Circle of Nerves

Timing Is Everything

A batter has little time to react to a pitcher's throw. In this activity we compare the limits of human reaction time to the time it takes for a ball to go from the mound to the plate and how it relates to our nervous system.



Some Background

A major league fastball can travel to the plate at a speed of 90 mph, or 132 feet/sec. The distance between the pitcher's rubber in the center of mound and the batter is just over 60 feet (60ft 6in). This means that the ball travels from the pitcher's hand to the bat in

Time = distance/velocity = 60 ft ÷ 132 ft/sec = **0.45 sec**

The ball travels about a dozen feet before the batter has a good visual fix on it. The batter now decides what kind of pitch it is, how fast it is going, and where it's going. Now the batter has about 0.3 seconds to swing. Is it possible to react this fast? Is human reaction time quick enough? Let's find out.

Procedure (for each group of 8-10 students)

1. Form a large circle. One person will be the "timer"
2. Decide which student will be the "starter"
3. Hold hands in the circle and close your eyes. (OR place a hand on the other person's shoulder)
4. The starter will start the activity by squeezing the left hand/shoulder of the person to his or her right. As soon as that person to the right feels the squeeze, he or she squeezes the left hand/shoulder of the next person in the circle, and so on around the circle until the "impulse" returns to the starter.
5. To time the process, the timer will tap a random student on the shoulder as s/he starts the time.
6. Once the impulse reaches the starter, the starter says, "stop" and the timer stops timing. Record the time. **Do 1-2 practice runs** and then 5 trials. The timer should randomly choose a new starter for each trial.
7. Write down the data and share it with the rest of the group. Each person is required to fill out the data table in their notebook.

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Data Table:

Trial	1	2	3	4	5	Average
Time (seconds)						

Read "What's going on?". After reading, answer the questions below in complete sentences. The article will help you answer some of the questions. I will know if you don't read it based on your answers!

1. Estimate how long it takes for the electrical signal to go from the visual cortex to the hands. Do this by dividing the average by the number of students in the circle. Show your work!

2. The average response time per person that you calculated is probably longer than the amount of time it actually takes. What are the possible sources of error in the way you arrived at this average response time?

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3. Why did we do a couple of practice run before collecting data?

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   What part(s) of the nervous system is/are involved in this lab? Explain.

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4. When you sent the hand squeeze from the person on your left to the person on your right, was your nervous system using a reflex response? Explain. How does it become "reflex-like"? Be sure to name the *specific* part of the brain responsible for building "muscle memory".

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What's Going On? (from www.exploratorium.edu/baseball)

Task: Read the following information to help understand how neurons play a part of the nervous system. Use the information to help you answer post lab questions of *Circle of Nerves*.

The nervous system has three major subunits: the central nervous system (CNS), the peripheral nervous system (PNS), and the autonomic nervous system (ANS). The central nervous system consists of the brain and spinal cord. The peripheral nervous system includes 12 pairs of cranial nerves that branch directly from the brain, 31 pairs of spinal nerves that branch from the spinal cord, and all the nerves that branch from these and form links between the CNS and all parts of the body. The ANS is largely separate from the other two systems and controls and coordinates the "automatic" basic life processes of the body, such as breathing, heartbeat, and digestion.

When a sensory nerve of the PNS receives a stimulus-such as a hand squeeze-a nerve impulse is relayed to the spinal cord and then to the brain. The brain interprets the stimulus and may send a message back to the PNS in response. For example, it may send an impulse through the spinal cord to motor nerves on the other hand, telling the muscles in that hand to squeeze. Nerve impulse makes the round trip from the PNS to the CNS and back at lightning speed, but there is always a measurable delay between stimulus and response. This delay is called response time.

The nervous system communicates through a network of nerve cells (also called neurons). When one nerve cell signals another, it does so by releasing a chemical substance that crosses a tiny gap between the cells, called the "synapse." It takes about half a thousandth of a second for the chemical transmitter to flow across the gap, a period called "synaptic delay."

The longest delays probably involve the nerve cells that make the decision to swing. These decision-making cells receive their input from the eye by way of the brain's visual cortex. It takes at least 0.04 seconds for information about the velocity and trajectory of the baseball to be sent from the retina to the higher visual cortex. What happens during the actual "decision" is a neurological mystery - -but once the decision is made, a signal is sent to the cerebellum initiating a series of pre-programmed, reflex-like actions (for a practiced batter).

Moving a single group of muscles may require the interaction of numerous nerve cells and involve multiple synaptic delays, as the body receives sensory information (sees the ball), processes it (makes a decision), and coordinates muscle action (swings the bat). Practice eliminates wasted time by speeding up the decision-making -- somehow the obvious mistakes and fruitless actions a novice spends time thinking about are simply ignored by the practiced player, and his brain saves the time needed to consider them. *But basic reaction time due to nerve conduction and synaptic delay remains an irreducible constant of the game – like it was when you did "Circle of Nerves." No matter how much you practiced, there was a time your group could not beat.*

Obviously, the remarkable skill of batting is learned through long practice. Eye-brain-body coordination is acquired only by going through the motions over and over; even so, the batter fails most of the time. Getting a hit three times out of ten at bat is considered an excellent average.

Expected Results After the Exploration

The response time per person is likely to be a bit shorter than 1 second, and it may be as fast as a third of a second. Generally, the response time will improve slightly with each subsequent trial of the activity. The most dramatic improvements occur between the first two or three trials, which is why it is important to have one or two practice runs before gathering data.

What's going on?

The following sequence of events occurs in the nervous system of each person in the circle:

a. Pressure receptors in the left hand are triggered.
b. Nerve impulses generated by the pressure receptors travel along a sensory (afferent) nerve to the spinal cord.
c. The nerve impulses are conducted along tracts (bundles of nerve fibers) in the spinal cord up through the medulla, pons, and midbrain to the somatosensory cortex of the brain.
d. The brain interprets the sensation as a “squeeze.”
e. The primary motor cortex of the brain sends the instruction to use the right hand to squeeze the hand of the next person.
f. A nerve impulse travels from the primary motor cortex through the midbrain, pons, and medulla to the cortico-spinal cord.
g. The impulse travels from the spinal cord to the hand along the motor (efferent) neuron.
h. The impulse reaches effectors (muscles in the hand and arm).
i. The muscles are instructed to squeeze the hand of the next person.

It is difficult to calculate exactly how long the process takes because the speed with which nerve impulses travel varies from nerve to nerve. The larger the diameter of the nerve fiber, the more quickly an impulse travels. Impulses along nerves with myelin sheaths (those in the peripheral nervous system) travel much more quickly than unmyelinated nerves. Some large, myelinated nerves conduct nerve impulses at 200 meters per second, compared to only a few millimeters per second in small, unmyelinated nerve fibers. Another important variable is the response time of the brain itself because it must use conscious thought to interpret the squeeze and make the decision to squeeze the other hand.