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Rats, reasoning, and rehabilitation: Neuroscientists uncovering how we reason

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Even rats can imagine: A new study finds that rats have the ability to link cause and effect such that they can expect, or imagine, something happening even if it isn't. The findings are important to understanding human reasoning, especially in older adults, as aging degrades the ability to maintain information about unobserved events.

"What sets humans apart from the rest of the animal kingdom is our prodigious ability to reason. But what about human reasoning is truly a human-unique feature and what aspects are shared with our nonhuman relatives?," asks Aaron Blaisdell of the University of California, Los Angeles. "This is the question that drives my passion for research on rational behavior in rats."

Blaisdell hopes that his work with rats will teach us more about what it means to be human. His recent studies are part of a growing body of work on reasoning - the ability to figure out how to move from one state of affairs to another, to achieve a particular outcome.

From reasoning in rats to differences in reasoning among people with autism and schizophrenia, researchers are discussing the latest science on reasoning in a symposium today at the Cognitive Neuroscience Society (CNS) conference in San Francisco.

"Although great strides are currently being made in the understanding of the biobehavioral, cognitive, and neurobiological bases of reasoning in healthy persons, far less is known about the typical and atypical human development of this ability and the biological underpinnings of this developmental process," says Kathy Mann Koepke of the National Institute of Child Health and Human Development (NICHD).

Mann Koepke is chairing today's symposium, which highlights the work of members of a special NICHD working group on reasoning. "Understanding these reasoning skills has emerged as a critical priority in the study of developmental cognition and learning," she says. "Coming at the topic from many different perspectives will likely add to the richness and depth of our understanding of reasoning."

Linking cause and effect in rats

Blaisdell's work draws from long-understood ideas from Pavlov and others that when a rat (or dog or pigeon) observes one event followed by another, such as a tone followed by food, it forms an association between the events. After the association is formed, whenever the rat hears the tone, it expects food to follow.

But his work goes further, showing that rats reason: "What I have shown in my research is that rats not only acquire these types of Pavlovian associations between two events, but that they can form a causal link between them as well," Blaisdell explains. The rat appears to believe that the tone causes the food.

Blaisdell and colleagues have tested the extent of these causal beliefs in a range of conditions, as presented today at the CNS meeting. For example, if a rat learns that a light is a common cause of both tone and food, then when the rat hears the tone, it makes the prediction that the light must have occurred. "And if the light had just occurred, the food, which is the other effect of the light, should also be available," he says.

Rats, the researchers have found, also can make rational inferences about their own actions. Take the example of the light as a common cause of both tone and food. If researchers allow the rat to press a lever to turn on the tone, then the rat no longer expects food; the rat understands that it was the cause of the tone and not the light, thereby changing the expectation of food. "This is similar to predicting bad weather to arrive when you observe a drop in air pressure in the reading on a barometer," Blaisdell explains. "You don't predict bad weather to arrive if you tamper with the barometer and artificially make its reading drop."

In his latest work, Blaisdell and colleagues have found that once rats observe two events together, it not only forms an association but also an expectation. For example, if two lights occur at the same time, a rat will expect one light to occur whenever the other one does. But even more remarkably, if researchers cover one of the lights so that the rat cannot see it and then the researchers present the other light, the rats take actions as though the hidden light might be on.

"They maintain an image or expectation that the light is present even though they can't see it," Blaisdell says. "They then use this imagined event to guide decision-making about actions that may or may not produce food, depending on the available evidence."

This type of reasoning is the basis of counterfactual reasoning - the ability to maintain information about, and make hypotheses based off, absent events. Thus, Blaisdell says, elements of counterfactual reasoning appear to have an origin deep in evolutionary time.

Counterfactual reasoning declines in old age, especially when a neurodegenerative disease is involved. Thus, understanding this process is key to informing clinical treatments.

Blaisdell and his colleagues have found a shared neurological mechanism between rats and people for counterfactual reasoning in the hippocampus - a brain structure very vulnerable to age-related decline, including in Alzheimer's disease. Researchers already know that the hippocampus is involved in counterfactual thinking in people. When Blaisdell's team temporarily inactivated part of the hippocampus in rats, they were no longer able to hold in their mind the image of the absent light.

"Rats, and many other nonhuman species, continue to provide a treasure trove of information about cognition and reasoning," Blaisdell says. "Looking at an animal is like looking into a mirror that reflects back a part of ourselves. I see as much of them in us as I see of us in them."

Creating new rehabilitation tools

There are clear differences between how animals reason and how humans do, says Daniel Krawczyk of the University of Texas, Dallas. "Reasoning is one of the major functions we carry out in daily life," he says. "People also have a lot of conscious insight about their reasoning, while having some critical gaps in insight, which makes it a fascinating topic in life and in science."

Krawczyk's work looks at differences in reasoning between healthy populations and those with clinical disorders, such as autism or schizophrenia, with an aim toward developing rehabilitation tools. "These are conditions in which much of the information processing done by the individual is different from most people," he explains.

He and colleagues use tasks in the lab to test relational reasoning ability, a skill associated with how we reason by analogy. Often, these studies include EEG recordings or an MRI scanner, which are increasingly helping researchers better categorize types of reasoning and the sub-processes that are important for the skill.

In a recently published study in Frontiers in Human Neuroscience, Krawczyk used cartoon scenes to test how individuals diagnosed with schizophrenia and autism-spectrum disorders process analogy compared to healthy controls. The participants had to compare two different scenes and match a situation in one scene to another; some scenes involved living items while others non-living items, and cartoons varied in the number of distracting items they contained.

For all three groups, more complex scene analogies with more distractions posed greater difficulty. Participants with schizophrenia made more errors in the scene analogy than did the healthy control group. They tended to make local comparisons of just one or two objects and thus failed to notice broader relational context within problems.

Individuals with autism, however, "drew appropriate analogies between cartoon scenes the same way that healthy control individuals do," Krawczyk says. Surprisingly, those with autism tended to have more difficulties on problems that involved non-living objects - running contrary to the researchers' hypothesis that living items would cause greater challenge. Nonetheless, he says: "We have found that young adults with mild autism-spectrum disorder are excellent at relational reasoning when it relies on relational and visuo-spatial information.

Krawczyk hopes that his work and others on reasoning will not only provide a better basic understanding of the processes involved but also help guide development of rehabilitation tools, particularly for conditions such as strokes, brain injuries, and schizophrenia. "The future looks promising for the use of new methods in both brain-based measurement and for more sensitive measurements for behavior," he says.

These new methods include game-based virtual reality tools. "This is already happening in the realm of rehabilitation for conditions such as traumatic brain injury," he says. "Using game-based tools enables you to better capture the actual daily life functional complaints of the individual," Krawczyk says. "That is where a lot of the emphasis needs to go in the future."

Mann Koepke of NICHD also emphasizes the need for better tools for studying reasoning across different age groups and species, as well as more real-world studies. "As large amounts of data become available to people via the Internet, for example, people are increasingly challenged to prioritize and incorporate large amounts of data into their everyday reasoning - such as "which medical treatment is best for me?" - so the need for research on reasoning 'in the wild' is becoming increasingly urgent."

More information: Blaisdell and Krawczyk are presenting their work, along with Silvia Bunge and Ben Rottman, in the symposium "Reasoning: Origins and Development," Sunday, March 29, 2015, at the CNS annual meeting in San Francisco.

Provided by Cognitive Neuroscience Society