**Title and Focus of Activity:** Appreciating Proprioception

*Linking foundational and clinical sciences*

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**Course Information:**

Human Neurobiology; 3 semester credits; first year of curriculum in either the 2nd or 3rd semester

**Learning Experience Description:**

Proprioception is a largely subconscious sensory modality, therefore we (and our patients) are not aware of the importance of this sensory feedback until it is decreased or lost. This active learning experience is based on two sources (see references) and modified for a physical therapy curriculum. It is designed to make it obvious to the students how these senses are fundamental to everyday movements and activities. Basically, vibrators are used to trick the nervous system into misinterpreting muscle length, with dramatic consequences.

Instructions to the students: Exercise 1. Choose a subject and have them sit with their elbows placed on a table, palms towards their face. Have the subject close their eyes. The investigator then holds one of the subject’s wrists and moves their arm into different degrees of elbow flexion/extension (moving between 100º-160º. The subject is told to match the new position with their other arm. How accurate are they? Note their accuracy; if they are not completely accurate estimate how many degrees they are from correctly matching their other arm. What sensory receptors provides them with the information to accomplish this task, and what part of the brain is responsible for integrating the sensory input with the motor output?

Now place a vibrator on the subject’s biceps muscle while holding the arm still. With the vibrator on the muscle and starting with the elbow at about 135º, flex the subject’s arm slowly (up to as much as 160º) and ask them to match the position with their other arm. Now move the arm into more extension (135º to 110º range) and ask them to match this position. How well do they do? Again, keep track of their accuracy by noting how many degrees they are from correctly matching their other arm position. If they are not accurate, note if they are in excess flexion or excess extension and note if the mismatch is consistently in excess flexion or excess extension. Everyone should be tested and be a tester. After everyone has participated as a subject and a tester the group should discuss among themselves if they noted a consistent pattern of performance when the vibrator was applied. If the group noted an effect of the vibrator on proprioception they should be prepared to explain the effect and come up with an explanation for how the vibrator influenced the ability to match limb positions.

Exercise 2. Have each subject hold their arm out in front and then touch their nose with their index finger. Now have them pull their finger back about a centimeter from their nose, so it is not touching their nose. The subject closes their eyes and is instructed to hold their finger in the same position until told. Now the investigator applies the vibrator to the triceps muscle. What happens to the subject’s arm when it is vibrated? Now ask the subject to slowly move their finger to their nose. What happens when they attempt to do this and are they successful? What subjective feelings, if any, do they report? Each student should be a subject and a tester. The group should discuss their collective observations and experiences as a group and create an explanation for their findings and be prepared to present this to the class.

Exercise 3. For this exercise you will need a subject, an investigator and 2 spotters. The subject should not be wearing high-top shoes or thick socks. The subject stands with their arms folded and feet together. There should be 1 spotter on each side of the subject. The spotters need to be alert and paying attention and ready to catch the subject if they lose their balance. The spotters must be instructed to not let the subject fall to the ground! The investigator should apply a vibrator to each Achilles tendon. The spotters and other members of the group should carefully note any changes in body position. These changes should be noted as movements into more plantarflexion or more dorsiflexion, and the observers should estimate the amount of change in degrees. It should be noted if the individual loses their balance. This information should be noted for each participant. Now have the subject close their eyes and apply the vibrators to their Achilles tendons a second time. The response of the subject should be noted as above. Now have them tilt their head back as far as they can and apply the vibrators. Again, note the response to the application of the vibrators. The group should discuss their collective findings and answer the following questions: What is the response to vibration of the Achilles tendon? Is this response the same for each subject? Why does it make a difference to have the eyes closed or head tilted back? Explain why this is not an example of a muscle stretch reflex.

Remember that when you are moving a joint the agonist muscles will be getting relatively shorter in length, while the antagonists will be stretched. You have muscle spindles in both sets of muscles. If you are actively moving a joint then each set of spindles will be sensitive and firing; the agonist spindles because of alpha and gamma coactivation keeping the agonist spindles on some degree of stretch, and the antagonist spindles because they are being passively stretched. If a joint is passively moved (as in exercise 1) then only one set of muscle spindles would be active, the spindles of the muscle that is being stretched. There would be no alpha/gamma coactivation (because the movement is passive), so there are no action potentials from the alpha and gamma motor neurons in the ventral horn of the spinal cord, the spindles of that muscle will be put on slack and will not be sensitive to muscle length.

Explanation to Instructors: These activities are very engaging as the students experience firsthand the effects inaccurate proprioceptive processing. The cerebellum interprets the repeated quick stretches supplied by the vibrator as sustained “stretch” (it is important to make it clear to the students that this is not a stretch reflex). The cerebellum thinks the vibrated muscle is longer than it is, and thus that the antagonist muscle is relatively more contracted than it is. This is true for all 3 exercises. This becomes apparent in Exercise 1 where the subject will not be accurate in matching their elbow positions while being vibrated (their matching arm is normally in a more extended position than the vibrated muscle). The mismatch is more obvious in the relatively more extended elbow positions, as there is some skin contact between the arm and forearm in the more flexed position that provides the CNS with proprioceptive input. The proprioceptive influence in static joint position is shown in Exercise 2, as the vibrator is applied to the triceps the finger will involuntarily move away from the nose. Again, this experience is very effective in demonstrating the role of proprioception in positioning of limbs in space. This is also a good time to discuss the significance of motor memory, as the student has to exert concentrated effort to touch their nose (the most common expression is of surprise as they feel like they are putting their finger into their skull). Lastly the standing balance activity, while slightly risky since some students react strongly and would fall to the ground if not caught by the spotters, is very effective at making it very clear that proprioceptive processing is going on continually while we are upright. There will be individual variability in the subject’s response to vibration, just as there is in almost all human behavior.

The exercises are wrapped up with a discussion about the importance and power of proprioception in the activities of daily living. This is a good time to bring up the roles of the visual system and vestibular system in posture and balance and how the loss of one system can often be compensated for if other systems are intact. This naturally transitions into a discussion of how individuals with certain disorders have impaired proprioception and how this loss can affect function.

Time for student to complete the activity: 1. preparation for activity outside of/before class: - 2. class time completion of the activity: 30 minutes

Readings/other preparatory materials: The students should have been introduced to muscle spindles, joint receptors, the stretch reflex, ascending sensory tracts and the cerebellum. One vibrator per 6-10 students is needed to make this an active experience; only 1 vibrator is needed if this experience is a demonstration. The vibrators should have a setting that vibrates at about 100 cycles per second, with a displacement of 2-3 mm (these settings are found on most vibrators in PT departments).

Learning Objectives: 1. Review the PNS structures that contribute to proprioception and draw/illustrate the route that this sensory modality takes as it moves from the periphery into the spinal cord, ascends in the spinal cord and terminates. Identify and name the receptors, the types of fibers, location of tracts in the white matter, and the point of decussation (where appropriate) and place of termination.

2. Review how muscle spindles contribute to standing balance and movement and contrast their function to the function of Golgi tendon organs. Distinguish which of these two types of sensory receptors are active during concentric, eccentric and isometric muscle contractions.

3. Construct a hypothesis to explain how the application of a vibrator to a muscle can result in the misinterpretation of body position and a decrease in the accuracy of limb placement. Compare the accuracy of the proprioceptive system with and without the input of a vibrator.

4. Generalize the above phenomenon to show how the application of a vibrator to the Achilles tendon can result in a loss of standing balance and distinguish these effects from vibrator stimulation to the dorsiflexor muscles.

Methods of evaluation of student learning: The final exam for this course includes a component of short answer questions. One of the questions on this exam is:

List the structures (receptors, tracts, brain area) that mediate the sense of proprioception and explain how vibration can disrupt proprioception.

\*For the student to get all the points on this question they must explain that the brain interprets sustained vibration to a muscle as stretch of that muscle (presumably via muscle spindle activation), and that the vibrator “fools” the cerebellum into thinking that the antagonist muscle is more contracted than it is. No credit is given if the student describes this as if it were a stretch reflex or if they cannot identify any of the relevant sensory receptors (muscle spindles), tracts (spinocerebellar tracts) and brain area (cerebellum).

References:

1. Goodwin GM, McCloskey DI,Matthews PBC. The contribution of muscle afferents to kinesthesia shown by vibration induced illusions of movement and by the effects of paralyzing joint afferents. *Brain.* 1972;95:705-748.

2. Keating JG, Martin TA, Fiez JA et al. Altered limb position sense by muscle vibration. Department of Anatomy and Neurobiology, Washington University School of Medicine, St. Louis, MO 63110. Derived from a motor systems laboratory for first year medical students at Washington University and an outreach program, *Hands on Neuroscience*.