Demystifying action potentials: Making sense of neuroscience for all educational backgrounds

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Background

Neuroscience is a challenging topic to teach, regardless of the student's educational level or prior experience in the biological and health sciences. The purpose of this project was to:

1) Facilitate neurophysiology instruction to first year medical students at the **Virginia Tech-Carilion School of Medicine** (VTCSOM).

2) Provide an opportunity for Virginia Tech medical students and graduate students to work together and gain experience teaching neuroscience through Science-Technology-Engineering-Math (STEM) outreach.

3) Introduce neuroscience to elementary school students in the Roanoke, Virginia community.

Video synopsis of outreach event

About VTCSOM

- Founded in 2007, VTCSOM is a fully accredited medical school located in Roanoke, Virginia.
- Grants the Doctor of Medicine (M.D.) degree.
- Annual class size of 42 students.
- 100% of its graduates have matched to residency programs.
- The school has four "value domains" - basic science, clinical science, research, and interprofessionalism - that are all interwoven throughout the four-year curriculum.
- Closely affiliated with the Fralin Biomedical Research Institute (FBRI), a tier-one Virginia Tech research institute that is located on the same campus as VTCSOM.
- For more information, visit: https://medicine.vtc.vt.edu/

Support

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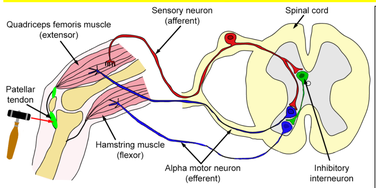
Lesson Plan at VTCSOM

Lecture to Med Students

During their neuroscience curriculum, first year medical students participated in a 2-hour session that combined didactic lecture and hands-on activities. Topics covered included neural circuitry, reflexes, plasticity, and the autonomic nervous system.

Guiding Question: How do reflexes work?

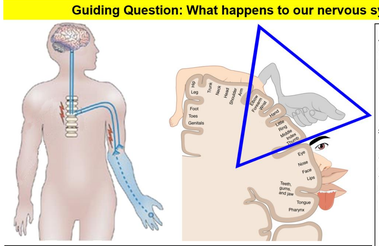


Equipment:
Ipad
Physician's hammer
Backyard Brains Muscle Spikerbox

Activity:
Use the Muscle Spikerbox to visualize the electromyograph (EMG) of the rectus femoris when eliciting a reflex using a tap to the patellar tendon (knee jerk reflex). Modulate the reflex using the Jendrássik Maneuver (decreases descending inhibition, and enhances the reflex).

CLINICAL APPLICATION:
Generally, decreased reflexes indicate a peripheral problem, and lively or exaggerated reflexes a central one.
When you decrease inhibition, you increase excitability.
Stroke patients have Upper Motor Neuron Lesions (UMNL), and so in some cases this decreases (or removes) descending inhibition from the brain. This is why tendon reflexes in stroke and other UMNL patients have exaggerated reflexes.

Guiding Question: What happens to our nervous system when we lose a limb?

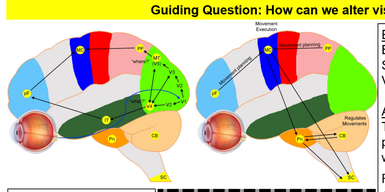


Equipment:
Stackable item
Backyard Brains
- Robotic Claw
- Human-to-Human Interface

Activities:
1. Use the Human-to-Human Interface to control one another.
2. Use the Robotic Claw device to pick up wooden blocks and stack them into a pyramid.

DISCUSSION QUESTIONS:
- What is the signaling pathway for getting a hand to move?
- What is neural plasticity, and where/when does it occur?
- How do neuroprosthetic devices work?
- What are the variables and important considerations for developing a neuroprosthetic device?

Guiding Question: How can we alter visual plasticity?



Equipment:
Bucket
Squishy brains (stress balls)
Vision distortion goggles
(https://www.exploratorium.edu/snacks/distortion-goggles)

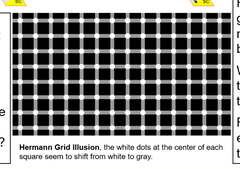
Activity:
Throw a squishy brain into a bucket placed several meters in front of you, first without wearing the distortion goggles.

Record how long it takes to successfully get a brain into the bucket, and how many squishy brains you can get into the bucket (out of 10).

Wearing the distortion goggles, repeat the experiment to see how long it takes to adapt to the novel visual cues.

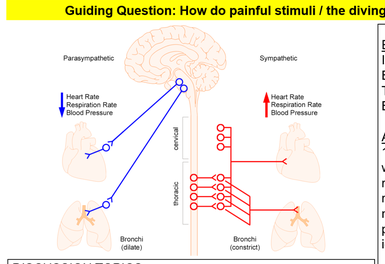
Remove the goggles and repeat the experiment to determine whether or not the adaptation persists.

DISCUSSION TOPICS:
- What is the neural pathway from the eyes to the visual cortex?
- How is the visual system connected to the motor system?
- How do illusions work?



Hermann Grid Illusion, the white dots at the center of each square seem to shift from white to gray.

Guiding Question: How do painful stimuli / the diving reflex influence HR and BP?



Equipment:
Ice water
Bowl
Towel
Backyard Brains Heart & Brain Spikerbox

Activities:
1. Electrodes are placed on the chest, with leads to the Spikerbox and Ipad to record the heartrate, blood pressure, and respiration rate. Activate the sympathetic nervous system using a common model pain stimulus, dunking your hand in cold ice water. This is the "Cold Pressor Test".

2. Using the same set-up as above, activate the sympathetic nervous system by dunking your face in cold (but not icy) water.

DISCUSSION TOPICS:
- Identify the ANS divisions, pathways, neurotransmitters.
- What happens to the vascular system and cardiac system?
- Is the systolic or diastolic pressure influenced more?
- Is the baroreceptor reflex functioning?

Advance Practice Session

Prior to our outreach event at Grandin Court Elementary School, VTCSOM medical students and FBRI graduate students met in advance to plan and run through the activities.

Lesson Plan at Grandin Court Elementary

VTCSOM medical students and FBRI graduate students introduced basic neuroscience to 150 third, fourth, and fifth graders and their teachers at Grandin Court Elementary School (Roanoke, VA). We met with 50 students at a time.

Introduction

First 10 minutes – Interactive discussion of the functions of the brain (and why we need one).

Activity Rotation

Next 40 minutes – Kids were split into smaller groups and rotated through four interactive neuroscience demonstrations every 10 minutes:

A. Electricity of the Nervous System: Demonstration of the electrical activity hidden within our muscles, using an EMG device. Kids volunteered to have their arm muscles tested. We explained the general concept of action potentials, and how they propagate up and down neural pathways to help their brain communicate with their muscles.

B. Reflexes: We used reflex hammers and the patellar reflex to explain why we do not always need a brain. Kids volunteered to have their reflexes tested, and also tested the reflexes of the medical students and graduate students.

C. Comparative Neuroanatomy: We used models and images to compare/contrast structure and function in humans, sheep, and mice.

D. Visual Plasticity: We explained how our visual system adapts to the world around us. We showed illusions and explained how our brain adjusts to fill in missing information. We also used visual distortion goggles to demonstrate how our brains can quickly change to accommodate new perceptions of reality.

Conclusion

Last 10 minutes - Wrap-up session with the entire group that focused on how we can keep our brains healthy. We had squishy brains from the Visual Plasticity activity for each of the kids to take home.

Response

- For the medical students, the hands-on activities were a welcomed addition to the purely didactic lectures that typically cover this topic, and they performed well on their end-of-block exam. The students who participated in the outreach event "felt personal satisfaction and enjoyment having had the experience", conveyed a "desire for future opportunities to teach in the community", and felt that they "understood neurophysiology better after having to teach it to the children".
- The elementary school children seemed to greatly enjoy the experience. The activities kept them engaged for the duration of the event, and they learned about several important topics related to their bodies.
- The elementary school teachers also enjoyed the experience, and have already invited us back for next year.
- Thanks to word-of-mouth, the success of this project has also opened up new opportunities with additional community partners and additional schools.