INSIGHTS

PERSPECTIVES

Corvid birds, like this Florida scrub jay (*Aphelocoma coerulescens*), exhibit behaviors reminiscent of techniques used in magical effects.

NEUROSCIENCE

An unexpected audience

Experiments with magic effects might be informative about cognition in animals

By **Elias Garcia-Pelegrin, Alexandra K. Schnell, Clive Wilkins, Nicola S. Clayton**

In the past decade, the study of magic effects has started to gain attention from the scientific community, particularly psychologists. This interest stems from what magic effects might reveal about the blind spots in our perception and roadblocks in our thinking. The study of magic effects may offer researchers opportunities for new lines of inquiry about perception and attention. Moreover, because magic effects capitalize on our ability to remember what happened and our ability to anticipate what will happen next, using magical frameworks elicits ways to investigate complex cognitive abilities such as mental time travel (i.e., remembering the past and anticipating the future). Moving beyond the intersection between magic and the human mind, the application of magic effects to investigate the animal mind can prompt the comparison of behavioral reactions among diverse species, in which magic effects might exploit similar perceptive blind spots and cognitive roadblocks.

The internet is filled with videos of magicians performing magic effects to animals (mostly captive primates and domesticated pets), in which the attentive animal spectators appear to react with awe and exultation when objects or food magically vanish. Without further investigation, it cannot be assumed that the animal audiences in the videos are amazed and surprised by the magic effect, akin to a human spectator. However, these encounters prompt investigation about the extent to which animals are susceptible to the same techniques of deception commonly used by magicians.

Over the past several decades, comparative psychologists, perhaps unintentionally, have been using magic effects as a methodological tool to explore a diverse range of cognitive abilities in animals. For instance, when investigating how dogs and great apes mentally represent different kinds of objects, experimenters have used devices inspired by props commonly used in magic effects, such as boxes with false bottoms (*1*). Researchers have also investigated causal cognition in New Caledonian crows using invisible string, a see-through thread frequently used for levitation effects, to determine how crows respond to objects moving "without" human interaction (*2*). Moreover, violation of expectation paradigms, in which a subject is presented with a series of expected and unexpected outcomes, has been extensively used in comparative cognition (the investigation of cognitive mechanisms in diverse species and their origins). Such a premise is directly comparable to magic effects, given that the result of both magic and violation of expectation paradigms aim to elicit the same reaction from the observer, namely being surprised by witnessing the unexpected. Although animal subjects do not typically verbalize their surprise at unexpected events, surprise can be measured by using looking time. For example, if the subject finds an event surprising, they spend significantly longer looking at the event compared with an event that is deemed ordinary.

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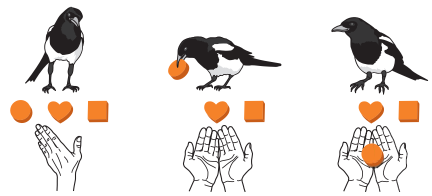
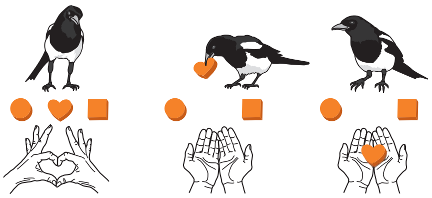
Hand gestures influence choice

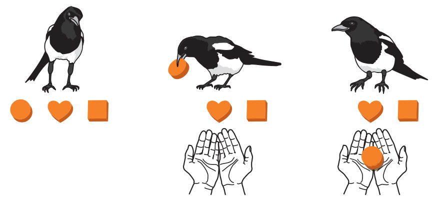
A priming experiment to observe whether a magpie's choice can be influenced by human hand gestures is shown. Magpies are first trained to discriminate between three differently shaped objects and exchange any shaped object for a food reward.



Condition 1: Random priming
A random priming hand gesture is followed by asking the subject for any object.



Condition 2: Priming
A heart-shaped hand gesture is made before asking for an object.



Control condition: No priming
The experimenter does not make any hand gesture before asking for an object.

GRAPHIC: A. KITTERMAN/SCIENCE

Although magical effects have permeated the field of comparative cognition, the scientific community has yet to study whether animals can be deceived by the same magic methodologies that would deceive a human observer. This is an interesting query because the use of magic effects to deceive animals could only be feasible if both human and animal spectators shared some analogous cognitive processes that capitalize on perceptive blind spots and cognitive roadblocks. Investigating the psychology behind magic effects in humans offers comparative psychologists an accessible pathway to formulate initial hypotheses to test in animal audiences. For example, the vanishing ball—an effect in which the magician seemingly vanishes a ball in thin air—could be used to investigate whether past experiences and current expectations alter the animal's perception. In humans, the illusion's success appears to be reliant on the spectator's expectation of the ball's movement and the social cues elicited by the magician (*3*). Using a similar design with animals could be insightful, regarding both the animal's expectations (i.e., throwing a ball toward the ceiling will make the ball go upward) and whether human body language offers an animal audience social cues when priming such illusions.

A popular magic technique is misdirection, the manipulation of the spectator by the magician to prevent the discovery of the cause of a magic effect. Controlling the audience's attention is an important skill for magicians, otherwise spectators might discover the mechanics behind the effect. Some species have been observed using behavioral tactics that can be considered analogous to misdirection. For example, chimpanzees sometimes divert their gaze from a desired object to detract a competitor's attention from it (*4*). Jays (i.e., corvids) will protect their food caches from possible pilferers by moving them several times or discretely hiding the food while performing several bluff caching events, thereby making it difficult for the observer to trace the genuine cache location (*5*).

The use of analogous methodologies by a diverse range of animal taxa to deceive conspecifics suggests that some misdirection techniques could exploit similar blind spots in attention. It also prompts the question of whether misdirection techniques used by magicians can also effectively fool animal minds. However, when doing so, experimenters must engage the attentional mechanisms of their spectators, because misdirection techniques are contingent on this. This might be challenging with animal subjects who might not pay sufficient attention to humans. Engaging the undivided attention of our closest relative, the chimpanzee, is one of the major challenges of implementing experimental designs on apes (*6*). Offering them long periods of intensive training, during which the ape must pay close attention to human movement, might ameliorate the challenge. By contrast, corvids possess sophisticated attentional mechanisms and are a suitable candidate for this line of research because they follow human gaze around particular objects and monitor human attentional states (*7*, *8*).

In addition to misdirection, magicians often rely on our cognitive abilities to create a magical illusion. One such ability is object permanence—the ability to represent objects in the mind's eye when the object is out of sight. This ability appears to be adaptive for diverse taxa. For example, object permanence is harnessed by corvids during caching to successfully cache and recover because individuals must understand and remember that hidden items continue to exist even when they are out of sight (*9*). The ability to form a mental representation of an object when it is out of sight and to maintain it in memory is also vital for conjuring magic effects, because most effects tend to involve the appearance and disappearance of objects. Thus, object permanence paradigms grant a suitable starting point for comparative psychologists to investigate the analogous mechanisms of both human and animal observers of magic.

Interesting insights into object permanence have been made when adopting magic as a framework of study. When using a fake transfer technique (i.e., where the magician pretends to place an object in one hand while keeping it in the initial hand instead), human observers appear to retain the erroneous belief that a coin is placed inside the hand only for a limited period of time. Elongated reveal times seem to decrease the strength of this belief significantly (*10*), suggesting that inducing a false belief of object permanence might be contingent on not allowing enough time for the spectator to replay the events in their mind. Given the current research on object permanence in diverse taxa, translating the fake transfer technique to a suitable animal and paradigm (e.g., corvid caching) might elucidate the degree of commonality with object permanence abilities in humans and highlight whether perception of object permanence and memory of the hidden location in animal minds can be manipulated in analogous ways.

Although the science of magic has mainly focused on the exploitation of simpler mechanisms such as attention and perception, magic effects also use techniques that affect complex cognitive abilities such as memory and mental time travel. For example, magicians often alter the spectator's recollection of an event and induce fake memories through suggestions. When researchers suggested to human subjects that a "magic" key, which had been previously bent, would continue to bend once the effect finished, the spectators were more likely to report that they had observed the bending process during and after the magic effect (*11*). Other effects such as the "one ahead principle" exploit the spectator's inability to effectively deconstruct memories to make them think that the magician can read their mind. This is done by the magician forcing the outcome of one of the predictions while altering the order of events that the spectator is experiencing. Given the reconstructive nature of human memory, the spectator will recall the sequences in the order they occurred, instead of dissecting it into the events that were key for the experience (*12*). Such effects could only be investigated with species that possess mental time travel abilities, given that, evidently, one cannot exploit the faults of a nonexistent mechanism. Current research suggests that corvids exhibit sophisticated mental time travel abilities (*13*, *14*) and therefore are ideal subjects for experiments with such magic effects.

The application of similar techniques adapted to an animal audience might reveal whether animals that possess complex memory abilities also encounter comparable constraints. The imperative use of language in this kind of research is a strong barrier if one is to transpose it to an animal audience. However, recent research on humans raises the possibility that simple choices can be influenced by using hand gestures (*15*), thus offering a more relevant way to test for analogous roadblocks in animal memories. Magical frameworks ought to be the subject of in-depth methodological inspection and theorization. A good starting point might be the use of hand gestures depicting simple primes to observe if humans can influence choice in corvids. For example, subjects could be trained to discriminate between three differently shaped objects and asked, by the experimenter, to retrieve any object in exchange for a reward. Experimental conditions could include whether making heart-shape gestures, when asking, primes the subject to retrieve the heart object instead of the circular or rectangular object (see the figure).

The psychology of magic offers the scientific community a powerful methodological tool for testing the perceptive blind spots and cognitive roadblocks in diverse taxa. Studying whether animals can be deceived by the same magic effects that deceive humans can offer a window into the cognitive parallels and variances in attention, perception, and mental time travel, especially those species thought to possess the necessary prerequisites to be deceived by magic effects. Magical frameworks offer alternative and innovative avenues for hypothesis testing and experimental design, and it is hoped that future researchers will incorporate them into their investigations of the animal mind. ■

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BIOMEDICINE

The gut microbiota in kidney disease

Dietary changes induce posttranslational modifications of microbial proteins to alter metabolite production

By **Jennifer L. Pluznick**

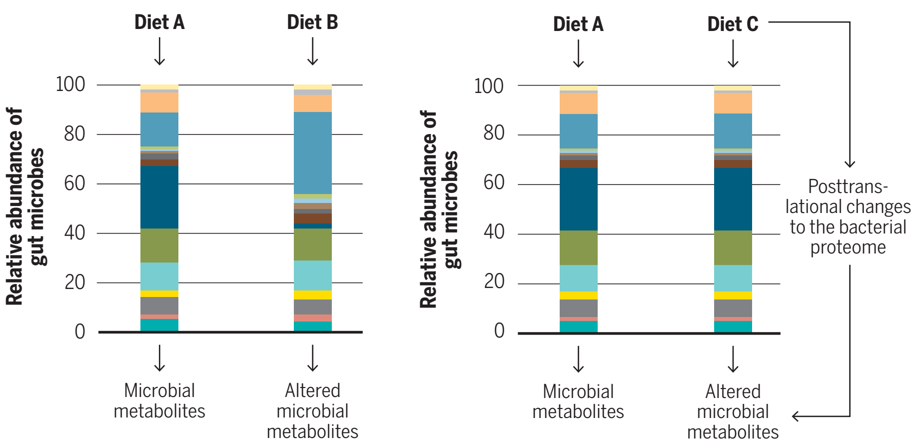
Chronic kidney disease affects 9% of the global population (*1*) and can have severe impacts on both the individual and societal levels. Although various conditions, such as diabetes, are well known risk factors for chronic kidney disease, in recent years interest has been growing regarding a potential role for the gut microbiota in modulating outcomes in kidney disease (*2*). Simultaneously, in the microbiology field, there has been a growing appreciation for the intersection of diet and the gut microbiota as a driver of changes in host health (*3*). To date, a common model has been that diet acts to alter the relative abundances (or diversity) of gut microbes, which can then lead to changes in gut microbial metabolite production (*4*). However, on page 1518 of this issue, Lobel *et al.* (*5*) report that diet can posttranslationally modify the gut microbial proteome, which can alter microbial metabolite production to drive changes in renal function.

The primary function of the kidney is to maintain homeostasis against the many insults and challenges from the external and internal environment. Functions including acid-base balance, water balance, blood pressure regulation, and glucose homeostasis require exquisite coordination and regulation by the kidney. Thus, it is not surprising that when kidney function falters, chronic kidney disease is associated with symptoms that are emblematic of the wide influence of renal function on health, including uremia (the retention of waste products in the blood that would normally be excreted in the urine), as well as edema, acidosis, anemia, and bone disease.

Risk factors for chronic kidney disease include conditions such as diabetes, hypertension, and heart disease. In addition to these comorbidities, the progression of kidney disease can be strongly influenced by dietary modulations—for example, the DASH (dietary approaches to stop hypertension) diet has shown to be protective (*6*). The positive influence of the DASH diet on kidney disease progression has been suggested to be due to a lowering of blood pressure, a lowered dietary acid load, and/or a lower likelihood of promoting inflammation and endothelial cell dys-

Dietary influences on gut microbiota

The diet can modulate the gut microbial taxa (represented by different colors), thereby influencing metabolite production (left side of the figure). By contrast, Lobel *et al.* find that diet does not modulate the bacterial taxa, but rather posttranslationally influences the bacterial proteome, which alters microbial metabolite production (right side of the figure).



GRAPHIC: X. LIU/*SCIENCE*