The Phantom in the Mirror!

I placed a coffee cup in front of John and asked him to grab it. Just as he said he was reaching out, I yanked the cup away.
"Ow!" he yelled. "Don't do that!"
"What's the matter?"
"Don't do that," he repeated. "I had just got my fingers around the cup handle when you pulled it. That really hurts!"
Hold on a minute. I wrench a real cup from phantom fingers and the person yells, ouch! The fingers were illusory, but the pain was real - indeed, so intense that I dared not repeat the experiment.

V.S. Ramachandran *Phantoms in the Brain*

Document Overview:

Teacher lesson plan
Additional teacher resources
Student data sheet

Standard(s):

9.1.1.1.4 Explain how societal and scientific ethics impact research practices.
9.1.1.2.1 Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations and draw conclusions supported by evidence from the investigation.
9.1.3.3.2 Communicate, justify and defend the procedures and results of a scientific inquiry or engineering design project using verbal, graphic, quantitative, virtual or written means.
9.4.4.1.1 Describe the social, economic and ecological risks and benefits of biotechnology in agriculture and medicine.

Objectives:

Upon completion of this lesson, students will be able to:

- Describe what phantom limb pain is and how it occurs.
- Create a testable scientific question based upon current knowledge of phantom limbs.
- Carry out a scientific experiment that addresses the question posed about phantom limbs.
- Describe how phantom limb pain can be treated through a process called “mirror therapy.”

Type of activity: lab activity/class demonstration, class discussion

Duration: 20-30 minutes, depending upon length of class discussion

Connection to Nobel Speakers:

Vilayanur Ramachandran, M.D., Ph.D., Director of the Center for Brain and Cognition and Professor, Psychology Department and Neurosciences Program, University of California, San Diego.

- V.S. “Rama” Ramachandran has pursued research in two areas, one in the study of visual perception (what a subject is seeing based on what they report), and the other in behavioral neurology (in which his experiments, despite their seeming

simplicity, have had a significant impact on the way we think about the brain). He is credited with introducing the use of visual feedback as a treatment for phantom limb pain and complex regional pain syndrome and for stroke rehabilitation.

Teacher Tips:

For successful completion of this lesson we recommend the following:

a. Construct an adequate number of "hand-stimulating" devices prior to starting this activity. A simple and economical device can be constructed using a small block of wood at least 8-inches in length and two paintbrushes. We recommend constructing them in the following manner:

- Drill two holes in a small block of wood approximately 6-8 inches apart from one another. (Make sure that the diameters of the holes you are drilling are the same size as those of the paintbrush handles you will be using.)
- Insert the paintbrushes into the drilled holes. (Optional: insert wood glue to adequately secure the brushes)

b. It may be wise to do some pre-teaching on MRI's and Functional MRI's (fMRI's). A great resource to use would be "How fMRI works" at the following website: http://science.howstuffworks.com/fmri.htm

c. Part 1 could be delivered as a lab experiment, an experiment done in stations with other related activities, or a whole class demonstration depending upon teacher preference or logistical concerns. Visit BrainU for related activities for station work at http://brainu.org/experiential-stations

d. In Part 1, it is very important that the participants real hand be stimulated in the EXACT position as the fake hand. Stimulating different areas makes it difficult for the participant to associate with the fake hand.

Recommended prior student knowledge:

a. The human brain is comprised of neurons.
b. Nerves in the human body consist of interconnected neurons.
c. Basic information on the topographic map of the brain (for example, see http://brain.oxfordjournals.org/content/121/9/1603.full.pdf .
d. Basic anatomy of the nervous system.
e. Current medical imaging technology (fMRI) allows us to see regions of the brain that are undergoing higher amounts of activity.

Concepts, Connections, and Terms addressed in activity:

a. Phantom limb pain
b. Mirror neurons
c. Mirror therapy
d. Scientific method
e. Medical imaging (Functional MRI images)

Acknowledgements:
Modified from Brain U at http://brainu.org/c-elegans-and-alcohol

Materials:

a. Paper bag large enough to conceal participants entire forearm.
b. Scissors and tape
c. Fake rubber arm (available at many novelty stores)
d. Ruler or piece of wood at least 8 inches in length
e. Two paint brushes

Description of Activity:
Working in pairs, students will perform a two-part experiment in which they will first experience the sensation of a phantom limb firsthand, answer some questions related to phantom limb pain, and will then engage in a whole-class discussion of how phantom limb pain may be treated with a relatively new therapy procedure called mirror therapy.

Procedure:
Part 1: Experiment (adapted from BrainU, http://brainu.org/phantom-limb)

a. Put your left arm (palm-up) inside a paper bag on the table, so you can't see it. Make sure the bag has a hole cut out of the bottom.
b. Put the rubber arm (palm-up) next to the bag so your arm and the rubber arm are parallel. Try to make your hand as much like the rubber hand as possible.
c. Focus on the rubber hand.
d. Now get your friend to brush both your fingers, and the fingers on the fake hand.
e. They must stroke both identically, with the same timing and at the same part of your hand.
f. Continue this for approximately 1 minute
g. (Optional) For added emphasis, after 1 minute of stimulus or when the subject reports the sensation that the rubber hand is there own, strike the rubber hand with force and watch the student's reaction. Some students will respond with a significant pain response!
h. Have students record their responses to the questions below on their Student Data Sheet.

Questions to answer:
1) Which arm felt like your arm?
2) What information does your brain use to give you your sense of self?
3) What did you experience when your partner struck the rubber hand without warning?
4) Why did we ask you to test this on your fingers?
5) Analyze the image in Figure 1 consisting of three Functional MRI images (fMRI) of seven patients. What are some observations that you can make from these images? Why do you suppose the "Phantom limb pain" image looks a little different than the other two images?

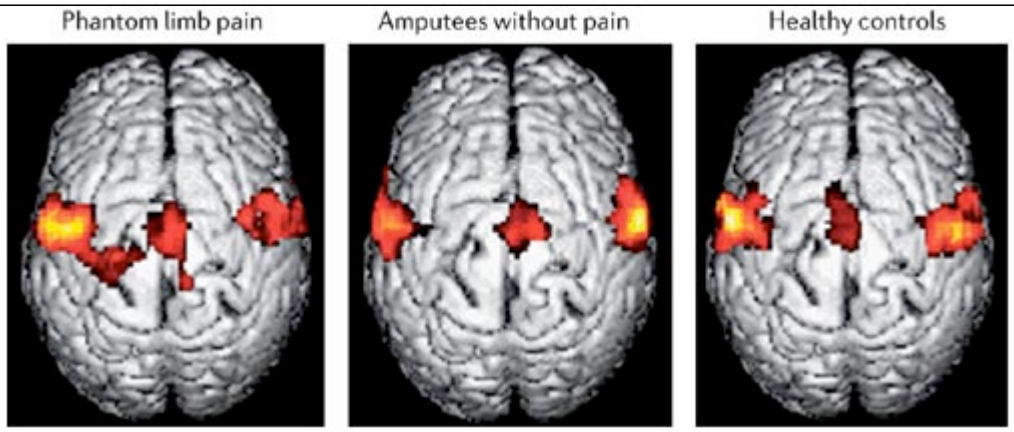

Figure 1: Functional MRI images from seven patients with phantom limb pain, seven amputees without phantom limb pain, and seven healthy people serving as a control.
http://www.nature.com/nrn/journal/v7/n11/fig_tab/nrn1991_F2.html#figure-title

Part 2: Classroom Discussion

1. Once every group has successfully carried out their experiment from Part 1, engage the students in a discussion related to their results. Some discussion points may include:
    a. *Which arm felt like your arm?*
    b. *What information does your brain use to give you your sense of self?*
    c. *What did you experience when your partner struck the rubber hand without warning?*
    d. *Why did we ask you to test this on your fingers?*
    e. *What were some observations that you made by analyzing the three fMRI images? Why do you suppose the image illustrating phantom limb pain looks different from the other two? (Two hints: 1. The subjects were pursing their lips, and 2. See page 1611 in http://brain.oxfordjournals.org/content/121/9/1603.full.pdf)*
2. Finally, lead the students in a discussion related towards the treatment of individuals suffering from phantom limb pain. Introduce them to the procedure called Mirror Therapy as well as the work done by Dr. Ramachandran with "Mirror boxes." Listed below are some resources that can be used either during the discussion or to help facilitate the discussion:
    a. http://www.ted.com/talks/lang/eng/vs_ramachandran_the_neurons_that_shaped_civilization.html (Dr. Ramachandran outlines the fascinating functions of mirror neurons. Only recently discovered, these neurons allow us to learn complex social behaviors, some of which formed the foundations of human civilization as we know it.)
    b. http://www.youtube.com/watch?v=Tl70d9MR_so&feature=related (Episode of the TV show House, where Dr. House uses Mirror therapy to treat patients with phantom limb pains.)
    c. http://www.youtube.com/watch?v=YL_6OMPywnQ (Treating phantom limb pain with Mirror therapy at Walter Reed Army Medical Center)
    d. http://www.nejm.org/doi/full/10.1056/NEJMc071927#t=article (Mirror Therapy for Phantom Limb Pain. N Engl J Med 2007; 357:2206-2207.)

Extension: Part 3 (Optional): (adapted from BrainU, http://brainu.org/phantom-limb)

With your partner, brainstorm a *researchable* scientific question based on the information you have so far. Write out how you would test this question. Don't forget to consider scientific controls!

Want more information? Here are some keyword suggestions you can use to find more information on this subject, use one of them when describing your test: Primary sensory cortex, body image, brain topographic map, proprioception.

Assessment: Student Data Sheet (attached on next two pages)

Additional teacher resources:

- *Projecting sensations to external objects: evidence from skin conductance response.* A very fascinating article co-written by V.S. Ramachandran that provides possible evidence for an actual physiological response to the phantom limb. http://rspb.royalsocietypublishing.org/content/270/1523/1499
- *fMRI background tutorial* (Gustavus/Howard Hughes Medical Institute Outreach Program, 2001-12 Curriculum Materials.) Another great resource that could be used to teach students about Magnetic Resonance Imaging (MRI) and Functional Magnetic Resonance Imaging (fMRI) https://gustavus.edu/events/nobelconference/2011/teachers/
- *BrainU*. http://brainu.org

"The Phantom in the Mirror" Student Data Sheet

1. *Part 1: Procedure* (adapted from BrainU, http://brainu.org/phantom-limb)

a. Put your left arm (palm-up) inside a paper bag on the table, so you can't see it. Make sure the bag has a hole cut out of the bottom.

b. Put the rubber arm (palm-up) next to the bag so your arm and the rubber arm are parallel. Try to make your hand as much like the rubber hand as possible.

c. Focus on the rubber hand.

d. Now get your partner to brush both your fingers, and the fingers on the fake hand.

- They must stroke both IDENTICALLY, with the same timing and at the same part of your hand.

e. Continue this for approximately 1 minute

f. (*Optional*) For added emphasis, after 1 minute of stimulus, have your partner strike the rubber hand with force and observe your reaction.

Answer the following questions once you have completed Part 1 of the experiment

1) Which arm felt like YOUR arm? _____

2) What information does your brain use to give you your sense of self?

_____

_____

3) What did you experience when your partner struck the rubber hand without warning?

_____

_____

4) Why did we ask you to test this on your fingers? _____

_____

5) Analyze the image in Figure 1 consisting of three Functional MRI images (fMRI) of seven

patients.

What are some observations that you can make from these images?

_____

Why do you suppose the "Phantom limb pain" fMRI image looks a little different than the other two images?

_____

_____

Part 2: Discussion

Answer the following questions after the class discussion

1) Briefly summarize in your own words what phantom limb pain is. _____

_____

_____

2) What is the idea behind Mirror therapy? How can it possibly help amputees that suffer from phantom limb pain? _____

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3) Briefly describe who Dr. Vilayanur Ramachandran is and some of his contributions to the expanding field of Neuroscience. _____

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