Abbreviated Motor/Vestibular Lesson

Core Concepts

1) Your sense of balance is a sense, just like the traditional 5 senses
2) Your sense of balance combines with the rest of your senses to help you move in the world
3) The vestibular system controls balance in your body, letting you know what direction you are moving, and what direction down is
4) You can have vestibular illusions just like you have optical illusions

Materials

- Laptop or larger tablet
- Video file loaded on laptop
- ¾ full water bottle
- 5 pictures of vestibular system per group
- Electrical tape (to lay down on the floor)

Lesson Outline

Expected Lesson Time: 20 minute
Expected Class Size: 15-25 students

This lesson will feature a lot of discussion between the mentors and the students. At the end of this document, there is a sample script about how this discussion might proceed (**seriously, you might try reading that first to get the 'spirit' of the lesson**), but please improvise however you see fit. The following 4 activities should be done and discussed as they relate to the core concepts.

Demonstrations

1 - Image Stabilization

Show the accompanying video in this folder (https://drive.google.com/file/d/18YZPi67xy6DWqSxWBxEQNfdEJUDvw7QvJw/view?usp=sharing), and discuss what's wrong with it. It should be immediately obvious that the camera is shaky

from the recorder walking. However, this was recorded literally with the camera placed next to my eyes - it's what my eye's 'see' as I'm walking. Why don't we perceive this in our everyday lives? The vestibular system helps the brain automatically compensate for movement.

2 - Balance Stabilization

Have a student stand on their toes for 10 second. Once they succeed, have them stand on their toes, and, once stable, close their eyes. They should fall very quickly, or at least have a visibly hard time doing the task. Discuss how vision helps keep us steady - the brain integrates (puts together) information from multiple different sources without you being aware of it.

3 - Which way is down?

Have a student walk down a line on the floor normally. Follow this with having them look to the left and walking down the line. Finally, have them walk down the line while tilting their head to the left. This last one should have them veering in the leftward direction. The reason behind this is that only the last one changes your vestibular system's understanding of what down is. The motor network tries to take all this information in and correct your motions for it, even though your eyes can tell you that these corrections are wrong.

The water bottle example of the vestibular system is very useful for the explaining how your perception of down changes. Using a half full water bottle, rotate it along the y-axis (line perpendicular to the ground). The water will not flow, and in the case of the inner ear, this means that the hair cells will not have anything flowing across them and activating them. However, tilting the bottle will cause a flow of fluid. This will cause a change in the perception of what is down.

4 - To everything, turn, turn, turn

Note: this is a 'stretch' activity. If you end up with extra time, go ahead and use this. If the students are enjoying the question/answer moments, and are still asking relevant questions, then skip this exercise.

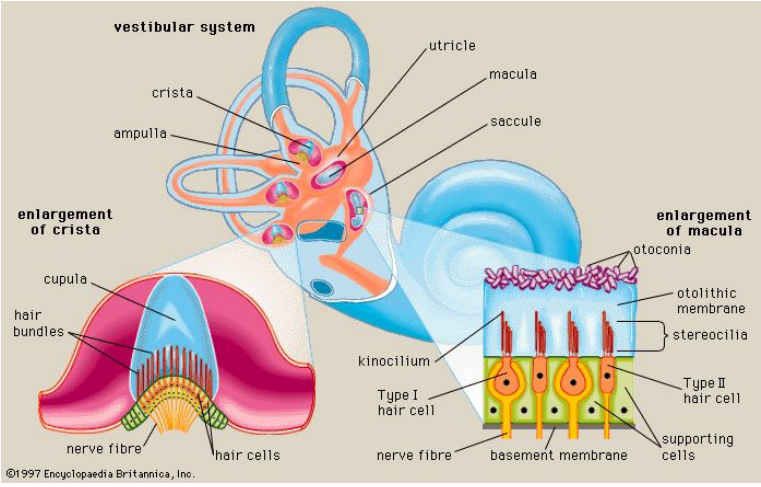
Have a student rotate 10 times, then stop. Have them describe what they are experiencing in as detailed a way as possible ("I'm dizzy" is not good enough). They will eventually tell you that they are feeling as if they are continuing to move in circles, even though they have stopped. This is a vestibular illusion, due to the fluid in the vestibular system continuing to rotate. This continues stimulating the hair cells in the inner ear, causing the feeling of rotational movement. It can be halted faster by rotating in the opposite direction.

To demonstrate what happens in the inner ear, lay the water bottle on its side and spin it. Even it will take a decent amount of time to stop spinning because of how fluid maintains momentum. The fluid in your ear keeps spinning in your ear, and thus triggering hair cells, That's why you still feel like you're spinning in the same direction.

How the Vestibular System Works - Teacher Edition

Function

The vestibular system is, functionally speaking, an accelerometer. It measures changes in acceleration that the body goes through. This is generally due to gravity (which exhibits a constant downward accelerational force on your entire body). However, acceleration is also generated during changes in velocity. These are the g-forces you feel on a rollercoaster, or whenever a plane changes direction. The brain uses both of these sources of information to make judgements about how the body has moved/should move through space. Sometimes, however, the brain makes a mistake a can confuse these two sources. The majority of aviation accidents are actually due to the brain poorly integrating accelerational and gravitional forces. While this is by no means required reading, the following link has some interesting categories of vestibular errors that pilots are trained to deal with (https://en.wikipedia.org/wiki/Sensory_illusions_in_aviation). Additionally, there is a nice mini-documentary on the same subject with some really helpful animations (https://www.youtube.com/watch?v=BQOxnUGpCE4). If you watch the video (not required), you will be vastly over prepared to teach the lesson.



Mechanism

Tight beside your ear drum, there is a series of 3 semi-circular canals that are perpendicular to one another (see figure right). These canals are lined with hairs, much like within the cochlear, and just like those hairs, they send electrical signals to the brain when they move. The fluid in the semicircular canals moves when rotational, accelerational, or gravitational forces are applied. The brain builds up a map of how these hairs respond to these forces, and makes inferences about what is happening to the body based on how these hairs move.

The electrical signals that are sent to the brain from the vestibular system have a massive amount of interconnectedness with the rest of the sensorimotor system. This means that, long before we are aware of our balance, the brain is taking the vestibular information and combining it with other sensory data to make up our representation of the world. The representation is not alway correct, hence the illusions we talk about in our demonstrations.

Sample Script

What are the 5 senses?

Allow for the group to shout out the answers

What if I told you that you have 6 senses? What's the 6th one?

You will get confused looks, then some people talking about ESP. Let them have fun for a second, then reign them back in.

What about your sense of balance? Is that a sense? What is it sensing?

Allow and encourage argument between individuals in the audience. Eventually push people to the correct answer if they don't come to it on their own.

Your sense of balance is, in fact, a sense. It lets you know when you are moving, and it lets you know which direction is down. We need it in our everyday life. Can anyone give me an example of what we use our sense of balance for?

Let them talk about sports and physical activities, then rein in.

These are all great answers, but let me show you something.

Show non stabilized video

What's wrong with the video?

Students answer

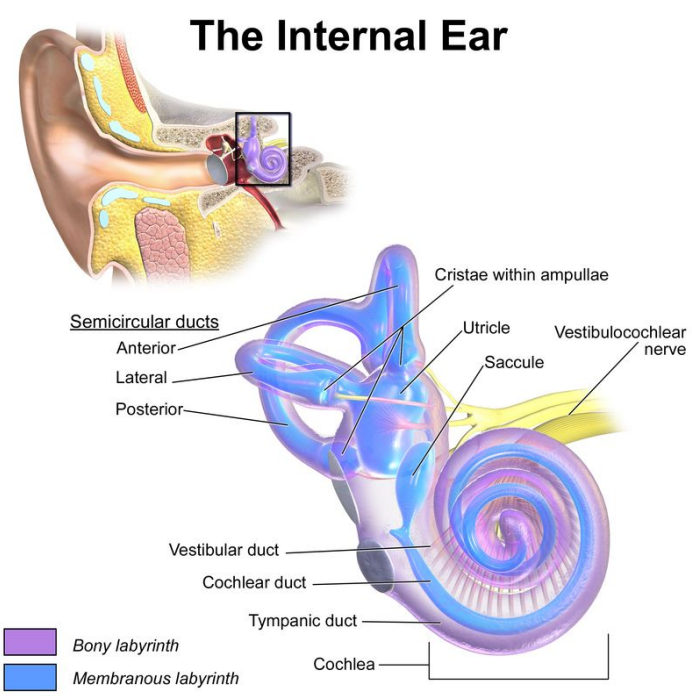
It's moving back and forth. It's not stable. But I promise you that all I did was walk down the hallway with my phone - I held it as stable as humanly possible. What happened? Well, we aren't very stable when we walk. This video is basically what's coming into our eyes every time we walk down the hall. What happens though is that our brain is smart enough to use our vestibular system - the vestibular system keeps track of the little movements that our head makes, and works with our visual system to show us what we should see, not what we actually see. Does that make sense?

Open floor for questions.

We can show a really strong connection in the other direction. Our vision helps out our vestibular/balance system greatly. Who here is really good at balancing?

Pick a volunteer, chat with them about why they think they have good balance.

Alright, I want you to come here and stand on your toes for ten seconds [Whistle the jeopardy theme]. Alright, now do it again. But try it with you eyes closed. [They will fall in about 10 seconds]. So your eyes and your vestibular system are connected. Your ability to see the environment gives you just a lot of cues about which way is down. Again, your brain is combining two of your senses (balance and vision) without you being aware of it.



So how does your vestibular system work?

Pass around printouts of the inner ear (see left). It will be ok if the elementary school kids don't get everything.

The inner ear works by having three fluid filled rings [point on your printout and hold up water bottle]. When you move a water bottle, the fluid follows gravity, right? [Invert bottle]. Just like in the bottle, when you change your position, the fluid in your ear moves due to gravity. This fluid moves across the small hairs in your inner ear, and they tell your brain that you are moving.

Of course, once your brain knows about which direction is down, it tells the rest of your body. As we showed, it's already talking to the vision part of your brain before you're even aware of it. It does the same thing with the part of the brain that helps you move. Can I get a volunteer for the next experiment?

Have them do the tape task with the 3 rotation

So the first two rotations were incredibly easy. Why was the 3rd one difficult?

Let the students discuss it. Guide them to the correct answer: we have changed the brain's perception of down, and the entire body is trying to compensate

The vestibular system can be tricked. By messing around with your balance, we can create vestibular illusions, just like we can create optical illusions. Can anyone describe an optical

illusion? [Wait for response] What we just did was a simple vestibular illusion. There are many others.

If there is time left

This one is one I'm sure you all have done, but I doubt anyone has paid much attention to it. Who here has spun in a circle for fun? [Wait for response] Can I get a brave volunteer to come up and demonstrate for me?

Have spin around 10 times, and describe the feeling and try to tie it back into the idea of the vestibular system. Be very careful to have them spin only 10 times, otherwise they might get sick - count it out, possibly with the group, depending on the engagement of the students.

It feels like you are still spinning, even though you aren't. This is a vestibular illusion. Can anyone explain why it feels like you're still spinning?

Guide to correct answer: the rings in your ear are circular. By spinning, you get the fluid in the rings to literally spin with you, and it takes a while to slow down.

Close out
What have we learned? How can we apply it in our everyday life? Any questions?

Burn down the time until everyone has to leave. If they run out of questions, have people compete to do the tape task