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It's not magic, it's neuroscience

By Laura Sanders
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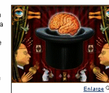
As the curtain lifts at Harrah's in Las Vegas, magician Mac King walks out on stage in a tacky plaid suit and pulls a spook/Howdy I'm Mac King!/ He then starts bending minds with more finesse and precision than a Jedi knight.



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HARNESSING ILLUSION TO REVEAL THE BRAIN
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Neuroscience taps the age-old tricks of magicians to gain insight into perception, attention and the mind.
Lou Beach

King convinces spectators that he can hook a fish out of thin air, eat it and then spit it back out — intact — into a wine glass. Such skill in manipulating people's perceptions has earned magicians a new group of spellbound fans: Scientists seeking to learn how the eyes and brain perceive — or don't perceive — reality.

Magicians' intuitions about human cognition have been passed down, along with their methods for entertaining, for thousands of years.

"We as scientists have a lot to learn from the art world," says Susana Martinez-Conde, of the Barrow Neurological Institute in Phoenix, who studies the neuroscience of visual systems. "If we had been paying attention to magic early on, cognitive neuroscience may have come around much faster."

In an article published in November 2008 in *Nature Reviews Neuroscience*, Martinez-Conde and other neuroscientists teamed up with famous magicians to argue that magic can be a powerful tool for probing how the human mind sees the world. Using cutting-edge methods to study how the brain and visual systems control perception, scientists are starting to figure out what magicians have known for ages — how your brain can play tricks on you.

"The interest for magic has been there for a long time," says Gustav Kuhn, a neuroscientist at Durham University in England and former performing magician. "What is new is that we have all these techniques to get a better idea of the inner workings of these principles."

These new techniques promise to give scientists front-row seats to magic's action in the brain and may yield insight into the very basis of consciousness itself.

"We do this because we want to know how the human brain works," says Stephen Macknik, a colleague of Martinez-Conde at the institute. "That's a fundamental question."

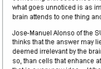
A recent brain imaging study by Kuhn and his colleagues, for example, revealed which regions of the brain are active when people watch a magician do something impossible, such as make a coin disappear. Another group's work in monkeys suggests that two separate kinds of brain cells are critical to visual attention. One group of cells enhances focus on what a person is paying attention to, and the other actively represses interest in everything else. A magician's real trick, then, may lie in coaxing the suppressing brain cells so that a spectator ignores the performer's actions precisely when and where required.

Other research asks whether individuals have different abilities to spot the critical moment in a magic trick, or if magicians are taking advantage of something intrinsic in every human brain.

Using magic to understand attention and consciousness could have applications in education — imagine a teacher directing students' attention in the same powerful way a magician does. And figuring out the workings of the brain might have medical uses, such as helping people who have attention impairments.

"We want to take these principles to the clinic," Martinez-Conde says. People with autism, attention-deficit/hyperactivity disorder and traumatic brain injuries have trouble focusing on just one thing. Figuring out how magicians mold the mind may ultimately lead to powerful new therapies that could shape and reshape the brain.

Imaging the impossible



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FOOLING THE BRAIN
View Larger Version | Magician and neuroscientist Gustav Kuhn performs the vanishing ball trick in these video stills. On the third "throw" (beginning at 4 seconds), Kuhn secretly palms the ball. In his study, 68 percent of spectators (who wore equipment to track their eye movements) reported watching the ball the entire time and seeing it vanish at its zenith. But a different story emerges from eye-tracking data showing where study participants actually looked. During the first two throws, most participants looked at Kuhn's face, then his hand, then above his head – tracking the ball's path (bars indicate the number of participants who looked at each spot). But during the fake throw, most never looked above Kuhn's head, where the ball supposedly vanished. Instead, they gazed at Kuhn's face or his hand. The eyes knew the ball didn't leave the hand, even though the brain thought otherwise.
G. Kuhn, M.F. Land/Current Biology 2006

In a lighthearted, (un)scientific report that appeared in the *British Medical Journal* in 2007, researchers from the University of Oxford proposed that magical abilities may be heritable. Evidence, the researchers argued, comes from the complex patterns of gene inheritance seen among young wizards and witches at Hogwarts School of Witchcraft and Wizardry (comprehensively recorded by author J.K. Rowling in her fictional series, which is also the source of this article's title).

Harry Potter may have inherited magical genes, but real-life magicians are not so lucky. Instead, they must rely on quick fingers and misdirection to sneak past spectators' perceptive brains. Kuhn and his colleagues are tracking down exactly what happens in the incredulous brain as it witnesses an impossible act, what the researchers call the "neurobiology of disbelief."

In particular, Kuhn is studying how people understand cause and effect relationships. Everyone knows that coins disappear because someone moves them, not because a magician waves his hand over them — and certainly not because Harry Potter mutters a spell.

"What magic is doing is producing disbelief and a sense of wonder," Kuhn says, "and that's what we are studying."

Kuhn and his collaborators performed brain scans while subjects watched videos of real magicians performing tricks that Harry Potter could do in his sleep, including coins that disappear (*evanesco*), cigarettes that are torn and miraculously put back together (*reparo*) and levitating napkins (*wingardium leviosa*). Volunteers in a control group watched videos in which no magic happened (the cigarette remained torn), or in which something surprising, but not magical, took place (the magician used the cigarette to comb his hair). Including the surprise condition allows researchers to separate the effects of witnessing a magic trick from those of the unexpected. Although magic is often unexpected, the reverse isn't always true, Kuhn says. A car crashing into your living room may be surprising, but not magical.

In terms of brain activity patterns, watching a magic trick was clearly different from watching a surprising event. Researchers saw a "striking" level of activity solely in the left hemisphere only when participants watched a magic trick, Kuhn says. Such a clear hemisphere separation is unusual, he adds, and may represent the brain's attempt to reconcile the conflict between what is witnessed and what is thought possible. The two brain regions activated in the left hemisphere — the dorsolateral prefrontal cortex and the anterior cingulate cortex — are thought to be important for both detecting and resolving these types of conflicts.

Such studies provide a glimpse of the tasks in the brain that ultimately shape a person's view of the world. "If we are to truly understand [cognition]," says Martinez-Conde, "we must understand the neural circuitry."

Masters of suppression

New studies on individual nerve cells in the brains of monkeys reveal something that seasoned magicians know well. When it comes to attention, what goes unnoticed is as important as what is noticed. But exactly how the brain attends to one thing and ignores another has been mysterious.

Jose-Manuel Alonso of the SUNY State College of Optometry in New York City thinks that the answer may lie in brain cells that actively suppress information deemed irrelevant by the brain. These cells are just as important, if not more so, than cells that enhance attention on a particular thing, says Alonso. "And that is a very new idea ... When you focus your attention very hard at a certain point to detect something, two things happen: Your attention to that thing increases, and your attention to everything else decreases."

Alonso and his colleagues recently identified a select group of brain cells in monkeys that cause the brain to "freeze the world" by blocking out all irrelevant signals and allowing the brain to focus on one paramount task. Counter to what others had predicted, the team found that the brain cells that enhance attention are distinct from those that suppress attention. Published in the August 2008 *Nature Neuroscience*, the study showed that these brain cells can't switch jobs depending on where the focus is — a finding Alonso calls "a total surprise."

The work also shows that as a task gets more difficult, both the enhancement of essential information and suppression of nonessential information intensify. As a monkey tried to detect quicker, more subtle changes in the color of an object, both types of cells grew more active.

To make tricks work, magicians may be exploiting this property of the brain, Alonso says. Magicians can "attract your attention with something very powerful, and create a huge suppression in regions to make you blind." In the magic world, "the more interest [magicians] manage to draw, the stronger the suppression that they will get," he says. It's the perfect cover for a trick.

Looking but not seeing

Magicians often rely on misdirection — getting the audience to look to the wrong place while the performer pockets the dove or switches a live fish for a fake. By carefully controlling the audience's gaze and using gestures to draw focus away from the trick, a magician can force spectators to look away, too.

Macknik explains a classic trick called the French Drop to illustrate this point. A magician holds a coin in the left hand and pretends to pass the coin to the right hand, which remains empty. "What's critical is that the magician looks at the empty hand. He pays riveted attention to the hand that is empty," Macknik says. The audience takes its cue from the magician and focuses attention on the right hand, believing it to hold the coin.

Controlling where spectators move their eyes takes skill. Perhaps more impressive, though, is controlling spectators' minds. Several experiments have now shown that people can stare directly at something and not see it.

For a study published in *Current Biology* in 2006, Kuhn and his colleagues tracked where people gazed as they watched a magician throw a ball into the air several times. On the last throw, the magician only pretended to toss the ball. Still, spectators claimed to have seen the ball launch and then miraculously disappear in midair. But here's the trick: In most cases, subjects kept their eyes on the magician's face or on the ball, which never left his hand. Only when the ball was actually at the top part of the screen did participants look there. Yet the brain perceived the ball in the air, overriding the actual visual information: The brains, not the eyes, were fooled.

Understanding how magicians carry off tricks by manipulating perception begs the question of whether their success depends on some people being less perceptive. (And, alternatively, of whether there really are tough crowds.) Researchers trying to answer that question get only one shot: Once the ball in the magician's hand is pointed out, it's impossible to miss. "The tough part with studying inattentional blindness, and with magic, is that you can only do it once," says Daniel Simons of the University of Illinois at Urbana-Champaign.

Simons and his colleagues found a way around this problem by first measuring how perceptive people are. Then the team asked whether more perceptive people succumb less easily to inattentional blindness, which is when a person doesn't perceive something because the mind, not the eyes, wanders. In a paper in the April *Psychonomic Bulletin & Review*, the researchers report that people who are very good at paying attention had no advantage in performing a visual task that required noticing something unexpected. Task difficulty was what mattered. Few participants could spot a more subtle change, while most could spot an easy one. The results suggest that magicians may be tapping in to some universal property of the human brain.

"We're good at focusing attention," says Simons. "It's what the visual system was built to do." Inattentional blindness, he says, is a by-product, a necessary consequence, of our visual system allowing us to focus intently on a scene.

Magical experiments

Magicians have perfected their tricks over the millennia. So the techniques magicians use on stage, says Macknik, are "exceptionally robust," which, in neuroscientists' lingo is very high praise for a strong effect. "Cognitive neuroscience's experiments are really crappy compared to magicians'," he says. In his experience, subjects often guess what the experiment is about, which ruins the experiment.

There's another reason the tricks up magicians' sleeves may prove more powerful than anything dreamed up in a lab. Many classic visual attention experiments completely ignore social context, something known to affect attention and perception and long exploited by magicians.

Martinez-Conde and Macknik plan to study the effects of one aspect of social context — laughter — on attention. Magicians like Mac King have the audience in stitches throughout a performance. Martinez-Conde says one of her collaborators, magician John Thompson, told her that when the audience is laughing, time stops, giving the magician a golden opportunity to act unnoticed.

Understanding how emotional states can affect perception and attention may lead to more effective ways to treat people who have attention problems.

"Scientifically, that can tell us a lot about the interaction between emotion and attention, of both the normally functioning brain and what happens in a diseased state," says Martinez-Conde.

Channeling attention within different settings — such as a hospital rehabilitation unit or a classroom of unruly fifth graders — is one lofty aim of this new marriage between magicians and neuroscientists. "Here we can take methods from magicians," Macknik says, and find new ways to treat people who have brain trauma, Alzheimer's disease and attention-deficit/hyperactivity disorder. "We don't know how it's going to work because no one's ever done it before."

He expects that the study of consciousness and the mind will benefit enormously from teaming up with magicians. "We're just at the beginning," Macknik says. "It's been very gratifying so far, but it's only going to get better."

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