

Lesson Four: Neuroprostheses and Sensory Substitution
Center for Sensorimotor Neural Engineering
Lesson Plan Author: Phelana Pang



LESSON OVERVIEW

Activity Time: Two 50 minute periods.

Lesson Plan Summary:

Students will differentiate between and provide examples of assistive devices and neuroprosthetics. Students will explain the basics of sensory substitution.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- Assistive devices help people with a disability to function successfully (for example, a magnifying glass or a wheelchair).
- Neuroprosthetics are devices that connect the external stimuli to the brain for processing (ex: cochlear implant) or that read brain signals to result in action (ex: thought controlled movement of robotic arm).
- Sensory substitution allows the replacement of an impaired or missing sense by another, and is often processed by the part of the brain that normally processes information from the impaired sense (ex: visual cortex processes information from a tactile map of the visual field sensed on the tongue).

Essential Question:

- How might a neuroprosthetic assist someone who has an impaired or missing sense?

Learning Objectives:

Students will know...

- The difference between assistive devices and neuroprosthetics. Assistive devices help a person with a certain disability. A neuroprosthetic uses a brain-computer interface to assist a person with a sensory or motor disability.
- That certain neuroprosthetics can help a person with an impaired or missing sense through sensory substitution.

Students will be able to...

- Identify and explain why certain devices are classified as assistive devices or neuroprosthetics.
- Provide examples of sensory substitution devices and explain why they are classified as neuroprosthetics.

Vocabulary:

- Assistive device
- Neuroprosthetic
- Sensory substitution

Standards Alignment: This lesson addresses the following middle school Next Generation Science Standards (NGSS).

NGSS Middle School Disciplinary Core Ideas

- **MS-LS1.A: Structure and Function:** Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.
- **MS-LS1.D: Information Processing:** Each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

NGSS Cross-Cutting Concepts

- **Structure and Function**
- **Cause and Effect**

NGSS Science & Engineering Practices

- **SEP:** Obtaining, Evaluating, and Communicating Information

MATERIALS

Material	Description	Quantity
<i>Student Handout 4.1: Assistive Devices v. Neuroprosthetics & Sensory Substitution</i>	Used for defining and writing examples, taking notes on video, and brainstorming ideas	1 copy per student

TEACHER PREPARATION

1. Preview the videos, read articles, and search for more current articles on assistive devices, neuroprostheses, and sensory substitution.
2. Make copies of handouts.
3. Make copies of articles or have links to articles and videos pre-loaded onto your class website.

PROCEDURE

Engage: Warm-up (10 minutes)

1. Students can journal on the following warm-up questions:
 - a. What do you think an assistive device is? What might be some examples?
 - b. Is it possible for devices to be directly controlled by the brain? What might be some examples?

Explore and Explain: Neuroprosthetics and Sensory Substitution (60+ minutes)

2. Use *Student Handout 4.1: Assistive Devices v. Neuroprosthetics & Sensory Substitution* to guide students in understanding the difference between assistive devices and neuroprosthetics and to gain a basic understanding of a sensory substitution device. The following can be explored through a whole class discussion, jigsaw, stations, etc. depending on the level/structure/make-up/energy of the class. Resources are included here.
 - a. What are **assistive devices**? Come up with definition, reasons, and examples.
 - i. <https://www.nichd.nih.gov/health/topics/rehabtech/conditioninfo/Pages/device.aspx>
 - b. What are **neuroprosthetics**? Come up with definition, reasons, and examples. (use computer to project pictures from articles)
 - i. “Neuroprosthetics: Once more, with feeling”, *Nature*, May 8, 2013, <http://www.nature.com/news/neuroprosthetics-once-more-with-feeling-1.12938>
 - ii. “Bionic Senses: How Neuroprosthetics Restore Hearing and Sight”, Harvard Blog, March 16, 2013, <http://sitn.hms.harvard.edu/flash/2013/issue138a/>
 - iii. “Neuroprosthetics”, *The Scientist*, November 1, 2014, <http://www.the-scientist.com/?articles.view/articleNo/41324/title/Neuroprosthetics/>
 - iv. “The Mind-Controlled Prosthetic Arm with a Sense of Touch from Motherboard”, https://www.youtube.com/watch?v=F_brnKz_2tl&t=6s (11:28) – Please preview to determine if it is appropriate to show as there are graphic images of the patient’s injury in the first 3 minutes
 - c. Focus on **motor output**:
 - i. Brain Controlled Wheelchair (non-invasive) from Swiss Federal Institute of Technology, <https://www.youtube.com/watch?v=JyJj32MsAUo> (2:18)

- ii. Brain Controlled Robot Arm (invasive) from Keck Medicine of USC, https://www.youtube.com/watch?v=Izgeb_HDb48 (4:00)
- d. Focus on **sensory substitution**:
 - i. Articles on Sensory Substitution for blind people, <http://blogs.discovermagazine.com/crux/2014/04/28/blind-sight-the-next-generation-of-sensory-substitution-technology/#.VeeAmdRVhBd> and <http://www.newyorker.com/magazine/2017/05/15/seeing-with-your-tongue>

Elaborate and evaluate: TED Talk (20 minutes)

3. Watch David Eagleman TED talk, part 1.
 - a. <https://www.youtube.com/watch?v=4c1lqFXHvqI> (to 13:58 minutes)
4. As students watch the David Eagleman video, they can take notes and write down questions onto the second page of the handout. Discuss the questions in small groups or large group (time-permitting).
5. Connect the content to the design challenge introduced in the beginning of the unit. Students can start brainstorming ideas for sensory substitution devices (use bottom of handout to list).

STUDENT ASSESSMENT

Assessment Opportunities: Student knowledge, skills, and concepts for this lesson will be assessed in a number of ways.

- *Student Handout 4.1: Assistive Device v. Neuroprosthetic* can be used to check for definitions and examples.
- Class discussions can be used to check for general understanding.

Student Metacognition:

- Provide students opportunities to come up with questions, reflect on their initial ideas about what they know and understand, and write them down in their lab notebook. They can add new/changing ideas to their lab notebook.

Scoring Guide:

Teacher Resource 4.1 provides a scoring key for *Student Handout 4.1*.

EXTENSION ACTIVITIES

Extension Activities:

- Read more articles/watch more videos about different neuroprosthetic and sensory substitution devices. Learn more about Brain-Computer Interfaces (BCIs) to more directly understand how neuroprostheses communicate with the brain.

Adaptations:

- A shorter version of the David Eagleman VEST video and more guided questions specific to the video (instead of students taking notes) are provided on *Student Handout 4.2: Sensory Substitution Video and Questions*.
- Articles can be assigned for homework rather than read in class.

TEACHER BACKGROUND & RESOURCES

Background Information:

Review the resources provided for students and choose what is most appropriate with time constraints and student needs.

Resources:

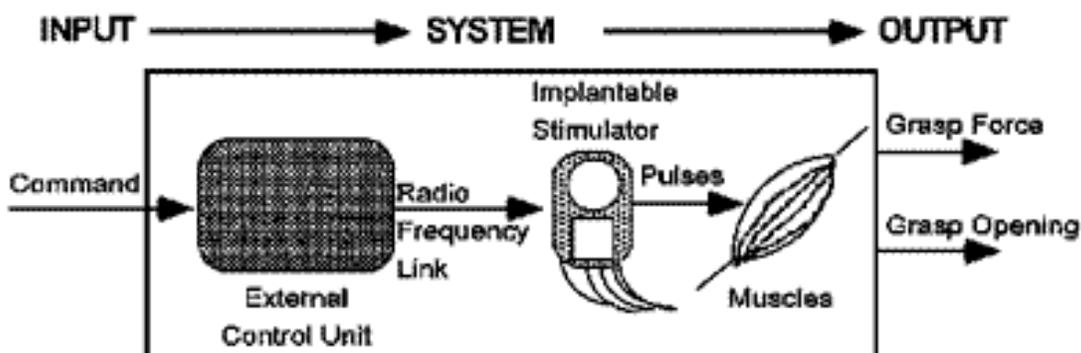
- **“Neuroprosthetics: Testing the Limits of the Brain”, The Aspen Institute**
 - <https://www.youtube.com/watch?v=CWBQyIOHomM>



Student Handout 4.1: Assistive Devices v. Neuroprosthetics

Name: _____ Date: _____ Period: _____

Definition	Examples
Assistive Device -	
Neuroprosthetic -	



<http://www.rehab.research.va.gov/jour/00/37/1/members.htm>

Sensory Substitution

Notes	Questions



<https://pixabay.com/en/toys-mr-potato-head-fun-happy-cute-488397/>

Brainstorm of Ideas for Sensory Substitution Devices

Impaired or Absent Sense	Substituting/ Replacement Sense	Description of Device



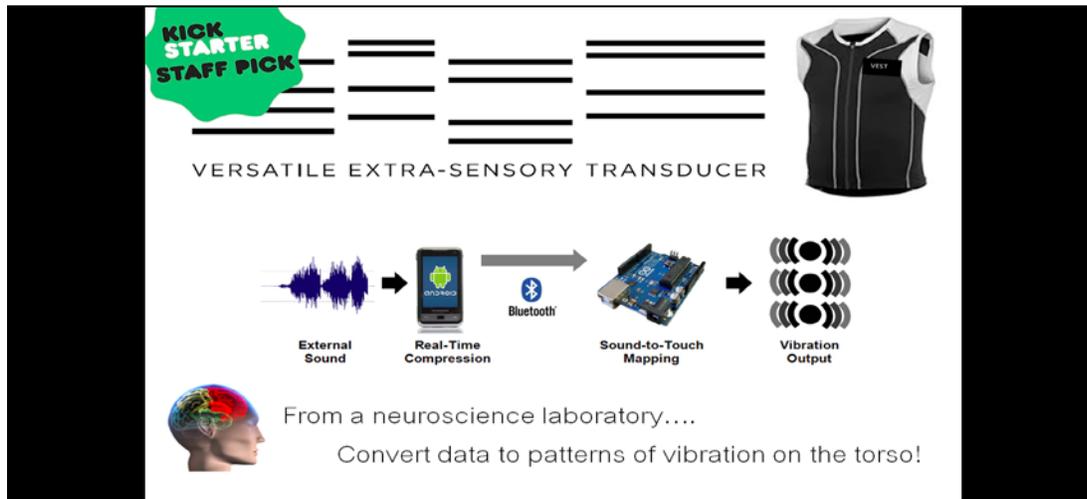
Student Handout 4.2: Sensory Substitution Video and Questions

Name: _____ Date: _____ Period: _____

The VEST by David Eagleman and Scott Novich

Watch this video: <https://www.youtube.com/watch?v=kbKzF8gKxT4> (3:13 minutes)

Background information: David Eagleman is a neuroscientist at Stanford. Scott Novich is his graduate student. Together they are working on VEST (Versatile Extra-Sensory Transducer).



Citation: From Kickstarter.org

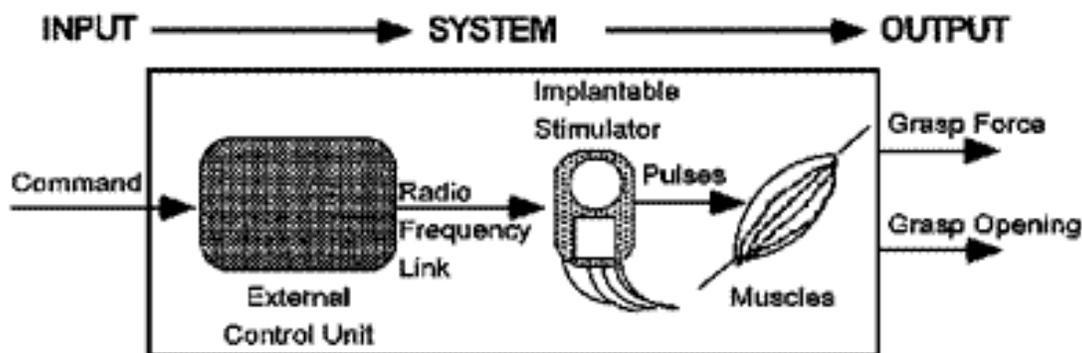
Questions to answer in your lab notebook as you watch the video:

1. What are the senses involved in the VEST?
2. What is the input of the VEST? What is used to process the information? What is the output?
3. Explain how this is an example of a sensory substitution device.
4. What are the advantages of this device over the cochlear implant?
5. What disadvantages can you imagine for this device?
6. Can you think of other sensory substitution devices that could be designed to do similar things?
7. Can you think of other senses for which you can design a sensory substitution device?



Teacher Resource 4.1: Assistive Devices v. Neuroprosthetics Answer Key

Definition	Examples
<p>Assistive Device - “Rehabilitative and assistive technology refers to tools, equipment, or products that can help a person with a disability to function successfully at school, home, work, and in the community.”</p> <p>from https://www.nichd.nih.gov/health/topics/rehabtech/Pages/default.aspx</p>	<ul style="list-style-type: none"> ● Wheelchairs ● Walkers ● Orthoprosthetics ● Hearing aids ● Glasses ● Computers ● Pencil Grippers ● Ramps ● Automatic doors
<p>Neuroprosthetic - “Neuroprostheses are devices that use electrodes to interface with the nervous system and aim to restore function that has been lost due to spinal cord injury (SCI). Neuroprostheses can restore some motor, sensory, and autonomic functions by stimulating various parts of the nervous system including muscles, nerves, spinal cord, or the brain”</p> <p>from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3758523/</p>	<ul style="list-style-type: none"> ● Cochlear implants ● Retinal implant ● Neuroprosthetic arm



<http://www.rehab.research.va.gov/jour/00/37/1/memberg.htm>

Sensory Substitution

Notes	Questions
<p>From TED Talk:</p> <ul style="list-style-type: none"> - Umwelt - reality created from what each organism can sense - We don't miss what we can't sense - Technology can expand our umwelt (therefore expanding what we experience as a human) - Brain figures out how to use electrochemical signals, extracting patterns, assigning meaning - Brain doesn't know where it gets the data from; whatever information comes in, it figures out what to do with it - Potato Head analogy - each of our senses is a peripheral plug and play device. Examples: heat pits in snakes, magnetite in birds, sensors for electrical fields, air compression in bats - Sensory substitution - feeding info to brain via unusual sensory channels, and brain figures out what to do with it - Examples: sonic glasses, electrotactile grid on forehead or tongue - From Eagleman lab, VEST provides perception of sound through vibratory motors on chest and back via processing by tablet which maps sounds 	



<https://pixabay.com/en/toys-mr-potato-head-fun-happy-cute-488397/>

Brainstorm of Ideas for Sensory Substitution Devices

Impaired or Absent Sense	Substituting/ Replacement Sense	Description of Device
Touch	Light	Light goes off if there's pressure on a part of body that can't sense touch
Sight	Sound	Different sounds made based on how close or big something is