The spotlight shines on the magician's assistant. The woman in the tiny white dress is a luminous beacon of beauty radiating from the stage to the audience. The Great Tomsoni announces he will change her dress from white to red. On the edge of their seats, the spectators strain to focus on the woman, burning her image deep into their retinas. Tomsoni claps his hands, and the spotlight dims ever so briefly before refilling in a blaze of redness. The woman is awash in a flood of redness.

Wha! Just a moment there! Switching color with the spotlight is not exactly what the audience had in mind. The magician stands at the side of the stage, looking pleased at his little joke. Yes, he admits, it was a cheap trick; his favorite kind, he explains devilishly. But you have to agree, he did turn her dress red—along with the rest of her. Please, indulge him and direct your attention once more to his beautiful assistant as he switches the lights back on for the next trick. He claps his hands, and the lights dim again; then the stage explodes in a supernova of whiteness. But wait! Her dress really has turned red. The Great Tomsoni has done it again.

The trick and its explanation by John Thompson (aka the Great Tomsoni) reveal a deep intuitive understanding of the neural processes taking place in the spectators' brains—the kind of understanding that we neuroscientists can appropriate for our own scientific benefit. Here's how the trick works. As Thompson introduces his assistant, her skirtlight white dress wordlessly lures the spectators into assuming that nothing—certainly not another dress—could possibly be hiding under the white one. That reasonable assumption, of course, is wrong. The attractive woman in her tight dress also helps to focus people's attention right where Thompson wants it—on the woman's body. The more they stare at her, the less they notice the hidden devices in the floor, and the better adapted their retinal neurons become to the brightness of the light and the color they perceive.

All during Thompson's patter after his little joke, each spectator's visual system is undergoing a brand new process called neural adaptation. The responsiveness of a neural system to a constant stimulus (as measured by the firing rate of the relevant neurons) decreases with time. It is as if neurons actively ignore a constant stimulus to save their strength for signaling that a stimulus is changing. When the constant stimulus is turned off, the adapted neurons fire a "rebound" response known as an afterdischarge.

In this case, the adapting stimulus is the red-lit dress, and Thompson knows that the spectators' retinal neurons will rebound for a fraction of a second after the lights are dimmed. The audience will continue to see a red afterimage in the shape of the woman. During that split second, a trap door in the stage opens briefly, and the white dress, held only lightly in place with Velcro and attached to invisible cables leading under the stage, is ripped from her body. Then the lights come back up.

Two other factors help to make the trick work. First, the lighting is so bright just before the dress comes off that when it dims, the spectators cannot see the rapid motions of the cables and the white dress as they disappear underneath the stage. The same transient blindness can overtake you when you walk from a sunny street into a dimly lit shop. Second, Thompson performs the trick right after the audience thinks it is already over. That gains him an important cognitive advantage—the spectators are not looking for a trick at the critical moment, and so they slightly relax their scrutiny.

The New Science of Neuromagic
Thompson's trick nicely illustrates the essence of stage magic. Magicians are, first and foremost, artists of attention and awareness. They manipulate the focus and intensity of human attention, controlling, at any given instant, what we are aware of and what we are not. They do so in part by employing bewildering combinations of visual illusions (such as afterimages), optical illusions (smoke and mirrors), special effects (explosions, fake gunshots, precisely timed lighting controls), sleight of hand, secret devices and mechanical artifacts ("gimmicks").

But the most versatile instrument in their bag of tricks may be the ability to create cognitive illusions. Like visual illusions, cognitive illusions mask the perception of physical reality. Yet unlike visual illusions, cognitive illusions are not sensory in nature. Rather they involve high-level functions such as attention, memory and causal inference. With all those tools at their disposal, well-practiced magicians make it virtually impossible to follow the physics of what is actually happening—leaving the impression that the only explanation for the events is magic.

Neuroscientists are just beginning to catch up with the magician's facility in manipulating attention and cognition. Of course the aims of neuroscience are different from those of magic; the neuroscientist seeks to understand the brain and neuron underpinnings of cognitive functions, whereas the magician wants mainly to exploit cognitive weaknesses. Yet the techniques developed by magicians over centuries of stage magic could also be subtle and powerful probes in the hands of neuroscientists, supplementing and perhaps expanding the instruments already in experimental use.

Neuroscience is becoming familiar with the methods of magic by subjecting magic itself to scientific study—in some cases showing for the first time how some of its methods work in the brain. Many studies of magic conducted so far confirm what is known about cognition and attention from earlier work in experimental psychology. A cynic might dismiss such efforts: Why do you yet another study that simply confirms what is already well known? But such criticism misses the importance and purpose of the studies. By investigating the techniques of magic, neuroscientists can familiarize themselves with methods that they can adapt to their own purposes. Indeed, we believe that cognitive neuroscience could have advanced faster had investigators probed magicians' intuitions earlier. Even today magicians may have a few tricks up their sleeves that neuroscientists have not yet adopted.

By applying the tools of magic, neuroscientists can hope to learn how to design more robust experiments and to create more effective cognitive and visual illusions for exploring the neural bases of attention and awareness. Such techniques could not only make experimental studies of cognition possible with clever and highly attentive subjects; they could also lead to diagnostic and treatment methods for patients suffering from specific cognitive deficits—such as attention deficits resulting from brain trauma, ADHD (attention-deficit hyperactivity disorder), Alzheimer's disease, and the like. The methods of magic might also be put to work in "tricking" patients to focus on the most important parts of their therapy, while suppressing distractions that cause confusion and disorientation.

Magicians use the general term "misdirection" to refer to the practice of diverting the spectator's attention away from a secret action. In the lingo of magic, misdirection draws the audience's attention toward the "effect" and away from the "method," the secret behind the effect. Borrowing some terms from cognitive psychology, we have classified misdirection as "overt" and "covert." The misdirection is overt if the magician redirects the spectator's gaze away from the method—perhaps simply by asking the audience to look at a particular object. When the Great Tomsoni introduces his lovely assistant, for instance, he ensures that all eyes are on her.

"Covert" misdirection, in contrast, is a subtler technique; there, too, the magician draws the spectator's attentional spotlight—or focus of suspicion—away from the method, but without necessarily redirecting the spectator's gaze. Under the influence of covert misdirection, spectators may be looking directly at the method behind the trick yet be entirely unaware of it.

Cognitive neuroscience already recognizes at least two kinds of covert misdirection. In what is called change blindness, people fail to notice that something about a scene is different from the way it was before. The change may be expected or unexpected, but the key feature is that observers do not notice it by looking at the scene at any one instant in time. Instead the observer must compare the postchange with the prechange state.

Many studies have shown that changes need not be subtle to cause change blindness. Even dramatic alterations in a visual scene go unnoticed if they take place during a transient interruption such as a blink, a saccadic eye movement (in which the eye quickly darts from one point to another) or a flicker of the scene. The "color-changing card trick" video by psychologist and magician Richard Wiseman of the University of Hertfordshire in England is a dramatic example of the phenomenon (the video is available online at www.youtube.com/watch?v=voAntzB7EwE). In Wiseman's demonstration—which you must see to appreciate—viewers fail to notice shifts in color that take place off camera. It is worth noting that despite its name, the color-changing card trick video does not use magic to make its point.

Inattentional blindness differs from change blindness in that there is no need to compare the current scene with a scene from memory. Instead people fail to notice an unexpected object that is fully visible directly in front of them. Psychologist Daniel J. Simons invented a classic example of the genre. Simons and psychologist Christopher F. Chabris, both then at Harvard University, asked observers to count how many times a "team" of three basketball players pass a ball to each other, while ignoring the passes made by three other players. While they concentrated on counting, half of the observers failed to notice that a person in a gorilla suit walks across the scene (the gorilla even strips briefly at the center of the scene and beats its chest!). No abrupt interruption or distraction was necessary to create this effect; the counting task was so absorbing that many observers who were looking directly at the gorilla nonetheless missed it.

Tricking the Eye or Tricking the Brain?
Magicians consider the covert form of misdirection more elegant than the overt form. But neuroscientists want to know what kinds of neural and brain mechanisms enable a trick to work. If the
Controlling Awareness in the Wired Brain

The possibilities of using magic as a source of cognitive illusion to help isolate the neural circuits responsible for specific cognitive functions seem endless. Neuroscientists recently borrowed a technique from magic that made volunteer subjects incorrectly link two events as cause and effect while images of the subjects' heads were recorded. When event A precedes event B, the brain's neural circuits react to it as if event B had occurred before event A.

Controlling Awareness in the Wired Brain

The possibilities of using magic as a source of cognitive illusion to help isolate the neural circuits responsible for specific cognitive functions seem endless. Neuroscientists recently borrowed a technique from magic that made volunteer subjects incorrectly link two events as cause and effect while images of the subjects' heads were recorded. When event A precedes event B, the brain's neural circuits react to it as if event B had occurred before event A.

Controlling Awareness in the Wired Brain

The possibilities of using magic as a source of cognitive illusion to help isolate the neural circuits responsible for specific cognitive functions seem endless. Neuroscientists recently borrowed a technique from magic that made volunteer subjects incorrectly link two events as cause and effect while images of the subjects' heads were recorded. When event A precedes event B, the brain's neural circuits react to it as if event B had occurred before event A.

Controlling Awareness in the Wired Brain

The possibilities of using magic as a source of cognitive illusion to help isolate the neural circuits responsible for specific cognitive functions seem endless. Neuroscientists recently borrowed a technique from magic that made volunteer subjects incorrectly link two events as cause and effect while images of the subjects' heads were recorded. When event A precedes event B, the brain's neural circuits react to it as if event B had occurred before event A.