Nervous System: Reaction Time

SC Academic Standards:

NGSS DCI:

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.4; S.1A.5; S.1A.7

Crosscutting Concepts: Patterns; Cause and Effect: Mechanism and Explanation; Systems and Systems Models; Energy and Matter: Flows, Cycles, and Conservation; and Stability and Change.

Focus Question(s): How does a reflex reaction work? What is my reaction time? How does distraction affect my reaction time?

Conceptual Understanding: Plants and animals have physical characteristics that allow them to receive information from the environment. Structural adaptations within groups of plants and animals allow them to better survive and reproduce.

Life is the quality that differentiates living things (organisms) from nonliving objects or those that were once living. All organisms are made up of cells, need food and water, a way to dispose of waste, and an environment in which they can live. Because of the diversity of life on Earth, scientists have developed a way to organize groups of organisms according to their characteristic traits, making it easier to identify and study them.

The Animal Kingdom includes a diversity of organisms that have many characteristics in common. Classification of animals is based on structures that function in growth, reproduction, and survival. Animals have both structural and behavioral adaptations that increase the chances of reproduction and survival in changing environments.

Multicellular organisms (including humans) are complex systems with specialized cells that perform specific functions. Organs and organ systems are composed of cells that function to serve the needs of cells which in turn serve the needs of the organism.

Background: The nervous system is divided into the central nervous system (the brain and spinal cord) and the peripheral nervous system (the cranial and spinal nerves and their branches). The peripheral nervous system (PNS) is then

subdivided into motor and sensory neurons. Sensory neurons bring information to the central nervous system (the CNS), where it is processed, and motor neurons deliver a motor command issued by the CNS to a muscle or gland where a response will take place. The responding muscles and glands are called effectors because they produce and effect in response to the motor command. Sometimes, the sensory information is processed in the spinal cord alone, but usually the spinal cord sends the signal to the brain, and the brain is the component of the CNS that responds.

Nerve impulses travel through the nervous system via a nerve pathway, which is a connection between neurons that transmit information between the CNS and PNS. A synapse is the space between two adjacent communicating neurons, or between a motor neuron and its effector (the muscle or gland). Some of the simplest nerve pathways consist of only two communicating neurons and a single synapse. More complex pathways involve bundles of neurons, called nerves, that sense and respond to stimuli.

Reflexes are rapid responses to stimuli and can be categorized as either voluntary (somatic) or involuntary (autonomic). One example of an involuntary reflex is the "knee-jerk" response when a doctor taps your knee (really, your patellar tendon). Involuntary responses are very fast, with the nerve signal travelling in milliseconds down the nerve pathway. Extremely rapid responses occur in a reflex arc, which consist of a single sensory neuron, an interneuron, and a motor neuron. Reflex arcs have five components:

1) a sensory neuron - this conducts the nerve impulse along the afferent pathway towards the CNS once it receives a stimulus.
2) a receptor at the end of the sensory neuron – this receives the stimulus.
3) an integration center, consisting of one or more interneurons and their synapses, located in the CNS.
4) a motor neuron, which conducts a nerve impulse along the efferent pathway from the integration center towards the effector.
5) an effector – the gland or muscle that responds to the nerve impulse. Responses include contraction (if it is a muscle) or secretion (if the effector is a gland).

So for example, say you step on a piece of sharp glass when you are walking barefoot. The sensory nerves in the bottom of your foot detect tissue damage and send a signal along the sensory nerve pathway to the brain / spinal cord. These interneurons "decide" how to respond – then send a signal down the motor neurons that lead to your leg and foot. This signal ends at your leg and foot muscles, and causes the release of the neurotransmitter acetylcholine, which causes a muscle contraction, which in turn causes your leg/ foot to lift up off the sharp object. This is an involuntary reflex – you don't need to think about it, it is automatic – you step on something sharp and you quickly, without thought, move!

The important parts: 1) nerve impulses are electric signals – a charge over the cell membrane of a neuron is set up by a sodium – potassium pump (a protein

embedded in the cell membrane which uses active transport to move sodium and potassium in opposite directions). This charge makes a neuron more negative (-70mV) on the inside compared to the outside. When a stimulus is detected (and the stimulus may be pain, pressure, temperature, light (eyes!), change in orientation (ears!), etc., then the sodium potassium pump is deactivated and the sodium and potassium diffuses back across the neuron's membrane, quickly enough that the gradient is releases and actually reverses making the inside of the nerve cell now positive (+30mV). This charge reversal is called an action potential, and the action potential races down the neuron (depolarization) from the dendrites to the end of the axon, much like dominoes in a live falling over. The action potential is set back up almost as soon as it is reversed (re-polarization). At the end of the axon, the action potential is stuck because it can't cross the synapse – but a neurotransmitter can! 2) between each nerve is a synapse, and the electrical nerve impulse can't cross that. Neurotransmitters (and you have many different types, there are over 60 chemicals (including dopamine and acetylcholine and serotonin), each type leading to a specific response) are released at the end of one nerve, they diffuse across the synapse, and start the nerve impulse in the next nerve (or trigger the effector to contract or secrete). This makes your nervous signal both an electric signal and a chemical signal.

In this lab we will investigate reaction time by looking at a voluntary reflex: catching a falling object. How fast can you catch a meter stick as it falls? When you are distracted, does that change your reaction time?
Materials: meter stick, stopwatch. For the extension, you need access to a computer / internet.

Procedure:

1. Have your lab partner sit in a chair, with their forearm placed on the desk. Make sure the arm extends over the desk, and have the hand slightly open so that the thumb and fingers are ready to make a pinching motion (about 4 cm apart).
2. The second partner should hold a meter stick above the open, ready to pinch, hand so that the "zero" cm mark is just even with the top of the thumb.
3. The second partner releases the meter stick (without warning) so that it falls between the thumb / fingers of first partner.
4. The first partner pinches thumb to fingers to try to catch the falling stick as soon as it is released (NOTE – the meter stick often bounces back up from a tile floor, so the second partner shouldn't stand too close, it could bounce up into your face).
5. Record the distance (in cm) that the meter stick traveled before it was caught (you started at 0 cm, did you catch it at the 24 cm mark? Or the 45 cm mark?)
6. Convert the distance to Reaction Time, using the following formula where t = reaction time, in seconds, and y = distance (in cm): $\boldsymbol{t} = \sqrt{\frac{\boldsymbol{2y}}{\boldsymbol{980}}}$

7. Do this at least 5 times to serve as a control.
8. Repeat this experiment but this time, while partner two is holding the meter stick waiting to drop it without warning, partner two should be asking partner one a series of distracting questions – at some point during the questioning, drop the meter stick.

Distance of Catch (cm)	**Reaction Time (sec) (Control)**	**Reaction Time (sec) (Distracted)**
AVERAGE reaction time =	**cm/sec**	**cm/sec**

Table 1. Reaction time for catching a meter stick while distracted (versus control)

<u>Data Analysis</u>: Convert the distance to reaction time using this equation, where t = reaction time, in seconds, and y = distance (in cm):

$$t = \sqrt{\frac{2y}{980}}$$

<u>Extensions</u>: Do a computer simulation for reaction time by checking out this website: http://www.happyhub.com/network/reflex/

<u>Reflection Questions:</u>

- **Was reaction time better or worse (or the same) when distracted?** (should be worse).
- **Did the student respond the same every time, or did they get better or worse with subsequent trials?** (depends on student, many "learn")

- **Can you think of a voluntary reaction that improves with experience?** (driving, catching a baseball, golf)
- **What effect would you expect a distraction (such as talking / texting on a cell phone) have on a person's voluntary reflexes?** (it will slow your reaction time)
- **When might "compromised" voluntary reflexes present a danger? (**when you are driving! Don't text and drive!)

Models and Explanations: In this lab we explored vegetative propagation of potato plants. **A student who demonstrates understanding** of these concepts can

Bibliography:

Barbeau, T., Camper, J., King, P., Knowles, T., Pike, L., Pryor, G., D., Eaton, E., and Turner, L. (2010). *Biology 104 Laboratory: Human Biology.* Francis Marion University custom publishing, Florence SC, USA.

Campbell Biology (9th edition). (2010). Benjamin Cummings Publishing.

Student Worksheet:

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How does it all work? Say you step on a piece of sharp glass when you are walking barefoot. The sensory nerves in the bottom of your foot detect tissue damage and send a signal along the sensory nerve pathway to the brain / spinal cord. These interneurons "decide" how to respond – then send a signal down the motor neurons that lead to your leg and foot. This signal ends at your leg and foot muscles, and causes the release of the neurotransmitter acetylcholine, which causes a muscle contraction, which in turn causes your leg/ foot to lift up off the sharp object. This is an involuntary reflex – you don't need to think about it, it is automatic – you step on something sharp and you quickly, without thought, move!

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<u>Reflection:</u>

- **Was reaction time better or worse (or the same) when distracted?**
- **Did the student respond the same every time, or did they get better or worse with subsequent trials?**
- **Can you think of a voluntary reaction that improves with experience?**
- **What effect would you expect a distraction (such as talking / texting on a cell phone) have on a person's voluntary reflexes?**
- **When might "compromised" voluntary reflexes present a danger?**

<u>Distraction Questions – ask in any order. Drop meter stick without warning while questioning.</u>

1. When is your birthday
2. What is your mother's maiden name?
3. What did you have for dinner last night?
4. When did you wake up this morning?
5. How do you spell "HIPPOPOTAMUS"?
6. How many characters can you name from "Walking Dead"?
7. What is your favorite singer?
8. What pattern of fabric is on the couch in your living room?
9. What other language do you speak?
10. Name the colors of the rainbow, starting with red
11. How many red stripes are on the American Flag?
12. What colors are there on Italy's flag?
13. Recite the alphabet backwards
14. What is 5 times 8, divided by 2?
15. What classes are you taking this semester?
16. What is your favorite class?
17. Which season is your favorite?
18. Name a song by Taylor Swift
19. What are Justin Bieber fans called?
20. Name a song by Michael Jackson
21. What is the last Charlie brown TV special you watched?
22. What is the last vegetable you ate?
23. Name one of "Charlie's Angels"
24. Define "Ecology"
25. Name three species of reptile.