COLUMBIA | Zuckerman Institute

BIOBUS

BRAIN STEM | Bringing Neuroscience to the Classroom

TOPIC 4

Neuroplasticity

Supported by: BNY MELLON

Neuroplasticity

In this topic students will explore an essential ability of the brain, termed 'neuroplasticity', the brain's ability to adapt to new experiences and respond to experience, learning or injury.

Suggested Duration

- 2 x 45 min classes

Essential Questions

- How does the brain change as we learn and experience new things?

Objectives

Overall STEM goal: The brain's structure is not fixed, it can change and adapt.

All students will...

- Be able to define the term neuroplasticity.
- Review and discuss research evidence that supports neuroplasticity.
- Participate in an experiment that illustrates the brain's rapid ability to adapt to changes in sensory input.

Advanced students will...

- Research the types of tools that can be used to study neuroplasticity.
- Understand how the visual and motor systems in the brain can make quick adjustments to changes in inputs received from our environment.
- Design their own experiment that illustrates the brain's plasticity.

Materials

- Visual distortion goggles (refer to 'Educator Resources' section for information on how to make goggles)
- Target (e.g. X mark with tape on floor)
- Bean bags

Supplementary materials

- Topic 4 activity sheet (level 1)
- Topic 4 activity sheet (level 2)
- Topic 4 exit ticket: 3-2-1

Prerequisite

Understanding of neural communication (refer to 'Topic 3: Neurons')

Instructional Activities

Class 1

1. Do Now | 5min

Give students five minutes to list as many things as they can think of that might affect or change the brain's structure and/or its functioning. Discuss their responses as a class, clarifying any misconceptions. Follow by discussing with students some of the key points below.

KEY POINTS

- Neuroplasticity is the term used to describe the brain's ability to change its structure as we learn new things and respond to experiences in our environment.
- Our brain is like a muscle that can be exercised.
- A number of things cause changes in our brain, including learning a new skill (such as playing an instrument), physical injuries, drugs and other substances, stress or trauma. Therefore, our brain is forming new connections all the time.
- Other examples of research demonstrating activities that affect or change our brain include: sleeping has a positive impact on our ability to consolidate our memories (Stickgold, 2005); physical exercise has been shown to be related to improved learning ability and mental performance (Cotman & Berchtold, 2002); practicing meditation can improve attention (Tang et al., 2007) and decrease anxiety (Beauchemin, Hutchings, & Patterson, 2008); training our memory through repetition when learning new things helps us recall things better in the future (Hintzman, 1976).

2. Think Pair Share | 5min

Show students the 2-minute video on Neuroplasticity (by Sentis).

After the video, ask students to think about what they know about how neurons communicate and participate in a think pair share, generating and sharing thoughts and ideas on:

- *Now that you know how neurons communicate, how might plasticity occur at the cellular level?*
- *What happens to our neural connections when we develop habits or when we learn something new?*

After students have discussed these questions in pairs, ask them to share their thoughts with the class.

KEY POINT

Neuroplasticity in the brain can occur in different ways, such as through changes in the number of neurons, changes in the number of dendrites in neurons, changes in the number of connections between neurons, or changes in the rate at which neurons fire.

3. Analyzing Research | 20min

Show students the video (by National Geographic) about the London cab drivers research conducted at University College London (or select another video from the student resources section).

Write the following questions on the board and instruct students to take notes answering these questions while watching the video:

- What are the research questions?
- What was the hypothesis?
- What were the research methods used?
- What were the results?
- Did the results support the hypothesis?

- How is this research evidence of neuroplasticity?
- How is neuroplasticity related to learning and memory?
- What are some of the limitations of this research?

After watching the video, divide students into groups of 3-5 (depending on class size) and instruct students to discuss their individual responses in their groups.

EXTENSIONS

- Assign groups resources from the student resources section (page 7). Instruct students to use the resources to research the above questions forward.

For differentiation, you can select which student reviews which resource or you can let students choose for themselves.

- Ask students to prepare graphic organizers or Powerpoint slides with their research.

Ask groups to share their responses with the class and generate a class discussion.

NOTE: Connect neuroplasticity to learning and memory, highlighting how neuroplasticity occurred as taxi drivers learned and memorized new information.

---

4. Exit Ticket | 5min

Refer to "Exit ticket: 3-2-1"

- What are three things you learned today?
- What are two things you found interesting?
- What is one further question you have?

BACKGROUND

In this research, conducted at University College London, neuroscientists investigated the brains of London cab drivers (Maguire, Woollett, & Spiers, 2006). Before being given the cab license, drivers must take "the Knowledge", an exam that asks students to memorize the location of all streets, routes and landmark locations (e.g. museums, hospitals, theaters) in central London.

Researchers compared the brain of the cab drivers before and after studying for the exam (which can take up to four years). They also compared brain scans with those of participants who did not study for the exam.

Results showed that a brain region called the Hippocampus was significantly larger in the brains of London cab drivers who studied and passed the exam, compared to those who did not study the exam (and the size of the hippocampus increased with number of years in career). They also found that the size of the hippocampus shrinks back to normal size after the drivers retire. The hippocampus is known for its role in memory and spatial awareness, skills that are heavily trained during "the Knowledge". Researchers cannot confirm why or how the brain changed exactly, only that the overall size of the brain areas increased. Researchers suggest that changes could be seen as increases in dendritic size formation, with neurons having increased numbers of dendrites, therefore capacity to catch more neurotransmitters.

This research changed our understanding of the brain as being fixed in size and shape, and demonstrated its neuroplasticity.

Class 2

5. Do Now | 5min

Show students the video on the experiment by Smarter Every Day. In this challenge, Destin Sandlin research's by testing himself how long it can take to learn to ride a "different" bike and then un-learn it again. Destin explores these questions, thinking about: "Is it true that we never forget how to ride a bicycle?" Discuss the video with the class.

Prompt students to think about what this example might tell us about neuroplasticity.

6. Class Experiment | 30min

Use Topic 4 activity sheet (level 1 or 2)

Students will design and/or participate in an experiment that demonstrates the brain's capacity to adapt to changes in our environment. Divide students in groups of 3-5 students (depending on class size and available goggles - you will need at least one pair of goggles per group). Distribute activity sheets and give students time to read. Allow time for questions and clarifications before starting.

NOTE: There are two levels to choose from for this activity. Level 1 is a guided inquiry activity. Level 2 is a free inquiry activity and more advanced.

ALTERNATIVE

If you don't have access to multiple goggles, this activity can also be done as a class fishbowl activity, with some students being volunteer participants and performing the experiment in the front of the class, and the rest of the class is observing, collecting data and talking through the method, their observations and the results.

BACKGROUND:

VISUAL DISTORTION GOGGLES

The visual distortion goggles experiment conducted in this class demonstrates how our brain can adapt quickly to changes in sensory information inputs it receives.

Our brain receives sensory information on the targets' location and uses a combination of visual and motor information to coordinate the throw. Reflected light from target reaches the eye and sends signals to the brain, forming a visual perception of the target. The visual distortion goggles distort our vision, changing the angle at which we perceive objects in space. When the goggles are placed, the prism changes the light signals reaching the eye, showing us a different location of the target. Once we try to hit the target and perceive that the visual input was incorrect, our brain collates this new information, adapting and reconfiguring itself.

Improvements in hits over time shows how our brains adapt quickly to changes in our environment. The brain relies on a process called "sensorimotor feedback" - the information input (or feedback) that it receives from our senses and movement actions. Our visual system and motor systems work together in the brain to coordinate our movements, and with the help of our cerebellum, we can correct movements quickly using this feedback mechanism.

This experiment also demonstrates how we rely on the brain to make sense of what are eyes are seeing. Therefore to see we need our brains, not just our eyes.

The structures and systems of the nervous system most involved during this task include:

- The cerebellum, involved in motor control and spatial activities, is helping us (using of sensory-motor information) make a map the visual world when visual perception is interrupted or modified.
- The visual system is processing and making sense of visual information (i.e. light information received through the eye), building a representation of our environments. Most visual information is processed in the occipital lobe.
- The motor system, including the primary motor cortex (located in the frontal lobe) and the spinal cord, are also involved in this task, responsible for our body's movements.

In **level 1**, students will participate in a designed experiment, following the instructions on the activity sheet. Explain to students what the goggles do (i.e. they distort our vision, changing the angle at which we perceive objects in space - refer to background section). Before writing their hypothesis, ensure students try out the goggles first to understand how they work. Instruct students to collect and analyze data.

In **level 2**, students will be asked to design their own experiments using the visual distortion goggles. Again, explain to students what the goggles do. Instruct students to have a go using the goggles first to observe what is happening, and design an experiment off that observation. Explain to students that their experiment design should be based on the question: *how doest the brain adapt to the use of visual distortion goggles?*

Ask groups to share with you their methods, and independent and dependent variables, before they start collecting data.

NOTE: In level 2, a third class may be needed for students to continue their design, research, data analysis and conclusions.

7. Class Reflection | 10min

Give time for groups to reflect on their findings and fill in the questions at the end of the activity sheet. To evaluate understanding, collect group activity sheets at the end of class or for individual evaluation, ask each student to fill out an activity sheet.

End the class with a group discussion, where groups share their results and conclusions. Discuss some of the key understandings highlighted in the background box below.

EXTENSIONS

- For level 2, you can plan a third class and ask groups to prepare presentations and share their research designs and findings with the class.
- Conduct another learning and memory activity with the class: mirror-tracing. Students can try this activity to observe how performance improves over time.
- Students are prompted to research what the sensitive periods of brain development are, when neuroplasticity is enhanced.

Resources for Students

FIRST LEVEL	London cab driver experiment (videos)	https://www.youtube.com/watch?v=LgadsPxYlkM https://video.nationalgeographic.com/video/london-taxi-sci (National Geographic) https://www.youtube.com/watch?v=Gimj3xgf0Fo (News report)
	London cab drivers experiment (article)	https://blog.nationalgeographic.org/2013/05/29/the-bigger-brains-of-london-taxi-drivers/
	Neuroplasticity (video by Sentis)	https://vimeo.com/234715084
MEDIUM LEVEL	London cab driver experiment (video)	https://vimeo.com/34715084
	Discover Magazine (article)	http://blogs.discovermagazine.com/notrocketscience/2011/12/08/acquiring-the-knowledge-changes-the-brains-of-london-cab-drivers/#.W_2WlpNKhE4
	Wellcome Trust (article)	https://wellcome.ac.uk/press-release/changes-london-taxi-drivers-brains-driven-acquiring-%E2%80%98-knowledge-study-shows
	BBC News article	https://www.bbc.com/news/health-16086233
	Neuroplasticity (Neuroscience for Kids)	https://faculty.washington.edu/chudler/plast.html
ADVANCED LEVEL	London taxi drivers and bus drivers: A structural MRI and neuropsychological analysis (Hippocampus science journal)	https://onlinelibrary.wiley.com/doi/abs/10.1002/hipo.20233
	Navigation-related structural change in the hippocampi of taxi drivers. (PNAS science journal)	www.ncbi.nlm.nih.gov/pubmed/10716738

Resources for Educators

Background Reading	
Book article: The Teenage Brain, F. Jensen.	http://www.dana.org/Cerebrum/2015/Review__The_Teenage_Brain/
Visual Distortion goggles (by Exploratorium)	https://www.exploratorium.edu/snacks/distortion-goggles
TED talk by Carol Dweck on the 'Growth Mindset'	https://www.youtube.com/watch?time_continue=20&v=_X0mgOOSpLU
Brain Facts (video) on Neuroplasticity	https://www.brainfacts.org/archives/2011/neuroplasticity
TED talk by Dr. Lara Boyd on Neuroplasticity	https://www.youtube.com/watch?v=LNHBMFCzznE
Scientific American (article) on Intelligence and brain size	https://www.scientificamerican.com/article/does-brain-size-matter/
Smarter Every day (video)	https://vimeo.com/157192392
Educational Activities	
Scholastic: Wiring your brain	http://headsup.scholastic.com/sites/default/files/NIDA12-INS2_TE.pdf
BioInteractive: Mirror Tracing	https://www.hhmi.org/biointeractive/classroom-activities-mirror-tracing-activity

Resources for Educators

Educational Activities	
Making 'visual distortion goggles'	Purchase affordable goggles: https://www.amazon.com/gp/product/B01IPV4B0A/ref=od_aui_detailpages00?ie=UTF8&psc=1 Purchase lens paper (1 sheet for 2 goggles): https://www.amazon.com/gp/product/B01HDSLBRC/ref=od_aui_detailpages00?ie=UTF8&psc=1 Cut out shapes from the paper and tape it to the goggles. Make sure that when you cut out shapes to tape onto the goggles that the lines are as parallel as possible. You won't be able to use every part of the paper. Then make sure they are tilted in the same direction (if you look at it from the side you can see the angle of the ridges). You can test them before taping it by looking through the goggles.

Vocabulary

Dependent variable	The variable being tested or measured in a scientific research experiment, dependent on the independent variable.
Hypothesis	In science, a hypothesis is a prediction or explanation that can be tested through experimentation and scientific methods.
Independent variable	In scientific research, the independent variable is the variable being changed or controlled to test its effects on the dependent variable.
Neuroplasticity	The ability of the brain to modify its neural connections to adapt to challenges in the environment.
Sensorimotor feedback	The information input (or feedback) that the brain receives from our senses and movements.

Standards

CONTENT SPECIFIC CURRICULUM STANDARDS	Developing and Using Models Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information
NEXT GENERATION SCIENCE STANDARDS (NGSS)	Life Sciences: HS-LS1-2: From Molecules to Organisms: Structures and Processes Crosscutting concepts: HS-LS1-1 HS-LS1-3 HS-LS1-4
COMMON CORE STATE STANDARDS	CCSS.ELA-LITERACY: RST.9-10.3 CCSS.ELA-LITERACY: RST.9-10.4 CCSS.ELA-LITERACY: RST.11-12.7 CCSS.ELA-LITERACY: RST. 11-12.9 CCSS.ELA-LITERACY: SL.9-10.1 CCSS.ELA-LITERACY: SL.9.-10.5 CCSS.ELA-LITERACY: SL.11-12.1

Credits and Sources

BrainFacts.org

Brain Facts Glossary: https://www.brainfacts.org/glossary

National Geographic

Scientific American

Sentis Digital: https://www.youtube.com/user/SentisDigital

Smarter Every Day: http://www.smartereveryday.com

Journals:

Beauchemin, J., Hutchins, T. L., & Patterson, F. (2008). Mindfulness meditation may lessen anxiety, promote social skills, and improve academic performance among adolescents with learning disabilities. *Complementary Health Practice Review, 13(1), 34-45.*

Cotman, C. W., & Berchtold, N. C. (2002). Exercise: a behavioral intervention to enhance brain health and plasticity. *Trends in Neurosciences, Vol. 25, No. g, 295- 301.*

Hintzman, D. L. (1976). Repetition and memory. *In Psychology of learning and motivation, Vol. 10, pp. 47-91.* Academic Press.

Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature, Vol. 437, 1272-1278.*

Maguire, E. A., Woollett, K., & Spiers, H. J. (2006). London taxi drivers and bus drivers: a structural MRI and neuropsychological analysis. *Hippocampus, 16(12), 1091-1101.*

Tang, Y. Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., ... & Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences, 104(43), 17152-17156.*

Acknowledgements

Francesca Anselmi

Alice Cardoso

Paula Croxson

Teacher Council 2018:

William Bertolotti

Jennifer Dahlstrom

Vince Joralemon

Vanessa Keen

Bonnie Lestz

Arlene Ramos

Deborah Reich

Charon Sioson