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Research Report

Childhood poverty: Specific associations with neurocognitive development

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ABSTRACT

Growing up in poverty is associated with reduced cognitive achievement as measured by standardized intelligence tests, but little is known about the underlying neurocognitive systems responsible for this effect. We administered a battery of tasks designed to tax-specific neurocognitive systems to healthy low and middle SES children screened for medical history and matched for age, gender and ethnicity. Higher SES was associated with better performance on the tasks, as expected, but the SES disparity was significantly nonuniform across neurocognitive systems. Pronounced differences were found in Left perisylvian/Language and Medial temporal/Memory systems, along with significant differences in Lateral/Prefrontal/Working memory and Anterior cingulate/Cognitive control and smaller, nonsignificant differences in Occipitotemporal/Pattern vision and Parietal/Spatial cognition.

1. Introduction

Beginning as early as preschool and persisting throughout childhood and beyond, individuals of low socioeconomic status (SES) perform below their middle class counterparts on tests of intelligence and school achievement (e.g., Bradley and Corwyn, 2002). Measured in standard deviation, SES gradients for cognitive achievement are even steeper than those for physical health (Duncan et al., 1998) and are likely to play a role in the persistence of poverty across generations.

Little is known about the underlying mental systems that mediate the SES disparities in cognitive performance. IQ tests and school achievement are valuable in that they have well-understood psychometric properties and predictive power concerning future life trajectory. However, they do not correspond in any straightforward way to the current scientific "parse" of cognitive function into underlying components. In the present investigation, we attempt to characterize the cognitive outcomes of childhood poverty in terms of the framework of cognitive neuroscience.

How and why might a sociological construct, SES, be associated with brain function? The answer lies in the nature of SES itself. Although SES is generally estimated by measuring parental education and occupational status, it encompasses far more than these simple indices, including associated differences in physical and mental health (Adler et al., 1994) and in physical and psychosocial aspects of the environment (Evans, 2004). Important psychosocial factors

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include the presence of both parents in the home and parental stress and depression. Physical factors include nutrition and exposure to pollutants. Any of these is, in principle, capable of influencing brain development and function. In addition, some of the variance in an individual's SES has been attributed to genetic factors (Lichenstein and Pederson, 1997), which could also be manifest in the brain.

Given the multiplicity of potential influences on brain development, it is possible that the SES gradient in cognitive achievement would have a broad and uniform neurocognitive basis, affecting all components of the developing mind and brain to a roughly equal degree. Alternatively, some components may be more sensitive to SES than others. In a preliminary study of low and middle SES kindergarteners (Noble et al., 2005), we found evidence of an uneven profile of differences between low and middle SES children. In that study, language and executive function were most strongly related to SES. The goals of the present study were to characterize the neurocognitive profile of SES in a new sample of older children, using a more fine-grained parse of neurocognitive systems, particularly prefrontal systems, as well as to rule out medical problems that could account for the SES disparities in cognitive performance.

Prefrontal/Executive function is of interest for several reasons. This brain region undergoes prolonged postnatal development (e.g., Casey et al., 2000; Fuster, 2002), as does its functional connectivity with other brain regions (e.g., Malkova et al., 2000), providing maximal opportunity for the different life experiences of lower and higher SES to influence the development of this region of the brain. Second, regions within prefrontal cortex have been associated with "general intelligence" of the kind tested by IQ tests (see Gray and Thompson, 2004, for a review), which is robustly associated with SES (Smith et al., 1997). Third, sociologists have attempted to generalize about socioeconomic status and cognitive style, with some suggesting that increasing SES is associated with increasing tendency to resist impulses and delay gratification (e.g., Banfield, 1968; Lewis, 1965), characteristics associated with prefrontal function (e.g., Miller et al., 2003). Fourth, earlier studies have found evidence that executive function differs as a function of SES in children. Mezzacappa (2004) assessed the sociodemographic correlates of performance on Posner's Attention Network Task (ANT; Rueda et al., 2004) and found the strongest relations with SES in what he terms "executive attentional" processes. The study of more general neurocognitive correlates of SES in kindergarteners, mentioned earlier, also found a large difference between the low and middle SES children in executive function (Noble et al., 2005).

What is unclear at present is which specific systems of prefrontal cortex might be involved with SES. The executive functions of prefrontal cortex are a complex assemblage of distinct (though highly interactive) neurocognitive systems. For example, the prefrontal subsystems associated with intelligence and with delay of gratification are different. The set of tasks used in the previous study of kindergarteners was heterogeneous, including working memory, cognitive control, set shifting, theory of mind and delay of gratification. In the present study, we attempt to discern with greater neurocognitive specificity the prefrontal correlates of SES, by separately assessing Lateral prefrontal/Working memory, Anterior cingulate/Cognitive control and Ventromedial prefrontal/Reward processing systems.

Our study of kindergarteners found that language ability, including vocabulary, syntactic ability and phonological awareness, is associated with SES, consistent with a body of literature on language development in poor and middle class children (Whitehurst, 1997). In more recent work, we have found that the relationship between phonological awareness and reading ability is modulated by children's SES (Noble et al., 2006), as is the relation between phonological awareness and brain activity in reading-related areas (Noble et al., in press). The present study focused on comprehension of single word lexical–semantics and sentence-level syntax.

Another system that will be examined anew in the present study is the memory system of the medial temporal lobes. This system underlies learning in the classroom as well as for virtually all real world activities, and its identity as a localized and dissociable neurocognitive system is well established on the basis of both functional neuroimaging and patient studies. Although the previous study of kindergarteners included tests of memory, they were in effect tests of immediate memory as each test was inadvertently administered immediately following exposure to the memory material. The present study addresses the relation between SES and the acquisition of more enduring memories.

In all, seven neurocognitive systems were assessed using pairs of dissimilar behavioral tasks, as described in greater detail in the Experimental procedures section. These comprised three Prefrontal/Executive systems, Lateral prefrontal cortex/Working memory, Anterior cingulate cortex/Cognitive control system and the Ventromedial prefrontal cortex/Reward processing system, and four other systems, the Occipitotemporal/Pattern vision system, Parietal/Spatial cognition system, Left perisylvian/Language system and Medial temporal/Memory system.

The final goal of this study was to assess the neurocognitive correlates of SES with minimal confounding by health factors. Given the higher prevalence of prenatal substance exposure, premature birth, illness and injury within low SES families (Adler et al., 1994), neurocognitive disparities could result from larger fractions of children with undiagnosed illness and injury being averaged together with healthy children at lower levels of SES. The low SES participants in the present study have been followed since birth by a pediatrician (HH) and have no known history of neuropsychiatric illness or neurologic insult. They give us a unique opportunity to study the neurocognitive profile of SES in healthy children.

2. Results

To reduce the effect of outliers, data from each task were Winsorized, that is, the two most extreme values at each end of the distribution of all 60 children's scores were replaced with the third most extreme value at each end. Performance in each task was then reviewed for ceiling and floor effects, defined as mean performance less than one standard deviation from the minimum or maximum possible. Performance on the Shape