CHAPTER 2: NEUROSCIENCE AS A BASIS FOR ADULT DEVELOPMENT AND AGING

Chapter Outline

The chapter describes how a surge in neuroscience research is greatly increasing our understanding of the brain. This may be because of numerous technological advances, such as the development of functional magnetic resonance imaging (*f*MRI). Because of these advances, we can now examine the links between brain function and behavior in living beings. Neuroscientific approaches are being applied to research that deals with both cognitive and social-emotional aging.

I) THE NEUROSCIENCE APPROACH
- A) Neuroimaging Techniques
  - 1) Structural neuroimaging provides highly detailed images of anatomical features of the brain
    - (a) X-rays
    - (b) Computerized tomography (CT)
    - (c) Magnetic resonance imaging (MRI)
  - 2) Functional neuroimaging provides an indication of brain activity but not high anatomical detail
    - (a) Single photon emission computerized tomography (SPECT)
    - (b) Positron emission tomography (PET)
    - (c) Functional magnetic resonance imaging (*f*MRI)
    - (d) Magnetoencephalography
    - (e) Near infrared spectroscopic imaging (NIRSI)
- B) Neuroscience Perspectives
  - 1) Three general methodological perspectives
    - (a) Neuropsychological approach
      - (i) Compares brain functioning of healthy older adults with adults displaying various pathological disorders in the brain
    - (b) Neurocorrelational approach
      - (i) Attempts to link measures of cognitive performance to measures of brain structure or functioning
    - (c) Activation imaging approach
      - (i) Attempts to directly link functional brain activity with cognitive behavioral data
      - (ii) Compensatory changes
        - Differential activation in younger and older adult brains may provide neurological evidence that older adults undergo changes
        - Allow them to adapt to the inevitable decline of specific areas of the brain

II) NEUROSCIENCE AND COGNITIVE AGING
- A) How Is the Brain Organized?
  - 1) The brain is made up of cells called neurons
    - (a) Neurons include dendrites, the axon, neurofibers, and the terminal branches
    - (b) The terminal branches release neurotransmitters across the synapse
  - 2) The study of the structure of the brain is called neuroanatomy

(a) The brain includes the cerebral cortex, the corpus callosum, the prefrontal and frontal cortex that are involved in executive functions, the cerebellum, the hippocampus, the limbic system, and the amygdala

B) What Age-Related Changes Occur in Neurons?
1) The number of neurons in the brain declines
2) The size and number of dendrites decrease
3) Also, tangles occur in the fibers of the axon, and proteins become deposited
4) The number of synapses decreases
5) These changes occur in greater numbers in diseases such as Alzheimer's disease

C) What Age-Related Changes Occur in Neurotransmitters?
1) Dopamine
2) Dopaminergic system is associated with higher-level cognitive functioning like inhibiting thoughts, attention, and planning
   (a) Clear evidence that effective functioning of the dopaminergic system declines in normal aging
   (b) Related to declines in episodic memory and speed tasks
   (c) Age-related deficits are greater in effortful cognitive tasks than automatic cognitive tasks
3) Other neurotransmitters
   (a) Serotonin
      (i) Abnormal processing of serotonin has been shown to be related to cognitive decline
   (b) Acetylcholine
      (i) Damage to structures that use acetylcholine is associated with memory declines

D) What Age-Related Changes Occur in Brain Structures?
1) Considerable shrinkage occurs in the aging brain
   (a) The atrophy is selective
      (i) Cerebral cortex, hippocampus, and the cerebellum show profound atrophy
      (ii) Areas associated with sensory functions show little shrinkage
2) White matter is nerves covered by myelin
   (a) White matter hyperintensities (WPH) are determined by the observation of high signal intensity or a bright spotty appearance on images, which indicates brain pathologies
3) Diffusion tensor imaging (DTI) assesses the rate and direction that water diffuses through the white matter
   (a) Results in an index of the structural health of white matter
      (i) Deterioration of white matter may represent a cause of increased dysfunction in the prefrontal cortex in older adults
   (b) WMH are linked to cerebrovascular disease, for example, hypertension, which is preventable and can be treated with medication and changes in lifestyles

E) What Do Structural Brain Changes Mean? The Theory of Mind (ToM)
1) ToM is the ability to understand that others have beliefs, desires, and viewpoints different from our own
   (a) Research shows age-related decline in ToM
2) Linking structural changes with executive functioning
   (a) Difficulty focusing solely on relevant information
   (b) Due to WMH and reduced volume of prefrontal cortex
3) Linking structural changes with memory
   (a) Specific structural changes (e.g., the hippocampus) result in memory decline
4) Linking structural changes with emotion

(a) Increased processing of positive emotional information with age
(b) Better emotion regulation with age
(c) Age-related increase in connections between prefrontal cortex and medial temporal cortex
(i) May show greater need for more connections to process information

5) Linking structural changes with social-emotional cognition
(a) Older adults may rely more on automatic judgment processes than reflective processing

6) Complex development in the prefrontal cortex
(a) The Positivity Effect: Older adults are more motivated to derive emotional meaning from life and to maintain positive feelings than younger adults
(b) Older adults show increased activity in the middle portion of the prefrontal cortex, the amygdala, and the cingulate cortex, bringing additional areas of the brain into play

III) MAKING SENSE OF NEUROSCIENCE RESEARCH: EXPLAINING CHANGES IN BRAIN-BEHAVIOR RELATIONS

A) The Parieto-Frontal Integration Theory
1) Also known as P-FIT
2) Proposes that intelligence comes from a distributed and integrated network of neurons in the parietal and frontal areas of the brain

B) Can Older Adults Compensate for Brain Changes?
1) Studies show that, when presented with similar tasks, younger adults exhibit focal, unilateral activity in the left prefrontal region, and older adults exhibit bilateral activity (both left and right prefrontal areas)
2) It appears older adults are compensating
(a) Research separating cognitive processes found consistent patterns in the brain activity in younger and older adults challenging the conventional view of broader activation as compensation
3) Bilateral activation in older adults plays a supportive role in older adults' cognitive function

C) Models of Brain-Activation and Changing
1) HAROLD (hemispheric asymmetry reduction in older adults)
(a) Suggests bilaterality is compensatory in older adults with reduced cognitive ability
2) CRUNCH (compensation-related utilization of neural circuits hypothesis)
(a) Similar to HAROLD but suggests additional mechanisms at work of aging brains over-utilizing other regions in the left hemisphere on demanding tasks before going to the right hemisphere
3) PASA (posterior-anterior shift in aging)
(a) An age-related reduction in brain activity in the back of the brain and an increase in the front of the brain
4) STAC-r (scaffolding theory of cognitive age-revised)
(a) Default network theory holds that when the cognitive demands are made on the brain, the default network is suppressed
(b) Older adults display less suppression of the default network suggesting a greater dependence on the default network results in less efficient, focused neural activity
(c) Neural resource enrichment and depletion interact with neural plasticity to account for age-related changes in cognitive functioning

IV) NEURAL PLASTICITY AND THE AGING BRAIN

A) Plasticity involves the interaction between the brain and the environment and is mostly used to describe the effects of experience on the structure and functions of the neural system
B) Neural stem cells give rise to new neurons, persist in adult brains, and can generate new cells throughout adulthood
C) Exercise and Brain Aging
    1) Brain plasticity is enhanced by aerobic exercise
D) Nutrition and Brain Aging
    1) Researchers are beginning to understand the relations between categories of nutrients and brain structures

Going Beyond the Book and Lecture Suggestions

1. Students are generally interested in neuroimaging. If possible, bring in examples of CT, MRI, and PET scans. The Whole Brain Atlas is a very good site that contains this type of information (www.med.harvard.edu/AANLIB/home.html).
2. Provide examples of research that uses each of the neuroimaging techniques. Discuss how the researchers conducted the research, what they found, and the implications for older adults. If the journal article includes images from the neuroimaging, present those to the class.
3. Interview an older relative about the strategies that he or she uses to remember information.
4. Older adults are concerned about their memory and will usually go to great lengths to improve it. Design a memory intervention for older adults. What types of tips would you give the older adults to use on their own?
5. Pose the following questions to your students to spur class discussion: After taking this course, you seek employment as an activity director at a retirement community for individuals who are living independently. You realize that a key factor in maintaining cognitive functioning is to engage in cognitively stimulating activities focusing on cognitive abilities and memory. What types of activities would you plan for the residents? Describe why each activity was selected and why it should stimulate memory.
6. Pose the following questions to your students to spur class discussion: While working at a retirement community, you have been asked to give a talk to the residents on memory in older adults and techniques for improving memory performance. What would you say?
7. If the students in the course are primarily from health-related majors, or have a strong interest in physiology, you could emphasize additional body and organ systems. Some that could be covered are the endocrine system, the gastrointestinal system, and the immune system.
8. Testing the memory of older adults can be quite difficult. Have students create a test that would accurately represent the memory abilities of older adults.
9. As a class, create an overview on the board of all of the normative age-related brain changes a person can be expected to experience over time. After compiling the information, step back and ask the students to brainstorm ways to psychologically prepare for these changes.
10. Provide more detail on the neuronal network and information loss theories. Walk students through the advantages and disadvantages of each.
11. There are several theoretical perspectives related to cognitive aging, such as failure to inhibit, generalized slowing, and reduced capacity. Describe the assumptions of these theories and illustrate why they are reasonable explanations of normative age-related changes in memory.
10. Discuss issues related to testing older adults' memory in a laboratory setting, such as task relevancy, speed, and motivation and how these could influence memory performance.

Discussion Questions

1. As a society, we seem to place brain research in high regard. In what ways is this sentiment positive for science and the care of humans, and in what ways might this be negative? Does neuroscience always hold the "best" answers?
2. What is the difference between normal cognitive and abnormal cognitive aging?
3. Human factors psychologists are constantly inventing better human and machine interface systems. What kinds of new devices to assist the aging do you think might be generated in the next 25 years? Is there any type of device you see yourself needing later in your life?
4. If laboratory performance in older adults is so poor, how do they cope so well in everyday life?

5. Typically, the respected leaders of our society are older and hopefully wise. There are even minimum age requirements placed on holding various public offices. Point out these age requirements and discuss if there should be maximum ages. If you can locate the ages of senators and congressmen, point out the most senior members. What about a president in his or her mid- to late 70s?
6. If you were teaching a group of older adults, what changes might you make to ensure that your class information was presented in the most efficient and effective manner?
7. In a world without financial boundaries, what changes could be made at a societal level to improve brain functioning for older adults? Should these changes actually be instituted?

Suggested Activities and Assignments

1. Search the science daily website to enhance the newly acquired knowledge on brain and memory. http://www.sciencedaily.com/articles/mind_brain/memory
2. Have the students visit http://www.pbs.org/wgbh/nova/body/epigenetic-therapy.html and read about epigenetic therapy. How does our stem cells and genetics relate to aging?
3. Students can examine firsthand normal and pathological neurological aging by using the World Wide Web. Some sites that provide descriptions and graphics of abnormal neurological changes include Alzheimer's site www.alz.org and the National Institute of Aging site www.nia.nih.gov.
4. Stroop Color Word Task (www.pbs.org/wgbh/nova/everest/exposure/stroopintro.html): At this site, sponsored by NOVA, students can take the Stroop color word task and other neuropsychological tests.
5. Investigate potential cross-cultural related changes in the aging brain by reading the article "Does Wisdom Really Come with Age? It Depends on the Culture" found at: http://www.psychologicalscience.org/news/releases/does-wisdom-really-come-with-age-it-depends-on-the-culture.html#.WTxNB7pFyFs. After students read the article, divide them into two groups, eastern and western cultures, and have them describe the similarities and differences from their assigned cultural perspective.
6. How do these compare with the United States? Why?
7. Have students visit http://www.pbs.org/wgbh/nova/musicminds/ask.html and read the questions and answers from ask the expert. What is their opinion on the effects of music and the brain?
8. Have students design a brief environmental intervention to prevent minor memory loss.
9. Conduct an interview with middle-aged and older adults to see if they notice changes in their memory. Have the adults describe the psychological consequences of noticing that their memory is not as good as it used to be.
10. This chapter points out many cognitive changes encountered by older adults. Think about some of the technology devices or products that you use in everyday life. Are these devices or products designed for younger adults or older adults? What characteristics of these products support your position? What modifications could you make to this product to be more appropriate for older adults?
11. Have students visit the Neuroscience for Kids page (http://faculty.washington.edu/chudler/neurok.html). Although it is intended for a slightly younger audience (K-12), its many educational activities can help anyone gain a better understanding of neuroscience and the brain. Ask your students to choose three of the experiments or articles (listed under "explore") and report back to the class about what they learned.
12. Ask students to choose a recent article listed on the neuroscience page of *The Guardian* (http://www.theguardian.com/science/neuroscience) and write a two-page report about the research discussed, including a summary, their thoughts on the validity and value of the research, and the research's connections to aging adults and Chapter 2. Students could also report back to the class orally.

Suggested Websites

1) Neurosciences website (http://www.nsi.edu/): This site contains a vast amount of information on neuroscience, research, collaborations, and publications.
2) Frontiers in Neuroscience (http://frontiersin.org/neuroscience/): The Frontiers in Neuroscience website provides information on a variety of aspects of aging and neuroscience. It also relays information about recent research and reviews.
3) Society for Neuroscience (http://www.sfn.org/): The Society for Neuroscience is the world's largest organization of neuroscientists and other professionals who work with the brain and spinal cord. On this site you can learn about the latest news, research, and public outreach efforts related to neuroscience.
4) Neuroscience Updates from *The Guardian* (http://www.theguardian.com/science/neuroscience): Learn about the latest developments related to neuroscience by visiting this site by the news publication *The Guardian*. The page also includes continually updated commentary about neuroscience.
5) Human Connectome Project (http://www.humanconnectomeproject.org/): This site contains images and activities for exploring the structure of the brain and interpreting activity within the brain.

Additional Suggested Readings

Have your students read the following articles and use the questions listed for each article either to stimulate in-class discussion or on an exam.

Ball, K., Berch, D., & Helmers, K. (2003). Cognitive training may improve targeted cognitive functions in older adults. *Evidence-Based Mental Health, 6*, 54–55. A101942851 http://ebmh.bmj.com/content/6/2/54

This brief article discusses cognitive training interventions for older adults. The intervention consisted of 10 sessions of either memory (verbal episodic memory), reasoning, or speed of processing training. There were also booster sessions. Prior to the sessions, adults were evaluated on a variety of tests of cognitive function and everyday functioning, then again just after completion of the program, and once again 2 years later. Results indicated that all three training interventions improved the targeted cognitive abilities compared to baseline, after treatment, and also at 2 years. Interestingly, the memory group showed the small percentage of adults showing improvement (26%) when compared to the reasoning group (74%) and the speed of processing group (87%). However, at 2 years, there was no improvement in everyday functioning.

- While all interventions were effective, why do you think the memory training had the smallest effect?
- Why do you think there was improvement in cognitive skills but not in everyday functioning?
- Do you think if the intervention programs were aligned with specific everyday activities that you would find a relationship between improved cognitive skills and improved daily functioning?

Pierce, J. D., Cackler, A. B., & Arnett, M. G. (2004). Why should you care about free radicals? *RN, 67*, 38–42. A112862262
http://www.modernmedicine.com/modern-medicine/news/why-should-you-care-about-free-radicals

This article, written to inform healthcare professionals, discusses the impact and the effects of free radicals on the aging process. This article also includes a quiz at the end that can be used to check comprehension.

- What are free radicals and how do they form?
- What diseases have free radicals been linked to?
- How do antioxidants work to reduce free radical damage?
- What are some common antioxidants?

Rizio A. A., & Dennis N. A. (2014). The cognitive control of memory: Age differences in the neural correlates of successful remembering and intentional forgetting. *PLoS ONE 9*(1): e87010. https://doi.org/10.1371/journal.pone.0087010

This article discusses differences between older and younger adults regarding intentional encoding and intentional forgetting via inhibition What are the main findings regarding attention found in previous research outlined in the introduction?

- Describe the procedure used in the study outlined in the article.
- What is the Kucera-Francis written frequency?
- Describe the basic findings of the study.
- How could the conclusions of the researchers be challenged based on the nature of the task of remembering words?

Hughes, V. (2013, March). How neuroscience will fight five age-old afflictions. *Popular Science*. http://www.popsci.com/science/article/2013-02/how-neuroscience-will-fight-five-age-old-afflictions

This article discusses cutting-edge techniques that may battle seizures, dementia, blindness, paralysis, and deafness.

- In what ways is the information in this article applicable to older adults?
- Summarize the basic techniques being investigated to cure each of the five afflictions.
- Do you believe that these techniques will be useful in humans? Do you believe they will fully wipe out all cases of the five afflictions? Why or why not?