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The neurological development of the child with the educational enrichment in mind

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A B S T R A C T

Early life events can exert a powerful influence on both the pattern of brain architecture and behavioral development. The paper examines the nature of nervous system plasticity, the nature of functional connectivities in the nervous system, and the application of connectography to better understand the concept of a functional neurology that can shed light on approaches to instruction in preschool and primary education. The paper also examines the genetic underpinnings of brain development such as synaptogenesis, plasticity, and critical periods as they relate to numerosity, language and perceptual development. Discussed is how the child's environment in school and home interact with and modify the structures and functions of the developing brain. The role of experience for the child is to both maintain and expand the child's early wiring diagram necessary for effective cognitive as well as neurological development beyond early childhood.

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El desarrollo neurológico del niño con el enriquecimiento educativo en mente

Palabras clave:
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R E S U M E N

Los primeros acontecimientos vitales pueden ejercer una enorme influencia tanto en el patrón de arquitectura cerebral como en el desarrollo del comportamiento. En este trabajo exploraremos la naturaleza de la plasticidad del sistema nervioso, la naturaleza de sus conexiones funcionales y la aplicación de la tractografía, para lograr una mejor explicación del concepto de neurología funcional que pueda arrojar luz sobre las teorías de la instrucción en la enseñanza preescolar y primaria. El trabajo analiza también los fundamentos genéticos del desarrollo del cerebro tales como la sinaptogénesis, la plasticidad y los periodos críticos en lo que respecta a su relación con el desarrollo numérico, lingüístico y perceptivo. Se aborda cómo interactúa el entorno del niño en la escuela y en casa con las estructuras y funciones del cerebro en desarrollo y las modifica. El papel de la experiencia temprana será tanto mantener como expandir los circuitos neurales necesarios para un desarrollo efectivo (tanto cognitivo como neurológico) más allá de la temprana infancia.

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From Camillo Golgi and Santiago Ramón y Cajal in the late 1890s, with their extensive observations, descriptions, and categorizations of neurons throughout the brain and the formation of the neuron doctrine and the start of modern Neuroscience, we have come a long way in understanding the nature of the nervous system in the control of human behavior. Little of that work has actually wound its way into the classroom and even less into public policy in education.

Basic principles have emerged that allow application to educational practice, especially in the early years from birth to five years that place great responsibility for brain development in the hands of parents and early childhood teachers. These principles include the following:

1. The human brain develops from conception to the early twenties from the bottom up with vital and autonomic functions and control coming first and cognitive-motor sensory and perceptual processes later and integration and decision making last (Melillo & Leisman, 2009).
2. The child's brain is influenced by the combined roles of genetics and experience (Leisman, Machado, Melillo, & Mualem, 2012; Leisman & Melillo, 2012; Melillo & Leisman, 2009).
3. The brain's capacity for change decreases with age (Leisman, 2011).
4. Cognitive, emotional, and social capacities are inextricably intertwined throughout the life course (Leisman, Braun-Benjamin, & Melillo, 2014).
5. Motor and cognitive functions interact with our brains, being the direct result of bipedalism (Melillo & Leisman, 2009).
6. Toxic stress damages developing brain architecture, which can lead to life-long problems in learning, behavior, and physical and mental health.
7. The child's environment directly affects synaptogenesis and allows for neurological optimization (Gilchreist 2011; Leisman, Rodriguez-Rojas et al., 2014).

The Effect of Environmental Enrichment on the Child's Brain: Playing with the Genetics

Early life events can exert a powerful influence on both the pattern of brain architecture and behavioral development. Both early as well as later experiences contribute to the wiring diagram of the child's brain, but experiences during critical periods establish the basis for development beyond the early years. The role of the kindergarten and nursery teachers becomes critical in establishing the solid functional footing of the developing child and the neurological adult.

The foundations of brain architecture are established early in life through a continuous series of dynamic interactions between genetic influences, environmental conditions, and experiences (Friederici, 2006; Majdan & Shatz, 2006). We have come to learn that the child's environment significantly impacts the timing and nature of gene expression directly affecting the child's brain architecture.

Because specific experiences potentiate or inhibit neural connectivity at key developmental stages, these time points are referred to as critical periods (Knudsen, 2004). Brain, cognitive, sensory, and perceptual development does not occur simultaneously but rather at different developmental stages as represented below in Fig. 1. Each one of our perceptual, cognitive, and emotional capabilities is built upon the scaffolding provided by early life experiences. Examples can be found in both the visual and auditory systems, where the foundation for later cognitive architecture is laid down during sensitive periods for basic neural circuitry.

The capacity to perceive stereoscopic depth requires early experience with binocular vision, (Crawford, Pesch, & von Noorden, 1996), which at a later point in development may have implications for perceptual and cognitive development. Likewise, the capacity to perceive a range of tones requires variation in the tonal environment, and exposure to such variation later leads to language processing and proficiency (Kuhl, 2004; Newport, Bavelier & Neville, 2001; Weber-Fox & Neville, 2001). The absence of tones associated with a given language will eradicate the discrimination of those developmentally unheard tones by the time the infant is one-year-old (Werker & Tees, 1983). Second language acquisition obtained early enough will have the same brain representation as the first language throughout the lifespan, but that second language, learned later in development, even when spoken at native level, will be represented differently in the brain relative to the first language (cf. Leisman, 2012; Leisman & Melillo, 2015).

Although early experiences are reflected in behavior, behavioral measures tend to underestimate (in part because of a lack of sensitivity and specificity) the magnitude and persistence of the effects of early neuronal development (Knudsen, 2004). In order to explore the role of timing and quality of early experiences on later cognitive function, we must therefore have a genetic framework of the developing brain.

We see no fundamental difference between the task of the educational system, rehabilitation after neurological insult or developmental disabilities, the task of parenting, the effects of social interaction, the effects on the nervous system of sport, or even the ability to intervene in the natural consequences of cognitive aging. The term education can be used interchangeably with rehabilitation as all directly relate to measurable dynamic plastic changes in neural connectivities.

Education has been grabbing at straws for a long time. Often when a preliminary finding is reported in the neuroscience literature or presented at a conference, it is grabbed and expounded upon with little consideration of the fundamental nature of biological processes that underlie those changes. For better or worse, over the last 10 years, education has been actively and aggressively looking to the biological sciences in order to inform education policy and practice.

A good example is that of the 1998 decision in Georgia to fund an expensive program, to provide CDs of Mozart's music to all new mothers. In establishing this policy, the governor of Georgia drew heavily on work in cognitive neuroscience conducted at the University of California, Irvine. The actions were taken in the hope of "harnessing the 'Mozart effect' for Georgia's newborns – that is, playing classical music to spur brain development." Despite what the program implied, Mozart effect research, upon close examination, had little to offer education. One study, reported in Nature (Rauscher, Shaw, & Ky, 1993), found that listening to Mozart raised the IQs of college students for a brief period of time. Another study found that keyboard music lessons boosted the spatial skills of three-year-olds (Schlaug, Norton, Overy, & Winner, 2005). Cognitive neuroscientists responsible for this work, were baffled by Georgia's program and actions based on their work. Since this debacle, major figures in the sciences have published articles emphasizing caution and care as scientists, educators, and practitioners proceed down this exciting, but pitfall-laden road. These cautionary articles have laid the groundwork for relationships between neuroscience and education. However, there is a paucity of publications that systematically examine an area of research where conservative but confident claims can be made of the benefits of interdisciplinarity.

Most currently prevailing patterns of education are heavily biased towards left cerebral functioning and are antithetical to right cerebral functioning. Reading, writing, and arithmetic are all logical linear processes, and for most of us are fed into the brain through

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