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**Cognitive Scientists Advance the Art of Magic with
a Study of Penn & Teller's "Cups and Balls" Illusion**

Cognitive brain researchers have studied a magic trick filmed in magician duo Penn & Teller's theater in Las Vegas, to illuminate the neuroscience of illusion. Their results advance our understanding of how observers can be misdirected and will aid magicians as they work to improve their art.

The research team was led by Dr. Stephen Macknik, Director of the Laboratory of Behavioral Neurophysiology at Barrow Neurological Institute, in collaboration with fellow Barrow researchers Hector Rieiro and Dr. Susana Martinez-Conde, Director of the Laboratory of Visual Neuroscience. The study, titled "Perceptual elements in Penn and Teller's "Cups and Balls" magic trick" was published today, Feb 12th 2013, as part of the launch of *PeerJ*, a new peer reviewed open access journal in which all articles are freely available to everyone (<https://peerj.com/>). "Cups and Balls," a magic illusion in which balls appear and disappear under the cover of cups, is one of the oldest magic tricks in history, with documented descriptions going back to Roman conjurers in 3 B.C. "But we *still* don't know how it really works in the brain," says Macknik, "because this is the first, long overdue, neuroscientific study of the trick."

The discovery concerns the way magicians manipulate human cognition and perception. The "Cups and Balls" trick has many variations, but the most common one uses three balls and three cups. The magician makes the balls pass through the bottom of cups, jump from cup to cup, disappear from a cup and turn up elsewhere, turn into other objects, and so on. The cups are usually opaque and the balls brightly colored. Penn & Teller's variant is performed with three opaque and then with three transparent cups. "The transparent cups mean that visual information about the loading of the balls is readily available to the brain, yet still the spectators cannot see how the trick is done!" said Martinez-Conde.

Magicians have performed and systematically developed the art and theory of this illusion for thousands of years, but each new generation of conjurers offers new insights and hypotheses about how and why it works for the audience. Here the scientists turned the power of the scientific method to the illusion. The experiments tracked when and where observers looked during video clips portraying specific element of the performance, filmed by a NOVA scienceNOW TV crew. By quantifying how well observers tracked the loading and unloading of balls with and without transparent cups, the scientists determined that some aspects of the illusion were even more powerful at controlling attention than aspects originally predicted by the magician.

The end result is that cognitive scientists now have an improved understanding of how (and by how much) observers can be misdirected. In addition, this knowledge can help magicians further hone their art.

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Link to the Published Version of the article: <https://peerj.com/articles/19>

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About Barrow Neurological Institute

Barrow Neurological Institute at St. Joseph’s Hospital and Medical Center in Phoenix, Arizona, is internationally recognized as a leader in neurological research and patient care and is consistently voted among the top hospitals for neurology and neurosurgery in the United States. Barrow surgeons perform more neurosurgeries annually than any hospital in the nation. Barrow treats patients with a wide range of neurological conditions, including brain and spinal tumors, cerebrovascular conditions, and neuromuscular disorders. Barrow is home of the Muhammad Ali Parkinson Center.

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Abstract (from the article):

Magic illusions provide the perceptual and cognitive scientist with a toolbox of experimental manipulations and testable hypotheses about the building blocks of conscious experience. Here we studied several sleight-of-hand manipulations in the performance of the classic “Cups and Balls” magic trick (where balls appear and disappear inside upside-down opaque cups). We examined a version inspired by the entertainment duo Penn & Teller, conducted with three opaque and subsequently with three transparent cups. Magician Teller used his right hand to load (i.e. introduce surreptitiously) a small ball inside each of two upside-down cups, one at a time, while using his left hand to remove a different ball from the upside-down bottom of the cup. The sleight at the third cup involved one of six manipulations: (a) standard maneuver, (b) standard maneuver without a third ball, (c) ball placed on the table, (d) ball lifted, (e) ball dropped to the floor, and (f) ball stuck to the cup. Seven subjects watched the videos of the performances while reporting, via button press, whenever balls were removed from the cups/table (button “1”) or placed inside the cups/on the table (button “2”). Subjects’ perception was more accurate with transparent than with opaque cups. Perceptual performance was worse for the conditions where the ball was placed on the table, or stuck to the cup, than for the standard maneuver. The condition in which the ball was lifted displaced the subjects’ gaze position the most, whereas the condition in which there was no ball caused the smallest gaze displacement. Training improved the subjects’ perceptual performance. Occlusion of the magician’s face did not affect the subjects’ perception, suggesting that gaze misdirection does not play a strong role in the Cups and Balls illusion. Our results have implications for how to optimize the performance of this classic magic trick, and for the types of hand and object motion that maximize magic misdirection.