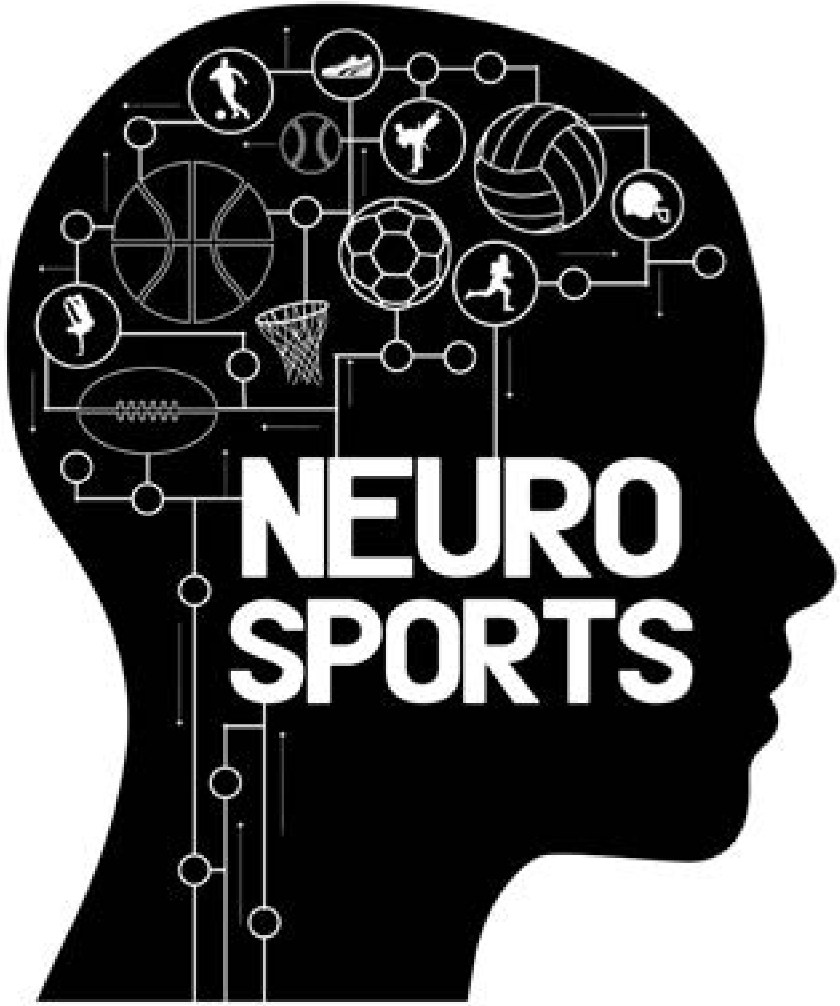


NORTHWESTERN UNIVERSITY

Authors

Rebecca Daugherty, Ph.D.
Suzanne Olds, Ph.D.
Janelle Myers
Amy Sebeson
Julianne Hatfield
Stephanie Rangel
Emma Flores
Allison Bradley
Alex Peroff
Jennifer Kay
Diana Monsivais
Antonia Navarro
Saurabh Malpani
Michael Kennedy, Ph.D.

Learn more about the science club initiative at scienceclub.northwestern.edu

About Science Club

Science Club is an afterschool science program developed and managed by Northwestern University and the Robert R. McCormick Boys & Girls Club in Chicago, Illinois.

It utilizes a mentor-based approach to provide fun, inquiry-based activities for middle school youth. On a weekly basis, throughout the academic year, Northwestern science graduate students and staff travel to the McCormick Club to serve as youth mentors, guiding them through the initiative's curriculum. Field trips and social activities also promote mentor-youth relationship development.

At the conclusion of each quarter, Science Club members have the opportunity to share the results of their inquiry with fellow students, Boys & Girls Club members, and parents.

NORTHWESTERN UNIVERSITY

BOYS & GIRLS CLUBS OF CHICAGO

Disclaimer

The information contained in this activity is intended as an instructional resource for informal science educators. It should in no way be construed as medical advice, opinion, diagnosis, or treatment. All activities in this guide should be closely supervised by knowledgeable adults, and recommended safety practices followed. Northwestern University and the National Institutes of Health cannot be held responsible for any injury or accident that may result from the activities in this guide.

Acknowledgements

Science Club is supported by a Science Education Partnership Award (SEPA) from the National Center for Research Resources (NCRR), a component of the National Institutes of Health (NIH). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NCRR or NIH.

The authors would also like to acknowledge the contributions of Mitchell Day (McCormick Boys & Girls Club), Jennifer Lewin (Chicago Public Schools), and Patrick Rodrigues (Chicago Public Schools).

Science in Society

Northwestern University
Technological Institute, Suite L550
2145 Sheridan Road
Evanston, IL 60208
sis.northwestern.edu

Center for Genetic Medicine

Northwestern University
Robert H. Lurie Medical Research Center, 7-125
303 East Superior Street
Chicago, IL 60611
cgm.northwestern.edu

McCormick Boys & Girls Club

4835 North Sheridan Road
Chicago, IL 60640
bgcc.org

January 2013

Overview

About *NeuroSports*

NeuroSports is a project-based informal science education unit that introduces key concepts of nervous system structure and function while emphasizing student-designed experiments.

At the end of the unit, students will be familiar with neuron and brain structure. They will be able to explain how the nervous system communicates with the brain and will give examples of how the brain uses information from multiple sources. Each lesson incorporates a NeuroSports athlete with a particular sports-related weakness, and the students will design and perform an original experiment to help improve the athlete's performance. In addition to practicing developing scientific questions and experiments, the students will summarize their findings in journal posts.

The curriculum was designed for a mentor-led small group setting (3–4 youth per mentor). Mentors should feel free to adapt the activities and challenges according to the abilities and interests of the group. The activities have been used successfully for youth in grades 5–8.

Pedagogy

The curriculum follows the Legacy Cycle framework derived from *How People Learn* (Bransford, Brown, and Cocking, 1999). The Legacy Cycle helps ensure that the unit incorporates the four "centerednesses" of the *How People Learn* theory:

- Knowledge-centeredness: Appropriate information is presented in a sequenced and organized way.
- Student-centeredness: The lesson seeks out students' prior conceptions and helps students connect with prior knowledge.
- Assessment-centeredness: The learning experience provides students with opportunities to check their own understanding and provides mentors the opportunity to assess effectiveness of their teaching.
- Community-centeredness: Students are provided with opportunities to learn collaboratively.

All lessons in *NeuroSports* allow students the opportunity to compile and discuss their current knowledge with warm-up questions and provide formative assessment through a concluding discussion.

My Science Journal

Name: ______________________

Date: ______________________

Group #: ______________________

Draw or tape a picture of your experiment here.

My Scientific Question: ______________________

____

____

What I did: ______________________

____

____

____

____

What I learned: ______________________

____

____

____

____

My Science Journal
A guide for instructors

Name:
Date:
Group #:

Draw or tape a picture of your experiment here.

If cameras and printing are available, students can use photos to illustrate their journal post. If not, they can draw a diagram or sketch of the experiment.

My Scientific Question:

- ☐ *Is the question experimental or testable?*
- ☐ *Does it include the variables being tested?*

Possible formats: "What is the effect of X on Y?" "How does X change Y?"

What I did:

- ☐ *Does the journal post provide a brief description of the methods? Measurement techniques?*
- ☐ *Does the post includes information about control groups and variables?*

What I learned:

- ☐ *Does the post include quantitative data?*
- ☐ *Does the post include comparisons between experimental groups?*
- ☐ *Does the post use data to make a conclusion?*
- ☐ *Does the post describe possible sources of error?*

Tips for an AWESOME Journal Post

SCIENCE CLUB

My scientific question:

Good questions are scientifically testable. This means you can **design an experiment to figure out the answer**. Good, testable questions often start with **"What is the effect of...?"** or "**Does [X] affect [Y]...?**"If the answer to your question is a fact, or something you can easily find out on the internet, these are NOT good questions

AWESOME!

What is the effect of the amount of citric acid on the flavor of soda?

Needs some work...

Why does soda taste so good?

IDEA: Can you change any INGREDIENTS in pop and see if it's still tasty?

What I did:

List **ALL** the important steps. Always use **numbers** to describe amounts and measurements. Good scientists **change only one variable at a time**. Good scientists also **repeat their experiments more than once**. This adds confidence to the results.

AWESOME!

We used 3 cups of pineapple juice and 3 cups of water and experimented with different amounts of citric acid and sugar. In one trial we used 3/4 cup sugar and 1 tsp citric acid. In another trial we kept the sugar the same but added less citric acid (1/4 tsp). We made a 1-10 scale to rate the pop. 10 was perfect. We had 3 raters.

Needs some work...

We used some juice and water to make our soda. One time we changed the amount of juice we added, and we also added some sugar. Another time we we added more acid and juice, but didn't add any sugar.

IDEA: Use numbers, change only one variable at a time, share how you rated taste, repeat your experiment

What I found:

Summarize your results, using **numbers**. Compare your experimental data to your control data. If you repeated your experiments, calculate an **average**.

AWESOME!

With 1 tsp of citric acid, the soda was much too tart, scoring an average of 3/10. But with only 1/4 tsp of citric acid, the soda scored an average of 8.5/10. It tasted much better.

Needs some work...

All of our sodas were very tasty.

IDEA: What did you use as your comparison pop? Did some taste better than others?

Experimental Design

Name: ____________________
Date: ____________________
Group #: ____________________

If you run out of room, answer the question on a separate sheet of paper and attach it.

My experimental question: ____________________

My hypothesis: ____________________

What I will measure: ____________________

How I will measure it: ____________________

Variable	Changes	Constant	How?
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	

What I am going to do: ____________________

Experimental Design

My Data:

Data Analysis:

My results: ____

____

____

My conclusion: ____

____

____

My hypothesis was right wrong (circle one)

Why? ____

____

Table of Contents

LESSON 1: **10**
Reaction Time
The Grand Challenge for this module will be introduced- to help struggling athletes improve their sports performance. Concepts related to the major parts of the nervous system and reaction time will be discussed. *(90 minutes)*

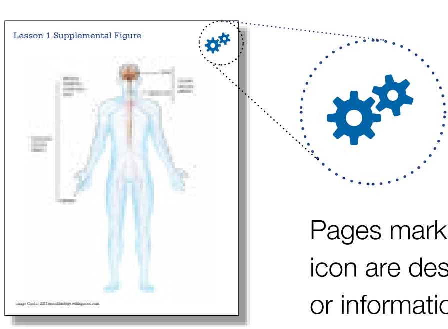
LESSON 2: **14**
Sidedness
The brain has a structure and specific functions are assigned to different regions of the brain. Groups will learn about sidedness and perform experiments related to foot dominance. *(90 minutes)*

LESSON 3: **19**
Vision
The eyes collect information from the environment and send a signal to the brain. Groups will learn about depth perception and perform an experiment to determine if both eyes are required for shooting accuracy. *(90 minutes)*

LESSON 4: **22**
Balance
The brain processes information from multiple sources simultaneously. In this module, groups will explore and test our sense of balance, which requires vision, proprioception, and the vestibular system. *(90 minutes)*

LESSON 5: **25**
Learning and Memory
Neurons communicate with each other using chemicals and learning changes the way that neurons communicate. Groups will conduct experiments on learning styles and memorizing a series of moves. *(90 minutes)*

LESSON 6/7: **30**
The Final Challenge
Groups will design a technique to help one of the struggling NeuroSports athletes and test their technique using an experiment. *(two 90-minute sessions)*



Pages marked in the upper right hand corner with a gear icon are designed to be shared with youth as worksheets or informational guides

Lesson 1: Reaction Time

Lesson Objectives

- Introduce the Grand Challenge
- Identify the key parts of the nervous system
- Answer the question: Is reaction time faster for an auditory or visual cue?

What You Need to Know

Most of us play games and sports, and we always want to get better. When we think about athletic ability, we often think about our muscles, heart, and lungs, but the nervous system is also important in sports. The nervous system controls and coordinates the functions of our bodies – how we move, think, and perceive our environment. In this module, we will explore the role of the nervous system in sports and will use neuroscience to develop and test coaching strategies that might help struggling athletes.

Neuroscience is the study of the nervous system, a network of special cells called neurons or nerve cells found throughout the body. The nervous system has three main parts: the brain, the spinal cord, and the peripheral nervous system. Neurons in the peripheral nervous system help sense information about the environment and our own bodies and communicate it to the brain. The brain and spinal cord make up the central nervous system.

In this lesson, students will learn that the brain and muscles communicate through a network of neurons. They will map out a neuron pathway, showing a signal that travels from a stimulus into the brain, down the spinal cord, and out to the muscles in the arms and legs. Students will test the difference betweeen the visual and auditory signaling pathways. They will measure reaction time, the time between an environmental signal and the body's muscular response, using an online game.

Materials

- ☐ Computers with internet access
- ☐ Copies of Neuron Map handout
- ☐ Headphones

Prep Work

- ☐ Watch/set up reaction time videos:
  - Cars: tinyurl.com/racecarstart
  - Track: tinyurl.com/trackstart
  - Swimming: tinyurl.com/swimstart
- ☐ Bookmark www.cognitivefun.net

Time

60–90 minutes (total)

Reaction Time

Reaction time is the time between the start of an environmental stimulus and the body's muscular response to that stimulus. The reaction to a sound is faster than one to something we see, partly because our brains process the signals differently.

When we hear a sound, it travels into the ear, and nerves inside the ear send a signal to the brain stem. From there it goes to the thalamus (a relay station for sensory information), and then to the temporal lobe of the brain. This whole pathway is fairly short and near the ear, which means that sound information has a short distance to travel.

Interpreting a visual cue is more complex. Light enters the eye and is first processed by special cells on the retina. This signal travels through the optic nerve to the thalamus, and then to the visual cortex in the occipital lobe of the brain. The occipital lobe is at the back of the head, which means that the signal has a relatively long way to go.

A visual signal is pre-processed by the retina and also has longer to travel to the right place in the brain. This makes our visual reaction time (20-40 milliseconds) slower than our auditory reaction time (8-10 milliseconds).

Lesson 1: Reaction Time, continued

Warm-Up Questions

What are your favorite racing sports?

What are some different ways to start a race? (Green light? Whistle? Flag?)

What are the steps between seeing/ hearing the start signal and starting?

Procedure

1. Spend some time getting to know the kids in your group. Introduce the Grand Challenge for this module: we are going to learn about the science of sports and about some athletes who are struggling with their favorite sport. Then we will use neuroscience to help them. What does neuroscience mean?

2. Use the warm-up questions and the videos (links in the prep work section) to start talking about racing and reaction time. Have the students pay attention to the starting stimulus in each video.

3. Use the trading cards to introduce the athlete for this unit: Megan is a sprinter on her school's track team. She is very fast but is slow off the starting block. How can Megan improve her reaction time?

4. Get the students thinking about visual stimuli and auditory stimuli. Introduce the concept of reaction time (see sidebar). Ask them to hypothesize which type of stimulus would lead to the shortest reaction time. Do they have any ideas about what may affect an athlete's reaction time?

5. Introduce the experiment for this unit: is reaction time faster for a visual or an auditory cue? You will be using an online game to compare the students' reaction times for a visual and an auditory cue. Have students work in pairs, taking turns performing the tests and recording results for another group member. Each student should perform the test a minimum of 5 times. The students should see improvement in their reaction time with more repetition.

6. Use the Experimental Design handout to guide your students.
   a. What is our hypothesis?
   b. How are we going to measure reaction time?
   c. What is the variable we are testing? Are there other variables that need to be held constant?
   d. Do we need a comparison group or condition?
   e. How many people will we test? Should we repeat the test?
   f. How are we going to record our data?

7. When your group is done planning, perform the experiment. Have the students go to the website www.cognitivefun.net. The tests are under the "Attentional" tab, titled "Visual Reaction Time" and "Auditory Reaction Time." The students will click the mouse or press the space bar when a green dot appears on the screen (visual test) or when they hear a tone (auditory test). The students should wear headphones when performing the auditory test. Their reaction times will be displayed after each run. Record this data.

8. Have each student calculate his or her average visual and auditory reaction time. Which is faster? Why do you think the reaction time was faster for one of the cues? Use the side bar to help explain the difference.

9. Map the signal pathway on the Neuron Map handout. Use the full body image to diagram the signal sent from the brain to the muscles.

10. Relate your experimental results to communication within the nervous system and to a race start. At the start of a race, the athlete sees/ hears the stimulus, the nerves in the eyes/ears send a signal to the brain, and the brain interprets it as "Start!" The brain then sends signals to the muscles to start.

11. Have the students write a journal post about their experiment.

Concluding Discussion

What are some of the roles of the nervous system? How do the different parts work together?

How can we help Megan improve her reaction time?

Lesson 1 Supplemental Figure

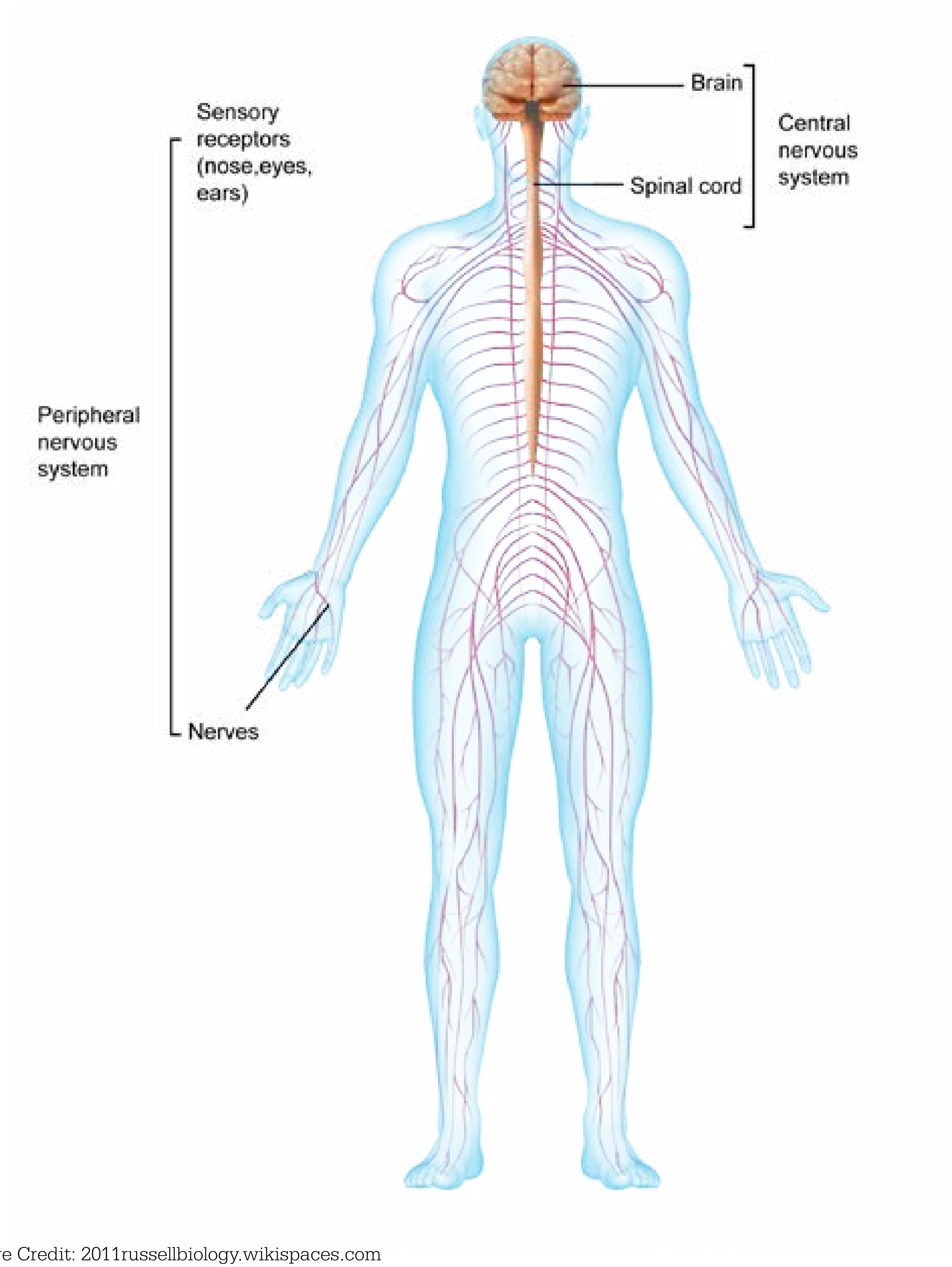


Image Credit: 2011russellbiology.wikispaces.com

Lesson 1: Neuron Map

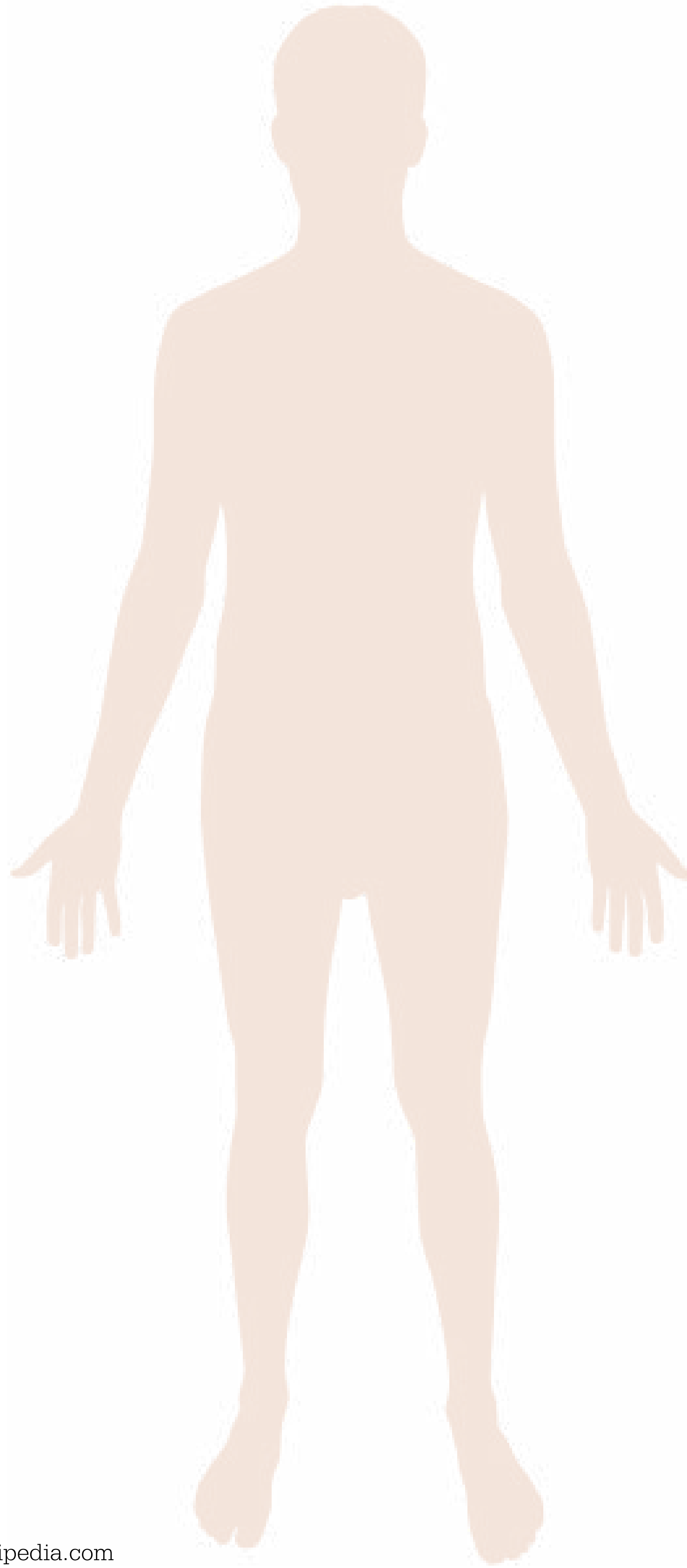


Image Credit: commons.wikipedia.com

Lesson 2: Sidedness

Lesson Objectives

- Describe the two hemispheres of the brain and how this division leads to sidedness
- Answer the question: Do people kick a soccer ball faster with their dominant or non-dominant foot?

What You Need to Know

The brain has a very complicated job: processing information from many sources. To more easily and efficiently process information, the brain has divided tasts to specific regions. At the most simple level, it is divided down the middle into right and left hemispheres. Each hemisphere is specialized to perform certain motor, visual, and sensory tasks. This specialization is called lateralization, and it makes the function of the two sides of the brain slightly different.

In general, the right brain allows us to better perform spatial tasks, recognize faces, and understand visual imagery. The left brain handles language, calculations, and logic. This division allows us to perform separate tasks (in each hemisphere) at the same time.

The difference in function between left and right sides can be seen easily by looking at sidedness. For example, most people are right-handed, meaning they prefer to use their right hand to write, eat, or throw. We call this "right hand dominance." People who prefer to use their left hands have "left hand dominance." There are a few people who use each hand equally; they are ambidextrous. Some people have mixed handedness, or cross-dominance, where they may bat well left handed, but throw better right handed.

In this lesson, students will perform activities to determine their dominant side for hand, foot, ear, and eye. In addition, they will use soccer activities to test differences in performance using their dominant vs. non-dominant side.

Materials

- ☐ Soccer balls
- ☐ Athletic goals or cones
- ☐ Measuring tape
- ☐ Stop watch
- ☐ TI sensor and iPhone app
- ☐ Copies of Dominance Tests handout

Prep Work

- ☐ Set up goals or cones
- ☐ Mark kicking positions
- ☐ Test method to measure speed

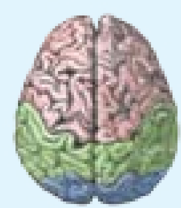
Time

60–90 minutes (total)

Parts of the Brain

The brain has many jobs. They include thinking and problem solving as well as remembering and controlling movement. To do all of these tasks, the brain assigns specific jobs to specific parts.

The cerebral cortex is the largest part of the human brain. It is divided into four sections called lobes: frontal lobe, parietal lobe, occipital lobe, and temporal lobe. Each has a specialized function. The frontal lobe mostly works on planning future actions and controlling movement; the parietal lobe on sensation and proprioception; the occipital lobe on vision; and the temporal lobe on hearing. The cerebral cortex also has deeper structures called the hippocampus and the amygdala that are important for learning and emotion.



Look at the picture: the cerebral cortex is very wrinkled. These wrinkles are called gyri and make the brain more efficient by allowing for more neurons to be packed into a small space. You can also see the groove dividing the brain into two hemispheres.

Lesson 2: Sidedness, continued

Warm-Up Questions

Do you always use the same hand to write, eat, or throw a ball?

Do you think you can learn to use your non-dominant side just as well as your dominant side?

Procedure

1. Begin by having each student write their name. Which hand did they use? Then ask them to write their name with the opposite hand and compare the handwriting. Is there a difference? There should be, because one hand is dominant for writing. Discuss the warm-up questions.

2. Discuss dominance. Do you think other parts of our body exhibit dominance? Review the Dominance Tests handout. Perform some of these tests to demonstrate how most of us have a dominant side when performing tasks with our hands, eyes, ears, and feet. Use the supplemental images to show that the brain has a structure and specific functions are assigned to different regions of the brain.

3. As you perform the tests, have students record their results. Talk about how dominance could affect sports performance.

4. Following the dominance tests, students should understand that we instinctively use one side more than the other for certain tasks. Have the students compare their results. Are more people right-side dominant or left-side dominant? Is anyone cross-dominant?

5. Use the trading cards to introduce the athlete for this unit, Manuel. He is a soccer player who plays the forward position. He has struggled with injuries to his right hamstring and knee, and his doctor told him to try using his left foot. He is having trouble scoring and passing with his left foot. Do you think that Manuel can learn to use his left foot?

6. Introduce the experiment for this unit: do people kick a soccer ball faster with their dominant or non-dominant foot? You will use a TI sensor and an iPhone app to measure the acceleration of the students' legs as they kick the ball. Attach the sensor to one leg and have the student kick the soccer ball as hard as they can. The iPhone program will record the acceleration of the sensor and will allow you to export the data as an Excel file. If you do not have the sensor and phone available, approximate the speed of the ball by marking a fixed distance and timing how long it takes the ball to travel it.

7. Work with your group to design their experiment. Use the Experimental Design handout to guide your discussion.
   a. What is our hypothesis?
   b. How are we going to measure kick speed?
   c. What is the variable we are testing? Are there other variables that need to be held constant?
   d. Do we need a comparison group or condition?
   e. How many people will we test? Should we repeat the test?
   f. How are we going to record our data?

8. After your group has discussed and planned your experiment, you can go to the gym to perform the experiment they designed. Make sure they record their data.

9. Help students compare differences in performance when using dominant and non-dominant feet. Have the students calculate averages and graph their results. Discuss the students' results. Was their hypothesis correct?

10. Write a journal post to share your data and to record your experiment.

Concluding Discussion

Did the ball travel faster after you kicked it with your dominant or non-dominant foot?

What did you learn about dominance? Do you have a clear dominant side?

How can we help Manuel strengthen his non-dominant side?

Dominance Tests

Test #1: Eye Dominance

- Identify a distant object across the room. Hold one hand in front of you and block that object with your thumb.
- Close your right eye. What happens to the object?
- Now open your right eye and close your left. What happens to the object?
- If you have a strongly dominant eye, the object will seem to "jump" when you close the more dominant of your eyes. Which one is it?

Test #2: Ear Dominance

- Stand in front of a wall or door. As if the wall were talking to you, put your ear to the wall to hear better.
- Which ear did you use to listen to the wall? That is your dominant ear.

Test #3: Foot Dominance

- Hop on one foot without stopping for 15-20 seconds.
- Which foot did you use? That is your dominant foot.

Test #4: Hand Dominance

- Draw a pair of simple shapes (two circles or two square, for example) on a piece of scratch paper.
- Hold a pair of scissors in your right hand and cut out one of the shapes, then hold the scissors in your left hand to cut out the other.
- Compare the shapes you cut out. Do they look the same? How easy was it to cut out each one?

Lesson 2 Supplemental Figure

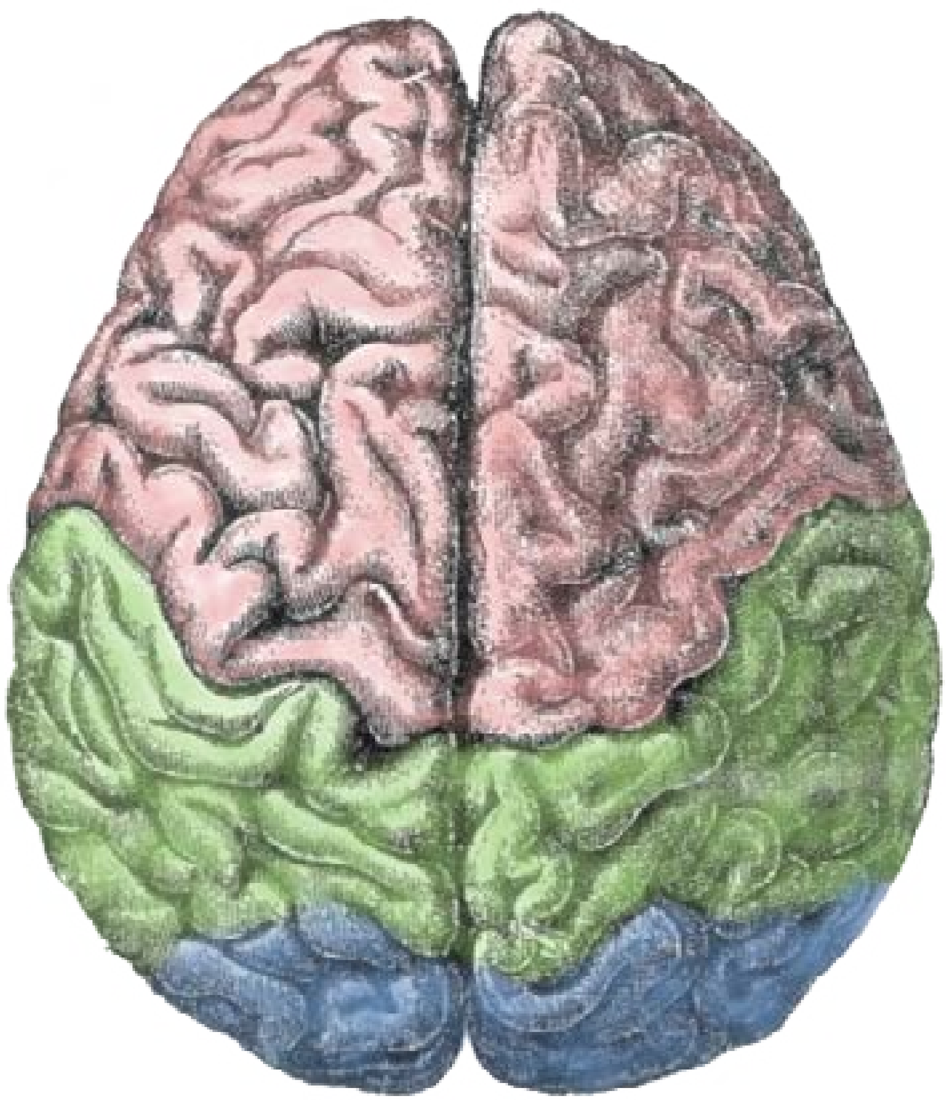


Image Credit: commons.wikipedia.com

Lesson 2 Supplemental Figure

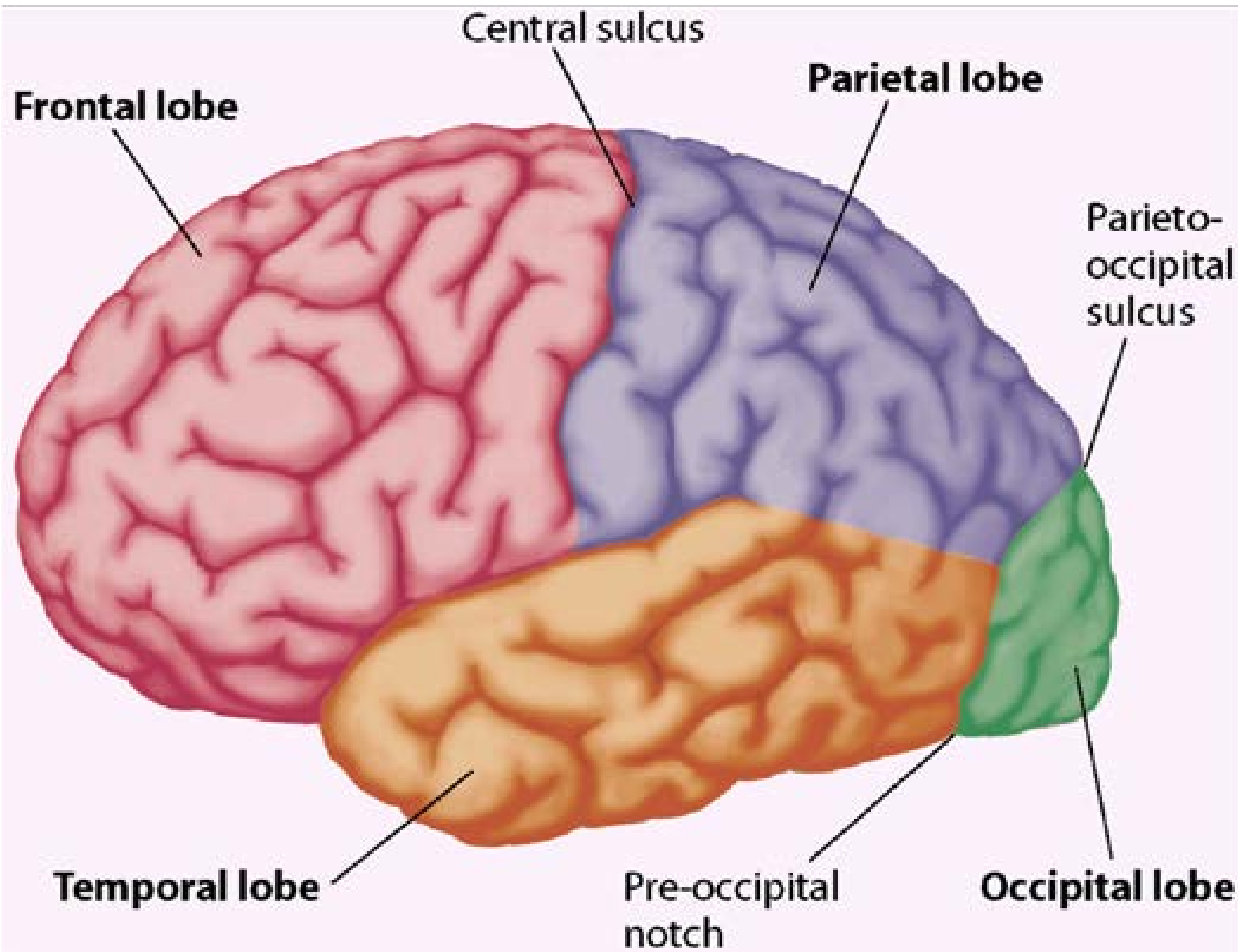


Image Credit: studyblue.com

Lesson 3: Vision and Depth Perception

Lesson Objectives

- Explain how the brain receives and processes information from our eyes
- Answer the question: Does altering depth perception affect free throw shooting accuracy?

What You Need to Know

The world is filled with all kinds of sensory information: sights, sounds, smells and tastes. To be able to use this information, our bodies have developed ways to sense the different types of stimuli in the environment. For example, our ears can detect vibrations in the air and our noses can sense chemicals released into the air. Our bodies must detect these stimuli and translate them into a form that our brains will understand, namely a nerve signal.

Let's look at one of our senses in more detail - our sense of sight. Our eyes can detect different wavelengths of light. Light is detected by special cells in the eye, called rod and cone cells, which can determine the amount of light that is present and what color it is (see sidebar). The neurons in the eye communicate this light and color information to the brain, where a part of the brain called the visual cortex processes these visual cues.

Both of our eyes detect light, but each eye sees the world from a slightly different angle. The eyes send these different signals to the brain and the brain is able to combine the images from both eyes to create a single three-dimensional view of the world. This 3D image can help us estimate the distance of an object, an ability called depth perception.

In this lesson, students will learn about how the brain processes visual information and creates a sense of depth. Students will perform an experiment to test the role of depth perception while shooting a basket.

Materials

- ☐ Pencils and pens for demo
- ☐ Basketball and hoop
- ☐ Eye patches
- ☐ Measuring tape
- ☐ Timer or stopwatch
- ☐ Graph paper or lab notebook
- ☐ Copies of Depth Perception Activity handouts

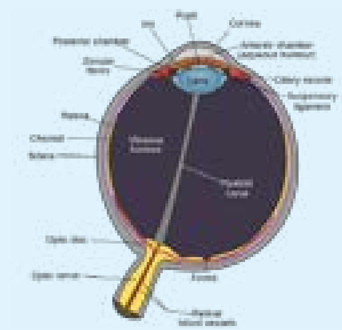
Prep Work

- ☐ Prepare basketball court or separate area for shooting

Time

60–90 minutes (total)

How do our eyes work?



Our eyes detect light. Light enters the front of the eye through a lens and is projected onto the back of the eyeball. The back of the eye is covered with the retina, your eye's light sensor, similar to film or sensors in a camera.

Light is absorbed by special cells in the retina, called rod and cone cells. Rod cells can detect low levels of light and help us see at night. Cone cells help us see color and are activated by red, blue, and green wavelengths of light.

Like all neurons, rods and cones communicate with other neurons by releasing chemicals called neurotransmitters. Light causes the rod and cone cells to change the amount of neurotransmitter they release which creates a signal that is transmitted to the brain.

Lesson 3: Vision and Depth Perception, continued

Warm-Up Questions

Why do you think we need two eyes to see instead of just one?

Have you ever tried to do something with one eye closed or both eyes closed? What happened?

Procedure

1. Discuss the warm-up questions with your group.

2. Introduce the concept of vision and explain how our eyes detect light. Brainstorm with your group ways that the sense of sight might be important for movement and sports. For example, we've talked about visual cues being used for race starts. Vision is also essential for responding to a moving object: hitting a baseball, catching a basketball, or trapping a soccer ball. Different types of visual cues will be important for coordinating different types of movements.

3. Illustrate how both eyes are needed to create a sense of depth by leading your group through this demo: take two pencils and attempt to touch the ends together from an arm's length with one eye closed. Now try with both eyes open. How much easier was the task with both eyes open? Talk about how our eyes communicate with our brain to estimate distance.

4. Introduce the challenge athlete, Feng, using her trading card. She is a basketball player who has been having trouble with her shooting percentage. She just returned from the ophthalmologist (or eye doctor), who found that Feng might have a problem with depth perception. Could this be causing her difficulties with making baskets?

5. Introduce the experiment for this unit: does impaired depth perception affect shooting accuracy? Your group will have basketballs and the hoops in the gym. The students will compare shooting with both eyes open to shooting with one eye closed (to simulate impaired depth perception). Adjust the shooting position to a point where your group can make at least half of their shots with both eyes open. If someone in your group is struggling to make baskets, they can play a different role, such as data recorder. Talk about whether or not you will count shots made using the backboard, or shoot from the baseline so that they cannot use the backboard.

6. Using the Experimental Design handout, work with your group to design their experiment.
   a. What is our hypothesis?
   b. How are we going to measure shooting accuracy?
   c. What is the variable we are testing? Are there other variables that need to be held constant?
   d. Do we need a comparison group or condition?
   e. How many people will we test? Should we repeat the test?
   f. How are we going to record our data?

7. When you are done planning, your group can go to the gym to conduct your experiment. Make sure to record your data.

8. Analyze and discuss your results. What does your data show? Did you prove your hypothesis? Plot your data using a graph.

9. Summarize the results of your experiment in a journal post. Make sure to include your calculations or graphs!

Concluding Discussion

What are some other factors that could influence shooting accuracy?

How can Feng improve her shooting ability?

Lesson 3 Supplemental Figure

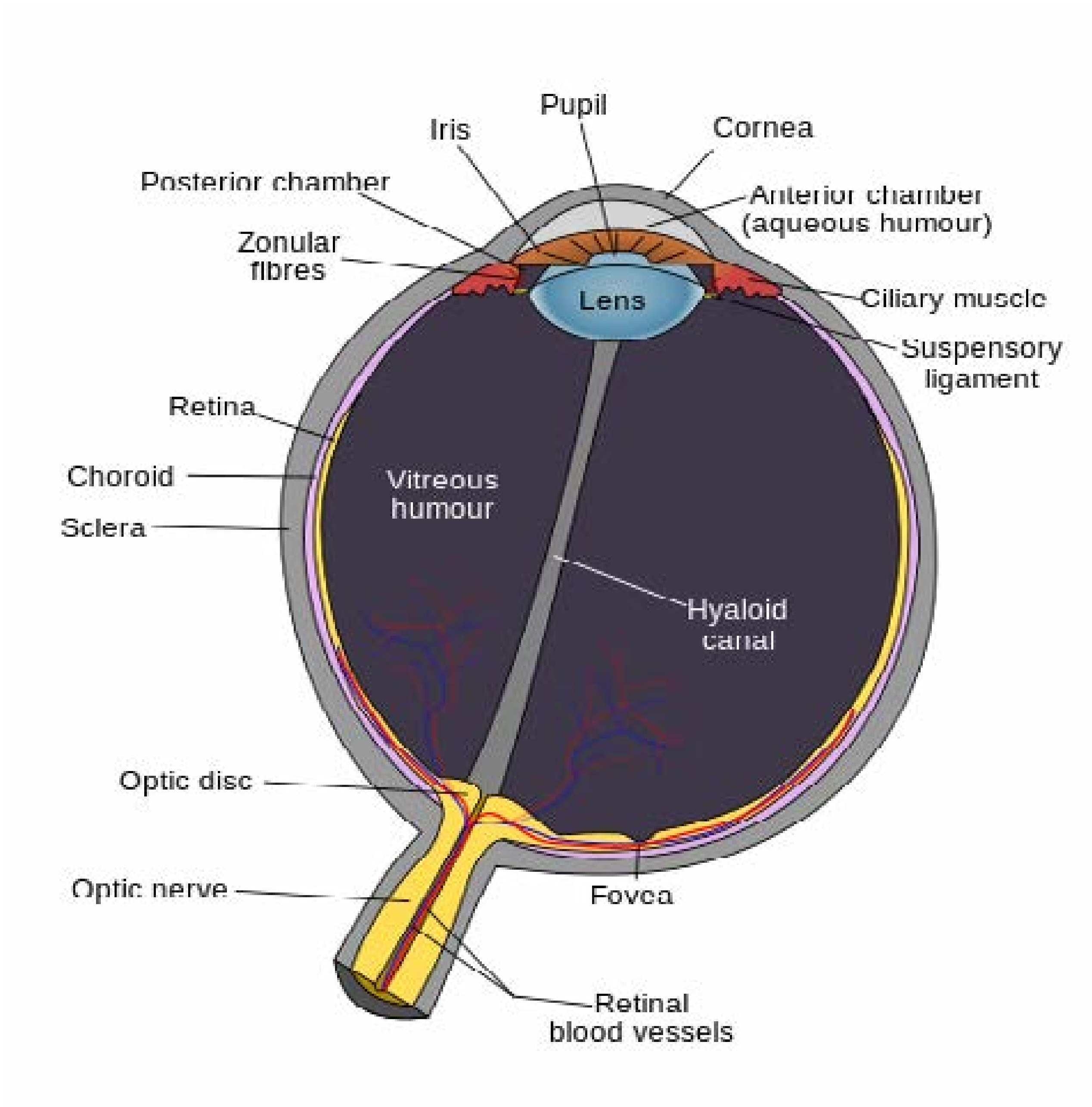


Image Credit: commons.wikipedia.com

Lesson 4: Balance

Lesson Objectives

- Understand how proprioception and the vestibular system interact with vision to keep us balanced.
- Answer the question: How does vision affect our ability to balance on one foot?

What You Need to Know

Balance is important in many sports: it's what keeps us standing as we bend and stretch our bodies. It's particularly important in martial arts, as kicking requires balancing on one foot and throwing tries to get your opponent off balance. To maintain balance, our brain must integrate signals from three sources:

- **The vestibular system of the inner ear**: there are three semicircular tubes in the inner ear with sensors (hair cells) that detect when fluid in the tube is moving and send signals to your brain. Since the three tubes are oriented perpendicularly to each other, this system can detect movement in each of the three directions of rotation.
- **Proprioception**: this is the sense of knowing where your body parts are in relative space. The main sources of proprioception are stretch receptors in muscles (see sidebar).
- **The visual system**: consider how balance changes when it's dark or you close your eyes. The brain integrates visual information with the information from the vestibular system and proprioception to maintain balance.

In this lesson, students will demonstrate the roles of the different components of balance. They will see how the vestibular system works using a model semicircular canal. Finally, they will design and conduct an experiment to determine how vision affects our sense of balance.

Materials

- ☐ Stop watch
- ☐ Paper
- ☐ Pencils
- ☐ Laptop
- ☐ Digital camera
- ☐ Transparent tubing
- ☐ Swivel board
- ☐ Tape
- ☐ Blind fold (optional)
- ☐ Ruler or stick (optional)

Prep Work

- ☐ Prepare the model ear canal

Time

60–90 minutes (total)

Proprioception

Although we're usually not aware of it, our bodies are constantly communicating information about the positions of its various parts. This is called proprioception. The main source of this information is specialized cells called muscle spindles that are buried deep in our muscles. Muscle spindles are sensors that measure how much each muscle is stretched, and the brain calculates where it is.

Body parts that are moved more often and require more control have more dedicated space in the brain. The area in the brain specifically for a certain body part can grow bigger if it is moved more. For example, musicians in general have larger areas in the brain devoted to finger movement than non-musicians do.

With practice, we can get faster and more accurate at interpreting the information from our muscles, contributing to better performance in many sports. We also must readjust this system as we grow because the same amount of stretch in the muscle could correspond to a different position.

Lesson 4: Balance, continued

Warm-Up Questions

Close your eyes and touch your nose. How do you know where your nose is? How do you know where your hand is?

What happens when you spin around quickly?

Procedure

1. Discuss the warm-up questions with your group. Start the kids thinking about balance. How do they use their sense of balance?

2. Introduce the science behind balance. To be able to stay balanced, your brain needs to know where all the parts of your body are. It does this in three ways: sight, proprioception (see sidebar), and the vestibular system.

3. Explain that the vestibular system contains three semi-circular canals that detect fluid movement. Why do we need to have three?

4. Use the model of the semi-circular canal to explain the vestibular system. Put the model semi-circular canal on the lazy susan and secure it with tape. Spin it gently. What happens to the fluid inside? What happens at the sensor? Spin it again, this time quickly. Have the students observe what happens to the fluid in the tube as the lazy susan spins and when it stops. Based on your observation of this model, what do you think happens to your vestibular system when you spin quickly? (The fluid continues to move after the spinning stops. This sends a signal from the sensors to your brain even though you're not moving, confusing your brain and making you dizzy).

5. Have students experience the role of the vestibular system, proprioception, and the visual system in balance with some demonstrations. For each, talk about which systems are providing the most input to keep you balanced:
   - Stand on one foot. (proprioception, visual system)
   - Stand on one foot and close your eyes. (proprioception)
   - Stand on one foot and move head up and down. (proprioception, visual system, vestibular system)

6. Use the trading cards to introduce the character Tyler, who is having difficulty in his martial arts class. His problem is that he has a hard time balancing on one foot.

7. In addition to proprioception and the vestibular system, the eyes are also very important for balance. Introduce today's experiment: how does vision affect our ability to balance on one foot? The groups can spread out into the extra room next door and/or other available spaces. Students will compare their ability to balance with eyes open and with eyes closed. They can simply stand on one foot, or they can make it harder by bringing the other foot up as high and straight as they can and making circles around a target (e.g., someone's hand). Bringing their arms straight over their heads will also make it harder to balance.

8. Use the Experimental Design handout to guide your group through designing an experiment.
   a. What is our hypothesis?
   b. How are we going to measure ability to balance?
   c. What is the variable we are testing? Are there other variables that need to be held constant?
   d. Do we need a comparison group or condition?
   e. How many people will we test? Should we repeat the test?
   f. How are we going to record our data?

9. When you are done planning, your group can perform their experiment.

10. Record the data in a data table, and graph the data. What is your conclusion?

11. Summarize your results in a journal post.

Concluding Discussion

How does vision affect balance?

What can Tyler do to improve his balance for his martial arts class?

Lesson 4 Supplemental Figure

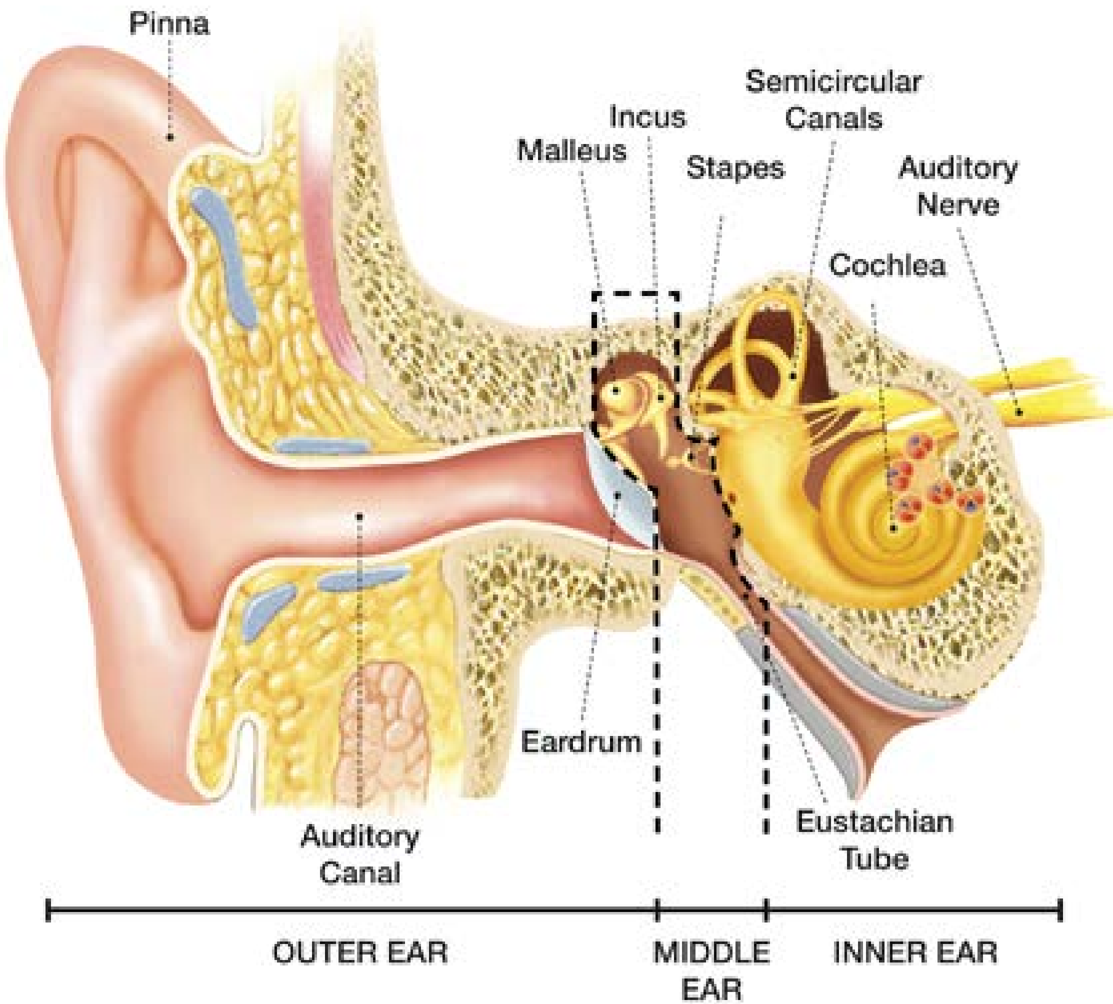


Image Credit: hearforlife.ca

Lesson 5: Learning and Memory

Lesson Objectives

- Explain how neural synapses communicate and the role they play in learning and memory
- Answer the question: What style of teaching works best to learn a series of moves?

What You Need to Know

There are billions of nerve cells (neurons) in the human body, but on its own a single neuron can't do much. To help us think, feel, and move, neurons have to be able to talk to each other.

Neurons communicate with each other at special connection points called synapses, where two neurons are very close together. At each synapse, one neuron is the sender of messages and the other is the receiver. Most neurons talk to each other using chemicals. When a sender neuron is activated, it releases a special chemical called a neurotransmitter, which attaches to the outside of the receiver neuron. Like a key that fits into a lock, the neurotransmitters fit perfectly into the receiving neuron and causes it to be activated too.

One neuron can be the receiver cell at one synapse but the sender cell at another. Think about playing a game of telephone: first you receive the message, then you send it on. Like in telephone, this process of sending and receiving in the brain usually happens many times. Sometimes one neuron sends the message to many other neurons so that the information goes to more than one place in the brain. When we learn or remember something, we're using our synapses! Learning strengthens the connections between neurons, and sometimes it even creates new synapses. The more we repeat information or practice a skill, the stronger the synapses become, and the better we remember.

In this lesson, we will explore several ways to improve memory. Students will do a demonstration of different teaching styles (visual, verbal, kinesthetic/tactile) and will design an experiment to test how people best learn a series of moves.

Materials

- ☐ Computer with internet access
- ☐ Five balls with different shapes, sizes, and textures
- ☐ Large space to dance

Prep Work

- ☐ Watch/set up video: tinyurl.com/learningmemory

Time

60–90 minutes (total)

Different kinds of memory

We have many different kinds of memories, and some of them we don't even know we have! Although we think of learning as the conscious effort to remember something, sometimes it's even simpler than that. Here are a few kinds of memories that we might not realize we have:

- Working memory: this kind of memory only exists for about 30 seconds, but it's important while it lasts! It holds information that we need in order to complete a task—for example, it helps us speak in complete sentences by holding the thought we want to say.
- Spatial memory: when we get to know a place (like a house, or an area of town) really well, we develop an internal map of it. When you're in your bedroom, you can picture where your kitchen is even though you might not be able to see it.
- Skills memory: this is why practice is so important! For something like playing the piano or shooting a basketball, our bodies know how to do it even though we might not be able to describe it. Think about tying your shoes. You can do it, but if you try to just explain it, it's really hard.

Lesson 5: Learning and Memory, continued

Warm-Up Questions

What helps you remember something you learn in school? Is it better to hear it? Read it? Write it?

How do you remember something like a football play or dance moves?

Procedure

1. Discuss the warm-up questions with your group.
2. We've spent the last four weeks learning about the brain and nervous system. Review what the students have learned. What is a neuron? What are the different parts of the brain? When you hear or see something, what part of the brain does that signal go to? Review the concept that the nervous system is responsible for communication and sending signals. What are these signals? How does the nervous system send them?
3. Talk about neuron communication and synapses. To help quickly illustrate neuron communication, wad up a piece of paper and pretend it is a neurotransmitter. Each person at your table is a neuron and as you pass the paper ball around the table, you can talk about how this is pretty similar to how neurons share information.
4. Watch the video about brain plasticity. Have students summarize the video. What happens when you learn something new? (make new synapses) What happens when you practice a new skill? (strengthen your synapses)
5. Briefly introduce the concepts of visual, auditory and kinesthetic/ tactile learning. Which part of the brain does each style activate? Based on the movie we just watched, what would happen if you activated a bunch of different areas of the brain at once?
6. Introduce the athlete for this unit with his trading card: Luis is a wide receiver for his school's football team. He has great hands, but he can't remember his team's plays.
7. Introduce the experiment for this unit: what style of learning works best to learn a series of moves? Mentors will lead students through three different routines taught with three different methods, described below.
   - Auditory: The mentor will tell the students the order of the moves
   - Visual: The students will watch the mentors go through the set of moves (this should not include talking)
   - Kinesthetic: The students will mirror the mentor going through the moves (again, this should not include talking)
8. For each of the different learning styles, the instructions will be repeated 2x before the students are asked to repeat the sequence of moves. Note: the sequence of the moves will be different each time and will contain approximately 10 moves (see appendix 1 for moves). Go through all of the moves as a group so that everyone understands them.
9. Work with your group to design an experiment. Use the Experimental Design handout to guide you.
   a. What is our hypothesis?
   b. How are we going to measure learning the series of moves?
   c. What is the variable we are testing? Are there other variables that need to be held constant?
   d. Do we need a comparison group or condition?
   e. How many people will we test? Should we repeat the test?
   f. How are we going to record our data?
10. When you are done planning, perform the experiment.
11. Discuss your results: which learning style worked best? Was it the same for everyone?
12. Ask the students to record their data as a journal post.

Concluding Discussion

Is there one learning style that worked best for everyone? Which?

How can we help Luis improve his memory of plays?

Lesson 5 Supplemental Figure

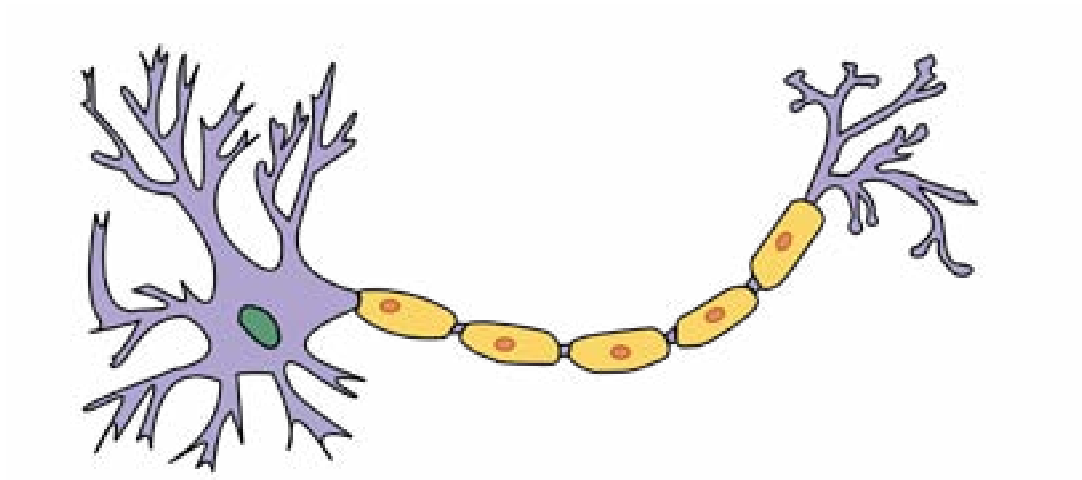


Image Credit: commons.wikipedia.com

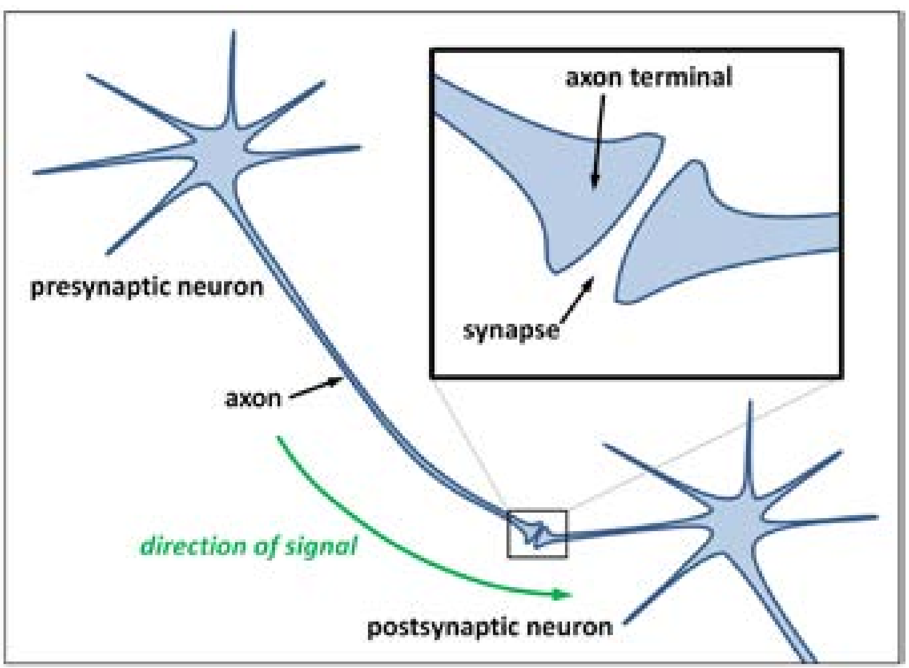


Image Credit: kaitlinbergfield.blogspot.com

Dance Moves

Show us your moves! Here are some suggested moves that you can use to create your three routines.

	Auditory routine	Visual routine	Kinesthetic routine
Right arm up			
Left arm up			
Both arms up			
Hop on right foot			
Hop on left foot			
Hop on both feet			
Spin around			
Walk forward			
Walk backward			
Grapevine right			
Grapevine left			
Clap			
Stomp right foot			
Stomp left foot			

Alternate Experiment: Having a Ball

1. If your group is very resistant to the idea of performing a series of moves, you can use this alternative demonstration of different learning styles. You should still go through the Experimental Design handout to create the experiment.
2. Before you begin, gather five different balls into a box. Make sure they have different shapes, sizes, and textures. Let the students familiarize themselves with the balls so that they will be able to identify them by touch.
3. Explain that you will introduce the balls in different ways and that they should remember the order of the balls. After you have introduced all of the balls for one style, ask the students to write down their order.
   - Auditory: name each of the balls (slowly).
   - Visual: pull one ball out of the box, show it to the students, and return it to the box. Repeat with each ball.
   - Kinesthetic: blindfold the students or have them close their eyes. Pass the balls around, giving the students time to feel each.
4. Tell students the correct order for each method, and have them count how many they got right.
5. Continue with discussion, analysis, and journal posting as described in the procedure above.

Lessons 6 and 7: The Final Challenge

Lesson Objectives

- Identify strategies and solutions to help the NeuroSports atheletes improve their sports performance
- Design an experiment to test the effectiveness of your solution

What You Need to Know

In the last five lessons, each group learned about the NeuroSports athletes and their struggles with their favorite sport.

- Megan Dominic wants to improve her reaction time for sprint racing
- Manuel Castillo needs to use his non-dominant foot more in soccer
- Feng Liu wants to achieve a higher scoring percentage in basketball
- Tyler Jones would like better balance for tae kwon do and kickboxing
- Luis Perez would like a memory technique to help him remember football plays

All the athletes want to improve their sports performance and they have asked for your help.

Each group will be assigned an athlete and working as a team, use your knowledge about the nervous system to identify some possible strategies to help the athletes overcome their weaknesses.

Brainstorm some ideas and once your group has picked a solution, design an experiment to test the effectiveness of that approach. Does your strategy actually help improve a specific sports skill?

Materials

- ☐ Sports supplies from previous lessons, as needed
- ☐ NeuroSports trading cards

Prep Work

- ☐ Collect sports supplies and make them available to the groups
- ☐ Assign a NeuroSports athlete to each group
- ☐ Make sure that each group has a copy of the trading cards

Time

Two sessions, 60–90 minutes per session

Careers in sports

If you love sports, there are many ways to build a career working with athletes. Here are a few possible careers:

Coach - supervises the teaching and training of athletes. Both a thorough understanding of the sport and at least a high school diploma are required to become a coach. To become a school coach, individuals often need a teaching certificate as well.

Physical Therapist - helps athletes recover from injuries and improve movement. Physical therapists know a lot about anatomy and neuroscience. This career requires both a college degree and a graduate degree, which together take about seven years after high school.

Athletic Trainer - helps prevent and treat athlete injuries. They often provide first aid to athletes injured in a game and help athletes manage their injuries by applying bandages, providing stretching, and using ice packs or baths. This career requires a college degree.

Personal Trainer - helps athletes improve fitness through exercise and strength training. This career only requires a special certification through a national organization.

Lessons 6 and 7: The Final Challenge

Warm-Up Questions

Have you ever wanted to become better at a particular skill?

How do coaches help a sports team? Why are they so important?

Procedure

1. Begin a discussion about the athletes introduced in the last five lessons. Review some of the key concepts covered during those sessions- reaction time, sidedness, depth perception, balance, and memory.

2. Use the warm-up questions to get the kids thinking about improving and strengthening skills, along with the role for coaches in helping athletes become better at their sports.

3. Introduce the Final Challenge- to help one of the NeuroSports athletes overcome a particular weakness. You will develop a technique or strategy and then test it with an experiment. You'll then share your data in a sports clinic for all the kids at the McCormick Boys & Girls Club.

4. To begin, each group has been assigned one of the NeuroSports athletes. Review the information about that athlete. What are their strengths? What are their weaknesses? How could they become better at their sport?

5. Each athlete has a weakness related to one of the neurobiology concepts covered in this curriculum:
   - Megan - Reaction Time
   - Manuel - Sidedness
   - Feng - Depth Perception
   - Tyler - Balance
   - Luis - Learning and Memory

   Go back and review the main concepts related to each athlete.

6. You have already done some experiments about the neurological basis behind these abilities. Do the results from these experiments help you understand the athletes better? How?

7. Using your knowledge about neuroscience and the results from your experiment, brainstorm some techniques and strategies to help the athletes improve a specific skill. Let the kids develop their own ideas but if they are struggling to find a solution, we have included some possible strategies as an appendix to this lesson. Record all the ideas in a notebook or on a piece of paper.

8. Pick one technique to test further. You will be designing a short experiment around this technique, so make sure that it is testable, relatively easy to implement, and can be achieved in a short period of time. *Note- Practice is probably the best way to improve sports performance but practice takes time. Since we only have two weeks for this experiment, there may not be enough time to see gains from practicing.*

9. Design an experiment to test your technique. You can use the materials from the previous lessons and can recruit other kids as test subjects. Follow the Experimental Design worksheet included with this curriculum. Pay attention to these keys steps:
   - What is the experimental question?
   - What is your hypothesis?
   - What is the variable that you are testing? Should other variables be controlled?
   - How will you test your technique?
   - What is your control group?
   - How many subjects and repititions will you need?
   - How will you record your data?

10. Perform your experiment and collect your data. Analyze the results by calculating averages and graphing the data. Was your technique effective at improving sports performance?

11. Summarize your conclusion in a data table and/or graph. You will use these figures during the Science Club sports clinic, where each group will demonstrate their technique and share their data with the other kids from the Boys & Girls Club.

Concluding Discussion

Was your technique effective at improving a sports skill? How do you know that?

Lesson 6 and 7 Appendix
Additional Ideas for the Final Challenge

Lesson 1: Reaction Time	Does auditory reaction time improve when your eyes are closed?
	Does fixing your eyes on a point in space improve auditory reaction time?
	Does reducing or increasing ambient noise affect visual reaction time?
Lesson 2: Sidedness	Does looking at your non-dominant foot improve its kicking speed?
	Does stretching or rubbing your non-dominant leg increase kicking speed?
	How much do you need to practice in order to improve non-dominant foot performance?
Lesson 3: Depth Perception	Does staring at the basket longer improve shooting percentage?
	Do you have to use both your dominant hand and dominant eye to make baskets?
	Does angling your head slightly away from the basket affect shooting accuracy?
Lesson 4: Balance	Does fixing your eyes at a point in space improve balance?
	Do people balance better barefoot or while wearing shoes?
	Do magnetic balance bracelets improve balance?
Lesson 5: Learning and Memory	Does visualization improve memory?
	Do mnemonic devices improve memory?
	Does playing music improve memory?