**PSY 847 Biological Psychology**

**Lecture 3**

Brain Plasticity

Introduction

The word *plastic* has several meanings depending on the context. When referring to the brain, the key meaning is "formative." One derivation is from the Greek word *plastikos,* meaning "to mold." Referring to the nature-nurture controversy, "plastic," or "formative," is an excellent description of how the brain develops embryologically and how it continues to form as the individual matures. During development, the brain is molded into an initial functioning organ. In adulthood, the brain grows very little, but it can change significantly. Humans are quite capable of learning at any age. Indeed, the very process of learning involves constant plasticity of brain function, as new connections are made to represent the new knowledge (Moser, Trommald, & Andersen, 1994).

Through research on the visual system, much has been learned about the ability of the brain to form and re-form itself. The eye and the connected pathways that result in the sense of vision are highly complex but well organized. Years of study have provided a great amount of information on how the brain processes light entering the eye into the perception of objects and movements. Much has also been learned about plasticity by examining how damage or disease to the visual pathways affects the recognition and interpretation of visual signals. This work has also provided proof that the brain can indeed recover, as least partially, from these events by re-forming pathways and connections (Fridriksson, 2010).

Nature and Nurture Form the Brain

During embryological development, the brain develops based on many different types of directions. While the basic architecture of the brain is genetically encoded, this code is open to interpretation and change based on the maternal environment. The presence of drugs or certain medications, for example, can have tremendous effects on neuronal growth and on the extent of synaptic connections that are made among neurons. For example, exposure to cocaine during prenatal development can affect preference for drugs as an adult (Thompson, Levitt, & Stanwood, 2009).

While substantial changes to the maternal environment caused by the presence of foreign chemicals such as drugs can have overt effects on the brain, modest changes caused by changes in naturally occurring chemicals (for example, hormones) can also have significant, but often more subtle, effects.

The Brain: Formative and Re-Formative

It used to be believed that, once formed, the brain did not change. If it was not capable of new growth, then any damage caused by injury or illness was essentially permanent. This belief affected treatment of brain injury victims for many years, and there was little help available in terms of intensive rehabilitation programs. However, by examining changes that occurred over time in thinking and behavior in brain-damaged patients, researchers and clinicians eventually came to understand that the brain exhibits significant plasticity and, following injury, can "rewire" itself to accommodate for damaged areas (Fridriksson, 2010). For example, this has occurred to the point where brain regions associated with hearing can partly be used to process sight. This is yet another area of intense interest in the study of the most interesting, and least understood, organ of the human body.

Illusions Are Anomalies in Perception

When the moon is observed rising above the horizon, it appears much larger than it does when high in the sky. However, if photographs are taken of the moon on the horizon it appears the same size as it does when it is higher in the sky. What causes this difference between the brain and the camera? Which is the correct image? For better or worse, the results of scientific studies have proven that the camera is sharper than the brain; the moon does not change, but the perception of it changes because of the way the brain interprets certain visual cues related to perceiving distance and horizons (L. Kaufman & J. H. Kaufman, 2000).

This illustrates the critical distinction between sensation and perception, and the way in which visual sensations, such as stimulation of cells that comprise the retina, can be inappropriately perceived when processed in the higher brain centers, such as the cortex. This example also shows that, while the brain constantly interprets and perceives most situations properly, there are limits based on the structure of various cell networks throughout the visual system.

Individual Differences in Sensation and Perception

Not everyone senses or perceives the world in the same way. Further, the perception of stimuli can be affected by the state of the body at any given time. The various senses receive countless signals and must determine whether they are real. In other words, there are thresholds at which the brain decides whether a stimulus exists. Psychologists have designed several ways of testing the ability to notice changes in the environment. One of these is called the just noticeable difference (JND*)*. For example, a test subject is asked to hold a series of different weights. The amount of difference required before the subject reports a new weight as being different from the previous weight is then recorded. The required difference is the JND (Torgerson, 1958). Note that there are four possible outcomes. The subject may

            Correctly report a difference (true positive)

            Report a difference when there is none (false positive)

            Correctly report no difference (true negative)

            Report no difference when there is one (false negative)

The threshold for a given subject is called their *decision criterion*. This value varies between persons and within the same person as a function of many internal and external factors. The decision criterion paradigm has been used in many studies and has much practical value, from determining minor differences in colors or sounds that influence how individuals perceive works of art to the accuracy of picking a criminal suspect out of a police lineup (Green & Swets, 1966; Stanislaw & Todorov, 1999).

Sensation and Perception Over Time

The presence and number of hormones in the body differs over time and can have dramatic effects on the ability of sensory receptor sensitivity, as well as the manner in which sensory input is perceived. In vision, an active field of study for over two hundred years been has been examining responses to temporal variations in visual stimuli. The primary method of research in this field has been the study of the critical flicker frequency (CFF) phenomenon (Egan, 1975). CFF is the frequency at which a flickering light is perceived to be solid. Changes in visual sensitivity have been shown to be affected by changes in hormone levels, including estrogen, progesterone, and testosterone (DeMarchi & Tong, 1972). For years, researchers have used the naturally occurring changes in hormones across the female menstrual cycle as a way to examine the effects of hormones on stimulus sensitivity and perception. Results from studies have shown that visual sensitivity, in terms of both sensation thresholds (e.g., CFF) and perception of these stimuli, varies across the menstrual cycle. It is noteworthy that changes in sensation appeared more related to progesterone levels, while differences in perception were more associated with variations in estrogen. While significant, these differences are not dramatic and have little real-world application. However, this was not always the belief. In fact, in the 1950s it was suggested that premenstrual tension be allowed as a criminal defense. This issue was not debunked until some 25 years later, when Julie Horney (1978), in a meta-analysis and thorough review, determined that no significant relationships existed between the menstrual phase and behavioral actions such as serious crimes, and that menstrual symptoms were not an appropriate cause for an insanity defense.

Conclusion

It is now clear that the brain is not a static organ: It develops and grows during childhood and does not reach optimum cognitive linking until the late teens. By examining the impact of disease and injury to the brain and the following ability of the brain to recover some, if not all, of the lost functions, it has been determined that the brain is capable of re-forming itself to accommodate damaged tissue. Furthermore, even the healthy brain constantly undergoes neuronal changes during the processes of learning and memory. Sensory-motor function, sensation, and perception are also affected on an ongoing basis by many natural endogenous events, such as hormonal fluctuations. Whether the results of these injuries, diseases, or natural changes affect the brain alone or also impact the mind is, of course, part of the great mind-body debate and broadens the perspective of what it means to exist.

References

DeMarchi, G. W., & Tong, J. E. (1972). Menstrual, diurnal and activation effects on the resolution of temporally paired flashes. *Psychophysiology, 9*, 362-367.

Egan, J. P. (1975). *Signal detection theory and ROC analysis.* New York, NY: Academic Press.

Fridriksson J. (2010). Preservation and modulation of specific left hemisphere regions is vital for treated recovery from anomia in stroke. *Journal of Neuroscience, 30*(35), 11558-11564.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics*. New York, NY: Wiley.

Horney, J. (1978). Menstrual cycles and criminal responsibility. *Law and Human Behavior, 2*, 25-36.

Kaufman, L., & Kaufman, J. H. (2000). Explaining the moon illusion. *Proceedings of the National Academy of Sciences, 97*(1), 500−505.

Moser, M. B., Trommald, M., & Andersen, P. (1994). An increase in dendritic spine density on hippocampal CA1 pyramidal cells following spatial learning in adult rats suggests the formation of new synapses. *Proceedings of the National Academy of Sciences, 91*(26), 12673-12675.

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers: A Journal of the Psychonomic Society, Inc.*, *31*(1), 137-149.

Thompson, B. L., Levitt, P., & Stanwood, G. D. (2009). Prenatal exposure to drugs: Effects on brain development and implications for policy and education. *Nature Reviews Neuroscience, 10*(4), 303-312.

Torgerson, W. S. (1958). *Theory and method of measurement.* New York, NY: Wiley.