Chapter 12

Computer-Presented and Physical Brain-Training Exercises for School Children:

Improving Executive Functions and Learning

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ABSTRACT

This chapter reviews the neuroscience foundation for understanding and harnessing neuroplastic processes that shape the structure and function of the human brain after birth, describes a newly developed, integrated series of computer presented and physical exercises to promote activity-related development of neurocognitive systems of attention and executive function in elementary school children, and reviews evidence of the efficacy of the program. The computer-presented brain exercises have new functionalities that more fully shape the training to each user's individual profile of cognitive strengths and weaknesses than was previously possible. The programs also provide assessments of each child's cognitive strengths and weaknesses based on built in formal tests of cognition and error analytic algorithms applied to 15-20,000 responses from each child while using the brain training program.

INTRODUCTION

The Problem

A recently completed study assessed attention skills in 2,000 elementary school children and followed them for 16 years (Pingault et al, 2011). Children with attention problems when they were six years old were 7.6 times more likely than their classmates to never graduate from high school. This poor attention group included 17% of the study population. Failure to graduate from high school is associated with underemployment, unemployment, drug use and jail time. Current estimates are that approximately

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7-10% of elementary-aged children have been diagnosed with ADHD. Childhood ADHD is similarly associated with many of the same undesirable long term outcomes. In some schools, attention problems are even more common. In all schools, children with attention problems require disproportionate teacher time and can affect the learning environment for all children in the classroom.

Neuroplasticity and the Scientific Foundation for Brain Training to Improve Attention

The neural basis of all cognitive functions are networks of hundreds of thousands of neurons distributed widely throughout the brain. The interconnections among nerve cells that create these functional systems are not determined by our genes, but instead are heavily influenced by stimulation and experience after birth. Hubel and Weisel (1970; 1988) were awarded the Nobel Prize for demonstrating the great extent to which early sensory experience shapes brain structure and function in mammals. Meaney and colleagues at McGill extended this work to show the particular importance of maternal stimulation in shaping life-long features of the brain and behavior(Champagne et al, 2008). They further demonstrated that these effects are produced in part by altering methylation of DNA and thus turning specific genes on (Weaver et al, 2004). In an experimental tour de force, Sur and colleagues at MIT converted normal auditory cortex into visual cortex by replacing auditory with visual input in new born ferrets (Sharma et al, 2000), suggesting that neuroplastic potential may have even fewer limits than previously thought. Merzenich and others have now conducted numerous experiments in animals elucidating training and stimulation parameters that maximize neuroplastic reshaping of structure and function (e.g., Jenkins et al, 1990).

The structure and function of the human brain are shaped after birth by stimulation from the environment to a much greater extent than are the brains of any other animal. Moreover, only human beings shape the environment that in turn shapes their brains, a transgenerational process called cultural evolution (Wexler, 2006). Education is an important component of these processes. Figure one shows basic sensory plasticity in humans; the white areas in the brain are activation during functional magnetic imaging (fMRI) of the “visual” cortex by auditory stimulation in people who were blind since birth or soon thereafter (Weaver and Stevens, 2007). Figure two shows the effects on brain structure of practicing a musical instrument for many hours as a child (Schlaug, 2001). Violin players make simple repetitive movements of their right hand with the bow, and the sensorimotor cortex in the left hemisphere (circled) which controls the right hand serves as a reference. The left hand, in contrast, makes rapid and complex movements controlling the strings. The volume expansion in the right hemisphere compared to the left is evident to the naked eye – it results from activity-dependent recruitment of neural resources, and increased connections among the neurons. Piano players make complex movements with the fingers of both hands and have “buffed up” motor cortices in both hemispheres. The human brain remains highly plastic for a much longer time after birth than do the brains of any other animals and parts of the brain associated with attention control and other cognitive executive functions continue to develop throughout childhood and adolescence.