SN EDUCATOR GUIDE

December 10, 2016

Animal Math

Cross-Curricular Discussion

After students have had a chance to review the article "Animal math," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your discussion into a different document for your students.

BIOLOGICAL SCIENCES

Discussion Question:

1a. Ask students why abilities with quantities could be beneficial to a species? What might be the potential benefits of recognizing discrete numbers versus continuous qualities for animals? [*Recognizing continuous qualities could help animals identify which set of objects provides more food. They may not need to spend the time figuring out the discrete quantity of food pellets, for example. But recognizing discrete quantities may allow animals to know how many offspring they have so they can properly care for those offspring.*]

Do scientists agree that many animals have some kind of number sense?

Would having a numerical system be beneficial?

What are the benefits of recognizing discrete quantities?

What are the benefits of recognizing continuous qualities?

Extension Prompt:

2b. Scientists look for certain behaviors that may be useful in designing animal numerosity studies. The article mentions imprinting and hoarding. Ask students to define these terms and have them brainstorm examples. [*In art, "imprinting" is the act of making a mark on a surface, but in science "imprinting" is used to describe learning an attraction at a young age, such as to a parent. "Hoarding" refers to the storage of food beyond what an animal is going to eat immediately. When the food is hidden, it is sometimes called "caching."*] Ask why these behaviors might have an evolutionary benefit. [*Imprinting helps offspring stay near a parent, for protection and so they don't get lost. Hoarding helps save seasonal food for when food is less plentiful, for example.*] Can students think of situations in which these behaviors might be detrimental? [*Once a behavior is learned, it may be difficult to change it, even when circumstances or information changes.*]

What is "imprinting"? Can you name an example from the article?

What is "hoarding"? Can you name an example from the article?

What are some pros and cons of imprinting?

What are some pros and cons of hoarding?

PHYSICAL SCIENCES

Discussion Question:

2a. Have students examine the graph on Page 26 of "Animal math," also available as Blackline Master 3. Ask them to explain the experimental variables described by the graph. What is each axis measuring? [*The x-axis displays the number of dots or musical tones presented to the monkeys (1–4). The y-axis measures the normalized mean activity of four specific monkey nerve cells, represented as a percentage.*] Given the labeling of the y-axis, ask students what they think the term "normalized" means. [*To normalize data generally means to apply a mathematical function to it in order to have the data points fit within a specific range. In this study, it appears that neural activity of specific cells is normalized to a percentage from 0 to 100. However, there is no other information about the normalization process here.*] Students should try to analyze the graphical data displayed. Are there overall trends that they notice? Remind students to justify their stated trends with specific data. [*Generally, it appears that specific neurons in a monkey's brain respond to a specific numerical quantity — whether that quantity is presented as dots or sounds. For example, Cell 1 is the most responsive to the quantity one in terms of normalized mean activity. Specifically Cell 1 has approximately 100% normalized mean activity when one dot is observed and approximately 95% normalized mean activity when one sound is heard. The next highest mean response is Cell 2, which has approximately 30% normalized mean activity to one sound.*] Ask students about the implications of such a study. [*If scientists can understand how the brain recognizes information, they may be able to gain clues to high-level brain functions.*]

What variables are measured by the graph? Define the axes specifically.

What does "normalized" as in "normalized mean activity" mean?

Are there overall trends communicated by the graph?

Why is this type of study important for understanding animal behavior, including human behavior?

Extension Prompt:

2b. Depending on the level of your class, you may preface this discussion with this brief NBC Learn video describing how neurons work. Scientists suggest that measuring neural responses to stimuli could be useful in tracing the evolution of animals' quantitative abilities. Ask students what they know about how information is transferred between nerve cells. They might want to draw a flow chart outlining the process of electrical and chemical activity. [*An electrical impulse specific to one neuron triggers a chemical release into the gap between neurons, called the synapse. The chemicals released, also called neurotransmitters, are received by a neighboring neuron which triggers a new electrical impulse on the second neuron. The process can continue to repeat.*] Relating back to the research mentioned in the article, how might scientists be able to measure the specific response of a neuron? [*Since neurons have electrical impulses, the cell voltage or cell potential may be measured with a type of voltmeter because it will change with a neural response.*]

How is information passed from one nerve cell to another?

What is the name of the location where nerve cells share information?

What part of the process is electrical and what part is chemical?

How might scientists be able to measure when a neural response occurs?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Question:

3a. The article refers to a number of experiments, each done to gain evidence about whether nonhuman animals have their own quantitative abilities. Students can explore whether there is enough evidence to reach a conclusion. Students may help to develop specific concepts from the article to research further, based on their interests (suggested prompts are included below). Once the prompts are established, have students work in groups to prepare a presentation of evidence supporting and opposing a statement. Give them enough time to review the article and perform additional research.

Do scientists have enough evidence to conclude that…

The genes behind specific animal behaviors can be inherited.

Nonhuman animals' brains are hardwired for specific mathematical abilities.

What scientists learn about how an animal's brain processes quantity can help them understand how a human brain processes quantity?

Extension Prompt:

3b. Before scientists collect data from an experiment, they have to decide how many animals will be involved in their study. In this instance, the animals are a sample of a larger population. What is the difference between a sample size and the number of trials in an experiment? [*The sample size is the number of units from a population suggested for testing. A number of trials is how many times the experiment is run.*] How many samples are needed to test a hypothesis? [*You need at least a test sample and a control sample.*] What are the consequences of not having a large enough sample size? [*If your sample size doesn't represent the population, you will not get meaningful results.*] What are potential consequences of having too big a sample size? [*Trivial differences might appear to be statistically significant even though they aren't meaningful for any practical purposes. Also, a larger sample size requires more testing time and resources.*] Students can become familiar with how to use a sample size calculator, such as this one, and discuss levels of confidence. How does a scientist decide which units of a population to include in a study or experiment? [*Sometimes a simple random sample is OK, but sometimes samples need to be adjusted or stratified.*]

Define how a sample is different from a trial in an experiment.

What are the potential consequences of too small a sample size? What about too big a sample size?

What information is needed to determine a sample size needed for an experiment?

How does a scientist decide which units of a population to include in a study or experiment?

SN IN HIGH SCHOOLS
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Directions: Use this graph from "Animal math" to answer the related discussion questions assigned by your teacher.