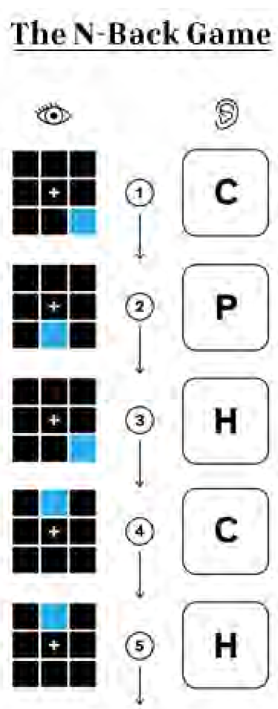

Games based on N-back tests require players to remember the location of a symbol or the sound of a particular letter presented just before (1-back), the time before last (2-back), the time before that (3-back) and so on. Some researchers say that playing games

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.

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" like this may actually make us smarter.

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.

Play a free online version of the N-back game.

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.

Dan Hurley is working on a book about intelligence. His last article for the magazine was about a drug being tested to raise intelligence in people with Down syndrome.

Editor: Ilena Silverman

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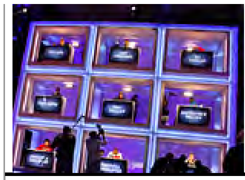

There should be a criminal prosecution that holds BP individuals responsible for the oil spill in the Gulf of Mexico.