Advance Endorsements Included from:

Stephen Pinker V.S. Ramachandran Dan Ariely Jonah Lehrer
Mahzarin Banaji Michael Gazzaniga Mac King Apollo Robbins

Sleights of Mind

Surprising Insights from the New Science of NeuroMagic

(working title)

by

Stephen L. Macknik & Susana Martinez-Conde

with

Sandra Blakeslee

Submitted by:

James Levine
Levine Greenberg Literary Agency, Inc.
307 Seventh Avenue – Suite 2407
New York, NY 10001
(212) 337-0934
jlevine@levinegreenberg.com

Contents

Overview

In SLEIGHTS OF MIND, Macknik and Martinez-Conde, two of the world's leading neuroscientists and the founders of the new discipline of NeuroMagic, meet with magicians from all over the world to explore the interplay between magic, the brain, and everyday life.

This sort of cross-disciplinary meeting of strange bedfellows happens every now and then in science. In the last decade, for example, neuroscientists began taking a serious look at the practice of Buddhist meditation. This ancient inner-directed discipline has yielded, to the surprise of many, a trove of neuroscientific insights into the workings of the mind, brain and body. If Buddhist meditators are the athletes of attention and awareness, then magicians are the martial artists. Like mental jujitsu masters they turn the brain's own highly sophisticated faculties against itself. There is good reason to believe that the magician's arts will yield their own trove of new insights into the mysteries of consciousness, memory, perception, attention, and belief.

The implications of NeuroMagic are far-ranging. Early research points to new approaches for the diagnosis and treatment of attention-based disorders such as ADHD and autism, for marketing (as well as marketing resistance), for police eyewitness procedures and legal standards of evidence, for the design of cognitive and clinical neurological and psychological testing, and for education.

And NeuroMagic has significant implications for our daily lives. The magical arts work because humans have hardwired processes of attention and awareness that are hackable. By understanding how magicians hack our brains, we can better understand how we work – for good and for ill:

- If you've ever subtly changed the subject in the midst of an uncomfortable conversation, you were using attentional "misdirection," a core technique of magic.
- If you've ever bought an expensive item you'd sworn you'd never buy, the salesperson was probably a master at creating the "illusion of choice."
- If you were unfortunate enough to invest with Bernard Madoff or to have been taken in by any other fraud, you were victim to the "illusion of trust."
- If you've ever felt positive that you do most of the housework while your spouse insists that you have it exactly backward, at least one of you is under the spell of an illusion of judgment known as "availability bias".
- If you've ever stumbled onto proof that an autobiographical story you've been telling for decades is false, you can appreciate the unnerving slipperiness of memory – which can mutate on its own, or be jiggered by a skilled manipulator.

This book comes with a significant author platform and advance endorsements. Jonah Lehrer, author of *How We Decide,* says "Steve and Susana are two of the most innovative scientists I know. …. they're determined to explore those places where neuroscience intersects the mysterious and the magical." According to Steven Pinker, "This looks like the book we've all

been waiting for." Dan Ariely adds, "I've followed the development of this project and can't wait to read – and start recommending – the finished book."

The authors will deliver a manuscript of 75,000 – 85,000 words by July 1, 2010.

Authors

Stephen L. Macknik, Ph.D & Susana Martinez-Conde, Ph.D

Stephen and Susana are husband and wife. Both are laboratory directors at the Barrow Neurological Institute (BNI) in Phoenix, Arizona, where they study various aspects of visual, sensory and cognitive neuroscience.

Their research and outreach activities have been written up in hundreds of media stories including many that have appeared in *The New York Times, The Wall Street Journal, The Chicago Tribune, The Boston Globe, National Public Radio, The Discovery Channel, Der Spiegel, New Scientist* and *Wired* magazine.

Both are monthly columnists for ScientificAmerican.com. Their shared column on the neuroscience of illusions gets hundreds of thousands of hits every month. One of their recent column contributions is the most downloaded article in sciam.com history. Further, the editor-in-chief of the Scientific American family of magazines, Mariette DiChristina, has just informed the authors that SciAm will be publishing a special issue of Scientific American: MIND (issue #7 of 2010) dedicated completely to the authors previous and ongoing contributions on illusion.

Stephen and Susana are founding board members of the Neural Correlate Society, and Susana serves as its Executive Chair. NCS hosts the annual "Best Visual Illusion of the Year Contest." The contest's website maintains an archive of visual illusions and their explanations for a broad audience, and receives over three million hits per year. They both serve on the board of advisors for *Scientific American: Mind* and in addition to their column have published several feature articles in *Scientific American* (circulation > 1,000,000 readers) and several of its family of journals. Their academic publication credits include contributions to *Nature, Nature Neuroscience, Neuron, Nature Reviews Neuroscience,* and the *Proceedings of the National Academy of Science*, and they have each authored over 50 academic publications.

The two serve on the editorial board of John Benjamins Co. They together organized both the 28th annual meeting of the European Conference on Visual Perception (which Susana chaired) and they co-chaired the 11th annual conference of the Association for the Scientific Study of Consciousness (ASSC).

Stephen is Director of the Laboratory of Behavioral Neurophysiology at BNI. He received a B.A. in Psychobiology, Psychology, and Biology from the University of California, Santa Cruz, and a Ph.D in Neurobiology at Harvard University. He was a postdoctoral fellow with the Nobel Laureate Prof. David Hubel at Harvard Medical School, and also with Prof. Zach Mainen at Cold Spring Harbor Lab. He led his first independent laboratory at University College London before coming to BNI in 2004.

Susana is Director of the Laboratory of Visual Neuroscience at BNI. She received a B.S. in Experimental Psychology from Universidad Complutense de Madrid and a Ph.D in Medicine and Surgery from the Universidade de Santiago de Compostela. She was a postdoctoral fellow with Nobel Laureate David Hubel at Harvard Medical School, and then an Instructor in Neurobiology

at the same institution. She was a Lecturer at University College London from 2001 to 2003 before assuming her directorship at BNI the following year.

Susana is an Executive Board Member and Executive Treasurer of the ASSC, and she serves on the editorial board of the *Journal of Eye Movement Research* and the ASSC's official journal, *Psyche*. She has served as a guest editor at the *Journal of Vision,* and on numerous advisory boards for conferences, foundations and other institutions.

Sandra Blakeslee

Sandra Blakeslee is a science correspondent at the *New York Times* who specializes in the brain sciences. She has witnessed firsthand the major developments and discoveries in neuroscience, both in the United States and abroad, for well over 40 years. Of all the reporters who cover the brain sciences, she is arguably the best known and admired in the country.

Blakeslee also co-authored with V.S. Ramachandran *Phantoms in the Brain* in 1998 (William Morrow), a bestselling classic that has been translated into more than a dozen languages. It explores the mysteries of brain plasticity, especially after injury. She also co-wrote four books with Dr. Judith Wallerstein on the state of American marriage and divorce, particularly on the long term effects of divorce on children.

Blakeslee is also co-author with Jeff Hawkins of *On Intelligence,* a groundbreaking book published in fall 2004 (Times Books/Henry Holt). She considers it a watershed in the history of neuroscience, if not the history of science for all time. The book describes a fundamental theory of how the cortex works. The brain is nothing like a computer. It predicts everything that it sees, knows and believes based on memories.

Blakeslee's latest book, coauthored with her science writer son Matthew Blakeslee and published in 2007, was *The Body Has a Mind of Its Own.* The book presents a unique survey the brain's amazing quilt of body maps which represent the physical body, touch, movement, intentionality, empathy, social emotion, body image, and a range of other quintessential human abilities and traits.

Audience and Promotional Opportunities

The field of neuromagic is quickly becoming one of the hottest fields of science. This book will have strong front list and back list appeal to:

- ***Science Times*** **Readers/*NPR* Listeners/*The Discovery Channel* Viewers:** *Science Times* is the *New York Times'* most popular special section. When the Magic of Consciousness Symposium was featured in August 2007, the story made the cover and was the *New York Times'* number-one e-mailed piece, for all categories, for two days in a row – a rarity for a science story. In November 2008, when our article about the Symposium appeared as the cover story of *Nature Reviews Neuroscience*, it generated coverage from *Public Radio International, National Public Radio,* the Nature.com main home page and Neuropod Podcast, *The New York Times* (Aug 11, 2008), *The Boston Globe, The Chicago Tribune, Der Spiegel, New Scientist,* and many other international radio, newspaper, magazine and internet outlets. The story is being broadcast on *The Discovery Channel* this fall and is expected to be seen by millions of viewers.
- ***Scientific American*** **Readers:** A feature story about neuromagic ("Magic and the Brain") made the cover of *Scientific American* in December 2008. We write a monthly column for sciam.com which already has several hundred thousand readers. In 2010, *Scientific American MIND* will devote a special issue to our work on illusions, which may reach over one million people.
- **The Best Visual Illusion of the Year Website:** The annual competition we host now receives over three million page views per year, a number which has been doubling every year since 2007.
- **Academics in Neuroscience and Psychology:** A article about our magic symposium was printed in *Nature* in August 2007 and our November 2008 article for *Nature Reviews Neuroscience* was released six months early, free to the public, as an Advanced Online Publication before being released in print, a rare honor. And a new version of our magic symposium will be the featured presentation at the annual Society for Neuroscience (SFN) conference in October 2009, which will be attended by over 30,000 people.
- **Magic Enthusiasts, Hobbyists, and Professionals:** More than one million people a year attend the major magic shows in Las Vegas alone, and we expect endorsements from all the headliners (some can already be found in the advance endorsement section below). Worldwide, magic is one of the most popular hobbies, and we expect the book to receive considerable attention in all the amateur and professional magic magazines and to sell at conferences and in specialty shops.
- **Colleges and Universities**: Psychology is one of the top majors among undergraduates in the United States. With endorsements from some of the world's leading scholars in cognitive psychology and neuroscience – and with an unusual way of introducing people to science – we expect this book to become assigned reading in many courses.

Competing and Related Titles

The last few years have seen the successful publication of several books based on research in cognitive psychology and/or neuroscience that explain the ways in which human beings are irrational or prone to error. But at least three factors distinguish *Sleights of Mind* from other titles.

First, other books report solely on controlled laboratory experiments. This one is based on an investigation of the world's best deceivers and tricksters – many of them very colorful characters. Their "laboratory" reaches way beyond the confines of academia and human subject protocols. Stephen and Susana get to meet these masters of deception up close, getting an inside look at what they know and how they figured it out.

Second, this book shows how the authors' understanding of neuroscience leads them to create the first truly new magic trick to be developed in over 100 years. They will perform this trick in their own personal quest to gain membership in The Magic Castle, the world's premier magical society.

Third, it's a heck of a good story, serving up both its science and practical implications in an engaging way.

We do know that physics graduate student Alex Stone is turning his July 2008 article for Harpers ("The Magic Olympics") into a forthcoming book, *Fooling Houdini* (HarperCollins, date of publication unscheduled at this point). But Stone's approach is very different from that taken in *Sleights of Mind*. Alex is a professional writer, physics graduate student and amateur magician. He emphasizes the physicality and dexterity required to perform magic at a world-class level – the physics of magic. His story is also partially about his attempt to make a comeback after being disqualified from the World Championship of Magic. Alex is mostly examining what's going on with his hands when he performs magic; Stephen and Susana are investigating what's going on in the spectators' minds when they observe a magic performance.

Advance Endorsements

WRITERS

Steve and Susana are two of the most innovative scientists I know. They aren't content to just conduct elegant experiments (although they do plenty of those, too). Instead, they're determined to explore those places where neuroscience intersects the mysterious and the magical, from visual illusions to Vegas card tricks. This book doesn't just promise to change the way you think about sleight of hand and David Copperfield - it will also change the way you think about the mind.

- **Jonah Lehrer**, contributing editor at *Wired Magazine*. Author of *How We Decide* and *Proust Was A Neuroscientist*.

SCIENTISTS

I've long wished that there was a book that explained the art of magic from the point of view of cognitive neuroscience. Magic is a goldmine of information about the brain, as well as a source of fascination to laypeople. This looks like the book we've all been waiting for.

- **Steven Pinker PhD,** Harvard College Professor and Johnstone Family Professor in the Department of Psychology, Harvard University. Author of *The Stuff of Thought*

This is a highly original book. Science and magic have much in common. They both take seemingly inexplicable events and provide elegantly simple answers that enthrall the observer. The authors have done an admirable job in exploring this idea and also suggest ways in which the two disciplines can cross fertilize each other.

- **VS Ramachandran MD PhD,** Distinguished professor and Director, Center for brain and cognition, University of California, San Diego. Author of *Phantoms in the Brain*

If a scientist and a magician were to meet on an airplane, what could they talk about? A lot, according to Macknik and Martinez-Conde, who have been involved in the marvelous adventure of bringing these two groups together to understand how our minds and brains work to produce magic-like effects. *Sleights of Mind* will be loved by anybody who wants to know who they really are, why they make the choices they do, and how to live a better life. Macknik and Martinez-Conde pull rabbits out of hats over and over and their show is one I can't wait to watch!

- **Mahzarin Banaji**, Richard Clarke Cabot Professor of Social Ethics, Department of Psychology, Harvard University. President-elect of the Association for Psychological Science. Fellow, Society for Experimental Psychologists. Fellow, American Academy of Arts and Sciences. Herbert A. Simon Fellow of the American Academy of Political and Social Science.

This book is going to be so cool! Stephen and Susana are two of the smartest scientists around; put them together with the world's leading magicians and you've got an irresistible combination. I've followed the development of this project and can't wait to read – and start recommending – the finished book.

- **Dan Ariely**, James B Duke Professor of behavioral Economics, Duke University and the author of the fabulous book *Predictability Irrational*

This book is a wonderful idea, and Macknik and Martinez-Conde are right on the money. I am totally behind it and my own institute here at the University of California, Santa Barbara has already been influenced by the work of these two young neuroscientists. We will join the fray with neuromagic this fall and we have booked Patrick Martin the magician to visit us to get the ball rolling. The concept is wholly original and will undoubtedly be highly influential in cognitive science and with the public. I look forward to reading and to recommending the book.

- **Michael S. Gazzaniga, Ph.D.** Director, Sage Center for the Study of Mind, University of California, Santa Barbara. Director, The Law and Neuroscience Project. President, Association for the Scientific Study of Consciousness (2007). Author of *Human*.

MAGICIANS

A ground-breaking exploration of the uncharted territory where science and magic intersect. Anybody interested in magic is going to be interested in this book.

- **Joshua Jay**, author of *MAGIC: The Complete Course*; youngest winner of the World Magic Championship

Stephen Macknik and Susana Martinez-Conde's *Sleights of Mind* is a dangerous book. It's going to give non-magicians a real up-close look at the true secrets of magic. These are techniques that professional magicians use that have little or nothing to do with the physical mechanics of their tricks, but involve actually changing and guiding people's perceptions of what they see and experience. They are revealing the real knowledge jealously guarded by all great performers. That said, I'm excited to be even a tiny bit involved, and can't wait to turn my fellow magicians on to this exciting project. I know they're all going to be as jazzed as I am to read about how sophisticated magical techniques and state-of-the-art brain science combine.

- **Mac King,** headliner, Harrah's Las Vegas

Sleights of Mind offers a revealing study of how magic really works. No rabbits. No hats. Stephen Macknik and Susana Martinez-Conde will take you on an exploration of the Ledgerdemain through the eyes of a Neuroscientist. How does a Magician direct your attention, re-frame your memories, and temporarily alter your reality? *Sleights of Mind* offers a glimpse into the neuroscience of magic and secret principles that may unlock questions about how our minds really work.

- **Apollo Robbins**, Speaker, Entertainer, Consultant

Chapter Outline

Chapter One: The Woman With the Chameleon Dress

This chapter is about visual illusions. We explore several tricks that exploit visual illusions, meet the magicians and talk about the neural principles at work (neural adaptation, after discharges.) Readers learn that brain mechanisms such as neural adaptation make us "miss" important changes throughout life. We give strategies to help people be reminded of these effects and to make gradual improvements in their lives.

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. Intrigued, 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 reflaring in a blaze of red. The woman is awash in a flood of redness.

Wait a minute! Switching color with an ordinary spotlight is not exactly what the audience has 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.

Tomsoni claps his hands. The lights dim again. Then the stage explodes in a supernova of whiteness. But wait! Her dress really has turned red. Bright crimson red. The Great Tomsoni has done it again.

This trick reveals a deep intuitive understanding of neural processes taking place in your brain—the kind of understanding that we neuroscientists can appropriate for our own scientific benefit. Here's how the trick works. As Tomsoni introduces his assistant, her skintight white dress wordlessly lures 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 Tomsoni's patter after his little "joke," each spectator's visual system is undergoing a brain 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 Tomsoni 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 temporary blindness can overtake you when you walk from a sunny street into a dimly lit shop. Second, Tomsoni performs the real trick only 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.

For example, retention of vision is a trick that exploits the fact that an object – say, a coin – leaves an afterimage on your retinas even after it has been removed. The observer literally sees the (image of the) vanished coin fade to nothing before her very eyes. Afterimages can linger in all our sensory systems. When you were a child you may have learned how to create a muscle-memory afterimage by pressing the backs of your wrists outward against a doorframe for a count of thirty, after which your arms seemed to levitate. Sensory afterimages abound in day-to-day life, and insofar as we are even consciously aware of them, they are usually only minor, fleeting annoyances. But to magicians, they are gold. Magicians have learned to use these and other similar effects against you to create the illusion of objects that are no longer there.

Adaptation and afterimages are one of several systemic "security flaws" in the brain's ability to make sense of its experience, flaws that skilled manipulators can exploit to "hack" our perception and belief. In this same vein we go on to describe some of the other prominent "flaws" that riddle the mind and brain and make us susceptible to various forms of trickery and illusion. Magicians use these various perceptual pitfalls and brain processes against you in a form of mental jujitsu. The samurai invented jujitsu as a way to continue fighting if their swords broke in battle. Striking an armored opponent would be futile, so jujitsu is founded on the principle of using an attacker's own energy against him, rather than opposing it. Magicians have a similar M.O. Their arts are founded on the principle of using your mind's own intrinsic properties against you. They reveal your brain for the liar that it is.

Chapter Two: The Ventriloquist's Secret

In this chapter we explore multisensory illusions. The takeaway for readers is that one sensation can be manipulated by another. This helps us navigate the world and recognize objects. Phantom limbs, and their cure, are caused ultimately by these same systems. Also motion sickness.

For a long time, studies of how we use our senses (sight, hearing, touch, smell, taste, balance, self-motion, feelings from the body) focused on one sense at a time. But in recent years, scientists have begun looking at multisensory perception -- the fact that our senses are integrated as we interact with the world. Two converging stimuli can produce a perception that is different from the sum of its parts. Ventriloquists exploit this by shifting what you hear to what you see (the dummy's mouth.)

If you have a computer handy, check out the McGurk effect (www.media.uio.no/personer/arntm/McGurk_enlgish.html). In this auditory-visual illusion you will see a film clip of a person saying "da da da." But if you close your eyes, you will hear him saying "ba ba ba." Then if you mute the sound and just watch his lips, you will clearly see that he is saying "ga ga ga." The effect is quite amazing. It happens because your brain does its best to reconcile mismatching information whenever it can.

Next time you go to a movie theater, consider the fact that speech is not coming from the actors' lips. Sound is being piped into the speakers far removed from their actions. Your brain creates the illusion of actors talking to one another, thanks to your multisensory cells.

In the same vein, what you hear influences what you feel. In the parchment skin illusion, you rub your palms together while listening to different sounds. Higher frequencies will make you feel as if your hands are rough. Lower frequencies give you the impression of your hands being smooth, although nothing about them has changed.

Magicians are masters of multisensory illusion. We will describe several tricks and settings from our travels meeting the masters. Neural principles include the binding problem (how do senses converge in your conscious mind?), plasticity and attentional feedback in one sensory system activated and controlled by another.

Chapter Three: Welcome to the Show but Please Leave Your Blinders On

In this chapter we explain illusions of misdirection and attention, which include inattentional blindness and change blindness. Readers will take away lessons for how to enhance their "situational awareness" and how to misdirect other peoples' attention. Magic may also prove to be a tool in diagnosing autism as it pertains to deficits in joint attention.

Apollo Robbins is sweeping his hands around the body of the fellow he has just chosen from the audience. “What I'm doing now is fanning you,” the master pickpocket informs his mark, “just checking to see what you have in your pockets.” His hands move in a flurry of gentle strokes and pats over the man’s clothes. More than two hundred of us are watching him like hawks, trying to catch a glimpse of fingers trespassing into a pocket. But to all appearances it’s a perfectly

innocent and respectful frisking. “I have a lot of intel on you now,” Apollo continues. “You scientists carry a lot of things.”

Apollo is demonstrating his kleptic arts to a roomful of neuroscientists who have come to Las Vegas for the Magic of Consciousness Symposium. What we and our new magician friends hope to do here tonight is show these scientists how much magicians can teach them about the subjects of their life’s work: attention, awareness, perception, and even the holy grail, consciousness. Magicians and neuroscientists share a passion for understanding the nuts and bolts of the human mind, but we have been developing our respective arts and theories more or less independently of each other for generations. But starting tonight, our two communities are stepping through the illusory wall that kept us from paying close attention to the other’s discoveries. For us, this is sheer consummation.

Apollo has dared everyone in the auditorium to try and catch him pilfering this man’s belongings up on stage in plain view. I watch intently just like everyone else, but none of us really stand a chance. This is Apollo Robbins, the infamous “gentleman thief” who once pickpocketed ex-president Jimmy Carter’s Secret Service detail, relieving them of their watches, wallets, badges, confidential itinerary and the keys to Carter’s limo.

So Apollo can keep the joke on us for as long as he feels like it, but at least we know one thing he doesn’t. As soon as we saw who Apollo had plucked randomly from the crowd,. This man isn’t a scientist at all, as Apollo assumes, but the one person in the room who will be explaining to the wider world what went on here tonight. He is the *New York Times* science reporter, George Johnson. George is a man of great humor and intelligence, but he is fundamentally quite shy. His awkwardness makes for great theater.

The fanning continues as Apollo engages in his highly honed rapid-fire patter. “You have so many things [in your pockets] I’m not sure where to begin. Here, was this yours?” he asks, thrusting something into George’s hand. George frowns down at it. “You had a pen in here,” Apollo says opening George’s breast pocket, “but that’s not what I was looking for. What’s in that pocket over there?” George looks over. “There was a napkin or a tissue, maybe? You have so many things it’s confusing to me. You know, to be honest I’m not sure that I’ve pickpocketed a scientist before. I’ve never had to do indexing as I went through someone’s pockets.”

Patter, it turns out, is one of the most important tools in the magician’s toolkit for attention management. There are only a dozen or two (depending on who you ask) main categories of tricks in the magician’s repertoire; the apparent wide variety of them is all in the presentation and details. Sleight of hand is of course critical, but so is patter, the smooth and confident stream of verbiage that can be used to hold, direct or divide attention. Apollo tells George one thing while doing two other things with his hands. This means that in the best-case scenario George has only a one in three chance of noticing when something of his gets snatched. His real chances are actually far below one in three: in the psychic sparring ring of attention management, Apollo a tenth-degree black belt.

Apollo is one step ahead the whole time. By continually touching George in various places – his shoulder, wrist, breast pocket, outer thigh – he jerks George’s attention around the way a magnet draws a compass needle. While George is trying to keep track of it all, Apollo is delicately

dipping his other hand into George's pockets, using his fast-driving voice to kept George's attention on his face, or on some spurious demonstration.

Apollo steals George's pen, notes, digital recorder, some receipts, loose cash, wallet, and, very early on, his watch. One classic way to lift somebody's watch is to first grab their wrist over the watchband and squeeze. This creates a lingering sensory afterimage. Afterimages can occur in any sensory system, but the kind you're probably most familiar with are the visual variety. For instance, if you glance at the setting sun, you wind up with sun-shaped spots or streaks that float in your field of vision for a minute or so after you look away. Even now, if you simply shut your eyes and pay attention, you can see greenish and bluish blobs that rapidly fade from your vision. These are afterimages of whatever you happen to have been looking at over the past minute or so. Apollo is exploiting the same principle, only in this case the afterimage is tactile. The afterimage renders the touch neurons in George's skin and spinal cord less sensitive to the watch's removal, and creates a conveniently lasting perception of the watch long after it has disappeared. I notice the watch when I see Apollo folding his arms behind his back, buckling it onto his own wrist as his patter leads George down some garden path of attention.

A few times during the fleecing, without ever skipping a beat, Apollo holds up a pilfered object high behind George's head for the audience to see. This makes everyone laugh but George, who smiles and looks around sheepishly, wondering what the joke is.

Then, to more laughter, Apollo returns all of George's belongings one by one. "If you're recording [which was not allowed at the event], I think we have evidence," he says as he hands over the digital recorder. Proffering a folded stack of bills he says "I presume this is your gratuity money?" Finally he turns to George and says, "We all pitched in to buy you a watch, very similar to the one you were wearing when you got here." He unstraps George's watch from his wrist and passes it over. George gasps and rolls his eyes.

You have to ask yourself, how could George be so inattentive? Why can some joking thief walk up to him and manipulate his attention the way a master potter shapes a spinning lump of clay? It's truly amazing that this can happen to a professional, trained observer like George while he's on stage (and therefore has heightened awareness) and has been told what is about to happen to him. The answer is that *we do it to each other all the time*. When a conversation edges into uncomfortable territory your natural instinct is often to change the subject. That is a form of attentional misdirection. Often the other conversant plays along, as if you weren't just talking about your testicular cancer, and pretends that yes, we really are talking about last night's Red Sox box scores. Our brains are (unintelligently) designed to be flexible with respect to what we are paying attention to, both at the sensory and cognitive level. Without this flexibility we would be unable to drive home, thinking about what's for dinner, and then instantaneously swerve the car to avoid the child chasing her ball into the street.

Evolutionarily, it makes perfect sense for our brains to work this way. Imagine you are a stone-age hunter-gatherer in what is now the Auvergne region of France, and you are gathering berries on a fine summer day, perhaps in preparation to invent the parfait. You need to pay attention to the berries because if you fail to gather enough of the correct berries quickly and at the appropriate level of ripeness, your child could starve (you can't just let him eat cake because you haven't invented that yet, either). But you don't want such Ritalin-like focus that you aren't open

to serendipity – say, a tasty kind of mushroom growing by your berry bush. And of course, your species has yet to exterminate the saber-toothed tiger form the face of the Earth. You need to be ever on guard, ready change your mode of attention to immediately run-and-hide.

Change is a powerful stimulus for perception. But not every change is noticed, as magicians know well. Slow or gradual changes are very difficult to notice, especially if we are not focusing our attention on the changing object. This has been compellingly demonstrated by our colleague Dan Simons: whole buildings, boats, people and other highly salient things may appear and disappear unnoticed, right in front of our eyes, if they do so slowly enough. It is tempting to speculate on how many things in our lives may slowly change without our awareness. The small aches and pains that colonize our bodies as we age would be intolerable if suddenly imposed on a healthy 20-year old, but as we gradually grow older these changes creep in for the most part undetected. Other aspects of our lives, jobs and marriages may similarly change, worsening or improving in a very gradual and thus unnoticed fashion.

The Greek philosopher Epicurus knew that we tend to adapt to and thus ignore gradual improvements in our lives. He wrote: “Do not spoil what you have by desiring what you have not; but remember that what you now have was once among the things you only hoped for.” It’s sage advice, provided your pocket isn’t being picked while you’re distracted by your gratitude.

Illusions of misdirection and attention are bread and butter ingredients for cognitive illusions. Misdirection includes manipulation of attention and awareness as in stealing a watch. Apollo tells how a magician seeks to generate internal dialogue in an observer. If you are the observer, you have a conversation with yourself about what is taking place. This, he says, results in a great deal of confusion. It slows your reaction time and leads you to second-guess yourself.

Inattentional blindness is the phenomenon of not being able to see things that are actually there. Each of us has a limited capacity for attention which limits how much information we can take in at any given time. Magicians exploit this feature of the human brain to maximum effect. They also tap into other brain mechanisms including top-down attentional feedback, suppression and enhancement of the "attentional spotlight", joint attention and mirror neurons. We explore each of these in colorful detail.

Chapter Four: Why Magic Wands Work

In this chapter we discuss illusory correlations. Imaging studies of possible and impossible cause-effect relationships. Readers will take away lessons on the misperceptions of probabilities and statistics, revealing basis for much superstitious thinking.

Teller (the silent partner of Penn and Teller fame) performs the routine known as the Miser’s Dream. His right hand snatches at the empty air, and from it appears to pluck a glittering coin. In his left hand he holds a tin bucket, and drops the coin in. Clink! Then Teller starts to move

around the room, pulling coins out of people's heads, eyeglasses, jackets. Then more from thin air. Snatch. Clink! Snatch. Clink! The bucket is filling up with coins.

When the act is over, Teller returns to the stage and explains how the trick works. He says one of the magician's greatest assets is the audience's instinct to infer cause-and-effect relationships.

He explains that he is only pretending to drop coins in the bucket. He is only faking the action of tossing, and uses the flick-down motion to re-conceal the coin in his hand. But the faked action engages our mirror neurons, so we are predisposed to see it as the same natural tossing action we ourselves perform daily with coins, car keys, cooking ingredients and so on. The illusion of each "toss" is completed with a small shake of the bucket, which causes the small number of coins that are actually in there to go, Clink! But the bucket isn't filling up at all, and we're seeing the same coin flash in the miser's hand over and over and over again. Our assumptions have misled us.

Teller continues, "One of the things magicians do is take advantage of our natural inclination to study something we see done over and over again, and to think that we're learning something. ... Your natural inclination as an observer is to assume that what I'm doing is the same thing over and over again. We take for granted that a repetition is a repetition [even] when it's not."

"We all infer cause and effect in everyday life," says Teller. When A precedes B, we conclude that A causes B. The skilled magician takes advantage of this inference by making sure that A always precedes B. However, A does not really cause B.

Psychologists call this effect illusory correlation. In most circumstances, our inborn instinct for inferring cause-effect relationships serves us well. Want an egg? Look in a bird's nest. Dark clouds gathering overhead? Rain is likely, so find some shelter. That's all well and good, but this is a highly imperfect, eminently fallible faculty. It goes amiss all the time and leads us to believe all kinds of things.

For instance, illusory correlation is at the root of why some people honestly and in all good faith believe they are psychic. You may know someone who believes he has predicted the future in a dream – a plane crash, say. But what he doesn't tell you is that he has premonitions of a plane crash several times a week. He tends not to notice or remember these false predictions; but the one that coincides with an actual plane crash sets off wild alert bells in his brain. His mental correlation detector is screaming, Correct! True! Valid! In extreme cases illusory correlation can lead to extreme beliefs, such as the ancient Aztec theory that a human sacrifice had to be performed each morning in order to make the sun rise. It's gruesome and easy to condemn in hindsight, but as the Aztecs saw it, it worked every single morning, just as advertised.

A similar and related effect in the brain is called the availability bias. This illusion is caused by a failure of memory. It pops up often in everyday life. For example, I change our son's diaper waaaaaay more than Susana does. Evidently because she's lazier than I am. But the puzzling thing is that Susana thinks exactly the opposite. She thinks she changes Iago's diapers more than I do. The fact is that we are both wrong. We each change Iago's diaper more or less evenly (maybe me a little more). But in our own minds our own contributions and sacrifices are magnified by the fact that we remember our own actions better than we remember each other's. We incorrectly draw stronger correlations between the facts that we remember.

Magicians are well aware of these little brain foibles, and they pump them like a lab rat on a cocaine lever.

“When a good magician repeats an effect,” Teller continues, “he varies the method in an unpredictable rhythm.” That way, each time observers begin to suspect one method, they find their suspicion disproven by the subsequent “repetition.” For instance, a disappearing ball is first secretly palmed by the other hand, but in the next “repetition” it is instead dropped on the magician’s lap, allowing the magician to show that the other hand is empty. “Much of our life is devoted to understanding cause and effect,” Teller says. “Magic provides a playground for those rational skills.”

Chapter Five: The short sighted magician

This chapter deals with illusions of expectation, revealing our assumptions, biases and preconceptions. Expectations affect the different ways in which children and adults view magic tricks.

James the Amaz!ng Randi is a short man with a long Santa Claus beard and a gigantic personality. He commands the room wherever he goes. It is no wonder that he plays the role of elder statesman for the entire American magic community. He is the founder of the James Randi Educational Foundation, which serves to protect society at large from charlatans and frauds of the paranormal. The Foundation offers a one-million dollar challenge to anybody who can prove that they have psychic powers of any kind. After more than twenty years and numerous challenges, no one has collected the money.

Randi explains that you will easily accept unspoken assumptions and that you tend to believe information that you learn for yourself as opposed to being told it. For example, halfway through a recent lecture he reveals that the microphone he appears to be speaking through is a dummy. (He was wearing the real mike.) Further on, he shows us that his glasses are fakes by sticking two fingers through where the lenses are supposed to be. The moral of the story: people don't question lies that have no reason to be lies.

But why don’t people question unspoken assumptions? The reason is that such assumptions *have already been questioned* and established as fact. As children, we pulled our grandparents glasses off of their faces, stuck them in our mouths, and tested the diopter of the lenses with our tongues. As adults, we feel no further need to continue to lick the glass. We’ve become habituated to the fact that glasses frames have actual glass lenses in them. But this is just an observation, not an explanation. It is critical to go further into the neuroscience here and ask how the brain actually accomplishes habituation, and why.

The why is easy: thinking is expensive. It requires brain activity, which takes energy, and energy is a limited resource. More importantly, thinking takes time and attention away from other tasks, like finding food and mates and avoiding cliffs and saber-toothed tigers. The more you can safely file away as established fact, the more you can concentrate on your goals and interests. The less you wonder whether somebody’s glasses frames actually contain glass, the better off you are.

Habituation is created through a neuronal process called synaptic plasticity. Eric Kandel, of Columbia University, recently won the Nobel prize for his work establishing this process in a little-appreciated sea slug called an Aplysia. Kandel recorded from neurons in the Aplysia nervous system while blowing air onto their gill. Aplysia don't like air puffs on their gill, so they retract it. But air puffs aren't really harmful, and retracting the gill is tiresome and burns precious calories, so as the air puffs are repeated, the Aplysia habituates and eventually stops retracting the gill in response. Neurally, the sensory information concerning the air puff becomes more and more minute until signals concerning the air puffs are not even sent from one neuron to the other. That's synaptic plasticity, and it's the neural mechanism of habituation. We humans do the exact same thing as the lowly sea slug, only we do it with more fancily processed perceptions and behavioral options. We don't question whether every pair of glasses we see contains glass because experience has taught us that we can safely assume that they do, and the synaptic pathways responsible are habituated to that fact.

Once you've habituated to a feature of the world, it becomes a humdrum and seemingly immutable part of the fabric of life. Stable, reliable, unchanging. That's why magicians prefer to rely on unspoken assumptions over explanations whenever possible.

In this chapter we provide a quick review of cognitive development with respect to how our models of probability and impossibility evolve through childhood. At one point I show Iago, our two-year-old son, one of my best tricks. I feel like I've gotten pretty good at it, but he is not impressed. Here's a person who's endlessly delighted and entertained by the fact that he can blow out a candle, but finds it banal that I know how to do something utterly impossible. Fascinating. He's still young enough, I muse, his brain is still naïve enough about the laws of physics and causality, that I could show him how to make an object travel through a magic space-time wormhole and he would simply note it, and maybe play around with this new fact for a while – in exactly the same way he plays around with pouring liquid from one container to another, or pulls his socks on and off, on and off – and that would be that. There is a whole body of cognitive development research documenting at what age a baby, say, starts expressing surprise when a ball rolls down a ramp, rolls across the floor, disappears behind a thin sight barrier, and fails to emerge on the other side. Developmental psychologists perform (very simple) magic tricks for babies and toddlers all the time to test their "mental models" of reality. We will summarize this science framed around the question of when children start to find various forms of magic surprising, convincing and delightful.

Chapter Six: Bernie Madoff's Magic

Magicians, pickpockets and scam artists use persuasion techniques to earn the trust of their audience or marks. They are "confidence men" who convince people to lend them something valuable and then walk off with it. Or, like Apollo the gentleman pickpocket, they steal while chatting away amiably, earning the trust of their marks. In this chapter, readers will learn how to avoid falling victim to the "Nigerian" and other scams plus when and how much to trust other people.

Pickpocketing is a branch of magic that combines illusions of the senses with illusions of the mind, including trust. Apollo has a toolkit of techniques for misdirection, which he can use to get his audience to attend to something irrelevant while the real trick is performed outside of their awareness, even if it occurs technically in plain sight. And he is also a master of engendering trust, including a diabolical technique for cozily slipping into the personal space of a person he is planning to rob.

Magicians need to be very good at manufacturing and manipulating trust, as do various other professions including con men, salespeople, politicians, trial lawyers, parents, and counselors. There are lessons here for all of us. The misdirection used in pickpocketing reveals principles involved in various frauds and scams. For instance, Apollo tells us about the Nigerian scam, also called the 419 fraud, in which e-mails are sent to victims (or just annoyed non-victims) stating that the sender is a prince/king/politician from a generally African nation, and begs the receiver of the e-mail to accept a large wire transfer to his or her bank account in exchange for a percentage of the money. Just one issue... to make the enormous transfer, the sender needs only the detailed banking information of the receiver.

Mentalists, who have been scamming people long before the Internet came along, are magicians who use mathematical probabilities, human nature and trust to make it appear as though they can read your mind. Advertisers and politicians also exploit this property of the mind.

Brain imaging studies reveal the activation of distinct circuits when people play trust building games. They must infer their partner's intentions so as to predict their behavior. We'll discuss this research to explain the illusion and neuroscience of trust.

Apollo also establishes some parallels between magic and martial arts. Practicing magic at home, or performing a well practiced trick in front of an audience, he says, is similar to mastering "forms" in karate and other martial arts. Pickpocketing a mark from the audience is akin to sparring. Apollo also says he has aikido training, and uses aikido principles to subtly control and restrain the degrees of freedom of his victims.

Chapter Seven: Mind Control and Personal Choice

In this chapter we discuss illusions of choice and the illusion of free will. Takeaway lessons: we must learn to live with restricted choices, as in choosing a mate, and to maximize satisfaction with each "selected" option.

The Great Tomsoni is back on stage, demonstrating the illusion of choice. His real name is Johnny Thompson but he says we should call him by his first name. Johnny asks people in the audience if they believe in mind reading, psychic ability, mentalism. He calls up a volunteer, whose name is Dan, and asks again, “Do you believe in mind reading?”

“No.”

“Neither do I. I'm a faker, fraud, phony and cheat.” But then, says Johnny, “nobody's perfect.” Only he is perfect, at fakery. The trick, he says, is based on psychology, behavior patterns, and in “closing the doors” to all rational explanations for what we are about to see. Johnny takes out his wallet and removes a $100 bill. He also takes out a small envelop and asks Dan to examine it. The money and envelop go back into the wallet which then goes to Dan's breast pocket.

Next Johnny pulls out a “perfectly ordinary deck of cards,” shuffles them and asks Dan to cut the deck. From my angle, seated behind him, there is no apparent trickery going on. As far as I can tell, he doesn't put anything into, or pull anything out of, any of his pockets. After the cards are cut he asks Dan to turn them over slowly, one at a time, and stop whenever he "feels" a precognition that the card matches the one inside the envelope in his breast pocket. Dan stops at the nine of clubs. And lo and behold, when they open the envelope, inside is a nine of clubs. Also embossed on a plaque in the wallet, in gold letters is this: You will choose the nine of clubs.

Johnny now helps close all the doors in this trick by going back over the apparent choices Dan made, and the availability he had to information about his decisions.

“Now if you were to walk away right now you might happen to think that that was the cleverest card trick or feat of sleight of hand that you’d ever seen,” says Johnny. “But it wasn’t a card trick. Were the cards shuffled?”

“Yeah,” answers Dan.

“Did you cut them?” asks Johnny.

“Yes.”

“Did you deal them face-up and see that every card was different?”

“Yes.”

“Did you stop on the card that you wanted to stop on?”

“Pure impulse,” says Dan.

“And I saw that you stopped on the only losing card,” confirms Johnny. “Did I not offer you $100? I begged, implored, and I even *told* you to go one card further. If you had changed your mind, that wallet would still be in your hands, am I right?”

“Yes,” laughs Dan.

But, as you might suspect, Johnny’s retelling of the procedure was actually a clever rewriting of history, one designed to slyly gloss over the suspicious actions that he made. We don't actually know exactly how Johnny did this trick because he elected to keep the methods secret. But we can extrapolate from our knowledge of magic to explain how he could have done it.

First, it was Johnny who “shuffled” the cards, not Dan. It is very straightforward sleight of hand to make it appear that a deck of cards is shuffled. So were the cards really mixed up? Maybe not.

Second, Dan may have cut the cards, but Johnny made sure Dan cut roughly from the middle. He omitted this detail from his retelling as well.

Third, after the cards were cut, Johnny took a furtive glance at the bottom card. This told him the exact order of every card in the deck. How? Because he had stacked it. A stacked deck is one in which the magician has carefully placed every card in a pre-determined order and then memorized the order. When the deck is cut, only the position of two cards has changed; the rest of the order is preserved.

Fourth, Dan counted out the cards one at a time, starting at the top of the deck, and stopped on whichever card he wanted, right? Not really. Dan was standing in front of a crowd of hundreds of his peers. The likelihood that he was going to count out fifty-one cards in the most boring fashion imaginable was highly unlikely. Instead, Dan counted out seven cards before selecting one – which happened to be the nine of clubs. You can be sure that Johnny knew Dan would not choose the first card, nor would he count out very many cards before selecting. To count out more than about ten would be nerve wracking. Remember, Johnny knew the exact order of the cards in the deck, including the top ten. This means he knew pretty nearly which card was going to be selected, plus or minus five or so cards. Also note that even if Dan had behaved radically and counted out dozens of cards, Johnny could have simply recut the cards (masked by a quick flourish), or done one of many other possible procedures, to force Dan to make the necessary selection in a different way. Since the audience doesn't know the trick, they have no way of knowing if additional procedures were strange or unnecessary. So Johnny was holding all the cards in more ways than one. He could ensure that the card Dan chose was one that Johnny had in his pocket.

Finally, Johnny did not retrieve the wallet containing the matching card and embossed lettering until *after* Dan had made his final selection and presented it publicly. This too, was left out of the retelling of the trick.

All of this adds up to the fact that Johnny could have known ahead of time, before he even drove his Cadillac to the event, the narrow range of ten or so cards that were likely to be selected from. He could also force Dan to choose one of the ten cards in a seemingly magical way. If Johnny had on his body ten wallets stored in the various pockets of his suit, all with different cards and embossed messages matching Dan’s ten most likely selections, organized so that Johnny could grab the correct wallet in a natural fashion after Dan had made his choice, it would appear as though Johnny had precognition. And in a way he did. He knew exactly how Dan would behave because Johnny is a master of human observation. Then, by recounting the entire trick slightly incorrectly, leaving out the suspicious bits and distorting certain details, he created false memories for the audience. A confidently delivered, coherent-sounding story is much easier to remember than a quick series of subtle movements and visual impressions. Thus, Johnny effectively removed the possibility that the audience, or even Dan himself, could reconstruct the trick and work it out after the fact.

Johnny tells us, "When people see a wonderful piece of magic, they try to figure out how it's done. They have avenues of thought and logic. The magician, just before the dénouement or finish, must close all those doors. The only solution is magic."

What Johnny does not tell us today is that magic tricks also work because they exploit some basic psychological principles. For example, to get Dan to choose the nine of clubs, Johnny may have employed what magicians call a “force” – not the George Lucas “These aren’t the droids

you're looking for" kind of force, but not too different. That droids quote, by the way, is from a famous scene in Star Wars where Obi-Wan Kenobi psychically dominates the mind of an imperial storm trooper, forcing the weak-minded minion to believe and say whatever Obi-Wan tells him to. After the storm trooper waves the heroes past the checkpoint, Obi-Wan explains to the young Luke Skywalker, "The Force can have a strong influence on the weak-minded." Except that in the real universe, we are all weak-minded.

With Yoda-like skill, Johnny uses psychological manipulation to force Dan to make the necessary decisions. He succeeds because he knows that much of our free will is anything but. If we truly had free will, advertising and salesmen's pitches would have no effect.

How could Dan be so gullible as to be led down the garden path of decision making by a guy in a suit and a gorgeous head of hair? Why did he think he was making choices of his own free will? Forcing works because the brain is on a constant, active lookout for order, pattern and explanation and has a built-in abhorrence of the random, the patternless, the in-narrable. In the absence of explicability, we impose it. When we think we are choosing something, but the choice is changed on us, or distorted in some way, we nevertheless stick to our guns and justify our "choice."

The brain is constantly confabulating – a fancy term for making things up. Normally this process is beneficial. For instance, confabulation is what allows us to "see" people and objects in drawings, instead of the tangle of dark lines that we are actually looking at. It is also what allows us to "see" faces in clouds; it allows our perception to be flexible and creative. But when this sort of pattern imposition goes on at higher levels of cognition, the implications can get a little uncomfortable. The mind will go to surprising lengths to preserve its sense of agency and choice, and of the rationality and continuity of the self. When we are influenced by others, as Dan was by Johnny, we rationalize the influence as being good decision making on our part.

In another example of choice illusion, we see James the Amazing Randi perform an outstanding "book test" in which he appears to divine the word that an audience member randomly chooses from a book, from across the philharmonic hall, without the help of assistants.

The choices seem essentially infinite. But Randi has indeed asked the audience member to choose any word she wants from a book, and he will divine it. She is being fooled. She really feels like she has thousands of choices, and is being directed by nothing other than her own free will. But in fact, Randi has used mentalism tricks to restrict her choices to one, or just a few, possible words. So when he "reads her mind" he is actually just making an educated guess that has a low probability of failure. The details of how mentalists perform "book tests" will be explained further in this chapter. For now, suffice it to say that magicians who use mentalism tricks have an intuitive understanding of the fact that that people often feel like they have unlimited choices when in fact they have few to none.

Take human mating as an example. In the Western world we choose our own mates, right? Arranged marriages and professional matchmakers have joined siegecraft and alchemy in the dustbin of history, have they not? Perhaps. In theory, we can go forth and multiply with anybody we want, so long as there is mutual agreement. We are free, and our number of choices seem for all intents and purposes infinite. But in practice, most of us are no less restricted in our choice of

mates than a tradition-bound Eastern youth heading towards an arranged marriage. Consider the fact that we must actually know and interact with the person with whom we pair. We are therefore restricted, in general, to the same geographic location, socioeconomic background, religion, age, current state of availability, and in general roughly the same level of attraction. In reality, it's hard to find a mate who matches all of these parameters, especially after you've completed high school and college. That's why most people marry either their high school or college sweethearts. So how free are we really? Not very. Eastern practices of matchmaking seem fairly intelligent considering that the choices are made by people (usually parents) who care about the "lovers," who have hard-earned perspective on the full course of life, careers and parenthood, and take all of the issues listed above into account during their decision making process. Further, with notable exceptions in certain isolated rural parts of the world, the "lovers" nowadays usually have veto power, at the very least.

Finding a great mate, and one whose baggage is lifetime-tolerable (heard any good mother-in-law jokes lately?), requires real luck in the West, and yet it feels completely free. "I make my own luck," say the enlightened, empowered masses. "Believe you will get what you want," says the mega-bestselling self-help book, *The Secret* "and it will manifest." Truly this is staggering. This is one of the grandest magic tricks ever devised, a mass enchantment that over the course of just a couple of centuries has swept up whole civilizations. Why do these choices feel so free and unlimited, when they clearly are not?

The answer lies in a psychological principle called cognitive dissonance. This is when two competing ideas, behaviors, facts, or beliefs are in conflict in your brain. A common way that your brain reconciles the conflict is to change its attitude, beliefs, or behaviors to bring one of the competing ideas into prominence. When making a decision between two apparently equally attractive things, cognitive dissonance also comes into play. You elevate the value of your choice for the simple reason that it was your choice, even in the face of evidence that you chose poorly or even flat-out wrongly. Have you ever had a boss who made a dumb decision that became immutable policy long after she realized she had been in the wrong? Cognitive dissonance. Have you yourself ever made a dumb decision concerning your children, but then stuck to your guns so as to "provide consistency?" Cognitive dissonance. Have you ever looked down on sports fans who happen to live in zip codes that put them in camp with a losing team? Cognitive dissonance. Have you ever fallen in love with the only single person you see in the lab everyday for seven years, who's your approximate age, and whose socioeconomic status matches yours? We did. Cognitive dissonance. We should hasten to point out that cognitive dissonance is not all bad: it keeps your eye on the ball and focused on your correct choices too. It may be necessary for falling in love to take place, because it helps hide the inevitable imperfections that any given mate will have. Magicians love cognitive dissonance, because it protects them from audience scrutiny, since the audience like to feel as though they've made decisions freely for themselves.

The illusion of free will has been described behaviorally for decades, but only recently have scientists begun to look at how it works in the brain. It's a hot field of research. A colleague of ours named John-Dylan Haynes, of the Max-Planck Institute in Berlin, Germany, has done some recent brain scanning with fMRI to see what happens when people make conscious choices (as opposed to unconscious choices, which we will explore more in another chapter). He reprised a classic experiment by Benjamin Libet, an American neurosurgeon who recorded responses in the

motor cortex (which controls voluntary movement) of people during surgeries, and found that there are neurons that fire fractions of a second before the patient made the conscious choice to push a button. Presumably those neurons were playing a role in the decision to push the button. Haynes's work goes much further, and with surprising results. He has shown that frontal lobe areas can exhibit responses up to *seven seconds* before a conscious choice is made. That means that parts of your brain know what choices you are going to make several seconds before you become consciously aware of it. Because these brain bias your upcoming choices, and since they will tend to respond in the same way to the same impending choice made multiple times, you will tend to make the same decision again and again. Each time, you will be convinced it was a free, open-ended choice. Cognitive dissonance works because our free will isn't truly free; it's highly constrained by our context and history. And history, as they point out in political science, is written by the victors. This is as true of the potential thoughts and deeds that populate our minds as it is of cultures and nations: The winning choice orchestrates emotion, language and memory to make itself the inevitable and infallibly correct one.

Chapter Eight: The Indian Rope Trick and Other Memory Illusions

We discuss the neural bases of memory acquisition, storage, forgetfulness and false memory formation, as well as broader philosophical thoughts about human consciousness, illusion and the origins of magic in the brain. Readers will take away strategies to improve their memories and stave off cognitive decline.

In the Indian Rope Trick, a boy climbs a magically suspended rope and disappears at the top. The magician follows the boy up the rope into the invisible area at the top and cuts him into piece as evidenced by the bloody parts falling from the invisible area down to the ground. The magician then descends the rope and magically reintegrates the boy with no harm done.

Or so it was claimed. Although a multitude of people in the 19th century attested to having witnessed the Indian Rope Trick, historians, who carefully analyzed the spread and growth of this meme, concluded that the trick never actually happened. Illusions of memory and the techniques and mechanisms that underlie them ramify to several areas of practical importance, including the reliability of eyewitness accounts, the controversial psychology of "recovered memories," and national, political and religious narratives.

In another exploitation of memory, mentalists and sleight-of-hand masters use techniques to memorize large amounts of information – say, the names of every person in the theater, or the order of cards in a "random" deck – and methods for manipulating people's recollections. With proper technique, a magician can cover his or her tracks, so to speak, by immediately recapping the trick the audience has just seen. In the retelling, the magician elides certain details, focuses in on others and plants fillers and decoys. This renders the audience unable to accurately reconstruct what they actually saw, as their true memories have now been polluted with false ones.

Earlier we discussed some of the basic principles that allow magic and illusion to hold sway on our perceptions of reality. For the purposes of that discussion we framed these as "security flaws," but from a higher perspective they are not flaws at all, they are features. What most people fail to appreciate is that the illusions that we find so entertaining in magic shows and coffee table books are not just strange and curious corner cases where our perceptual faculties go amiss. In fact, they just happen to be particularly palpable demonstrations of the kinds of systematic illusion-spinning that is happening all the time in the brain, at all levels of perception, awareness and thought. In other words, illusions are not errors of the brain. Far from it. Illusions arise from processes that are critical to our survival. Our brains have developed illusory processes so that we may experience the world in a ready-to-consume manner. Remove the machinery of illusion, and you unwind the entire tapestry of human awareness.

Your conscious experience is not a function of the world, it is a function of the neural networks of your brain. Therefore, the biology of the brain is as fundamental to understanding the universe as the high-energy physics of subatomic particles. This is especially true for the study of sensory and cognitive illusions, since they represent effects that clearly stand out as not representing the real world. That is, since illusions don't match reality we can know that by studying illusions we are studying exactly what the brain is actually doing, and not just what we think the brain should be doing. Your brain does a staggering amount of pragmatic self-dealing, half-assed guesswork and outright confabulation in order to construct the highly imperfect mental simulation of reality known as "consciousness." This is not to say that objective reality isn't "out there" in a very real sense – but no one lives there. No one's ever even been there for a visit. Ironically, the fact that consciousness feels like a solid, robust, fact-rich transcript of reality is just one of the countless illusions your brain creates for itself.

Chapter Nine: Enter the Castle

Magic has a long legacy of informal experimentation on the manipulation of human attention and perception. However, it is only in the past few years that magic techniques have been applied to brain science. In this chapter we show, for the first time, how brain science can be applied to magic. Using our understanding of neuroscience, we perform a new magic trick – the first truly new magic trick to be developed in over 100 years – in our quest to gain membership in The Magic Castle, the world's premier magical society.

We are strolling just a stone's throw north on Orange Drive, up from Grauman's Chinese Theater and the Walk of Fame, towards a funky little mansion nestled into the Hollywood hills. As we got closer we realize, "That's it." The Magic Castle!

Cross Hogwarts School of Witchcraft and Wizardry with an English Pub and Disney's Haunted Mansion, and you'll get the Magic Castle. The building is the Area-51 of magic and serves as the home of the Academy of Magic Arts, which bills itself as the most exclusive club of magicians in the world. On second thought, we're not sure why we are surprised that this particular mansion is the Castle. It's certainly impressive enough, even from a distance. It must be that the building

seems too small to hold four theaters plus several other performance rooms and seven bars (as described on the website). It is only after the tour is in full swing that we start to suspect that the building truly is bigger on the inside than it is on the outside.

Outside the entry hall we meet up with Roz Dauber, a documentary film maker who has expressed an interest in making a film about our immersion into magic. Once past the foyer, we are inside and immediately overwhelmed by the sheer number of things to look at. The entry room is darkly lit. Walls are lined with dark hardwoods with crown molding and wainscots, bringing gravity to the room. There is a very friendly receptionist behind a podium, and she is surrounded by – and we mean surrounded as in every-single-nook-and-cranny – thousands of books on shelves lining the walls. We introduce ourselves and she points us to the small gift shop area of the room, where Tom Meseroll, the Martial Magician, is waiting for us. After greetings, he asks, "Shall we go in?" with a big devilish smile on his face. We enthusiastically answer in the affirmative and turn back toward the receptionist in search of the door into the rest of the Castle. Susana, who is ahead, stops, turns around, says "oh", and pushes by going in the other direction. That's odd. "Susana, where are you going?" She says she is looking for the door. And that's when it hits us. *There is no door.*

This chapter describes our adventure that night as we immerse ourselves into the world of magic. This is the club where the world's greatest magicians let down their goatees, hang out and relax. We describe our escape from the entryway as well as our explorations of the rest of the club and our run-ins with some of the world's most famous magicians. We attend five performances tonight, interact with Irma (the invisible Piano player) and all the while discuss magician's secrets plus advice on obtaining membership to the club. This is critical information for us, as we plan to win entry to this exclusive academy as performers, or forever stay on the outside.

We have a trick we want to perform but we need some high tech support. Through the 19th century magicians had always been at the very forefront of technology and invention, but then at some point the development of new effects essentially stopped and magicians clung to their (now) old traditions and technologies. Much of the low hanging fruit had been plucked and it was easier to continue to do the same old tricks. Our magician friends also expressed the desire to come up with something completely new. Teller especially feels that magicians are not portrayed well in society, as if they were all tuxedoed balloon manipulators and birthday party entertainers, when, in fact, many of them are some of the high intellectuals of the entertainment field. The perception of magic as entertainment is that it has declined from being the highest paid form of entertainment in the U.S. to being only slightly cooler than clown shows. But this perception is distorted. There have never been as many shows of magic than there are now, never as many conventions, never as many magic shops or tricks sold to burgeoning new amateurs. The highest paid variety entertainer in the world is magician David Copperfield. So magic is alive and well and the problem has been in overcoming the perception that magicians are not as relevant to today's audiences as the boy band of the week.

The magician Jason Latimer has addressed this issue by embracing the most modern of technologies – lasers, special materials in glass, cutting-edge optics, electronics, robotics – and

uses them to make wholly modern magic and live onstage special effects. The basic effects on the brain are still the same (to the best of our knowledge, he hasn't developed truly new magic yet), but he makes fresh and exciting new variants on old tricks using high technology.

Latimer is especially important to us because the trick we want to develop, The Magical Standing Wave (based on a novel optical illusion Stephen discovered as a grad student) is decidedly high-tech, and we're going need professional help to make this a successful stage trick. If it works, this will be a truly new magic trick – not just a variant on existing tricks, as every "new" trick in 20th century magic was, but a new trick based on a never-before exploited brain circuit for the purpose of magic.

This chapter includes discussions on the history of magic, including the history of magical engineering, which has brought inventions such as the parachute and house alarm. We discuss ways magic has been used to manipulate political decisions, such as when Napoleon asked the famous magician Robert-Houdin to convince Arab chieftains that the French war machine had magical powers – thus avoiding a war in Algeria.

Magic and engineering is an especially interesting topic. In the 16th century magicians began inventing and developing their own technology for astounded audiences. For example, the Besson Keg could dispense wine, water and oil through a single spigot. Some of these mechanical devices were so convincing that the inventors were tried by the church for practicing supernatural methods, but then acquitted once the effects were explained to their inquisitors.

The first magical device to become world famous was "The Turk," an automaton that played master-level chess, invented by the Hungarian Baron Wolfgang von Kempelen in 1769. Spectators were welcomed to see the calculating machinery inside its box after each show. The real workings of The Turk remained a secret until 1827, when two skeptical young boys from Baltimore hid and watched backstage as a man climbed out of a hidden compartment. The local newspaper broke the story that the chess-playing "automaton" was a hoax.

In the mid-19th century, Jean Eugéne Robert-Houdin (the father of modern magic and main inspiration for Erich Weiss, aka Harry Houdini), used his engineering skills as a clock maker to make amazing mechanical contraptions that seemed to operate as if by magic. Robert-Houdin's famous automaton trick "The Orange Tree" is featured in the 2006 movie "The Illusionist". Robert-Houdin also invented the first electric house security alarm, and other Rube Goldberg contraptions such as a three-tiered alarm clock system that set off alarms at different places around the house and at different times, while also triggering the release of morning oats to his mare in the barn. Other renowned magicians, such as Jaçques Garnerin and John Nevil Maskelyne, made important technological advances by inventing the parachute (Garnerin), the first ribbonless typewriter and the coin-operated lock for vending machines (Maskelyne).

Magicians have also made important contributions to debunking pseudoscience. In 1922 Scientific American magazine offered a $2,500 prize to the first medium who could produce a ghost manifestation under controlled conditions. Houdini was one of the investigators in the team evaluating the supposedly paranormal manifestations. All the "ghostly" activity was exposed as more or less clever magic trickery: nobody won the prize. Several contemporary magicians, such as James Randi, and Penn&Teller, have also put their training and skills to the service of

exposing so-called psychics and faith-healers. Penn&Teller host the popular Showtime cable TV show Bullshit!, in which they debunk modern charlatans and various urban myths. The James Randi Educational Foundation offers the One Million Dollar Paranormal Challenge: a million dollars plus eternal bragging rights to anybody who can produce an objective proof of the paranormal—to date, no one has passed the preliminary tests.

Chapter Ten: Will the magic go away?

We are often asked, why should people be interested in magic if you explain how the tricks are done and how magicians hack into our brains? We should be interested because the fact that magicians can do so little, to so powerfully pull the wool over our eyes, suggests that they are tapping into fundamental processes of our brains and cognition. We absolutely must understand them if we are understand what it means to be human. Will the study of magic do away with the mystery? No. The wonder and awe of perceiving magic will no more disappear than did the beauty of the sunrise after Copernicus' seminal discovery that the Earth was a sphere that rotated while circling the sun. On the contrary, both discoveries, that we are hurling around the sun and that magic works because humans are inherently quite dumb, are simultaneously deeply humbling and awe inspiring. Increased humility and awe deepens the mystery, rather than rids us of it.

Try it yourself: go to the peak of Haleakala on the island of Maui in Hawaii (where Steve was raised) and watch the sunrise. Steve's dad ran an observatory on this particular mountain top, shooting lasers at the moon to measure how long it took for the light to return from the mirrors that Apollo 11 left in the Sea of Tranquility. Since the only conceivable reason that the round-trip time of the light would change from one measurement to the next is that the Earth had moved, geologists use this astronomical data to measure the movements of the Earth's tectonic plates. The Hawaiian Plate has at its east edge the San Andreas fault in California. So the motion of Steve's dad's plate helps to define how soon LA and San Francisco will be sucked down into the Earth in the Cascadia subduction zone. He was so proud of his job, which earned him accolades in *The New York Times*, that it was here, next to LURE observatory, that Steve's dad wanted his ashes spread after he died from ALS a few years ago. As you are standing there next to Steve's dad, with the sun coming up to burn holes through the clouds with its rays from 93 million miles away, you should consider that you are on the highest peak that exists at that particular longitude of the Earth. That means that, at that very moment of sunrise, the two of you are the fastest moving people on Earth with respect to the Sun, and you are hurtling towards it at over 1000 miles/hour (the angular velocity of the Earth at this altitude near the equator). That's more than twice the escape velocity needed to leave the orbit of the Earth. If the Earth's rotation happened to suddenly stop during that sunrise, and your speed became 1000 miles/hour relative to the Earth as well as to the sun, you would see nothing but that sunrise until you burned up in the heliosphere on your way to the center of our solar system -- approximately 11 years later. Now imagine all this as you enjoy the incredible raw beauty of the moment, and try not to pee your pants.

OK, now that it's over, your blood pressure has dropped to normal, your breathing rate is within normal limits, and you can tell yourself that it was really all trivial. You are standing at an arbitrary position on a not-very-special-planet that happens to rotate once every 24 hours so that the local star's solar terminator passes over an island in the middle of one of the planet's oceans every 12 hours. Big deal.

Tell the truth, which one of these descriptions would represent best how you felt about the Haleakala sunrise? They are both physically true and both are communicated with scientific facts. But is the beauty of Steve's most meaningful sunrise really lost by understanding what is physically happening? On the contrary, the scientific facts enrich the experience. The fact that Steve's dad contributed to our understanding of the motion of our planet and that Steve can stand next to his dad's desiccated molecules, now with Steve's own son on his shoulders, while watching this sunrise and considering these facts, certainly makes it more beautiful to Steve, and not less so.

Now consider magic. In fact, imagine you are Susana seeing Mac King magically transport a card across the stage from one audience member's pocket and into a different audience member's pocket. Imagine that you had chosen to study the mind and brain using illusions from the moment you entered college. That you had then attended graduate school for over 4 years in the pursuit of a more refined understanding of how it all worked. That after studying in a neuroscience lab and receiving your PhD in Medicine and Surgery, you then joined the lab of Nobel Laureate David Hubel, at Harvard Medical School, for another 4.5 years. And then, after these 13 years of advanced training, you ran your own lab studying illusory perception for over 8 years. Imagine that with your over 20 years of professional experience in the neuroscience of illusions, including several years of specific study of magic with the world's most famous magicians, and as a leader in the field of NeuroMagic, that some hayseed in a bad suit, spewing hokey jokes, can not only mystify you, but can leave you wondering, flat out, "What the HELL just happened?" No, it is certainly not true that deeper understanding of the brain, of magic, or of how the brain perceives magic, is going to hurt our ability to enjoy magic, or that the knowledge will ruin the experience.

On the contrary. It was that very expertise that made it clear that magicians are special, and that magic is not so much a bag-of-tricks, but an untapped corpus for understanding the human mind. Magic has never been more popular. The Internet has blown it wide open so that more people than ever before can explore its pleasures and mysteries.

Writing Sample

This writing sample below explains the background and captures the voice of the book. In the finished book, elements from this sample will be distributed across different chapters.

June 2007, Las Vegas, Nevada —

Apollo Robbins is sweeping his hands around the body of the fellow he has just chosen from the audience. "What I'm doing now is fanning you," the master pickpocket informs his mark, "just checking to see what you have in your pockets." His hands move in a flurry of gentle strokes and pats over the man's clothes. More than two hundred of us are watching him like hawks, trying to catch a glimpse of fingers trespassing into a pocket. But to all appearances it's a perfectly innocent and respectful frisking. "I have a lot of intel on you now," Apollo continues. "You scientists carry a lot of things."

Apollo is demonstrating his kleptic arts to a roomful of neuroscientists who have come to Las Vegas for the Magic of Consciousness Symposium. What Susana and I and our new magician friends hope to do here tonight is show these scientists how much magicians can teach them about the subjects of their life's work: attention, awareness, perception, and even the holy grail, consciousness. Magicians and neuroscientists share a passion for understanding the nuts and bolts of the human mind, but we have been developing our respective arts and theories more or less independently of each other for generations. But starting tonight, our two communities are stepping through the illusory wall that kept us from paying close attention to the other's discoveries. For Susana and me, this is sheer consummation.

Apollo has dared everyone in the auditorium to try and catch him pilfering this man's belongings up on stage in plain view. I watch intently just like everyone else, but none of us really stand a chance. This is Apollo Robbins, the infamous "gentleman thief" who once pickpocketed ex-president Jimmy Carter's Secret Service detail, relieving them of their watches, wallets, badges, confidential itinerary and the keys to Carter's limo.

So Apollo can keep the joke on us for as long as he feels like it, but at least I know one thing he doesn't. So does Susana, sitting next to me at the panelists' table on the dais. As soon as we saw who Apollo had plucked randomly from the crowd, we shared a glance of pure glee. This man isn't a scientist at all, as Apollo assumes, but the one person in the room who will be explaining to the wider world what went on here tonight. He is the *New York Times* science reporter, George Johnson. George is a man of great humor and intelligence, but he is fundamentally quite shy. His awkwardness makes for great theater.

The fanning continues as Apollo engages in his highly honed rapid-fire patter. "You have so many things [in your pockets] I'm not sure where to begin. Here, was this yours?" he asks, thrusting something into George's hand. George frowns down at it. "You had a pen in here," Apollo says opening George's breast pocket, "but that's not what I was looking for. What's in

that pocket over there?" George looks over. "There was a napkin or a tissue, maybe? You have so many things it's confusing to me. You know, to be honest I'm not sure that I've pickpocketed a scientist before. I've never had to do indexing as I went through someone's pockets."

Patter, it turns out, is one of the most important tools in the magician's toolkit for attention management. There are only a dozen or two (depending on who you ask) main categories of tricks in the magician's repertoire; the apparent wide variety of them is all in the presentation and details. Sleight of hand is of course critical, but so is patter, the smooth and confident stream of verbiage that can be used to hold, direct or divide attention. Apollo tells George one thing while doing two other things with his hands. This means that in the best-case scenario George has only a one in three chance of noticing when something of his gets snatched. His real chances are actually far below one in three: in the psychic sparring ring of attention management, Apollo a tenth-degree black belt.

Apollo is one step ahead the whole time. By continually touching George in various places – his shoulder, wrist, breast pocket, outer thigh – he jerks George's attention around the way a magnet draws a compass needle. While George is trying to keep track of it all, Apollo is delicately dipping his other hand into George's pockets, using his fast-driving voice to kept George's attention on his face, or on some spurious demonstration.

Apollo steals George's pen, notes, digital recorder, some receipts, loose cash, wallet, and, very early on, his watch. One classic way to lift somebody's watch is to first grab their wrist over the watchband and squeeze. This creates a lingering sensory afterimage. Afterimages can occur in any sensory system, but the kind you're probably most familiar with are the visual variety. For instance, if you glance at the setting sun, you wind up with sun-shaped spots or streaks that float in your field of vision for a minute or so after you look away. Even now, if you simply shut your eyes and pay attention, you can see greenish and bluish blobs that rapidly fade from your vision. These are afterimages of whatever you happen to have been looking at over the past minute or so. Apollo is exploiting the same principle, only in this case the afterimage is tactile. The afterimage renders the touch neurons in George's skin and spinal cord less sensitive to the watch's removal, and creates a conveniently lasting perception of the watch long after it has disappeared. I notice the watch when I see Apollo folding his arms behind his back, buckling it onto his own wrist as his patter leads George down some garden path of attention.

A few times during the fleecing, without ever skipping a beat, Apollo holds up a pilfered object high behind George's head for the audience to see. This makes everyone laugh but George, who smiles and looks around sheepishly, wondering what the joke is.

Then, to more laughter, Apollo returns all of George's belongings one by one. "If you're recording [which was not allowed at the event], I think we have evidence," he says as he hands over the digital recorder. Proffering a folded stack of bills he says "I presume this is your gratuity money?" Finally he turns to George and says, "We all pitched in to buy you a watch, very similar to the one you were wearing when you got here." He unstraps George's watch from his wrist and passes it over. George gasps and rolls his eyes.

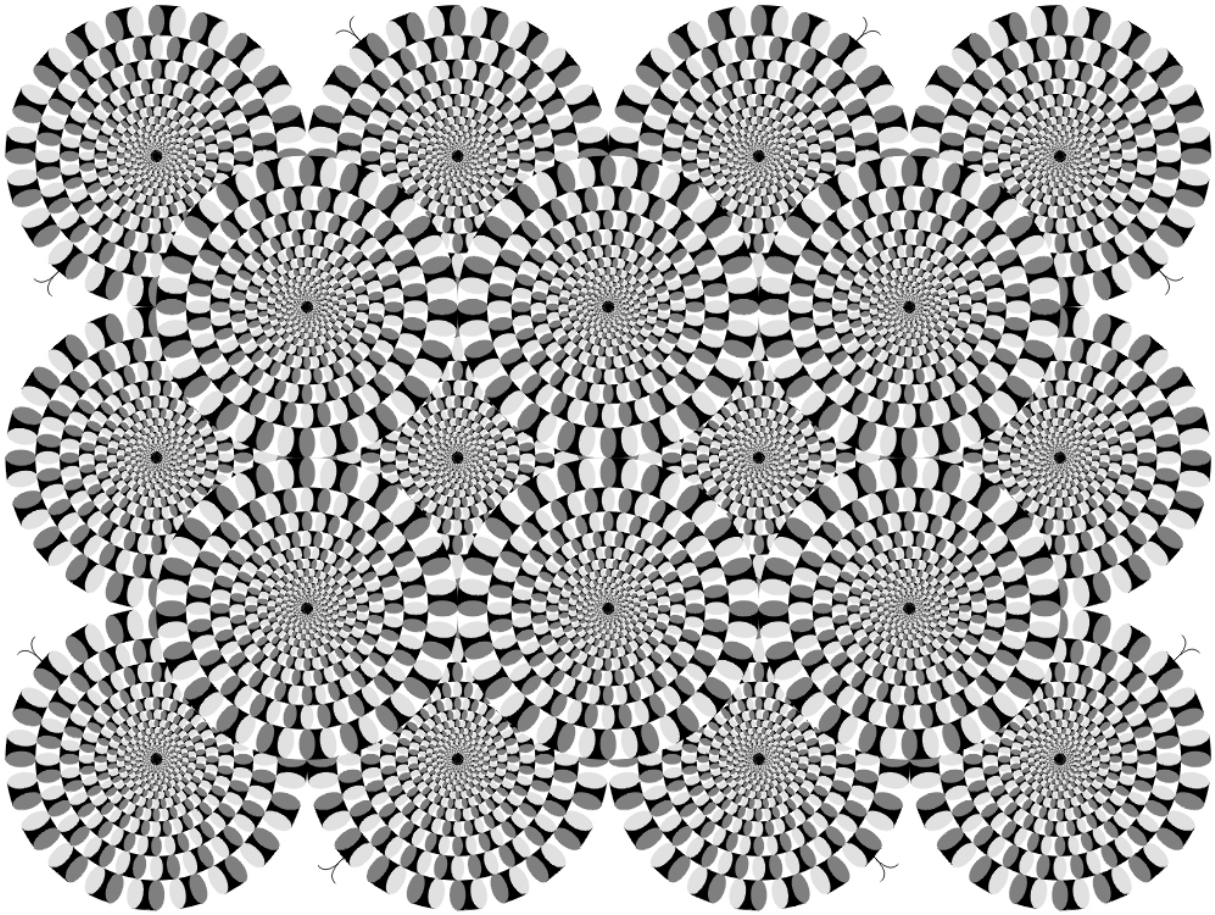
Then Apollo turns to the audience and says "Now I'll show you how that works. Would you like to see the behind-the-scenes of how I did all that?" Magicians are famously loath to give away

their secrets, but this is not your grandfather’s magic show and Apollo is here tonight to instruct, not just to entertain. Tonight is all about a meeting of minds between two very different disciplines that turn out to have a great deal to teach each other. Apollo is not going to disappoint.

space break

We never planned to become experts in magic. Our journey to this dais had begun a couple of years earlier when, as young scientists seeking to make a name for ourselves, we tried to think of a way to rustle up some public enthusiasm for our specialty of visual neuroscience. In 2003 we both accepted jobs at the Barrow Neurological Institute in Phoenix, Arizona. That same year, we were tapped to organize the annual meeting of the European Conference of Visual Perception which was being held in Susana's home town of A Coruña, Spain. We wanted to try something new, something that would showcase visual science in a way that would interest the media and the public. We knew that people love it when science can explain something about the visual arts. An example is Margaret Livingstone's work on why the Mona Lisa's smile is so ineffably enigmatic, or why Monet's use of similar hues allows you to see depth and spatial organization without objects being defined. We also knew that visual illusions are eternally popular, and also fundamentally important to understanding how the brain turns raw visual information into perception.

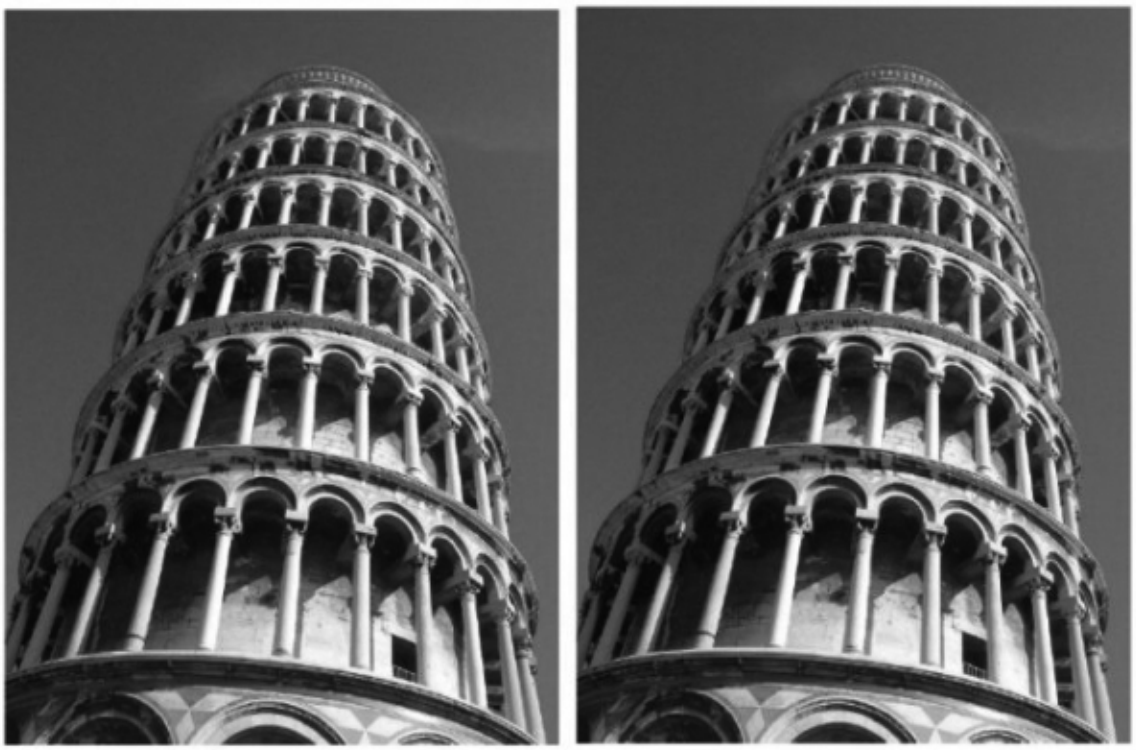
For example, some stationary patterns can create the illusory perception of motion. See the rotating snakes figure below.



In the Rotating Snakes illusion, invented by Akiyoshi Kitaoka, the "snakes" appear to twist. But nothing is really moving, other than your eyes! If you hold your gaze steady on one of the black dots at the center of the "snakes," the motion will slow down or even stop. Because holding the eyes still stops the illusory motion, we speculate that eye movements are required to see it. This is supported by the fact that the illusory effect is usually stronger if you move your eyes around the figure. Vision scientists have shown that illusory motion activates brain areas that are similar to those activated by real motion.

The idea we came up with was simple: We would create The Best Visual Illusion of the Year Contest, which mixed science, art and the public in one room. We asked the scientific and artistic communities to contribute new visual illusions and got over 70 entries. The audience got to see the ten best illusions and then choose the top three.

The contest has been a huge success. Our internet audience doubles every year and we currently get over three million visitors each year. Aside from the personal gratification, it's astonishing and inspiring. Astonishing, because you would think that after generations of talented, dedicated, sometimes OCD-driven visual artists tinkering and laboring at their easels, drafting tables, scratch pads, dark rooms and PC graphics programs, that this particular vein of ore would be all mined out. But it isn't. Consider the Leaning Tower illusion:



The two images of the Leaning Tower of Pisa are identical, but to you it seems like the tower on the right leans more. This is because your visual system treats the two images as if they were part of a single scene. Normally, two neighboring towers will rise skyward at the same right angle, with the result that their image outlines converge as they recede from view. This is one of the ironclad laws of perspective, so invariant that your visual system automatically takes it into account. Since the outlines don't converge, your visual system is forced to assume that the two side-by-side towers must be diverging. And this is what you "see."

This illusion is so basic, so simple, it is almost beyond belief that no one ever reported it before 2007. And that is what also makes it inspiring: It just goes to show that there is still plenty of low-hanging fruit just waiting to be discovered. Each new illusion adds depth and definition to cognitive theory. Each bolsters certain hypotheses while weakening others or inspiring new ones. Some suggest new experiments. Each inches us just that much closer to understanding perception, awareness and consciousness.

space break

Because of our success with the illusion contest, the Association for the Scientific Study of Consciousness asked us to chair their annual meeting to be held in June, 2007. The ASSC is a society of philosophers, psychologists and neuroscientists united in the aim to understand how conscious experience emerges from the interactions of mindless, non-conscious brain cells.

As our opening move we proposed holding the conference in our home town of Phoenix, but the Association's board nixed that right away because the city is an inferno midyear. Instead, they suggested... Las Vegas. Hmmm. This seemed a bit disingenuous. Las Vegas is every bit as blisteringly hot in June as Phoenix, and if you take the lap dancing, gambling and show girls into

account, it is probably several degrees hotter due to friction. So apparently our colleagues in consciousness studies were looking for a bit of real excitement to spice up their thought experiments.

So Vegas it was. We flew out there in October 2005 to do some scouting. On the flight over we tried to figure out the really important thing: What hook could we attach to this conference to make it memorable and newsworthy? What theme could raise the visibility of consciousness research to the public? We didn't want to do another contest. The answer began to germinate the moment our plane dipped its wings on approach to the Las Vegas airport. Out of the window we could see, all at once, the Statue of Liberty, the Eiffel Tower, an erupting volcano, the Space Needle, the Sphinx, Camelot and the Great Pyramid. It felt like a dream. Soon we were driving up and down the Strip, checking out hotels for our meeting space. We passed Aladdin's castle, the Grand Canal of Venice and Treasure Island. People from every culture on the planet seemed to mill around us. It seemed too strange to be real. Then, bingo: The answer appeared. Festooned on billboards, taxi cabs and buses were huge images of magicians: Penn & Teller, Criss Angel, Mac King, Lance Burton, David Copperfield. They stared out at us with mischievous eyes and beguiling smiles. These tricksters seemed like scientists from Bizarro World – doppelgangers who had outpaced us real scientists in their understanding of attention and awareness, and had flippantly applied it to the arts of entertainment, pickpocketing, mentalism and bamboozlement, as well as to unique and unsettling patterns of facial hair.

One of the things Susana and I study is visual art. Artists have been making important discoveries about the visual system for hundreds or years, and visual neuroscience has learned a lot about the brain by studying their techniques and ideas about perception. We realized that magicians are just a different kind of artist: Instead of form and color, they manipulate attention and awareness.

Magicians basically do cognitive science experiments for audiences all night long. But unlike most experiments in cognitive labs, they don't suck. Now, before my inbox fills up with flames from angry colleagues, let me explain. Cognitive neuroscience experiments often suck insofar as they are strongly susceptible to the state of the observer: If the experimental subject knows what the experiment is about, or is able to guess it, or sometimes even if she incorrectly thinks she has figured it out, the data are often corrupted or impossible to analyze. Such experiments are fragile and clunky. Extraordinary control measures must be put in place to keep the experimental data pure.

Now compare this with magic shows. Magic tricks test many of the very same cognitive processes we study, but they are incredibly robust. It doesn’t matter in the slightest that the entire audience knows it is being tricked; it falls for each trick every time it is performed, show after show, night after night, generation after generation. We thought, if only we could be that deft and clever in the lab! If only we were half so skilled at manipulating attention and awareness, what advances we could make!

The idea rapidly came together: We would bring scientists and magicians together so scientists could learn the magicians’ techniques and harness their powers. We grew excited; and this was before we realized that we were setting our expectations far too low.

But there was just one problem: We were just a couple of clueless muggles. We did not know any magicians. Neither of us had ever even seen a real magic show. Moreover, we would need celebrity magicians if we were going to attract news coverage and public interest. Furthermore, they would have to be celebrity magicians who were willing to divulge their most precious secrets.

Fortunately, our colleague Dan Dennett got us our big break. Dennett is a fellow scientist and philosopher who also happens to be a good friend of James the Amaz!ng Randi, a famous magician and skeptic who has spent decades debunking claims of the paranormal. Randi wrote back, enthusiastically endorsing our idea. He told us that he knew three more magicians who would be perfect for the symposium: Teller, Mac King and Johnny Thompson. All of them lived in Las Vegas and all were personally interested in cognitive neuroscience. Apollo, the pickpocket, Teller's friend, joined our group a few months later.

space break

Apollo calls the ever amiable George back for more fleecing, but this time he explains what he is doing. He instructs rather than patters. He slows his techniques way down, occasionally pausing and rewinding.

Most people call what magicians do "misdirection," says Apollo, but that is like saying doctors make people well with their curing skills. The term is so broad it is next to meaningless. He prefers to discuss specific principles and techniques such as "frames" and "attention management."

Frames are windows of space that the magician creates to localize the audience's attention. A frame can be a whole room or a tabletop or a volume no bigger than a shoe box. "You have no choice but to watch in the frame," says Apollo. "I use movement, context and timing to create each frame and control the situation." Apollo demonstrates by moving very close to George. He grabs George's hand and pretends to press a coin into it, though all he is really placing there is another sensory afterimage. "Squeeze hard," says Apollo. George gazes intently at his hand, now caught within a frame. He squeezes. "Do you have the coin?" teases Apollo. George nods. He thinks so. "Open your hand," says Apollo. The palm is empty. "Look on your shoulder," says Apollo. George glances to his shoulder where a coin is resting.

Apollo explains that if a subject's attention is localized to a frame, then maneuvers outside the frame will rarely be detected. Magicians, he says, thoroughly manage attention at all times. People tend to think of "misdirection" as the art of making someone look to the left while some fast move is pulled on the right, but that is far too simplistic. Apollo says it is more about force-focusing the spotlight of attention to a particular place where it will get caught up. Pickpockets are masters of shifting frames around.

Another important concept, says Apollo, is that tricks are embedded in natural actions. He demonstrates by making a pen disappear. He dangles it in front of the audience with one hand. When he flicks his other hand past his ear, as if to scratch, no one notices. The movement is natural, unremarkable, quick. Suddenly everyone sees the pen has vanished. Apollo turns his head around to reveal the pen tucked behind his ear.

Later in the show Teller, the mute half of the duo Penn & Teller, explains the same concept. "Action is motion with a purpose," he says. In normal social interactions, we constantly search for the purpose motivating other people's actions. An action with no obvious purpose is anomalous. It draws attention. However, when the purpose seems crystal clear, we look no further. Teller explains that he will draw suspicion if he raises his hand for no apparent reason, but not if he performs a seemingly natural or spontaneous action like adjusting his glasses, scratching his head, or draping his coat over the backrest a chair. Teller calls this "informing the motion."

"Skilled magicians inform every necessary maneuver with a convincing intention," Teller says.

Neuroscientists now have a good idea why such decoy actions are so good at fooling us. It comes from a remarkable type of brain cell called mirror neurons.

You are familiar with the idea of the "mind's eye": Pretty much at will, you can conjure a quasi-visual experience of just about anything that can be seen or depicted in images. You also have your "mind's ear," where you can replay songs and noises and voices you are familiar with. Similarly, there is your "mind's body." This is your brain's virtual representation of your physical self. When you plan out how you are going to cook tonight's dinner, when you daydream that you are an action hero, whenever you re-live a painful memory of gym-class humiliation, you are running a virtual simulation of those actions in your mind's body. It is an invaluable psychic tool for action planning, execution, skill learning and memory.

Mirror neurons form an important part of your mind's body because they help you understand the actions and intentions of other people. They do this by automatically mimicking others' actions and assuming their intentions using your own mind's body. So when you see Teller reach for a glass of water, you instantly do the same thing in your mind's body. You also ascribe a simple, natural motivation to him, namely that he is thirsty and will raise the glass to his lips and take a drink. In your mind's body, you do this too. Literally: many of the same neurons that are active when you take a drink are active when you think someone you can see is about to take a drink. Your brain makes a prediction and runs a simulation, automatically and usually subconsciously.

Mirror neurons are a very important element of human social intelligence. They are part of how we are able to understand each other, to imitate, to learn and teach, to empathize. But they can also mislead us. A good magician can disguise one action as another or convincingly fake an action he isn't really performing, prompting your mirror neurons to feed you false inferences about what he is actually doing or not doing. You see Teller raise the glass to his lips and seem to drink, and your automatic prediction seems to be fulfilled. But did he really take a drink? Maybe he transferred something from hand to mouth, or from mouth to hand.

space break

Apollo turns to face George for another demonstration. "When I approach somebody," he says, "I find that if I go straight in, I enter their personal space. It's like a bubble surrounding their body. The distance is different in different cultures and in different people, but everyone senses the space and tries to protect it." Apollo then turns his body to stand shoulder to shoulder with George. "But if I move to the side, like this, the gap is much smaller. You don't feel invaded."

One more thing. “As I move into your personal space, I need to break eye contact with you, so that you don’t keep your gaze on me.” Apollo looks down. George looks down. Apollo pops up next to George's shoulder. He is now safely inside George's bubble. He can get away with magical murder.

Apollo's observation is fascinating. What he calls personal space, neuroscientists know as peripersonal space. (Scientists can never resist a good game of Pin the Greco-Latin Root on the Simple Word.) People have always had a strong intuitive sense of this space, and neuroscience has recently begun to decode its neural foundation in the brain. It turns out to be more than a mere metaphor, but less than a real, tangible aura. It is a construct your brain actively creates as part of your mind’s body. As far as your brain is concerned, the space immediately around you is literally a part of your body. This is why you can tickle a child by wriggling your fingers in the air over her ribs, and why you are physically as well as emotionally sensitive when someone “punctures” your bubble uninvited.

Finally, Apollo reveals a principle of the pickpocket's art that thrills Susana and me. “In years of doing shows,” he says, “I noticed that the eye is more attracted to arches than to straight lines.” He starts patting George's pockets again. George looks on with interest. “If I want to take something out of his pocket, I can keep his eyes occupied on my free hand if I move it in an arc. But if I move it in a straight line, his attention will snap back to my other hand” like a rubber band, he explains.

Susana and I had first heard Apollo describe this principle when we had come out to Las Vegas a few months prior to the Magic of Consciousness Symposium, in one of the meetings where we got together with these magicians to share knowledge and ideas and to brainstorm. I don't mind telling you that after every meeting with Apollo I check the credit cards in my wallet to see if they've been swapped for fakes. He's really that good.

Teller had called for this particular meeting in his office so that Susana and I could present our scientific research on illusions and visual perception to the magicians. It was a great idea. The purpose of the collaboration was to enable us to use magic in the lab, but it would obviously help for the magicians to know what cognitive research looked like. I showed them some of my work on visual illusions. They were delighted and amazed by the latest examples.

Susana then taught the magicians about the neuroscience of eye movements. There are two main kinds, and they serve different purposes and are probably controlled by different subsystems of the oculomotor system.

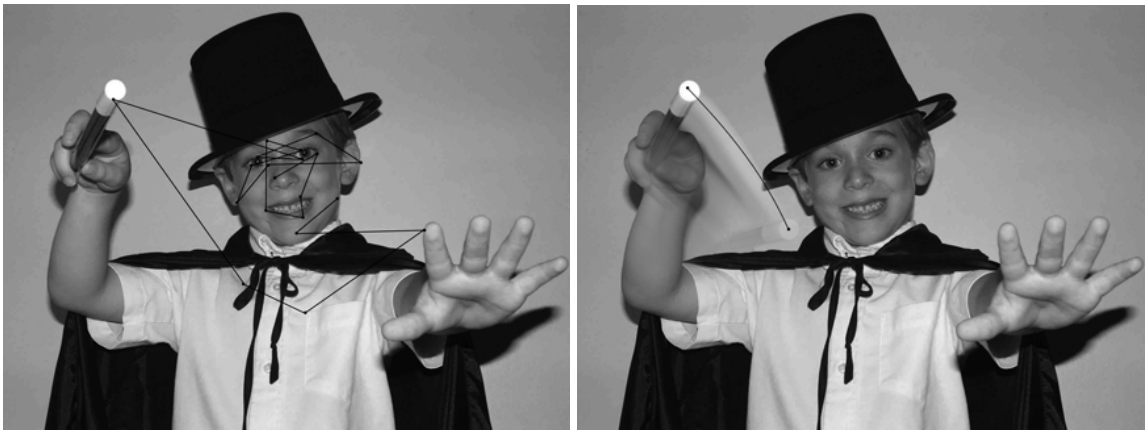
The first kind are called saccades, in which your eye jerks almost instantaneously from one point to another. The fleeting moments when the eyes are motionless between saccades are called fixations. Saccades are critical to vision because our eyes can only make out fine detail in a keyhole-sized circle at the very center of our gaze covering 0.1% of the retina; the vast majority of the surrounding visual field is of shockingly poor quality.

You can prove this to yourself with an ordinary deck of cards. Separate out the face cards and shuffle them. Fix your gaze on something directly across the room and don’t let your eyes move at all. Draw a random face card and hold it out at arm’s length at the very edge of your peripheral vision, then slowly pivot your arm forward, bringing the card toward the center of your

unflinching forward gaze. Assuming you can resist the urge to let your eyes dart off to steal a glimpse, you will find that the card has to come quite close to your center of vision before you can identify it.

The reason it doesn't *feel* like your vision is 99.9% garbage is because of saccades: Your eyes are constantly darting around the world like a hummingbird on meth. Your brain edits out the motion blurs and integrates the small bits of information received from each fixation to present your visual awareness with a detail-rich, stable-seeming portrait of the visual scene before you.

The second kind of eye movement is called smooth pursuit. This means that your eyes move in a continuous, uninterrupted path without any pauses or jerks along the way. Smooth pursuit takes place only when you are tracking a moving object. It cannot be faked. This is one of the reasons that some visual effects scenes in movies fail: when an actor pretends to track an object that doesn't actually exist, but is added in post-production, the action inevitably looks wrong on screen. Pursuit eye movements like this allow you to track moving objects, while saccades are used to systematically search and gather information from a visual scene.



Saccadic eye movement vs. smooth pursuit. The left figure shows the zig-zagging path an observer's eyes might trace while looking at a magician. The right figure shows the eyes' smooth, unbroken pursuit path as they follow the tip of his wand as it is raised in a gentle arc.

You can observe the difference between these two types of eye movement by holding up your thumbs in front of you about a foot apart. Now, holding your hands still, ask a friend to slowly move her eyes as smoothly as possible from one thumb to the other. Notice that her eyes make little jumps along their journey. Those little jumps are saccades. No matter how hard she tries, she cannot make her eyeballs swivel smoothly between the targets. Now try it again but this time ask her to watch your left thumb as you move it slowly over to touch the right one and then back out again. Notice this time how her eyes track perfectly smoothly.

All of the magicians were fascinated by these facts, but for Apollo they triggered a Eureka! moment. He said that pickpockets differentiate between straight-line versus curved hand movements when managing their marks' attention. He now realized that the dichotomy between saccades and pursuit eye movements could explain why.

When you see a hand moving in a straight line, your eyes – and your attention – automatically jump to the (anticipated) end point. So a pickpocket will make a fast, linear gesture if he wants to

minimize your ability to pay attention to the path itself. But a hand that moves in an arc triggers a different tracking mechanism. You cannot predict where the hand is headed, so you fixate on and follow the hand itself, and so you fail to notice when Apollo's other hand slips into your pocket.

Pickpockets have a whole toolkit of misdirection techniques. Susana and I were already familiar with some of them. Such thieves often ply their trade in dense public spaces and rely heavily on socially based misdirection – eye contact, body contact and slipping, ninja-like, inside the personal space of the mark. But Apollo's observation was really new to us, and it immediately spawned new insights and ideas for experiments.

If Apollo and his colleagues were right, they knew something important about the brain that neuroscientists did not. It is very well established that visual perception is suppressed during saccades, which seemed to explain the way pickpockets made use of fast linear movements. But it was still unknown whether attention was also affected during eye movements. Apollo's experience seemed to indicate that it was. This was new.

This conversation marked a sea change our relationship with the magicians. Our original intention had been simply to poach their best techniques so that we could design better experiments, but now we realized that magicians might actually know things about mind and behavior that neuroscientists do not. Instead of helping us to discover new things about the brain, these artists and entertainers could be a source of neuroscientific discovery themselves. This was going to be so cool! We named a new field: Neuromagic.

space break

Teller performs the routine known as the Miser's Dream. His right hand snatches at the empty air, and from it appears to pluck a glittering coin. In his left hand he holds a tin bucket, and drops the coin in. Clink! Then Teller starts to move around the room, pulling coins out of people's heads, eyeglasses, jackets. Then more from thin air. Snatch. Clink! Snatch. Clink! The bucket is filling up with coins.

When the act is over, Teller returns to the stage and explains how the trick works. He says one of the magician's greatest assets is the audience's instinct to infer cause-and-effect relationships.

He explains that he is only pretending to drop coins in the bucket. He is only faking the action of tossing, and uses the flick-down motion to re-conceal the coin in his hand. But the faked action engages our mirror neurons, so we are predisposed to see it as the same natural tossing action we ourselves perform daily with coins, car keys, cooking ingredients and so on. The illusion of each "toss" is completed with a small shake of the bucket, which causes the small number of coins that are actually in there to go, Clink! But the bucket isn't filling up at all, and we're seeing the same coin flash in the miser's hand over and over and over again. Our assumptions have misled us.

Teller continues, "One of the things magicians do is take advantage of our natural inclination to study something we see done over and over again, and to think that we're learning something. ... Your natural inclination as an observer is to assume that what I'm doing is the same thing over and over again. We take for granted that a repetition is a repetition [even] when it's not."

“We all infer cause and effect in everyday life,” says Teller. When A precedes B, we conclude that A causes B. The skilled magician takes advantage of this inference by making sure that A always precedes B. However, A does not really cause B.

Psychologists call this effect illusory correlation. In most circumstances, our inborn instinct for inferring cause-effect relationships serves us well. Want an egg? Look in a bird’s nest. Dark clouds gathering overhead? Rain is likely, so find some shelter. That’s all well and good, but this is a highly imperfect, eminently fallible faculty. It goes amiss all the time and leads us to believe all kinds of things.

For instance, illusory correlation is at the root of why some people honestly and in all good faith believe they are psychic. You may know someone who believes he has predicted the future in a dream – a plane crash, say. But what he doesn’t tell you is that he has premonitions of a plane crash several times a week. He tends not to notice or remember these false predictions; but the one that coincides with an actual plane crash sets off wild alert bells in his brain. His mental correlation detector is screaming, Correct! True! Valid! In extreme cases illusory correlation can lead to extreme beliefs, such as the ancient Aztec theory that a human sacrifice had to be performed each morning in order to make the sun rise. It’s gruesome and easy to condemn in hindsight, but as the Aztecs saw it, it worked every single morning, just as advertised.

A similar and related effect in the brain is called the availability bias. This illusion is caused by a failure of memory. It pops up often in everyday life. For example, I change our son’s diaper waaaaaay more than Susana does. Evidently because she’s lazier than I am. But the puzzling thing is that Susana thinks exactly the opposite. She thinks she changes Iago’s diapers more than I do. The fact is that we are both wrong. We each change Iago’s diaper more or less evenly (maybe me a little more). But in our own minds our own contributions and sacrifices are magnified by the fact that we remember our own actions better than we remember each other’s. We incorrectly draw stronger correlations between the facts that we remember.

Magicians are well aware of these little brain foibles, and they pump them like a lab rat on a cocaine lever.

“When a good magician repeats an effect,” Teller continues, “he varies the method in an unpredictable rhythm.” That way, each time observers begin to suspect one method, they find their suspicion disproven by the subsequent “repetition.” For instance, a disappearing ball is first secretly palmed by the other hand, but in the next “repetition” it is instead dropped on the magician’s lap, allowing the magician to show that the other hand is empty. “Much of our life is devoted to understanding cause and effect,” Teller says. “Magic provides a playground for those rational skills.”

Mac King is up next. He elaborates on Teller’s point by demonstrating the negative repercussions of doing the same trick twice. Mac looks a bit like Danny Kaye in a bad plaid suit, but he is one of the most influential magicians in the world. He is not only one of the few major magic headliners on the Las Vegas Strip (one of the dream jobs of the magic world), but also one of the few primary inventors of new illusions. In fact, Mac often creates new tricks for other magicians’ shows, such as Penn & Teller’s. Mac is also considered by many to be the finest comedy magicians alive. Tonight, he first performs one of the most spectacular tricks from his

show at Harrah's. He complains of a pebble in his shoe, which he then pulls off to reveal that it contains an impossibly giant rock. It's an incredible and extremely smooth magical production of a surprising object, to be sure. Everybody in the room is wondering where that huge rock came from. “I had it in a secret hiding place,” Mac deadpans with an embarrassed look on his face, in answer to the unspoken question.

From our angle on stage, behind the performers, I can't see the rock very well but I had seen it earlier during Teller's talk, when Mac accidentally dropped it from his back pocket as we sat behind the panel table. It made a loud thud that everyone in the room must have heard, but only those of us at the dais could see what had actually happened. I'll never forget the mirth and chagrin on Mac's face as he retrieved his rock unceremoniously from behind his chair, on all fours, and looked up at me on his way up from the floor. Even without having seen the actual rock behind the table, the loud noise should have been a bigger clue to the audience, telegraphing what Mac was about to do. But it might as well have fallen on deaf ears, as the audience did not seem to process the noise whatsoever. They didn't even remember the thud later on, after having seen Mac's trick. It occurred to me that magicians, like all of us in our jobs, must make mistakes all the time. But since a magician’s mistakes involve unlikely objects and actions, untrained spectators do not realize their significance. Magicians know this and it gives them the courage to simply keep going even in the face of glaring logical errors. Indeed, one of the hallmarks of a good magician is to be able to recover smoothly and seamlessly from mistakes and unexpected turns. Certainly in this case the audience heard the noise and saw Mac scramble under the table before his performance, but they simply forgot the episode because they were unable to assign significance to it.

The rock weighs about five pounds and is the size of a small melon. To demonstrate that doing the same trick twice is a mistake, Mac purposely performs the same exact trick once again, using the same exact method as before. It is much easier to understand the trick the second time around. “I'm so happy that some of you noticed,” Mac says. “I've been a little worried that it wouldn't get easier for any of you [the second time]!” He then seems to do the same trick again, for a third time, and asks the audience if they could see how he did it. But this time the trick has again become impenetrable. The reason is that Mac didn’t *actually* do the same trick again, he only *appeared* to do so. The third time around Mac changed the method by pulling a fake but realistic-looking sponge rock out of his shoe. Unlike the real 5-pound rock he had used in the first two iterations of the trick, the newly produced sponge rock was actually hidden inside his shoe. Mac’s demonstration illustrates how apparent, but not actual, repetition is as a powerful ally to the magician. Spectators become habituated to the seemingly repeated actions and gloss over the details. For a magician, the devil is in those details. The audience has a deep-seated bias to assume that effects that look the same are done in the same fashion. It’s human nature. For all our modern enlightened skepticism, deep down there is an Aztec high priest in all of us.

Using apparent repetition, a magician can even deliberately raise suspicion about a possible method, only to then show that suspicion to be unfounded. This principle is known as the Theory of False Solutions, formulated by Spanish magician and magic theorist Juan Tamariz. The next magician in our lineup, Johnny Thompson, calls it “closing all the doors” on every possible explanation for the trick. Johnny, a.k.a. the Great Tomsoni, is elegantly dressed in his usual

double-breasted suit and sports the most incredible comb-over you've ever seen. It's so amazing it was featured on Penn & Teller's TV show, “Bullshit!”

Johnny asks people in the audience if they believe in mind reading, psychic ability, mentalism. He calls up a volunteer, whose name is Dan, and asks again, “Do you believe in mind reading?”

“No.”

“Neither do I. I'm a faker, fraud, phony and cheat.” But then, says Johnny, “nobody's perfect.” Only he is perfect, at fakery. The trick, he says, is based on psychology, behavior patterns, and in “closing the doors” to all rational explanations for what we are about to see. Johnny takes out his wallet and removes a $100 bill. He also takes out a small envelop and asks Dan to examine it. The money and envelop go back into the wallet which then goes to Dan's breast pocket.

Next Johnny pulls out a “perfectly ordinary deck of cards,” shuffles them and asks Dan to cut the deck. From my angle, seated behind him, there is no apparent trickery going on. As far as I can tell, he doesn't put anything into, or pull anything out of, any of his pockets. After the cards are cut he asks Dan to turn them over slowly, one at a time, and stop whenever he "feels" a precognition that the card matches the one inside the envelope in his breast pocket. Dan stops at the nine of clubs. And lo and behold, when they open the envelope, inside is a nine of clubs. Also embossed on a plaque in the wallet, in gold letters is this: You will choose the nine of clubs.

Johnny now helps close all the doors in this trick by going back over the apparent choices Dan made, and the availability he had to information about his decisions.

“Now if you were to walk away right now you might happen to think that that was the cleverest card trick or feat of sleight of hand that you’d ever seen,” says Johnny. “But it wasn’t a card trick. Were the cards shuffled?”

“Yeah,” answers Dan.

“Did you cut them?” asks Johnny.

“Yes.”

“Did you deal them face-up and see that every card was different?”

“Yes.”

“Did you stop on the card that you wanted to stop on?”

“Pure impulse,” says Dan.

“And I saw that you stopped on the only losing card,” confirms Johnny. “Did I not offer you $100? I begged, implored, and I even *told* you to go one card further. If you had changed your mind, that wallet would still be in your hands, am I right?”

“Yes,” laughs Dan.

But, as you might suspect, Johnny’s retelling of the procedure was actually a clever rewriting of history, one designed to slyly gloss over the suspicious actions that he made. Susana and I don’t know precisely how Johnny did this trick because he elected to keep the methods secret. But we can extrapolate from our knowledge of magic to explain how he could have done it.

First, it was Johnny who “shuffled” the cards, not Dan. It is very straightforward sleight of hand to make it appear that a deck of cards is shuffled. So were the cards really mixed up? No.

Second, Dan may have cut the cards, but Johnny made sure Dan cut roughly from the middle. He omitted this detail from his retelling as well.

Third, after the cards were cut, Johnny took a furtive glance at the bottom card. This told him the exact order of every card in the deck. How? Because he had stacked it. A stacked deck is one in which the magician has carefully placed every card in a pre-determined order and then memorized the order. When the deck is cut, only the position of two cards has changed; the rest of the order is preserved.

Fourth, Dan counted out the cards one at a time, starting at the top of the deck, and stopped on whichever card he wanted, right? Not really. Dan was standing in front of a crowd of hundreds of his peers. The likelihood that he was going to count out fifty-one cards in the most boring fashion imaginable was highly unlikely. Instead, Dan counted out seven cards before selecting one – which happened to be the nine of clubs. You can be sure that Johnny knew Dan would not choose the first card, nor would he count out very many cards before selecting. To count out more than about ten would be nerve wracking. Remember, Johnny knew the exact order of the cards in the deck, including the top ten. This means he knew pretty nearly which card was going to be selected, plus or minus five or so cards. Also note that even if Dan had behaved radically and counted out dozens of cards, Johnny could have simply recut the deck (masked by a quick flourish), or done one of many other possible procedures, to force Dan to make the necessary selection in a different way. Since the audience doesn't know the trick, they have no way of knowing if additional procedures were strange or unnecessary. So Johnny was holding all the cards in more ways than one. He could ensure that the card Dan chose was one that Johnny had in his pocket.

Finally, Johnny did not retrieve the wallet containing the matching card and embossed lettering until *after* Dan had made his final selection and presented it publicly. This too, was left out of the retelling of the trick.

All of this adds up to the fact that Johnny could have known ahead of time, before he even drove his Cadillac to the event, the narrow range of ten or so cards that were likely to be selected from. He could also force Dan to choose one of the ten cards in a seemingly magical way. If Johnny had on his body ten wallets stored in his suit, all with different cards and embossed messages matching Dan’s ten most likely selections, organized so that Johnny could grab the correct wallet in a natural fashion after Dan had made his choice, it would appear as though Johnny had precognition. And in a way he did. He knew exactly how Dan would behave because Johnny is a master of human observation. Then, by recounting the entire trick slightly incorrectly, leaving out the suspicious bits and distorting certain details, he created false memories for the audience. A confidently delivered, coherent-sounding story is much easier to remember than a quick series of subtle movements and visual impressions. Thus, Johnny effectively removed the possibility that the audience, or even Dan himself, could reconstruct the trick and work it out after the fact.

Johnny tells us, "When people see a wonderful piece of magic, they try to figure out how it's done. They have avenues of thought and logic. The magician, just before the dénouement or finish, must close all those doors. The only solution is magic."

What Johnny does not tell us today is that magic tricks also work because they exploit some basic psychological principles. For example, to get Dan to choose the nine of clubs, Johnny employed what magicians call a “force” – not the George Lucas “These aren’t the droids you’re looking for” kind of force, but not too different. That droids quote, by the way, is from a famous scene in Star Wars where Obi-Wan Kenobi psychically dominates the mind of an imperial storm trooper, forcing the weak-minded minion to believe and say whatever Obi-Wan tells him to. After the storm trooper waves the heroes past the checkpoint, Obi-Wan explains to the young Luke Skywalker, “The Force can have a strong influence on the weak-minded.” Except that in the real universe, we are all weak-minded.

With Yoda-like skill, Johnny uses psychological manipulation to force Dan to make the necessary decisions. He succeeds because he knows that much of our free will is anything but. If we truly had free will, advertising and salesmen's pitches would have no effect.

For example, when I was a postdoctoral fellow splitting my time between two labs, I needed a car to drive between Harvard Medical School in Boston and Cold Spring Harbor Laboratory on Long Island. So I bought a shiny new black Dodge Intrepid ES with the moon roof, leather motorized seats, upgraded rims, Infiniti Surround-Sound system, and automatic air temperature controls. It was expensive for a postdoc’s salary and put a drain on my resources, but I rationalized the decision because it was an incredibly safe car with side air bags (which were new at the time), traction control, automatic braking system, and other cool safety features. After all, the long drives between Massachusetts and New York required an extra measure of safety.

Sure they did. My decision had nothing to do with the fact that chicks dig a cool car.

To be fair, I did go to the car dealership with a list of desired safety features. I arrived at the car lot driven by a strong sense of responsibility. The salesperson took one look at my list, knew that the high-end models were the only ones that came with the features I wanted as standard, and then preyed on the fact that I was a single male with needs. I could have ordered a cheaper, drearier, smaller model with the same safety equipment, and then waited two to three months for the new car to arrive. But the salesman forced me (in the sense that magicians use the word) to buy the fancy car instead. Why wait and potentially die when I could drive off the lot with a dream car today and start my new babe-filled safety-conscious lifestyle right away?

Why does forcing work for non-Jedis like Johnny Thompson or Darth Car Salesman? How could Dan be so gullible as to be led down the garden path of decision making by a guy in a suit and a gorgeous head of hair, or me by a guy with a set of keys? Forcing works because the brain is on a constant, active lookout for order, pattern and explanation and has a built-in abhorrence of the random, the patternless, the in-narrable. In the absence of explicability, we impose it. When we think we are choosing something, but the choice is changed on us, or distorted in some way, we nevertheless stick to our guns and justify our “choice.”

The brain is constantly confabulating – a fancy term for making things up. Normally this process is beneficial. For instance, confabulation is what allows us to “see” people and objects in

drawings, instead of the tangle of dark lines that we are actually looking at. It is also what allows us to "see" faces in clouds; it allows our perception to be flexible and creative. But when this sort of pattern imposition goes on at higher levels of cognition, the implications can get a little uncomfortable. The mind will go to surprising lengths to preserve its sense of agency and choice, and of the rationality and continuity of the self. When we are influenced by others, as Dan was by Johnny, and as I was by the car salesman, we rationalize the influence as being good decision making on our part. We will discuss this much more deeply in Chapter 9, when we describe the phenomenon of "choice blindness," and its relationship to magic and the brain's mechanisms of decision making.

space break

James the Amaz!ng Randi is a short man with a long Santa Claus beard and a gigantic personality. He commands the room wherever he goes. It is no wonder that he plays the role of elder statesman for the entire American magic community. He is the founder of the James Randi Educational Foundation, which serves to protect society at large from charlatans and frauds of the paranormal. The Foundation offers a one-million dollar challenge to anybody who can prove that they have psychic powers of any kind. After more than twenty years and numerous challenges, no one has collected the money.

Randi begins by explaining that you will easily accept unspoken assumptions and that you tend to believe information that you learn for yourself as opposed to being told it. For example, halfway through the lecture he reveals that the microphone he appears to be speaking through is a dummy. (He was wearing the real mike.) Further on, he shows us that his glasses are fakes by sticking two fingers through where the lenses are supposed to be. The moral of the story: people don't question lies that have no reason to be lies.

But why don't people question unspoken assumptions? The reason is that such assumptions *have already been questioned* and established as fact. As children, we pulled our grandparents glasses off of their faces, stuck them in our mouths, and tested the diopter of the lenses with our tongues. As adults, we feel no further need to continue to lick the glass. We've become habituated to the fact that glasses frames have actual glass lenses in them. But this is just an observation, not an explanation. It is critical to go further into the neuroscience here and ask how the brain actually accomplishes habituation, and why.

The why is easy: thinking is expensive. It requires brain activity, which takes energy, and energy is a limited resource. More importantly, thinking takes time and attention away from other tasks, like finding food and mates and avoiding cliffs and saber-toothed tigers. The more you can safely file away as established fact, the more you can concentrate on your goals and interests. The less you wonder whether somebody's glasses frames actually contain glass, the better off you are.

Habituation is created through a neuronal process called synaptic plasticity. Eric Kandel, of Columbia University, recently won the Nobel prize for his work establishing this process in a little-appreciated sea slug called an Aplysia. Kandel recorded from neurons in the Aplysia nervous system while blowing air onto their gill. Aplysia don't like air puffs on their gill, so they retract it. But air puffs aren't really harmful, and retracting the gill is tiresome and burns precious calories, so as the air puffs are repeated, the Aplysia habituates and eventually stops retracting

the gill in response. Neurally, the sensory information concerning the air puff becomes more and more minute until signals concerning the air puffs are not even sent from one neuron to the other. That's synaptic plasticity, and it's the neural mechanism of habituation. We humans do the exact same thing as the lowly sea slug, only we do it with more fancily processed perceptions and behavioral options. We don't question whether every pair of glasses we see contains glass because experience has taught us that we can safely assume that they do, and the synaptic pathways responsible are habituated to that fact.

Once you've habituated to a feature of the world, it becomes a humdrum and seemingly immutable part of the fabric of life. Stable, reliable, unchanging. That's why magicians prefer to rely on unspoken assumptions over explanations whenever possible.

This same process may contribute to why it is so difficult to lose a loved one. My grandmother died from complications surrounding emphysema (certainly smoking-induced) in her late eighties. My grandfather lived on for a few more years, but never got his mojo back after her death. This was despite the fact that my grandmother had been sick for a long time, and it took a lot of effort for my Grampa to care for her in her final years. In many ways, Grampa's life got objectively easier when she died, even better in some ways. But the oxygen might as well have been removed from his air, Grampa was so despondent. Habituation is part of the basis of how we learn, and my grandparents were together for so long that Grampa had learned that Gramma was a fundamental feature of life. Without her, he was just counting the days. The unspoken assumption that she would always be there was only evident when she wasn't.

space break

The Magic of Consciousness Symposium was a watershed event in our careers. The Symposium, plus the three scientific papers we published in its wake, garnered huge interest in the new science of neuromagic from scientists, magicians and members of the public. It took over our lives and set us firmly on the path of looking deeper into the possibilities of what had been unleashed, and ultimately to our determination to write this book. By the end of 2008 we had put together our agenda and travel itinerary for the year 2009, our year of intensive travel and adventure, our year of learning and apprenticeship and practice, practice, practice – our year of living magically.

Why did we take to the road, and why did we decide to become magicians ourselves? Quite simply, because we knew our neuromagical enterprise would fail if we did not.

Performing magic is like hacking the brain, and to truly understand hacking, you need to become a hacker yourself. It's one thing to read and write about hacking, another thing to actually do it, and still another thing to do it well. To create workable, replicable experiments that reveal something new and significant about the brain, you need to really know what you're doing. Designing new scientific experiments is part science, part art. No two are the same. No mathematical formula can design them for us. Since our goal was to import the techniques and principles of magic into the scientific setting, we would need to be experts. We would have to learn and practice with real live magicians.

And how would we know when we were ready? We decided to do what many wannabe magicians have done. To determine our prowess, we would audition for the most prestigious and

exclusive magic club in the world – The Magic Castle in Hollywood. If you can perform at a professional level in front of top magicians, you are awarded club membership. This gives you access to secrets of the trade and credentials for getting jobs in the industry.

We began working with a great local magician, Tony Barnhardt, who agreed to show us the ropes (and rope tricks), and is moreover a fellow cognitive scientist and collaborator. But to compete to enter the Magic Castle and Magic Circle, and to do it within *one year*, we would also need a massive crash-course from the world's top performers. We would need to go meet the magicians where they live and work – at magic conventions, competitions, shows, workshops, and conferences. We would pick their brains as they picked our pockets, all the while exploring the various corners of the magical, and real, world.

This book is based on the research we've done in our own neuroscience labs and on our adventures in the deranged and arcane world of magic in Hollywood, London, Las Vegas, Beijing, Benasque (Spain), Shanghai, Madrid, and, last but not least, Wisconsin.