How Does the Brain Work?

Investigate the psychology of magic tricks, magnetic wands that treat depression, artificial intelligence, and more. Airing September 14, 2011 at 9 pm on PBS Aired September 14, 2011 on PBS

Program Description

This episode of NOVA scienceNOW delves into some pretty heady stuff, examining magic and the brain, artificial intelligence, magnetic mind control, and the work of neuroscientist and synesthesia researcher David Eagleman. Can we really believe our own eyes? Will machines one day think like us? Can magnetic wands effectively control brain functions and treat depression? Explore this and more.

Transcript

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NEIL DEGRASSE TYSON: Hi, I'm Neil deGrasse Tyson, your host for NOVA scienceNOW, where this season, we're asking six big questions. On this episode: How Does the Brain Work?

CHAPTER 1: Magic and Change Blindness

To find out, I head to Las Vegas, where brain researchers are placing their bets on magic.
MAC KING (Magician)*:* That's a dang real fish.
NEIL DEGRASSE TYSON: Some of the world's top magicians...
PENN JILLETTE (Magician)*:* Place the ball...
NEIL DEGRASSE TYSON: ...are making the mysteries behind our most powerful organ disappear...
I saw it go over! I swear I saw it go over.
The illusionists reveal their secrets
That motion will draw the eye
...giving us new insight into how our brain pays attention.
STEPHEN MACKNIK (Barrow Neurological Institute)*:* This would be a major contribution to science from the magicians.
NEIL DEGRASSE TYSON: Also, a magnetic wand ...
MO ROCCA (Correspondent)*:* Oh! That was nice.
NEIL DEGRASSE TYSON: ... that can control your body,...
MO ROCCA: Ooh, wow!
NEIL DEGRASSE TYSON: ...and your speech...
MARK GEORGE (Medical University of South Carolina)*:* ...twenty-five, twenty-six.
We can turn a part of the brain up or down, or temporarily turn it off.
NEIL DEGRASSE TYSON: Could it even change the way you think?
ALVARO PASCUAL-LEONE (Harvard Medical School)*:* It's a remarkable thing, that one can put something over somebody's head and modify the way they behave.
NEIL DEGRASSE TYSON: And I've met some professors who are tough on their students, but this one gets the prize.
*DAVID EAGLEMAN (*Baylor College of Medicine):You're dropped from a 150-foot-tall tower, in freefall, backwards.
NEIL DEGRASSE TYSON: This brain researcher isn't afraid to go to extremes to solve one of the biggest puzzles in science.
DAVID EAGLEMAN: Brains are like fingerprints, and they're slightly different in everybody.
NEIL DEGRASSE TYSON: Especially, when some of us see a whole other reality.
JOSEPH ZERR (Synesthete/Research Subject)*:* As are always red, and Ms are green.
DAVID EAGLEMAN: How does the brain, with its hundreds of billions of neurons, put together reality for us?
NEIL DEGRASSE TYSON: All that and more on this episode of NOVA scienceNOW.
Everything we do, every thought we've ever had, is produced by the human brain. But exactly how it operates remains one of the biggest unsolved mysteries, and it seems the more we probe its secrets, the more surprises we find.
Here's one of the biggest surprises: as clever and perceptive as the human brain can be and as talented as it might be, it can still be fooled by a simple magic trick.
Keep your eye on the ball, son.
For centuries, magicians have intuitively taken advantage of the inner workings of our brains. Usually, they keep their tricks secret, but I met up with some magicians who were willing to come clean...
Eyes on the the ball, son.
...to help unlock hidden mysteries of how the brain really works.
This one? You sure? Sorry.
Welcome to Las Vegas, the entertainment capital of the world. I'm not here to get rich quick.
MAC KING: Neil deGrasse Tyson, right this way!
NEIL DEGRASSE TYSON: I've come to be tricked by some of the best magicians on Earth.
MAC KING: Now, in order to fish you have to have the proper fishing pole, and you have to have the proper bait: the Fig Newton®.
NEIL DEGRASSE TYSON: With just a Fig Newton as bait, Mac King takes me fishing.
MAC KING: You and I are fishing out here in mid-air, but we're not looking for just any fish, we're catching goldfish.
NEIL DEGRASSE TYSON: Suddenly, a flicker of orange appears on our hook.
MAC KING: Neil, hold that glass over here. Check him out.
NEIL DEGRASSE TYSON: And, voila, we've caught a goldfish.
MAC KING: That's a dang real fish.
NEIL DEGRASSE TYSON: It's real, it's real.
Magic is a sophisticated art form, practiced by seasoned professionals...
MAC KING: You know the rule here in Las Vegas?
NEIL DEGRASSE TYSON: ...who know exactly how to trick your brain.
MAC KING: Whatever you catch, you've got to eat.
He's still there. He's still there.
NEIL DEGRASSE TYSON: Oh.
MAC KING: Oh, he's still there. He's still there.
NEIL DEGRASSE TYSON: So, can the age-old art of magic shed light on how the brain works?
With more than 100-billion nerve cells, each making thousands of intricate connections, the human brain, a lump of tissue small enough to hold in your palm, is so powerful it can contemplate the vastness of the universe. Yet it can be fooled by the simplest coin trick.
Meet Apollo Robbins, stage name: Apollo, The Gentleman Thief.
A few years back, he embarrassed President Jimmy Carter's Secret Service agents when he picked their pockets during a visit to Las Vegas. Today, Apollo has agreed to share some of his secrets with me.
First, he shows me a special motion he uses to distract his victims when he's picking their pockets.
APOLLO ROBBINS (Magician)*:* So, when I go for a pocket, and I'm coming out of it like this, that motion, done in natural time, will draw the eye.
NEIL DEGRASSE TYSON: I'm going to follow that hand out of my pocket even if that's just a decoy for me?
APOLLO ROBBINS: Mm hmm, and I have a second longer with this hand to do something else.
NEIL DEGRASSE TYSON: According to Apollo, it's this curved motion that diverts my attention from what's he's really doing: stealing something from my pocket or making a coin disappear.

Neuroscientists Susana Martinez Conde and Stephen Macknick have come to watch Apollo. They're hoping he can help them solve a fundamental mystery: how does the brain decide what to pay attention to?
STEPHEN MACKNIK (Barrow Neurological Institute)*:* Neuroscientists know a lot about how the brain works. We know where the visual centers are; we know where the auditory centers are. But we don't really have a very good idea about attention and awareness yet.
NEIL DEGRASSE TYSON: They decide to video Apollo using his curved motion to make a coin disappear.
Back in their lab, they prepare test subjects to watch it. They fit them with this contraption, equipped with tiny cameras aimed at their subjects' eyes.
STEPHEN MACKNIK: We're measuring the eye position 500 or a thousand times a second. And what we're analyzing is: where are the eyes at every given moment of time in comparison to what's being presented on the screen?
NEIL DEGRASSE TYSON: The experiment reveals their eyes follow the path of Apollo's hand, just as he'd predicted.
SUSANA MARTINEZ CONDE (Barrow Neurological Institute)*:* I'm going to move my index finger from left to right, and I'm going to follow it with my eyes. What my eyes are doing right now is smooth pursuit. A smooth pursuit allows you to track a moving target.
NEIL DEGRASSE TYSON: Vision is a coordinated effort between the eyes and the brain. When our eyes see an object, the light reflected from its surface travels to the retina where it's transformed into neural signals. These signals go to a part of the brain dedicated to vision. Here we start to form an image.
But we don't pay attention to everything we look at. How does the brain control what we focus on and what we don't?
In a new study, Susana and Stephen, working with Jose Manuel Alonso, found that when our eyes track something like Apollo's curved motion, there's more than one type of brain cell at work. One type of cell detects motion, while the other suppresses the background.
SUSANA MARTINEZ CONDE: Your brain is actively suppressing the parts of the visual scene that you don't pay attention to.
STEPHEN MACKNIK: And this relates to what Apollo was telling us: that when you're tracking something, that you ignore everything around it.
JOSE MANUEL ALONSO (State University of New York)*:* These two types of neurons that we are beginning to understand could explain, you know, why magicians are so good at what they do.
NEIL DEGRASSE TYSON: In another trick, I think I see a coin flying through the air, but it never lands.
That was good!
MAC KING: So you see the coin, the shininess flicking through the air. You see the light glint off.
NEIL DEGRASSE TYSON: I see it.
MAC KING: Yeah. And then it disappears.
NEIL DEGRASSE TYSON: And I saw it go over.
MAC KING: You saw it go over.
NEIL DEGRASSE TYSON: I swear I saw it go over.
MAC KING: And it doesn't go over.
NEIL DEGRASSE TYSON: I'm sure I saw Mac toss the coin. Why did I see something that didn't actually happen?
Back at the lab, when volunteers watch the trick on a monitor, they're stumped, just as I am.
STEPHEN MACKNIK: So Mac's creating this illusion of inferred motion. So you see this motion that didn't actually take place.
NEIL DEGRASSE TYSON: It turns out our brain is sensitive, maybe too sensitive, to motion. It's a survival mechanism.
MAC KING: That motion detection, I mean, that's really a useful, useful brain skill.
NEIL DEGRASSE TYSON: The fact that I detect motion, even though it's not actually there?
MAC KING: Yeah, you make these assumptions to ensure that, you know, you don't get hit by a spear coming from your left side.
NEIL DEGRASSE TYSON: It's better to think there's a tiger moving in the brush and be wrong...
MAC KING: Yeah.
NEIL DEGRASSE TYSON: ...than to not notice it and get eaten.
MAC KING: Yeah, exactly.
NEIL DEGRASSE TYSON: But sometimes, even the most astute magicians, like the world-renowned Penn and Teller, aren't sure why a trick works.
Penn and Teller have been performing magic tricks for more than 25 years.
Penn is the boisterous talker, Teller his silent partner.
This time, it's the magicians who are asking the neuroscientists to explain a trick. It's one of their favorites: where they make balls appear and disappear under plastic cups.
PENN JILLETTE: You take the ball, you place it in our hand, we vanish it, and it appears underneath the cup. Here's a little variation Teller came up with, where he takes the ball, places it in his hand and shows you underneath the cup, yet it still appears underneath the cup. You take that center ball, place it visibly in the center cup, these side balls, we put them away, we don't need them anymore. We have three balls underneath here, and that's what we regroup: a giant ball underneath the center cup, one more giant ball either side, and, of course, for the finish, it's an American baseball, right there.
NEIL DEGRASSE TYSON: My head is still spinning.
Amazingly, the trick works even when they do it with clear plastic cups.
PENN JILLETTE: This is the Penn and Teller easy-to-follow version of the cups and balls.
NEIL DEGRASSE TYSON: Teller has asked Susana and Stephen to explain one part of the trick.
He's so curious he's agreed to give an interview, provided we don't actually show him speaking.
TELLER (Magician)*:* The thing that I'd like to see Susana and Steve study is, that very elemental move when the ball's on top of a cup and I tip it off, while secretly loading the ball.
NEIL DEGRASSE TYSON: Teller wants to know why we don't see him sneaking a second ball underneath that cup. To him, it's obvious.
The neuroscientists record him performing this move and show it to their volunteers. Then they show a different version, one that block's Teller's face. That turns out to make a real difference.
Like the curved hand motion in a coin trick, the magician's face commands your attention just enough to distract you from what's really going on.
STEPHEN MACKNIK: Even though you may think that you're looking at the balls all the time, the fact that Teller's face is present can draw your attention away from the loaded balls in the cups.
TELLER: Magic is sort of cognitive juggling.

PENN JILLETTE: ...the center cup, these side balls...
TELLER: If you come to a magic show with the intention of exercising your ability to discern fact from fancy and you fail, that's a fine piece of entertainment. So it's this wonderful playground where you can sort of relax and go, "Oh boy, it's really hard to understand the world."
APOLLO ROBBINS: I'm hoping that our work here gives people a different perspective of magic. What's fascinating about our work is that we are a study of human nature, of human behavior, and we have certain information that has been passed down through generations that can be utilized in a way that interfaces with science. And I'm really excited about the collaboration.
Meet Alex and Vin.
Alex: age 26
Vin: age 48
Now watch Vin ask a passerby for directions...
Watch closely. Vin is going to be replaced by Alex.
She didn't notice!
Neither did she!
About half the people in the people in the experiment didn't notice the change.
The phenomenon is called "Change Blindness."
Why does it happen?