Mobilizing critical research for preventing and eradicating poverty

CROP Poverty Brief / November 2012

Developing Poor *Connected* Brains[1] // Sebastián J. Lipina[2] and Michael I. Posner[3]

The study of the influence of material and social deprivation on the central nervous system (CNS) has been an issue of interest in the agenda of neuroscience since the first half of the twentieth century. In recent years, neuroscience has begun to take seriously that experience shapes the brain in important ways.

This Poverty Brief argues:

1. **A child's reaction to stress is an important factor in success in school and our understanding of the stress reaction may also guide us in analyzing other brain systems more directly involved in schooling.**

2. **Brain connectivity of systems devoted to regulate thoughts and feelings develop over the early life of infants and young children, and lead to the ability to regulate other brain networks.**

3. **Training studies designed to improve decoding and phonological competences, have shown that children living in poverty with low reading skill can improve. In the same sense, training in numerical quantity before the start of school could reduce arithmetic difficulties through manual and computerized exercises.**

4. **Biological determinants associated with childhood poverty are also related with inequalities in cognitive and emotional development that poses a threat to educational attainment.**

In a previous CROP Brief on this topic, Lipina and Farah (2011) had highlighted: (a) how research on brain development allows the identification of basic processes in the cognitive and affective neural systems that underlie the effects of childhood poverty; (b) the importance of prenatal toxins and drugs exposure, nutritional variations, and stress as mediators; and (c) the preliminary efforts on neurocognitive interventions aimed at providing enriching environments to protect and foster control and language competences. In this new Brief, we deepen the topic through the inclusion of recent findings in epigenetics and neural connectivity and their implications for attentional control and academic skills.

Plasticity has been used as a blanket term to cover the changes related to experience. Experimental studies on rodents and non-human primates exposed to motor, sensory, and social stimulation in comparison to non-stimulated controls, show structural and functional changes in neuronal and non-neuronal components (Lipina & Colombo 2009). This means that development and learning alter the local neural environment and that leads to the observed changes in brain and behavior. Current studies in the developmental neuroscience field continue to advance in the understanding of the plastic mechanisms through which experience and environmental influences interact with genes, more specifically with the DNA biochemical markers and histone proteins that regulate gene activity.

The *stress* system has been used as a model for an examination of adverse early experience on a brain network (Lupien et al., 2009). There are two important implications of this work. First, it shows the importance of a distributed systems of brain areas in the control of stress, involving prefrontal cortex, hippocampus, amygdala and the Hypothalamic–pituitary–adrenal (HPA) axis which operate as a nonlinear, interactive network in which multiple mediators regulate each other, and promote adaptive activities and coping with aversive situations usually present in low-SES (Socioeconomic status) and poverty contexts (e.g., crowding, hunger, threats to mental and physical health). These areas and the white matter connection between them are important contributors to the influence of stress on the person. One of the effects of these processes (i.e., toxic stress) is altering hippocampal involvement in episodic, declarative, contextual and spatial memory, what in turn leads to alteration in the ability to process information in new situations and to make decisions about how to cope with new challenges (McEwen & Gianaros, 2010). A second implication of the stress work is the notion that epigenetic changes underlie the long-term impact of early experiences, and that epigenetic alterations are potentially reversible or modifiable through pharmacological and behavioral interventions. This means that the understanding of the role of genes and of the epigenome in behavioral modifications driven by early experiences could contribute to the field of childhood poverty and brain development. A child's reaction to stress is an important factor in success in school and our understanding of the stress reaction may also guide us in analyzing other brain systems more directly involved in schooling.

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Attention is a key factor in school readiness and success. An understanding of the underlying brain networks involved in attention has been a major contribution from research using neuroimaging (Posner & Rothbart, 2007). Attention networks are involved in obtaining and maintaining the alert state (alerting), orienting to sensory stimuli and resolving conflict between responses (executive). The latter network is a key to the role of ability of children and adults to regulate their thoughts and feelings. Adjacent areas of the ACC are involved in cognitive and emotional control (Bush et al., 2000). Connectivity of these control systems develop over the early life of infants and young children, and lead to the ability to regulate other brain networks, thus exercising executive control over behavior (Fair et al., 2011; Posner et al., ´2012). This control depends critically upon factors in the social environment such as parenting. Better understanding of the mechanisms by which control develops and is exercised can provide guidance to parents and to society. Critical to this is an understanding of the mechanisms, which switch control from the caregiver during infancy to later self regulation by the child. In studies of preschoolers, first graders, and middle school children, low SES children had reduced performance on many cognitive control tasks including attention, inhibitory control, and working memory, and in some cases different patterns of brain activation compared to middle SES children (Hackman et al., 2009, 2010; Lipina & Colombo, 2009). **These findings suggest that the prefrontal/executive system is one of the primary neurocognitive systems associated with social inequalities in early experience**. Recently, there has been considerable evidence that various types of attention training can be effective in children. Most of the evidence involves practice with attention related tasks either using computerized tasks or classroom curricula. Another type of training (i.e., physical exercise, meditation) involves changes in brain state that might influence some attentional networks as well as stress and immunoreactivity (Hillman et al., 2008; Tang et al., 2007).

Language and literacy are important in school and are functions found to be reduced in low SES children. There is evidence suggesting that the process of phonemic discrimination being developed in infancy is important for later efficient use of spoken and written language (Guttorm et al., 2005), which is critical in childhood poverty studies since SES modulates the early language environments (Hoff, 2003). In turn, reading has properties related to the phonemic structure of language. Adult studies of reading have revealed a complex neural network involved in the translation of words into meaning. Two important nodes of this network are the visual word form area, of the left fusiform gyrus and an area of the left temporal-parietal junction for translating visual letters into sounds. The activation of this left temporal-parietal junction is modulated by SES, among other factors (Monzalvo et al., 2012). For instance, Noble and colleagues (2006), showed a significant phonological awareness-SES interaction in the left fusiform visual word form area, indicating that at similar low phonological awareness levels, children from higher SES were more likely to evidence increased responses in the left fusiform cortical gyrus, while children from lower SES did not. In another recent study of healthy 5-year-old children performing an auditory rhyme-judgment task, Raizada and colleagues (2008) found that the higher the socioeconomic status, the greater the degree of hemispheric specialization in Broca's area, suggesting that the maturation of Broca's area in children may be governed by the complexity of the linguistic environments in which they grow up. Training studies designed to improve decoding have shown that children with low reading skill can improve and when this occurs they show enhanced activation in areas related to phonological translation (McCandliss et al., 2003).

Significant differences in the *numerical proficiency* of preschoolers and kindergartners from different SES backgrounds have been described on a wide range of tasks such as reciting the digits, counting sets of objects, counting up or down from a given number other than one, recognizing written numerals, adding and subtracting, comparing numerical magnitudes, and the ability to describe thinking and explain ideas in the context of mathematical problem solving (Crane, 1996; Pappas et al., 2003).

The overall network of brain activity in processing number has also been studied in children and adults by applying neuroimaging. Results suggest that **children as young as five years of age showed similar brain mechanisms underlie quantity discrimination as found in adults** (Ansari et al., 2005; Cantlon et al., 2006). And there is wide agreement that learning of arithmetic operations depends on the early skill in the ability of children to understand quantity (Siegler, 2009). Training in numerical quantity before the start of school could reduce this deficit through manual and computerized exercises. Some training studies showed increased proficiency on several numerical tasks (i.e., magnitude comparison, number line estimation, counting and identification) (Ramani & Siegler, 2008; Wilson et al., 2009).

In summary, biological and psychosocial risk factors associated with low-SES and poverty conditions are related with inequalities in child cognitive and socioemotional development that poses a threat to educational attainment and adult productivity worldwide (Heckman, 2006; Walker et al., 2011). Low-SES and poverty can have profound effects on the brain and body, and thus influence both mental and physical health. Policies and interventions can affect neuroplasticity. Emerging translational animal and human research link poverty to neurobiological pathways through changes in gray and white matter (McEwen & Gianaros, 2010). We are at the very start of developing interventions that may aid in improving this situation through using classroom and individual exercises that have proven useful in some low-SES and poor populations.

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