NEUROBIOLOGY OF LEARNING

PAY ATTENTION! UNDERSTANDING THE NEUROBIOLOGY OF ATTENTION

JENNY L. WILLIAMSON, HELEN T. BUCKLAND, SUSANNA L. CUNNINGHAM

"To pay attention, this is our endless and proper work."
– Mary Oliver
http://www.goodreads.com/author/show/23988.Mary_Oliver

As a crucial first step in learning and remembering, teachers urge students to "pay attention." But just what is involved in paying attention? In the last issue, we examined long-term potentiation and memory. Working memory accepts, stores, and manipulates information about our internal and external world. With attention we focus on salient input while ignoring the competing, extraneous input. Relevant information in working memory becomes the basis for decisions and actions (Knudsen, 2007). Additionally, attention is important for regulating emotions and behavior.

Genes and environment influence attention. Animal studies have identified two alleles of the brain-derived neurotrophic factor (BDNF) gene important in memory. One allele group of animals performed less well on learning and memory tests. Brain imaging revealed significant differences between the two groups' hippocampi, an area critical to memory storage and retrieval (Posner et al., 2012). Training (an environmental influence) given to children suffering from attention deficit hyperactivity disorder was shown in one study to improve attention (Klingberg et al., 2005).

Attention has been conceptualized as a neural system with three separate but cooperating networks, each with its own anatomy, neuromodulators, and functions, influenced by genes and experience (Raz, 2004; Posner & Rothbart, 2005; Posner, 2012). In Posner's model these alerting, orienting, and executive networks are all considered to work together (Shipp, 2004).

According to Posner, the alerting network is the foundation for other attentional networks. It involves the midbrain's locus coeruleus and uses the neuromodulator norepinephrine and its projections to the cortex to keep us vigilant and prepared for performance (Raz & Buhle, 2006). The anterior cingulate cortex coordinates this network, heavily lateralized in the right hemisphere's frontal and parietal regions. Activity in the left hemisphere is associated with linking temporal and spatial information and presenting warning signals. Alertness changes over the day, along with circadian rhythms, body temperature, and cortisol secretion. Reaction times peak in the early morning and decline over the course of the day, rising again during the night (Petersen & Posner, 2012). Stress influences the alerting network, impairing long-term potentiation and reducing working memory (Blank et al., 2004).

Posner's orienting network involves cell bodies in the basal forebrain structures projecting to the superior parietal lobe, temporal parietal junction, and frontal eye fields. It uses acetylcholine as a neuromodulator to achieve fast, strategic attention (Schulte et al., 2000). The orienting network chooses salient information from sensory inputs for further processing. This sensory information is chosen either voluntarily or via a reflexive mechanism that allows a quick response to "unexpected but important events" (Chica et al., 2013). This orienting network organizes many brain areas to allow a simple shift of attention by increasing neural firing in a given sensory area or in working memory. This network has been the most studied, with research focused on visual orienting. Although there is independence between the alerting and orienting networks, both work together.

The executive network involves the anterior cingulate gyrus, anterior insula, basal ganglia, and portions of the prefrontal cortex; all are "areas rich in dopamine, and their function is modulated by dopamine from the ventral tegmental area" (Posner et al., 2012). This network is used for tasks that require resolution of conflict as well as self-regulation of thoughts and emotions, motivation, empathy toward others, and metacognitive attention. Tests of this executive network, such as the Stroop test, involve resolution of the conflict between dominant and nondominant responses. Colored words such as "blue" or "red" are written in matching and mismatching ink colors. Respondents are instructed to name the color of the ink the word is written in – as opposed to reading the word. The Stroop test is scored on how long it takes respondents to finish the trials. The interference of the mismatching ink color and word name increases the time it takes to finish.

The executive network is present in infancy but is not fully developed until adulthood (Arnsten & Rubia, 2012). During adolescence, the brain matures, increasing white matter. During post-adolescence, gray matter decreases. These changes result in teens developing increased capacity to attend to information and control their emotions and behavior. "This period of growth is marked by an increased ability to read social and emotional cues and an increased appreciation and dependence on interpersonal relationships" (Yurgelun-Todd, 2007).

Now that we have explored attention, we'll turn our attention next month to examining the connections among attention, music, and memory. Stay tuned!

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JENNY L. WILLIAMSON is Project Director for How Do I Learn at the University of Washington, School of Nursing, T610A Health Sciences, 1959 NE Pacific Street, Seattle, WA 98195-7266. HELEN T. BUCKLAND is Project Director of Online Neuroscience Education about Drug Addiction at the University of Washington, School of Nursing; e-mail: trezbuck@uw.edu. SUSANNA L. CUNNINGHAM is Professor at the University of Washington, School of Nursing; e-mail: susannac@uw.edu. For questions about this article, please contact Jenny L. Williamson at jenlw@uw.edu.