Chapter 2: Cognitive Neuroscience

Chapter Outline

Neurons: The Building Blocks of the Nervous System
- The Microstructure of the Brain: Neurons
- The Signals that Travel in Neurons
- Method: Recording from Neurons

Localization of Function
- Localization for Perception
- Method: Brain Imaging
- Localization for Language
- Method: Event-Related Potential

Distributed Processing in the Brain

Representation in the Brain
- Representing a Tree: Feature Detectors
- The Neural Code for Faces
- The Neural Code for Memory

Something to Consider: "Mind Reading" by Measuring Brain Activity

CogLabs: Receptive Fields; Brain Asymmetry

Web Links

Literature, Cognition, & the Brain

Research at the intersection of literary studies, cognitive theory, and neuroscience. The webpage includes abstracts, reviews, accounts of work forthcoming or in progress, links to related websites, and a regularly updated annotated bibliography.

http://www2.bc.edu/~richarad/lcb/home.html

Philosophy of Science and Physiological Psychology

A worldview of physiological psychology that contains many valuable citations of articles and books.

http://www.circadian.org/PPP/ppp.html

Animations: How Drugs Work

An excellent set of demonstrations showing how drugs work in the body and in the brain. An animation shows how brain cells communicate, with demonstrations depicting the effects of alcohol, cocaine, and opiates in the brain.

http://www.pbs.org/wnet/closetohome/science/html/animations.html

Brain and Behavior
Links to interactive exhibits about various brain phenomena and to other sites containing information about the brain.
http://serendip.brynmawr.edu/bb/

Probe the Brain
A website that lets you probe the brain to discover what area controls which part of the body. You could use it to ask students to explore the notion of localization of function versus distributed processing.
http://www.pbs.org/wgbh/aso/tryit/brain/#

Event-Related Potentials and Lie Detection
An abstract from a paper by Farwell and Donchin that investigates the usefulness of ERP techniques in lie detection (as an alternative to the technique of polygraphs). Students may find this application of ERPs compelling and intriguing. The full paper citation is also provided below.

http://www3.interscience.wiley.com/journal/119348239/abstract?CRETRY=1&SRETRY=0

Farwell, L.A. & Donchin, E. (1991). The truth will out: Interrogative polygraphy ("lie detection") and with event-related brain potentials. *Psychophysiology, 28*(5), 531-547.

Association for Psychological Science, Biological
A website on the Association for Psychological Science's webpage that contains an extensive list of links related to physiological psychology.
http://psych.hanover.edu/APS/teaching.html#biological

Discussion Questions

1. Students can be intimidated by the intricacy of the nervous system and sometimes insist that psychologists need not be biologists, too. Guide a discussion to convince them that any useful model/theory about cognition must be neurally plausible. Ask them to generate reasons why an understanding of the brain is an important component toward appreciating human cognition.
To drive these points home, you might supplement the text's ideas with additional descriptions of neuropsychological patient data (as students often find such cases of unique behaviors and dissociations fascinating). Ask them to draw conclusions about cognition from your supplemental examples (patient data, other types of physiological studies, etc.) to show that understanding neuroscience is an essential component to cognitive psychology.

2. Discuss the organization of the brain. Provide pictorial representations of the brain and have students locate and recognize a variety of structures, including the cerebral cortex and the lobes of the brain. Have students identify the cognitive processes associated with each area. Ask students to generate sample stimuli that might activate each of the areas. If possible, graphically link the stimuli to the associated area to provide visual memory cues for the students to assist in their learning.

3. Guide students in a discussion of how localization of function might create a disadvantage if the brain were solely organized around that principle. How might cognition be more fragile if important specific functions were located solely in one area? How does distributed processing create greater opportunities for protecting cognitive function and allowing for restoration of cognitive function in the event of a loss related to brain damage?

Demonstrations

1. Demonstrate the nature of the images obtained with the PET procedure and the subtraction technique. Explain the PET procedure. Provide a visual example of a PET scan. Explicate baseline activity (control task) and stimulation activity (target task). Explain that the brain activity associated with the target task is calculated by subtracting the baseline activity from the stimulation activity. Ask students to generate ideas for what may be the advantages and drawbacks of this brain-imaging tool.

2. If you have the ability to project the Internet to the class on a large screen, consider using the website listed below to demonstrate how researchers might measure one's ability to recognize faces. There are two tests that measure ability to recognize faces, and one is much longer than the other, so you might screen both to determine which will work best as a demonstration for your class. Once you have had a student perform the task, you might ask students how this sort of assessment differs from the brain-imaging techniques discussed in the text that might be used to assess the physiological reasons underlying prosopagnosia.

http://www.testmybrain.org/

3. Illustrate how learning and practice can impact the speed of neural transmission using a simple "squeeze chain" demonstration that will get students out of their seats. Have the students create a human chain by standing in a line around the perimeter of the room with their hands on the shoulders of the person in front of them. Have them close their eyes and then squeeze the shoulder of the person in front of them. At the same time, start a stop watch. Each student should squeeze the shoulder of the person in front of them when they feel the squeeze. Time how long it takes the squeeze chain to make it to the last person. Post the time where all students can see it and ask them to repeat this task a few more times (at least two). Most groups will show an increase in the speed of the chain with practice. This illustrates to them how neural activity, which is discussed on a very abstract level in the text, benefits from practice effects.

CogLab Instructor's Material:

Receptive Field

Introduction

The receptive field of a neuron consists of any stimulus that *changes* the neuron's firing rate. By definition, every neuron has a receptive field, although the receptive fields for some neurons are very complicated. It is often the case that a neuron responds only when light falls within a certain part of the visual field. Moreover, the light can have excitatory or inhibitory effects, depending on where it falls in the receptive field. Identifying the region of the receptive field and the excitatory and inhibitory parts provides a good deal of information about the role of the neuron in visual perception.

Part I

Student Projects and Critical Thinking Exercises

1) The definition of the receptive field in the present CogLab may be a bit dated. The new research area considers an additional dimension of time and defines receptive fields in the joint domain of space and time. Have students review the literature for further information on this new research area.
    a. Have them consider why the new line of research has been expanded or what anomalies could not be explained by previous theories.

2) Not all animals have complex visual systems because they may rely on other senses to survive. As a critical thinking project, ask students to pick an animal with a complex visual system and research its visual capacities, including receptive fields, and visual receptors.
    a. When considering this project, direct students to think about the evolutionary development of the visual systems.
    b. Some students may want to write their paper from a development or evolutionary perspective, including selective pressures for any evolutionary changes to occur.

Part II

Possible Test Questions

Basic or Introductory Questions

1) What is the difference between simple and complex receptive fields?

Answer: A simple receptive field is sensitive to light on only one fixed side. A complex receptive field can respond to light on either side of its receptive field, but it does not respond well to light on *both* sides of its receptive field.

2) In the practice examples, what did the green and red color fields represent in a receptive field?

Answer: The locations of the green and red pixels correspond to the location in visual space of the receptive field. The green region represented the excitatory area and the red region was the inhibitory area.

3) What are action potentials, and when do they occur?

Answer: Action potentials are the measurement for neuronal communication. When action potentials reach a certain level, an electrical signal is sent down the neuron. The frequency of action potentials increases as electrical potential increases, but action potentials can also occur without a stimulus.

4) How does an inhibitory signal affect a neuron's firing rate?

Answer: Since action potentials in a neuron fire as an all or none action, the firing rate depends on the accumulation of energy charges. The excitatory signals increase the probability for firing, whereas an inhibitive signal decreases from this potential. This is comparable to pluses and minuses added together. A certain charge level has to be obtained before firing can occur.

Research/Cognition-Based Questions

1) Why did participants have to complete four practice trials before the real testing?

Answer: To become familiar with the equipment in a neurological study, the participant has to practice first, before testing can begin. This allows an individual to be comfortable with the demands of the experiment and increases the reliability of the results.

2) What is a more scientific, objective way to measure action potentials?

Answer: Since they are electrical charges, action potentials can be measured through an EEG.

Advanced Questions

1) How are receptive fields related to perception?

Answer: Receptive fields and the properties of the specific neurons play a fundamental role in theories of visual perception. For example, neurons close to the retinas of your eyes have (relatively) circularly shaped receptive fields. For some neurons the center of this circle is excitatory, while the surround is inhibitory. Other neurons switch the locations of excitation and inhibition. Some neurons in area V1 of the cortex are sensitive to light-to-dark edges of a specific orientation. Other neurons in area V1 are sensitive to light-to-dark edges but are also sensitive to dark-to-light edges of the same orientation.

2) Why would it be adaptive for an animal to have specialized receptors that are stimulated by specific incoming information?

Answer: Some animals have specialized receptors because they need to be able to process specific information about their environment, like size (large, medium, or small), movement pattern (horizontal or vertical), or shape. If an animal eats a particular item, like a frog eats flies, it is beneficial for the frog to have special receptors for small, moving objects. If the frog's receptors were not working or couldn't detect small moving objects from large non-moving ones, it may starve to death or try to eat rocks.

Discussion Questions

1) Discuss how researchers could use an electrode to explore what an animal could visually detect and process in its environment.

Answer: A simple way to determine if an animal's brain is processing information in its environment is to use an electrode, which measures action potentials or electrical charges. The researcher could visually present a stimulus to the animal and record the cellular responses. By noting changes in the electrical potential, or the number of action potentials, the researcher can

determine if light at a particular location is excitatory, inhibitory, or not in the visual field. By carefully watching the cell's behavior as the stimulus changes, the researcher can map out the receptive field of a neuron and determine what the animal can detect and is processing.

2) Discuss firing rates of neurons in terms of excitatory and inhibitory actions and size of the receptive field.

Answer: Firing rates are related to the action potentials of a neuron, so the larger the receptive field, the greater the number of action potentials, or firing rates. For neurons with smaller receptive fields, firing rates (or action potentials) are not as great in number. Excitatory potential increases the firing rate, while inhibitory potential decreases the action of the neuron.

Part III

Group or Online Projects

1) Another visual phenomenon is color perception. Not all animals can see in color, while other animals see different wavelengths than humans. As a group or online project, have students research the two main theories of color vision and how each theory addresses changes in the receptive field or the special receptors for color.
    a. You may want to suggest they do their project on other animals that have color vision and compare receptor abilities and limitations to humans.
    b. Ask students to write an APA formatted paper on their findings.

2) Neurocognitive research often compares normal participants with those who have specific impairments. Have students explore the research for examples of disorders or lesions that alter receptive fields.
    a. After they find a disorder or specific lesion, have them compare the receptive field abilities, even if they are temporary to normal functioning receptive fields.
    b. They can write a paper or discuss their findings with the class, either through online or in classroom discussions.

Part IV

Multiple Choice Questions

1) Light falling on an off-center region of a receptive field has what effect on a neuron?
    a. An excitatory one
    b. It increases the frequency of action potentials
    c. An inhibitory one
    d. No effect at all

    (c)

2) Neurons close to the eye's retina have which sort of receptive field?
    a. Simple
    b. Complex
    c. Hypercomplex
    d. Center-surround

    (d)

3) Neurons in area V1 of the cortex have what sort of receptive field?

a. Center-surround
b. Simple
c. Complex
d. Simple and complex

(d)

4) Receptive fields are composed of what type of region?
   a. Excitatory
   b. Inhibitory
   c. Refractory
   d. Excitatory and inhibitory

(d)

CogLab Instructor's Material:

Brain Asymmetry

Introduction

The brain is separated into two halves: the right and the left. This hemispheric division of the brain has strong implications for cognitive behaviors. It is believed that the left hemisphere deals with language and analytical thought, while the right side deals with spatial relations and creativity. Visual stimuli, like most sensory information, is processed contralaterally, or enters the left eye but is processed in the right hemisphere of the brain. If you pair contralateral processing with hemispheric specialization, you may find some interesting results. Shapes presented in the right visual field may take longer to identify than shapes presented to the left visual field, while words presented on the left visual field may take longer to process than those presented to the right visual field.

Part I

Student Projects and Critical Thinking Exercises

1) The CogLab description suggests that results of brain asymmetry will be stronger for right-handed males and weaker for females and left-handed individuals. Have students review the literature for possible explanations for this phenomenon.
    a. Have them write an APA formatted paper summarizing their findings and explanations.
    b. You can also have them find the best answer and then discuss it as a class.

2) After completing the lab, ask students to write an APA formatted research paper, as if they were the researcher.
    a. Students could include a title page, introduction, method section, results, discussion, and references.
    b. Suggest creative writing and testing. For example, they could test gender effects, handedness, or age.

3) Have students explore the historical contributions or antecedents to neurocognition.
    a. They could write a paper on an important contributing person or a series of events that led up to the present findings.
    b. This can be done in groups or individually.

Part II

Possible Test Questions

Basic or Introductory Questions

1) What is meant by brain asymmetry? Give examples to support your answer.

Answer: Asymmetry suggests an imbalance or inequality in processing within the brain. The left hemisphere is said to process verbal and analytical information, while the right hemisphere processes spatial and geometrical information and is related to creativity.

2) Which of the four scenarios should show faster reaction times when presented to an individual's visual field: words presented to the left, words presented to the right, shapes presented to the left, or shapes presented to the right fields? Why?

Answer: Words presented to the right field and shapes presented to the left field should have the faster reactions times. Since these stimuli are processed by the opposite side of the brain, it suggests that words are processed in the left hemisphere and shapes processed by the right hemisphere.

3) If you were reading through a word-math problem that had geometrical shapes as well as a verbally described situation to critically think about, which hemisphere would process the words and which hemisphere would process the formula?

Answer: The verbal material would be processed by the left hemisphere and the non-verbal geometrical information would be processed by the right hemisphere.

4) Why is reaction time used in the Brain Asymmetry Lab as a measure for processing?

Answer: Reaction time is used as the measure of speed of processing because the slower the reaction time, the slower the processing speed or the inverse, the faster the reaction time, the faster the processing speed.

Research/Cognition-Based Questions

1) Name the independent variables in this study. Include the levels of the independent variable. What was the dependent variable? How was it measured?

Answer: One of the two independent variables was type of stimuli. Words and shapes were the levels. The other independent variable was side of presentation. The left or right sides were the two. The dependent measure was speed of processing as measured by reaction time to each of the stimuli presented.

2) What kind of statistics would you perform on the results if you were going to compare handedness for the four scenarios?

Answer: Since handedness has two levels (left or right), side of presentation has two levels (left or right), and type of stimulus has two levels (word or shape), you would perform a 2 x 2 x 2 ANOVA on reaction times.

3) How could you redesign this study from a between-subjects to a repeated-measures design? When would you want to do this?

Answer: A repeated-measures design could be done if the participant completed the study more than once, and her individual scores were compared between trials. A repeated-measures design might be more appropriate if you wanted to examine a pre-post test difference after some kind of manipulation, like caffeine or sugar intake. You may also want to have a person serve as his or her own baseline for comparison, rather than compare across participants.

Advanced Questions

1) What might it suggest if the past tense of words had a faster reaction time than the present tense of words when presented to the right visual field, but the present tense of words had a faster reaction time when presented to the left visual field compared to the past tense of words?

Answer: This might suggest that processing for past and present tenses were in different hemispheres. The present tense words may be processed by the right hemisphere and the past tense processed by the left.

2) Explain why a split brain patient would have trouble saying a word that was flashed to his left visual field but not his right visual field.

Answer: The word presented to the right hemisphere would be processed in the left hemisphere, which is the verbal center, so he could say that word. When a word flashes to the left visual field, it is processed by the right hemisphere; the severed corpus callosum impairs any message going from the right hemisphere to the left or the language center, so he could not say that word.

Discussion Questions

1) Besides observing split brain patients, discuss other research techniques that are used to study brain function and localization.

Answer: Other means of studying brain function are with brain-imaging techniques, like MRI, PET, and CT. Post-mortem studies are used as well; for example, Paul Broca used this to determine Broca's area. Comparing normal functioning individuals with patients with brain damage helps examine limitations or increased functions related to that specific brain damage.

2) Discuss the implications of the Brain Asymmetry CogLab.

Answer: Results of the lab on brain asymmetry give support to brain localization and hemispheric laterality. As scientists continue to research specific brain functions, they can learn to predict impairments with stroke or tumor patients or determine where a tumor is located depending on the outward behaviors displayed. It also suggests that even though the hemispheres have different functions, it is the communication between the two sides that enables certain behaviors.

Part III

Group or Online Projects

1) Contralateral processing of sensory information occurs in all senses, except smell. Have the students explore why this occurs.
    a. Classes can be broken down into groups to explore this subject and write a summary paper.
    b. Groups could also design an experiment that would test the processing pathway of odor or search through the literature for previously used methodologies that they could replicate.
    c. This could be posted as an online discussion point that students have to research and then respond to.

2) It has been said that the brain is like a Swiss Army knife. Have students review the literature for examples that support and contradict this simile.
    a. Break the class into smaller groups or post this as a discussion question for the students to think about and post the results from their searches. Have them think about how this lab supports this idea.
    b. You can ask them to write a paper using this concept as a thesis statement.

Part IV

Multiple Choice Questions

1) Right brain/left brain differences are strongest in
    a. right-handed males.
    b. right-handed females.
    c. left-handed males.
    d. left-handed females.

(a)

2) Information presented in the far left visual field arrives first in
    a. the left hemisphere.
    b. both hemispheres simultaneously.
    c. the right hemisphere.
    d. none of the above

(c)

3) If the left hemisphere is specialized for verbal information and the right hemisphere is specialized for spatial information, what should be true about the reaction times when shapes are presented to the right hemisphere and words are presented to the left hemisphere in a classification task?
    a. They should be low
    b. They should be high
    c. They should not be different
    d. It's not possible to predict what would happen

(a)