Socioeconomic Neurogradients of Attention: An ERP Study

by

Kylie Schibli

A thesis submitted to the Faculty of Graduate and Postdoctoral
Affairs in partial fulfillment of the requirements for the degree of

Master of Science

in

Neuroscience

Carleton University
Ottawa, Ontario

© 2014, Kylie Schibli

Abstract

This study examined children's socioeconomic neurogradients of selective attention. Indices of contextual socioeconomic family status (SES) and early development experience, the Early Development Instrument (EDI), were related to behavioural and neural correlates of an auditory oddball task in a sample including 52 preadolescent children (Aged 12-14 years) stratified according to SES: High (n = 14), Middle (n = 20), and Low (n = 18). Event-related potentials (ERPs) were recorded while children were asked to emit or withhold response to a series of rare/frequent and target/distracter tones. Despite SES-dependent differences in midline ERPs, children from the High- and Low-SES showed similar behavioural patterns with high performance. However, the Mid-SES group showed a markedly different performance pattern than their High-SES counterpart, correlated with differences in both ERP and EDI measurements. Confirming the joint role of SES and early childhood, these findings further our understanding of neuroimaging data across diverse experiential developmental contexts.

Acknowledgements

First and foremost I'd like to thank my supervisor, Dr. Amedeo D'Angiulli, for his ongoing support and guidance. His tireless motivation and endless wealth of knowledge encouraged me to challenge myself and to always ask questions – nothing was ever to be taken for granted. Thank you, Amedeo, for teaching me the value of critical thinking and for instilling in me a sense of confidence.

Secondly, I'd like to thank my thesis committee members, Dr. Alfonso Abizaid and Dr. Matthew Holahan, for engaging me in thoughtful debate and for providing effective feedback throughout this process. Thank you to Dr. Shelley Parlow and Dr. Shawn Haley for agreeing to be on my thesis defense committee. Shelley has also been an influential figure for me during my time at Carleton, and I'd like to thank her for our stimulating conversations during my undergraduate degree which urged me to pursue graduate school.

I'd like to express my sincere gratitude to my fellow lab member Patricia Van Roon who has been a mentor and a friend throughout my thesis. Her infinite patience when it comes to explaining ERPs has been absolutely instrumental for my learning. Her thirst for knowledge is contagious, and I am forever grateful for her willingness to help others.

A special thank you goes out to the research team involved with the data collection and preliminary analysis for the data used in my thesis. This includes, Dr. Amedeo D'Angiulli, Antonino Vallesi, and Patricia Van Roon.

Thank you to all of the students involved with the NICER lab that have volunteered and assisted me with data collection for other projects, and have listened and provided feedback to countless presentations in lab meetings! It has been so much fun getting to know you all, and your help has not gone unnoticed. A special shout-out to Christina Ou who has volunteered with me every step of the way, from my Honours Thesis in Child Studies to my Master's Thesis in Neuroscience – thanks for all the laughs Chrissy-Cat!

A special thank you to my family and friends for their endless support. Mom and Dad, thank you for always encouraging me to follow my passion and for being there for me when times were hard. I am so lucky to have such inspirational and hard-working parents with hearts of gold. I'd like to thank my sisters, Heather and Lori, for showing me what it means to be a strong and smart woman. I will forever look up to the two of you because you're both amazing! Thanks to Luke and his family for their encouragement and support.

Last but not least, thanks to my friends for keeping me sane these past two years! Sweet Sarah, thank you for being my unlicensed therapist – talking to you always makes me feel better. Thanks to my Neuro peeps – especially Shuaib – for sharing the good times and commiserating with me during the tough ones.

Table of Contents

Abstract.....	ii
Acknowledgements	iii
Table of Contents	v
List of Tables	vii
List of Figures.....	viii
1 Chapter: The cognitive social developmental neuroscience of socioeconomic status. Review of literature.....	1
1.1 Introduction	1
1.1.1 Definitions of Socioeconomic Status	4
1.1.2 The Neural Mechanisms Associated with Selective Attention	9
1.1.3 The Socioeconomic Gradients of Attention and Academic Achievement.....	13
1.1.4 Behavioural evidence	14
1.1.5 Structural Neuroimaging Findings	17
1.1.6 Functional neuroimaging evidence	21
1.1.7 At the other side of the spectrum: behavioral deviance risks in children from Affluent backgrounds.....	26
1.1.8 Early Development Instrument: A Population-Based Measure for Communities and how it relates to SES	29
1.1.9 The present Study: Hypotheses	34
2 Chapter: Design & Methods	34
2.1 Participants	35
2.2 SES Measures.....	37
2.3 Experimental procedure.....	39
2.3.1 Stimuli.....	39

2.3.2	ERP Data Acquisition and Recording Procedures	42
3	Chapter: Results.....	43
3.1	Analytic Design	43
3.2	Behavioural data.....	44
3.2.1	Accuracy	44
3.2.2	Reaction Times.....	45
3.2.3	Signal Detection Analysis	46
3.3	ERP Results	48
3.3.1	Visual Inspection of ERP Waveforms	49
3.3.2	Deviant: Attended vs. Unattended	49
3.3.3	Standard: Attended vs. Unattended.....	50
3.4	ERP Statistical Analyses	52
3.4.1	Analysis of negative (N2) waveform (250-300 ms).....	52
3.4.2	Analysis of positive (P3) waveform (350-500 ms)	53
3.4.3	Negative wave differences (attended versus unattended)	54
3.4.4	EDI scores, SES, and ERPs.....	58
4	Chapter: Discussion	60
4.1	Implications for neurocognitive training	65
4.2	Community-Based Interventions.....	66
4.3	Socioeconomic Neurogradients, Public Policy and the Shrinking Middle Class	67
4.4	Conclusion and Limitations.....	68
	References	71

List of Tables

Table 1 Family, neighbourhood and demographic characteristics of the three groups of children studied.....	36
Table 2. Behavioural profiles of the three groups of children for performance during the auditory selective attention task.....	48
Table 3. Results of regression models for examining relationship between negative difference waves at midline electrodes and SES rank, Hollingshead Total, and SES group.....	55

List of Figures

Figure 1. Graph representing the z-score values for the three groups of children based on regional information obtained on the EDI.....	38
Figure 2. Adapted from D’Angiulli et al. (2012): Layout of the auditory selective attention task and electrode positions.....	41
Figure 3. ERP activation in response to deviants at midline for the three groups, from left to right: high-, middle-,and low-SES.....	50
Figure 4. ERP activation in response to standards at midline for the three groups, from left to right: high-, middle-, and low-SES.....	51
Figure 5. Graph depicting the negative difference waves of deviants for the three groups.....	57
Figure 6. Graph depicting the negative difference waves of standards for the three groups.....	57
Figure 7. Graph representing the negative linear relationship between the percentage of vulnerable children and ERP response to attended versus unattended stimuli.....	59
Figure 8. Scatterplot depicting the linear relationship between SES and ERP activation.....	60

1 Chapter: The cognitive social developmental neuroscience of socioeconomic status. Review of literature.

1.1 Introduction

The effect of poverty on child development has been studied extensively and often involves comparing children from lower-socioeconomic status (SES) to children from higher-SES using an Extreme Group Approach (EGA) (Preacher, Rucker, MacCallum, & Nicewander, 2005). A common goal is to discover neuro-behavioural differences between groups of children following a task geared to a specific ability or neurocognitive process (Schibli & D'Angiulli, 2011). EGA has the advantage of increasing statistical power and reducing costs associated with greater sample sizes however, there are concerns involved with the assumptions underlying this method of analysis. Focusing on the lower and upper ends of a continuum suggests a monotonic if not specifically linear relationship, and excludes the effects of individual differences (Preacher et al., 2005). The current study introduces middle-SES as a comparison group providing a more accurate analysis of “socioeconomic neurogradients” (Schibli & D'Angiulli, 2013) as they relate to performance on an aspect of the broad spectrum of executive functions, an auditory selective attention task.

Children have been compared along a vast array of functions within the cognitive learning domain, including: language comprehension (Farah, Shera, Savage, Betancourt, Giannetta, Brodsky, Malmud, & Hurt, 2006), memory (Farah et al., 2006; Evans and Schamberg, 2009), attention (Stevens, Lauinger, and Neville, 2009; D'Angiulli, Van Roon, Weinberg, Oberlander, Grunau, Hertzman, & Maggi, 2012), and executive function (Farah, Shera, Savage, Betancourt, Giannetta, Brodsky, Malmud, & Hurt, 2006;

Kishiyama, Boyce, Jimenez, Perry, & Knight, 2008). Findings are then used to guide policy and practice in education and child services. In the last twenty years, there has been a dramatic increase in research focusing on brain training, which has led to the creation of computer programs geared at improving cognition, such as Cogmed (Pearson Education, 2014) and Fast ForWord® (Scientific Learning Corporation, 1997-2014). However, findings on the effectiveness of such interventions are mixed indicating the importance of critical examination and skepticism prior to implementation (Logie, 2012; Rapport, Orban, Kofler, & Friedman, 2013). Pilot and exploratory studies have involved school samples incorporating low SES children (Scientific Learning Corporation, 2004). Therefore, exploring the socioeconomic neurogradients can improve our understanding of how brain development is influenced by social inequities (Schibli & D'Angiulli, 2013) which can inform public policy and guide effective intervention practices such as Cogmed.

Scientists conduct research guided by a particular theoretical concept of human development influencing methodology, data analysis and interpretation (Lerner, Lewin-Bizan, & Warren, 2001). Linear outcome-based research targeting levels of SES as a comparison variable may be guided by explicit and implicit assumptions influencing data analysis and interpretation (D'Angiulli, Lipina, & Olesinska, 2012). For example, recent developmental research conducted by Noble, Norman, and Farah (2005) and Farah et al. (2006) suggest differences in neurocognitive systems among children from low-SES by examining performance on behavioural tasks associated with activation of particular brain regions. The researchers equate behavioural outcomes with neural disparities despite the lack of evidence. The implicit assumption that children from higher SES

backgrounds have typically developing brains suggests that differences in structural and functional brain activation incidentally found in other groups may be interpreted as deficits despite similar performance on cognitive tasks. Current research seems to create a perception of poverty being automatically or inevitably linked with detrimental outcomes. Such assumed position may place children from lower-SES at a disadvantage prior to project implementation, since researchers may inadvertently follow paradigms aimed at demonstrating developmental impediments.

Given the complexity of the constructs and influences surrounding issues related to SES and childhood development, it seems reasonable and plausible to approach current research questions from a theoretical framework that recognizes the role of individuals as active and contributing agents in their development influenced by interactions within a sociocultural context. The individual's reciprocal interaction with the environment and the history of such interactions may influence functional adaptive changes that support ontogeny for a particular time and place (Magnusson, 2003).

Research paradigms focused on creating a dichotomy between children from lower- and higher-SES lead to interventions targeting groups of children in isolation (i.e. "poor kids") presupposing that children within a specific income bracket are indistinguishable and failing to recognize the interrelatedness among all children during particular stages of development. It is widely understood that development is influenced by the interaction between internal (i.e. hormones, genetics) and external factors (i.e. environment, social interactions), however, these interdependent components are often teased apart in scientific research to target a particular variable of interest (for example, SES) without

appropriate consideration of both social and neurobiological contexts. Interpretations of results need to take into account the many factors influencing outcomes.

As an example of broad conceptualization, the Holistic-Interactionist Perspective on Individual Development (Magnusson, 2003) suggests that independent components of development cannot be understood unless interpreted as a whole. Strengths-based research that recognizes the diversity among humans yet focuses on the capacity for positive change through relative plasticity has the potential to increase our understanding of development and initiate applicable programs to support changes in growth. Specifically, programs designed to support development should be guided by developmental science that integrates biological, contextual and individual levels of influence while incorporating multidimensional and multidisciplinary perspectives (Lerner et al., 2001). Bridging this developmental science approach to neuroscience, the purpose of this study is to adopt a “neurocognitive” inclusive-interactionist perspective by focusing on the relationship between early childhood development and neurocognitive outcomes during early adolescence. In particular, the link between outcomes on an early development measurement tool, the Early Development Instrument (EDI), and behavioural and neural responses to a selective attention task during early adolescence will be examined.

1.1.1 Definitions of Socioeconomic Status

A challenge for scientists has been finding a concrete definition of poverty with many researchers referring to the educational status of the mother or the annual income of the family. These definitions fail to adequately describe the child’s experience with poverty

and may lead to an oversimplification of the complexities involved with the contextual, cultural and structural influences of social inequality (Schibli & D'Angiulli, 2013).

Prior to examining the many factors associated with childhood poverty, it is important to clarify the distinction between absolute and relative poverty. Absolute poverty refers to the lack of access to clean water, food, and/or shelter. Children experiencing absolute poverty are struggling to survive as they do not have access to basic resources.

Alternatively, relative poverty refers to earning less than is expected for the average family in a given society. Children experiencing this form of poverty may be unable to participate in extra-curricular activities, may not have suitable clothing or an adequate amount of food. The stigma associated with poverty may also lead to social exclusion. For the purpose of this paper, we will be focusing on relative poverty as this is what is commonly experienced for children in Canadian society.

In their review Maggi, Irwin, Siddiqi, and Hertzman (2010) describe the social determinants influencing children's development from prenatal development to eight years of age. Social determinants of child development refer to the interactions a child experiences in their social and physical environment influencing development. Maternal health and nutrition lay the foundation for fetal development. Pregnant women living in poverty may not have access to a nutritionally balanced diet resulting in physiological and physical impairments to their offspring, such as underweight or preterm infants (Barger, 2010). Physiological insults may not expose themselves until adulthood, as demonstrated in research examining the relationship between low-birthweight and coronary heart disease in adulthood (Barker, 1997).

An example of how maternal health impacts offspring can be seen in the effect of maternal stress on neurocognitive development and the immune system of the fetus (Ruiz & Avant, 2005). Animal studies have shown that exposure to prenatal stress leads to poor performance on a task commonly used to assess inhibitory control and sustained attention (The 5C-SRTT, for a description refer to Bari, Dalley, & Robbins, 2008) in rats (Wilson, Schade, & Terry, 2012). Human studies have shown that higher cortisol levels in pregnant women are associated with larger right amygdala volumes among female infants which appeared to mediate affective problems during childhood (Buss, Davis, Shahbaba, Pruessner, Head, & Sandman, 2012). Children exposed to maternal stress prenatally are more likely to express difficulties in social/emotional and cognitive functioning (For a review on the effects of maternal stress, the reader is directed to Talge, Neal, & Glover, 2007). Low-income mothers are more prone to chronic stress as they struggle to meet the demands of society with fewer resources. Maternal care and family influences continue to impact children's development throughout their lifetime.

The effect of maternal care on synaptogenesis in the hippocampus of offspring has been demonstrated in rat models. A series of experiments examining maternal licking/grooming in rats (i.e. maternal care) demonstrated that rat pups with high licking mothers performed significantly better on a spatial memory task as adults which was supported by synaptic markers suggesting an increase in synaptogenesis in the hippocampus. Furthermore, the effects of maternal care were evident when rat pups were cross-fostered. It was discovered that rats born from low licking mothers cared for by high licking mothers showed similar performance on the spatial memory task to rats that were born and raised by high licking mothers (Day, Diorio, Francis, Liu, & Meaney,

2000). Mothers dealing with the stressors associated with poverty may not have the time, resources, or energy to be readily available to their children. Maternal lack of child responsiveness (Berger, Paxson, & Waldfogel, 2009) and harsher parenting styles (Kohen, Leventhal, Dahinten, & McIntosh, 2008) have been associated with lower-income environments.

Mental health may be impacted by dire circumstances influencing the mother's ability to respond to her child. The effects of maternal depression on children's development have been widely researched, however, the combination of maternal depression and low-income appears to be especially problematic for children's emotional (Melchior, Chastang, Lauzon, & Galéra, 2012) and cognitive development (Pettersen & Albers, 2014). Lupien, King, Meaney, and McEwen (2000) found a positive correlation indicating that family income predicted both mother's depressive score and child's cortisol levels. Parenting styles also appear to vary as a function of SES. Higher-SES families typically implement authoritative parenting characterized by flexibility and providing the child with options, whereas lower-SES families tend to be more inclined to implement an authoritarian parenting style which is stricter and imposes parental control (Kohen et al., 2008). Harsher parenting styles might reflect the need to protect children from danger, and may be viewed as strategic when living in disadvantaged neighbourhoods.

The impact of neighbourhood disadvantage on children's development has been widely researched. Factors associated with neighbourhood disadvantage impacting children's development include: low social cohesion and social capital (De Coster, Heimer, & Wittrock, 2006; Kohen et al., 2008; Moren-Cross, Wright, LaGory, & Lanzi,

2006), chaotic and cramped living environments (Evans, Gonnella, Marcynszyn, Gentile, & Salpekar, 2005), exposure to violence and hazardous spaces (Lambert, Ialongo, Boyd, & Cooley, 2005), and lack of access to parks and community services such as libraries (Walker, Crawford, & Taylor, 2008). Children growing up in disadvantaged neighbourhoods are more at risk of experiencing mental health issues (Xue, Leventhal, Brooks-Gunn, & Earls, 2005), exhibiting violent behaviour in early adolescence (Patchin, Huebner, McCluskey, Varano & Bynum, 2006), experiencing early sexual activity for girls (Véronique Dupéré, Lacourse, Willms, Leventhal, & Tremblay, 2008), and are more at risk of suicidal attempts (Dupéré, Leventhal, & Lacourse, 2009).

Lack of investment in communities can lead to decrepit structures and the presence of hazardous materials, such as lead-based paint. Even minimal exposure to lead in childhood has been associated with cognitive difficulties (Davis, Chang, Burns, Robinson, & Dossett, 2004). Regional differences in relation to poverty present their own range of factors influencing children's development. For example, in Mexico City, children growing up in low-SES neighbourhoods located in the South are exposed to environmental pollutants of high ozone concentrations and fine particulate matter associated with lipopolysaccharides (endotoxin associated with septic shock in humans) (Calderón-Garcidueñas & Torres-Jardón, 2012). When compared with children of similar demographic who had not been exposed to high concentrations of air pollution, children from South Mexico City demonstrated deficits on a series of cognition tasks with 56% exhibiting prefrontal white matter hyperintensities (commonly associated with aging). Furthermore an autopsy report of 43 children revealed that nearly half exhibited frontal tau hyperphosphorylation with pre-tangle material and myloid diffuse plaques frequently

associated with Alzheimer's disease. However, the role of neuroplasticity to compensate for environmental factors can protect children from exhibiting negative neurological effects.

Given poverty is a multifactorial construct, influences on children's development expand beyond what was discussed here. The socio-political context of a country and more specifically how children's development is valued in a given society play a significant role in the opportunities and support provided (Maggi et al., 2010). Cultural groups will experience poverty differently based on their status in society with the historical context playing an instrumental role. Indigenous populations are often at the margins of society and have the heightened pressure of generations of discrimination. In Canada, children of Aboriginal status living on-reserve receive less public funding for education and health when compared with all other Canadian children (Canadian Human Rights Tribunal, 2013).

1.1.2 The Neural Mechanisms Associated with Selective Attention

Attention refers to the identification and integration of sensory information that allows us to be aware of our environment and regulate our thoughts and behaviour. Posner and Rothbart (2007) have developed networks to illustrate the brain areas associated with attention, and have discovered three subcomponents: alerting, orienting, and executive function. Each aspect of attention is associated with different regions of neuronal activation. Alerting and orienting are involved with the detection of sensory stimuli and function at the subcortical and cortical level; whereas executive function is associated with higher order cognitive processing and involves communication between the prefrontal cortex and the anterior cingulate gyrus.

The executive function system is comprised of several interactive neurocognitive skills, including: selection, target detection, conflict resolution, inhibition of prepotent responses, monitoring and error detection (Berger, 2011). The ability to divert and narrow one's focus to salient information is at the basis of selective attention, and is increasingly important for children as they are continually exposed to multiple sources of stimulation (i.e. internet, videogames, etc.). The "Cocktail Party Effect" (Cherry, 1953) laid the foundation for numerous psychological studies investigating people's ability to shift their focus and selectively attend to relevant auditory stimuli while ignoring irrelevant stimuli. This skill is significant as it is believed that humans have a limited cognitive capacity to store information (van der Molen, 2000).

There are two modes of processing that have been recognized for selective attention: top-down and bottom-up. Top-down processing is related to intentional shifts in attention; whereas bottom-up processing is commonly associated with automatic shifts of focus. Lee, Larson, Maddox, and Shinn-Cunningham (2014) provide the example of eavesdropping to a particular conversation in a crowd as top-down, and the reflexive reaction to attend to a baby's cry as bottom-up. Closely related to selective attention is inhibitory control.

Inhibitory control relates to the ability to withhold a dominant response, and involves the active suppression of processing irrelevant information (van der Molen, 2000). Response inhibition is especially beneficial in social situations where certain behaviors or responses are viewed as inappropriate (Berger, 2011). The ability to follow social norms within a classroom environment is highly dependent on this skill as children are expected to raise their hand if they have a question and wait their turn during class

discussions. Development of inhibitory control is thought to follow maturation of the frontal lobes, therefore improving over time. The frontal lobes are the last region of the brain to fully develop with myelinization not complete until early adulthood (van der Molen, 2000). The development of executive function, specifically attention and impulse control, is most prominent in later preschool years (Garon, Bryson, & Smith, 2008). Individuals with Attention Deficit Hyperactivity Disorder (ADHD) demonstrate deficits in selective attention and inhibitory control allowing an opportunity to research the neuromechanisms involved.

Individuals with ADHD appear to demonstrate dysfunction in the cingulate, frontal, and parietal cortical regions referred to as the cingulo-frontal-parietal (CFP) cognitive network. The CFP is comprised of brain regions associated with executive function including attention and inhibitory control. These include: the dorsal midcingulate cortex (daMCC), dorsolateral prefrontal cortex (DLPFC), ventrolateral prefrontal cortex (VLPC), and the parietal cortex. Structural differences such as, decreased volume of these regions and thinning of the cortex (cingulate and prefrontal regions) and functional differences including reduced activation during cognitive tasks have been associated with ADHD (for a review, refer to Bush, 2011). Although the neurobiology of ADHD is not fully understood, these findings help clarify the behavioural symptoms of the disorder including: impulsivity, hyperactivity, and inattention (Asherson, 2012). Recent research suggests a link between SES and ADHD diagnosis (Russell, Ford, Rosenberg, & Kelly, 2013).

Russell et al. (2013) analyzed data retrieved on 13305 children diagnosed with ADHD in the United Kingdom (UK). Using logistical regression, the authors report that

there was a relationship between SES and ADHD diagnosis with families that demonstrated an increase in factors associated with low-SES (i.e. lower maternal education, income below the poverty line, single families, etc.) having a higher incidence of children diagnosed with ADHD. Further analysis indicated that ‘labelling bias’ was not present since medical reports complemented teacher and parent ratings on a scale assessing children’s hyperactivity, impulsivity, and inattention. However, it is possible that parents and teachers also engage in labelling bias.

The authors discovered that conflict within families mediated the relationship between SES and ADHD with lower-SES families exhibiting more family conflict. Therefore, it is possible that the strain associated with poverty negatively impacts parents’ view of their child. Furthermore, the stigma of poverty can negatively influence teacher perceptions (Rosenthal & Jacobson, 1968). The increasing interest in neuroenhancement drugs to improve cognition has raised neuroethical implications especially when it concerns children and their inability to make decisions (Graf, Nagel, Epstein, Miller, & Nass, 2013). A recent journalistic investigation based on pediatric interviews and other informal evidence preliminarily suggests that medical clinicians are prescribing stimulants to young children from disadvantaged neighbourhoods to improve school performance (Tremonti, 2012; see also Schibli & D’Angiulli, in preparation). An attempt to understand the socioeconomic-achievement gap has led to research examining the neurocognitive mechanisms associated with poverty. Differential brain activation during cognitive tasks has been found when comparing children from lower-SES to children from higher-SES which has been implicitly interpreted as a deficit (D’Angiulli, Lipina, & Olesinska, 2012). We argue that the distinction between

pathology and adaptive learning must be taken into account when implementing research and analyzing findings.

1.1.3 The Socioeconomic Gradients of Attention and Academic Achievement

Standardized intelligence tests were initially created to identify “defective” children in need of special education (Binet & Simon, 1916, p. 9). It has been suggested that performance on Intelligence-Quotient (IQ) tests predicts academic achievement and lifelong outcomes, with children from lower-SES demonstrating lower scores than children from higher-SES. A meta-analysis involving sixty-five samples was conducted to examine the relationship between intelligence and socioeconomic success (Strenze, 2007). Findings indicated that intelligence as measured on standardized IQ tests, has a greater influence on socioeconomic success than parental SES or academic achievement. The author suggests that this demonstrates the importance of intelligence as a separate causal predictor for outcomes later in life. However, the determination that standardized IQ tests are a reliable indicator of intelligence has been debated (D’Angiulli et al., 2012).

D’Angiulli et al. (2012) describe the implications of IQ testing leading to insinuations that children from lower-SES and minority populations are generally less intelligent than their more affluent counterparts. Of interest, intelligence tests were created to address concerns with “feeble-mindedness”, a term commonly applied in early 20th century Britain (Binet & Simon, 1916). If we break down this term and focus on the concept of “feeble” defined as “lacking physical strength” (Feeble in Oxford Dictionary, n.d.) then we can presume that feeble-mindedness was perceived as a lack of mental strength, or, as presently defined, lacking cognitive capacity. Recently there has been a trend in Cognitive Neuroscience to associate poverty with “limited cognitive function”

leading to poor decision-making (Mani, Mullainathan, Shafir, & Zhao, 2013) and a lack of self-control (Vohs, 2013). This interpretation suggests a deficit within the individual and labels certain groups. Similar associations have been suggested when examining differential brain activation during cognitive tasks between children from low- and high-SES backgrounds. The influence of SES on cognitive development has been heavily researched in developmental cognitive neuroscience however the majority of studies involving humans focus on behavioural measures, we will briefly review the relevant evidence next (For an extensive review, see Raizada & Kishiyama, 2010).

1.1.4 Behavioural evidence

Typically, performance on cognitive tasks is compared with brain function by referring to lesion studies. Noble, Norman, and Farah (2005) had thirty kindergarten children from lower- and middle-SES backgrounds complete a series of tasks associated with five neurocognitive systems: the occipitotemporal/visual cognition system, the parietal/spatial cognition system, the medial temporal/memory system, the left perisylvian/language system, and the prefrontal/executive system. Behavioural outcomes were then compared with measures of income, and framed as evidence of the neurocognitive correlates of SES. Specifically, SES disparities were reported in the cognitive systems of language and executive function.

Each of the five neurocognitive systems was targeted by implementing 2-3 tasks commonly associated with activation in the allocated region of the brain. Overall, SES was found to have a main effect on these systems, however, five individual scores (3 from lower-SES, and 2 from middle-SES) were excluded from the analysis since they were more than 3 standard deviations from the mean. This is worth noting since it is

possible that the excluded data may indicate resiliency and emphasize the importance of individual differences, especially given the small sample size. When teased apart, performance was only significantly different across SES in the language and executive function tasks. The three tasks completed for the language domain assessed vocabulary understanding, phonological awareness, and syntax. The executive function domain involved 2 tasks assessing inhibitory control, and spatial working memory. Furthermore, false alarm rates were totaled across several memory tasks to explore prefrontal cortex activity. Scores from each task were converted into z-scores and used to create a total composite score.

Results demonstrated that children from low-SES demonstrated significantly lower performance on the tasks assessing vocabulary understanding and phonological awareness for the language system; and significantly lower performance on tasks assessing inhibitory control for the executive function system. According to the authors, these findings suggest a mediational pathway is responsible for the differences in SES, such that poverty impacts language which in turn influences executive function. Parental education was found to be the leading factor attributed to these differences accounting for 26.7% of the variance in the language system, and 11.9% of the variance in the executive function system.

Previous research has indicated that parents from lower-SES backgrounds tend to spend less time reading with their children due to excessive societal demands (Mistry, Benner, Biesanz, Clark, & Howes, 2010). This may explain the reduction in vocabulary and phonological awareness. However, follow-up studies have demonstrated that language skills increase among children from lower-SES households when parents are

provided with the resources and time to read to their children, while receiving teacher support (Sheridan, Knoche, Kupzyk, Pope, & Marvin, 2011). Noble et al. (2005) neglect to discuss the socio-political factors impacting families, and emphasize their discussion on interventions targeting children from low-SES. While it is important to explore the factors influencing children's development, neuroethical consideration for how interpretations of research results can label children must be explored. Farah, Shera, Savage, Betancourt, Giannetta, Brodsky, Malmud, and Hurt (2006) conducted research comparing low- and middle-SES children with the goal of determining a specific "neurocognitive profile" (p. 167).

Farah et al. (2006) compared the performance of low- and middle-SES children on a battery of cognitive tasks. Thirty-four African-American female children between the ages of 10 and 13 years participated in the study. Children were divided evenly into two groups, low- and middle-SES. The low-SES group had been followed since birth and had not been exposed to illicit drugs in utero. According to the authors, these were children whose health had not been impacted by exposure to environmental factors generally associated with low-SES (prenatal drug and alcohol exposure, lead exposure). They discovered that children from low-SES performed significantly worse than children from middle-SES overall, however when examined separately, this was only significant for tasks that assessed language, working memory and memory. Performance on tasks examining cognitive control, reward processing, spatial cognition, and visual cognition was not significantly different between groups. The authors linked performance on cognitive tasks with areas of the brain commonly known to be activated during task completion and proposed that children growing up in low-SES environments have

different brain functioning in the lateral prefrontal cortex (working memory), medial temporal (memory), and the left perisylvian (language). According to the authors, the differences in cognitive function reflect differences in brain function that can be directly related to SES disparities.

The authors make no mention of the implications of stereotype threat on test performance. The fear of validating negative stereotypes associated with race and gender affects the ability to perform in a testing situation as supported in research (Review Steele, 1997). More recently, stereotype threat has been associated with SES with children in the first and third grade. Désert, Préaux and Jund (2009) discovered that as early as the first grade children start believing high-SES is associated with improved academic ability, which translates into decreased performance on intelligence tests for children from low-SES. The children from low-SES involved with Farah et al.'s (2006) study possessed demographic backgrounds with a history of marginalization (i.e. female, and Africa-American) that was confounded by the stigmatization of poverty. Suggesting that behavioural performance is directly linked to brain function irrespective of the social context is incomplete. Furthermore, no measures were taken to explicitly demonstrate differences in activation indicating only indirect inferences to brain function (Lipina & Posner, 2012). Recently, research has focused on exploring the neural mechanisms associated with cognitive function and children from lower-SES backgrounds.

1.1.5 Structural Neuroimaging Findings

Interest in examining differences on executive function tasks among children from variable SES backgrounds has led to the investigation of structural brain differences.

Lawson, Duda, Avants, Wu, and Farah (2013) examined the relationship between SES

and prefrontal cortical thickness using structural magnetic resonance imaging (MRI). MRI is a neuroimaging technique that measures the radiation emitted from hydrogen atoms in response to a strong magnetic field. This technique allows the observation of density differences in hydrogen atoms with high water content reflecting areas high in neurons, and lower water content reflecting axon-rich areas. The brain is portrayed in a grayscale (or colour) static image, with regions varying from lighter to darker shades depending on the density of hydrogen atoms in the tissue (with lighter shades reflecting higher density) (Kolb & Whishaw, 2011). The authors focused on cortical thickness measured by the distance between the white matter surface (axon-rich) and pial gray matter surface (neuron-rich) with SES as the predictor variable. Ten prefrontal regions were targeted in healthy children.

Data on 283 children between the ages of 4-19 years with annual family income ranging from less than \$5,000 to \$150,000 was included in the study. Hierarchical linear regression was applied using parental education and family income as predictor variables and cortical thickness in each region of interest as the dependent variable. Two regions were significantly related to SES: (1) the right anterior cingulate gyrus, and (2) the left superior frontal gyrus. Parental education significantly predicted cortical thickness in both regions, whereas family income did not. This held constant when confounding factors were controlled for, including: age, sex, total brain volume, race, BMI, and IQ. Anterior cingulate regions are associated with functions in a variety of domains, including: motor and pain response, cognition and attention, and autonomic activity in response to emotions (Pujol, Lo'pez, Deus, Cardoner, Vallejo, Capdevila, & Paus, 2002). Surface area of the right anterior cingulate gyrus vary dramatically between individuals,

but has been found to be larger in women and in individuals reporting behaviours associated with harm avoidance (Pujol et al., 2002). Harm avoidance is characterized by worry and fear of uncertainty, and discomfort around strangers. Whereas other studies suggest that reductions in the right dorsal anterior cingulate cortex are associated with panic disorder (Asami, Hayano, Nakamura, Yamasue, Uehara, Otsuka, Roppongi, Nihashi, Inoue, & Hirayasu, 2008).

These contradictory findings address the concern with drawing conclusions from brain structure, although recent research has drawn parallels between structure and function. Hegarty, Foland-Rossd, Narrb, Townsenda, Bookheimera, Thompsona, and Altshulera (2012) discovered a positive correlation between thickness of the right anterior cingulate cortex and activation during an attention task. However, this relationship was not supported for other areas involved with functional brain activity, including the left anterior cingulate cortex and the prefrontal cortex, which includes the superior frontal gyrus.

The left superior frontal gyrus is implicated in working memory, particularly in spatial modalities (du Boisgueheneuc, Levy, Volle, Seassau, Duffau, Kinkingnehun, Samson, Zhang, & Dubois, 2006). This area matures relatively late in development with gray matter reaching its peak at approximately 10 years of age (Gogtay, Giedd, Lusk, Hayashi, Greenstein, Vaituzis, Nugent III, Herman, Clasen, Toga, Rapoport, & Thompson, 2004). Therefore, measuring cortical thickness in childhood appears counter-intuitive considering development is still progressing. Furthermore, structure does not necessarily associate with function (Hegarta et al., 2012). Noble, Korgaonkar, Grieve, and Brickman (2012) examined white matter in targeted tracts associated with cognitive

control to determine the influence of education on cognition in adolescence, and discussed the relationship to SES.

Data collected in Australia on forty-seven adolescents between 17-23 years of age was analyzed to determine the influence of education on cognitive development. Participants underwent MRI scans which were then analyzed for white matter tracts using diffusion tensor imaging (DTI). DTI is used to map the diffusion of water molecules in the brain, and allows for estimates of white matter connectivity patterns through fractional anisotropy (FA) (Alexander, Lee, Lazar, & Field, 2007). Noble et al. (2012) examined white matter tracts commonly associated with cognitive control: the superior longitudinal fasciculus (SLF), the cingulum bundle (CB), and the anterior corona radiate (ACR). Furthermore, the uncinate fasciculus was used as a control region since it is not associated with cognition. Behavioural measures assessing cognitive control were obtained as participants engaged in a verbal interference task.

Results indicated that education was associated with improved performance on the task independent of age. This relationship appeared to be mediated by differences in white matter tracts, specifically in the SLF. These findings suggest that higher education influences cognitive control and is evidenced through microstructural changes in white matter connectivity. However, the authors consistently discuss the influence of SES on cognition despite its lack of measurement in the study. The opening paragraph describes challenges with determining the influence of SES on cognitive and neural development encouraging the reader to conclude that the current study addresses this issue, yet there was no indication of SES measurement. Studies involving functional neuroimaging have

directly examined the influence of SES on cognition; however, interpretations of results may be framed by implicit assumptions and must be examined critically.

1.1.6 Functional neuroimaging evidence

Event-Related Potentials (ERPs) refer to a change in brain activity following an internal or external sensory stimulus. This is a non-invasive technique with effective temporal resolution providing an accurate measurement of when processing takes place in the brain. ERPs are characterized by their latency following stimulus presentation and by their polarity (negative or positive). They are calculated by averaging the summed potentials following the repetition of stimulus presentation during a task. They are often used in research involving the study of human cognition (Picton, Bentin, Berg, Donchin, Hillyard, Johnson, Miller, Ritter, Ruchkin, Rugg, & Taylor, 2000). Kishiyama, Boyce, Jimenez, Perry, and Knight (2009) applied this technique to explore the neurocognitive differences in children from lower-SES backgrounds.

Kishiyama et al. (2009) examined the influence of SES on the prefrontal cortex (PFC). Executive function is associated with development of the PFC and is responsible for second-order cognitive functions, including selective attention and inhibitory control. The authors had twenty-six children between 7 to 12 years perform a visual selective attention task where they were asked to press a button in response to a low-probability (10%) target stimulus of a tilted black triangle while ignoring high-probability (75%) standard stimuli of an upright black triangle and novel stimuli (15%) of affective pictures. ERP analysis was conducted during task participation. Furthermore, children were scored on a series of behavioural measures assessing executive function skills that rely on the

PFC, including: working memory, visuomotor attention, cognitive flexibility, inhibitory control, semantic fluency, and language.

The authors predicted children from lower-SES would have reduced amplitudes on early neural processing components including the P1, N1 and N2 in comparison to children from higher-SES. The P1 and N1 are thought to be PFC dependent and are associated with voluntary attention whereas the N2 has been associated with response to novelty. These predictions were confirmed as children from lower-SES demonstrated a reduction in the P1 and N1 following the presentation of standard stimuli, and a reduction in the N2 in response to novel stimuli when compared with children from higher-SES. In their discussion, the authors emphasize the finding that these three components are reduced in patients with lesions in the PFC, therefore, implying that children from lower-SES demonstrate activation associated with brain damage. Of interest is the finding that children did not differ on performance or neural activation in response to target stimuli. One interpretation of the reduction in brain response to novel stimuli may be adaptive from growing up in chaotic environments where the unexpected is the norm.

Stevens, Lauinger, and Neville (2009) aimed to investigate “if specific neurocognitive deficits could be identified in children from lower socioeconomic backgrounds” (p. 634). The authors examined thirty-two children between the ages of 3 to 8 years as they completed an auditory selective attention task. Socioeconomic status was defined using the mother’s education level, with children divided into two groups: higher maternal education (at least one year of college experience) and lower maternal education (no college experience). ERPs were measured to examine differences in early neural processing of attention.

Children listened to two stories occurring simultaneously and were told to attend to one while ignoring the other. Each child listened to four stories, with the attended channel evenly split between left and right. As a behavioural measure, children were asked three comprehension questions relating to the attended story. ERPs were analysed by examining linguistic and non-linguistic probes: “ba” spoken in a different voice than the story narrator, and a buzz-like sound of the syllable “ba”. A researcher sat beside the child throughout the experiment to monitor behaviour. ERP analysis was conducted on the frontal and central electrodes during early neural processing (100-200ms following stimulus onset) with greater amplitudes suggesting increased attention. Results indicated that children did not differ in their response to the attended probe however, children from the higher maternal education group demonstrated significantly greater amplitudes in response to the attended probe when compared with the unattended probe. Although a difference in amplitude was detected in the lower maternal education group, it was not significant. Therefore, suggesting that there was a difference between groups in response to the unattended stimulus, i.e. suppression of attention to irrelevant information. Behavioural measures indicated that there was no difference regarding children’s ability to correctly answer the comprehension questions.

Although children performed similarly, the authors interpret the differences detected in early neural processing as a potential impediment for children from lower-socioeconomic status. They explain that differences in performance might present themselves when the cognitive demands of the task are greater, and discuss the importance of interventions targeting attention skills for children from lower-SES. The authors frame the findings in terms of a vulnerability to “deficit in children from lower

socioeconomic backgrounds” (p. 644), and go on to describe effective attention training programs.

D’Angiulli, Van Roon, Weinberg, Oberlander, Grunau, Hertzman, and Maggi (2012) discovered similar findings when comparing adolescents on an auditory selective attention task and examined the relationship to emotional and motivational variables. D’Angiulli et al. (2012) compared the early neural processing, and daily cortisol concentration of twenty-eight children in grade-six from lower- and higher-SES neighbourhoods. SES was measured based on a variety of parental and environmental factors, including: parental education and occupation, family income, marital status, and neighbourhood quality.

These researchers collected six saliva samples throughout the school day, four prior to the child’s participation in the selective attention task and two after. EEG/ERP data was collected using a mobile unit stationed at the child’s school. The auditory selective attention task required children to listen binaurally to four tones involving two frequencies (800 Hz and 1200 Hz) and two duration times (100ms and 250ms). The child was asked to respond to a tone (i.e. target) at a specific frequency and duration (for ex. 800Hz and 250ms) by pressing a button, while ignoring all others. Finally, to assess emotional and motivational response to the task, each child completed an appraisal and affective questionnaire before and after task participation. ERP analysis was conducted 100ms prior to stimulus presentation, and 900ms following. Differences between attended tones (same frequency as the target) and unattended tones (different frequency and/or duration to target) were calculated and compared between the two groups. The difference was greater for children from higher-SES. This was analyzed further by

examining differences between electrode locations. Bonferroni pairwise comparisons indicated the difference between the two groups of children was significantly greater at the midline and midfrontal left electrodes. Furthermore, analysis on theta activity demonstrated right asymmetry for the lower-SES group and the reverse for the higher-SES group. Theta activation has been associated with greater attentional effort. According to the authors, these findings indicate children from higher-SES selectively attend to relevant information and demonstrate greater theta activation under this condition; whereas, children from lower-SES pay attention to relevant and irrelevant information with increased effort attributed to the latter as reflected in theta activation. Despite a difference in salience identification between the two groups, behavioural measures of response time and accuracy to the target tone were similar.

Results from the salivary analysis indicated that overall children from lower-SES had greater cortisol concentration than children from higher-SES; however, this was not found to be attributed to HPA reactivity or emotional/motivational state in response to the task. Furthermore, when controlling for boredom and HPA reactivity, theta power continued to change as a function of SES. The authors suggest that these findings indicate that differences in cognitive function cannot be attributed to perceived stress or emotional/motivational reactions to the task, and can therefore be viewed independently. These findings are supported by Pilgrim, Marin, and Lupien (2010) who discovered that a student's response time to socially stressful words in an attention task corresponded to cortisol levels during a stress-inducing task, which was unrelated to childhood SES. Therefore suggesting that difference in brain activation between SES groups during attention tasks is unrelated to HPA reactivity.

Having controlled for these potential confounds, D'Angiulli et al. (2012) state that their findings clearly indicate the differential neural activation associated with contextual experience. The importance of incorporating contextual factors not commonly included in SES research is supported by research demonstrating the differential impact of literacy activities versus electronic resources on children's executive function in a diverse Argentine sample (Lipina, Segretin, Hermida, Prats, Fracchia, Camelo, & Colombo, 2013). It was discovered that access to computers and the internet influenced children's performance on tasks associated with fluid intelligence, whereas the frequency of being read to mediated the effects of poverty regarding spatial working memory, and fluid processing. These findings support the idea that variable factors relating to SES may influence children's cognitive development in different ways, and that these changes should be viewed from the child's perspective by recognizing contextual and cultural influences.

It has been suggested that children's attention to relevant and irrelevant information may be influenced by contextual factors such as, exposure to chaotic and unpredictable living environments (D'Angiulli et al., 2012). These neural differences can be viewed as an adaptive response to contextual experience and provide evidence for neural plasticity and how environment shapes the brain (Lipina & Posner, 2012). A majority of research has centered on the effects of low-SES on children's development, disregarding the influence at the other end of the spectrum.

1.1.7 At the other side of the spectrum: behavioral deviance risks in children from Affluent backgrounds

Luthar and Latendresse (2005) describe research conducted on the outcomes of affluent youth in the last two decades. In a comparison between high-income suburban youth and inner-city youth, it was discovered that the former experienced significantly higher levels of anxiety and delinquent behaviour (i.e. increased use of drugs and alcohol). Affluent youth engaged in substance use showed increased signs of depression and anxiety supporting the self-medication theory. This is especially detrimental for lifetime outcomes as it cannot be characterized as a “teenage phase” or simple exploration. Furthermore, symptoms of depression and substance use begin to develop as early as the seventh grade among this population.

Possible explanations for this relationship refer to family functioning, including: emotional and physical isolation from parental figures, and excessive pressure from parents to achieve. Affluent youth were more likely to report weaker feelings of emotional attachment to parents and spent less time eating dinner as a family than did their inner-city counterparts. Emotional isolation from parents was linked with higher levels of distress and substance use. Secondly, youth who expressed higher demands for achievement – both personally and from parents – showed higher rates of depression, anxiety and substance use. Ansary and Luthar (2009) examined the link between psychopathology and academic achievement among youth from higher-SES backgrounds.

High school students from affluent neighbourhoods were followed from grade 10 to grade 12 and measured on a series of indicators for externalizing and internalizing behaviours. The median household incomes ranged from \$74,898 to \$102,121 US, with students attending a school ranked second highest in terms of family socioeconomic

status. The researchers characterized externalizing and internalizing behaviours using cluster analysis. Externalizing behaviours included substance use (cigarettes, alcohol, and marijuana) and delinquency (rule-breaking behaviour); whereas, internalizing behaviours included measures of depression and anxiety. Behaviours were measured using self-report and were validated with peer nomination. This led to the creation of five groups among the youth: conventional (C), internalized distressed (ID), cigarette/alcohol users (CA), marijuana users (M), and multiproblem (MP). School records and teacher reports on classroom adjustment were obtained to determine academic standing. Groups were compared for academic standing across time.

Results indicated that marijuana users and multiproblem students had lower academic standing when compared with the other groups. Specifically, conventional students had significantly higher academic standing compared with marijuana users and multiproblem students; and multiproblem students performed significantly worse than internalized distressed youth and cigarette/alcohol users. Overall, females outperformed males on both grades and classroom adjustment. However, female marijuana users had substantially lower grades than males at grades 10 and 11.

A secondary analysis involved examining behavioural outcomes associated with academic standing. Youth were divided into groups based on grades (low, medium, high) and classroom adjustment (low, medium, and high). As expected, students with lower grades and classroom adjustment were more likely to demonstrate externalizing behaviours and delinquency. Surprisingly, internalizing behaviours were not significantly different for the lowest achievement group. Internalizing behaviours were higher for females than males, and decreased over time for all groups except for the medium

grades/high classroom adjustment (MG-HCA) group who showed increases in depression. Of interest, the MC-HCA group also reported significantly higher alcohol and cigarette use and delinquency when compared with the highest achievement group.

These mixed findings reflect the intricacies among affluent youth, and demonstrate the problematic behaviours associated with this population. In particular, youth with mediocre grades that behave appropriately in the classroom setting may be overlooked but appear to be at increased risk for depression, substance use and delinquency. These findings support global interventions that monitor student progress across all demographic backgrounds and socioeconomic status. The current study extends on previous research examining the relationship between cognition and SES by introducing middle-SES as a comparison group providing a more accurate analysis of socioeconomic neurogradients as they relate to performance on an auditory selective attention task. Furthermore, cognitive performance will be compared with early childhood development as this allows for a more in depth understanding of the child's socio-ecological experience.

1.1.8 Early Development Instrument: A Population-Based Measure for Communities and how it relates to SES

The Early Development Instrument (EDI) reflects a social constructivist view by examining the child's school readiness based on how the community supports and influences the child's development (Janus & Offord, 2000). Guhn, Janus, and Hertzman (2007) describe the construct of school readiness as, "the child's ability to meet the task demands of school" (p. 370). Behaviours might include: the ability to wait one's turn and cooperate with others, the motivation to seek information and communicate effectively,

the capability to follow rules and pay attention, etc. Beyond the individual child's capabilities, the social constructivist approach to school readiness encompasses the interactions the child has with their family and the resources available in their community that support development (Forget-Dubois, Lemelin, Boivin, Dionne, Séguin, & Tremblay, 2007).

Emphasis is placed on measuring developmental-based abilities rather than curriculum-based skills with the data obtained analyzed at the population level (Janus & Offord, 2000). Focusing on groups of children avoids negative labelling of individual children, and encourages collective accountability for children's development. Therefore, the goal is to provide whole communities with information on children's development to promote public support and encourage interventions that target groups of children. Data can be compared across regions, provinces, and countries with other population-level databases to expand our understanding of the contextual factors influencing development which may lead to the creation of a universal framework promoting development (Guhn, Janus, & Hertzman, 2007).

The assessment tool is completed by the child's teacher midway through the first year of kindergarten, and covers five broad developmental domains: (a) physical health and well-being (13 items), (b) social competence (26 items), (c) emotional maturity (28 items), (d) language and cognitive development (26 items), and (e) communication skills and general knowledge (8 items). In addition, the child's demographic information (i.e. sex, date of birth, language), valuable information regarding classroom placement (i.e. English as a second language, special skills) and prekindergarten experiences (i.e. preschool, child care) are requested. The teacher is presented with questions to be scored

from 0 (lowest score) to 10 (highest score), answers vary from Likert 3- to 5-point scales while others require yes/no responses. The questionnaire takes from seven to twenty minutes to complete and does not need to be administered by a trained examiner making it time and cost effective.

Scores are separated into percentiles for each domain and communities are provided with a descriptive report detailing the average developmental profile of children in their region. Statistical analysis can be performed on variables of interest obtained in the additional information of the questionnaire, such as gender and age. Given that scores are combined at a population-level, assessments might include schools, communities, or entire school districts (Guhn, Janus, & Hertzman, 2007). The translation from research to policy or practice is facilitated as the purpose is to assess all children within a given community.

Forget-Dubois et al. (2007) discovered that the EDI accounted for 34% of variance in predicting school success at the end of the first grade with a sample of 795 children across 692 schools retrieved from the Quebec Longitudinal Study of Child Development (QLSCD). Further analysis demonstrated that the domain of physical health and well-being was the greatest contributor to this relationship and remained significant even when SES was taken into account. This finding suggests that children's health cannot be limited to differences in income. When combined with validated measures of cognitive and language abilities, two domains of the EDI continued to make a unique contribution to the variance: the physical health and well-being domain and the language and cognitive development domain. This lends support for use of the EDI as an assessment tool for predicting early school success.

The EDI is presented as a multidimensional measure to assess development across all children despite demographic differences. There has been discussion whether the tool adequately represents children from multiple cultural groups and linguistically diverse backgrounds (Li, D'Angiulli, & Kendall, 2007). Areas of contention include the appropriateness of the EDI for assessing the school readiness of children whose first language is not English and Aboriginal children. The authors explain that English-as-a-second-language (ESL) children commonly demonstrate advances in communication and literacy during the primary years but lag behind in the early years. This population of children may be falsely deemed 'at risk' given the EDI is implemented in kindergarten. The EDI may not be sensitive to cultural differences with questions formulated from a Western perspective. D'Angiulli et al. (2007) use the example of oral tradition being a core value of Aboriginal cultures whereas Western society places a higher significance on literacy. The question of whether the EDI assesses children based on their ability to integrate into the dominant culture of the school setting or whether it achieves the goal of assessing children's development in order to adequately succeed in school has been debated (Li, D'Angiulli, & Kendall, 2009).

Guhn, Gadermann, and Zumbo (2007) addressed this issue by assessing the validity of the EDI by examining item bias across three categories: ESL, gender, and Aboriginal status. The authors used ordinal logistic regression to examine differential item functioning (DIF, when groups have differing probabilities of correctly answering an item), which can suggest item bias or item impact. Their sample consisted of 43900 kindergarten children across 59 school districts in British-Colombia, Canada. Sex was

relatively even (48.6% female, 51.4% male), 17.0% were ESL students, and 6.7% were Aboriginal.

Results indicated that ESL children generally received lower scores (5 items out of 8) in the domain of communication skills and general knowledge than native English speakers. Two items found in the language and cognitive domain were also scored lower for this group but did not have an impact on their overall domain score. It was discovered that teachers' rate boys as more physically aggressive than girls but that this did not have an effect on the domain score for emotional maturity. Finally, DIF was not discovered for Aboriginal children. The authors conclude that groups of children are being assessed similarly making the EDI a valid instrument void of teacher bias. They explain that the items where DIF was presented reflect item impact since one would expect differences in these specific skills and abilities between groups. Of interest, is the fact that children living on Aboriginal reserves were not involved in the study as these communities did not agree to participate in the EDI assessment. Therefore, one might argue that these findings do not reflect all Aboriginal communities and the EDI may not be appropriate for measuring school readiness for children in schools on-reserve.

There appears to be a need for research examining the long-term, distal predictive value of the EDI for school success, especially for children from culturally and linguistically diverse communities (D'Angiulli et al., 2007). Janus and Offord (2000) explain that results can be examined by either "looking forward" (prospective) at how children's scores might predict academic achievement and how we can support it or "looking backward" (retrospective) at how children's school readiness relates to outcomes in later years (p. 74). The present study applies the latter as we compare

performance on a selective attention task and ERP patterns during early adolescence to EDI scores obtained during kindergarten.

1.1.9 The present Study: Hypotheses

The aim of the present study is to explore ERP modulations on an auditory selective attention task across socioeconomic groups. Three main hypotheses were tested:

(1) As demonstrated in previous research, we hypothesize that the ERP correlates of selective attention should vary with SES. In particular, we expect to replicate previously observed patterns according to the EGA approach and therefore predict differences in brain activation between low- and high-SES groups in response to unattended stimuli despite similar performance. This is expected to correspond with increased amplitude at the N200 and P300 for High-SES children for attended stimuli as compared to unattended stimuli. However, there should be no differences in the ERP correlates of attended vs unattended stimuli for the Low-SES group.

(2) However, differently than in the EGA approach, the inclusion of a middle-SES group should reveal a gradient or trend in the data. Specifically, we expect children in the mid-SES group to demonstrate different neuronal activation on the task than both low and high-SES groups, so that the neural responses would vary according to a pattern reflecting the ordinal differences in SES.

(3) Finally, on the hypothesis that SES is linked with early childhood experience, we expect differences between the three groups will be predicted by scores obtained on the EDI wherein SES will correspond with contextual experiences (biological embedding) as demonstrated in early development scores.

2 Chapter: Design & Methods

2.1 Participants

Participant data was collected from a larger scale study in medium-sized urban and rural areas in Western Canada (Human Early Learning Partnership, 2013). Children aged 12-14 ($M = 13.29$) years from three different schools in the British Columbia area were chosen from the dataset to represent the socioeconomic neurogradients of attention. Each school district reflected different socioeconomic neighbourhoods as measured by the EDI (Janus & Offord, 2007). From a pool of 101 children recruited, 62 were identified to meet the SES criteria for each non-overlapping group: low, middle, and high. Of these 62 children, 10 were excluded for the following reasons:

- 4 children (1 high SES, 2 middle SES, 1 low SES) were excluded due to incomplete and/or EEG data that was confounded by excessive artifacts because of technical issues;
- 4 children (1 high SES, 3 low SES) were excluded due to incomplete behavioural and/or EEG data and/or an insufficient proportion of artifact-free EEG data; and
- 2 children (high SES) were eliminated from the behavioural data due to underperformance during the task

The remaining 52 children met the performance threshold for the auditory selective attention task (accuracy > 75%) creating three groups: (1) *High SES*, involved students primarily from high SES ($N=14$); (2) *Mid SES*, involved students primarily from middle SES ($N=20$), and; (3) *Low SES*, involved students primarily from low SES ($N=18$).

Children were matched on age, gender, ethnicity, grades, and health. Table 1 summarizes the characteristics of the three groups of children.

Table 1. Family, neighbourhood and demographic characteristics of the three groups of children studied.

	Socioeconomic Status				
	Low	Middle	High		
N ^a	18	20	14*		
Mean Age (SD)	13.66 (1.17)	13.08 (0.53)	13.13 (0.51)		
Gender (%Females)	50.00	50.00	64.28		
Mean of Median Household Income ^b (SD)	38,366.83 (21,290.96)	54,138.3 (9,657.79)	70,507.88 (15,369.58)		
Mode of self-reported income range (%)	<30K (51%)	50K<<70K (83%)	>90K (66%)		
<i>Adapted Hollingshead Four Factor Index</i>				Max-Min	
Mean (SD) Occupation	2.61 (1.24)	4.85 (0.88)	8.29 (1.20)	9-1	
Mean (SD) Education*	2.56 (1.29)	2.70 (1.34)	5.86 (0.95)	7-1	
Residence Rank	1.17	4.00	7.00	7-1	
Mean (SD) Total SES	25.39 (7.23)	48.35 (7.90)	87.00 (6.76)	94-12	
Mean (SD) Rank ^c	9.67 (5.64)	28.58 (6.15)	46.69 (4.53)	1-52.50	
Composite Parent Social Position Class	IV	III	II	I-V	
<i>Early Development Instrument^d</i>				School District	Provincial
% Physical	12.4 (-0.53)	10.7 (-0.36)	3.6 (0.35)	11.23	10.00
% Social	21.0 (-1.54)	16.1 (-1.05)	3.6 (0.20)	9.04	10.00
% Emotional	21.0 (-1.52)	8.1 (-0.23)	6.1 (-0.03)	8.48	10.00
% Language/cognitive	26.7 (-2.13)	8.9 (-0.35)	3.6 (0.18)	9.35	10.00
% Communicative	10.5 (-0.58)	4.5 (0.02)	2.4 (0.23)	5.17	10.00
% Total Vulnerable Children ^e	43.8 (-3.38)	25.0 (-1.50)	9.6 (0.04)	5.56	6.45

^aFollowing the exclusion of two children from the High SES group that did not meet baseline criteria

^bCanadian Dollars (taken from Statistics Canada, 2001).

^cComputed using a revised version of Hollingshead Four Factor Index of SES (Bornstein et al., 2003).

^dPercentages of vulnerability obtained from Wave 1, Kamloops-Thompson, EDI Maps (unpublished).

^eBased on the cumulative number of children manifesting one or more types of EDI vulnerability.

*Included an additional two children for ERP analyses (N = 16).

Note. There was a significant difference between all three groups for every SES measure except education. *t*-test contrasts between SES variables among the three groups were adjusted for using the symes-Bonferroni correction ($t = 2.9917- 24.5929$ (30, 32, 36), $p < 0.025$). There was

no significant difference between Low SES ($M=2.56$, $SD=1.29$) and Mid SES ($M=2.70$, $SD=1.34$) for education ($t = 0.3273$ (36), $p = 0.7453$).

2.2 SES Measures

Demographic and socioeconomic information on each child's family was obtained with parental questionnaires. All participants recruited for the study were typically developing children with no history of medical or referral to disability assessment or services based on parent and teacher reports. School records provided verification of this information. There was no history of neurological disease. Written informed consent was obtained from a parent according to a protocol approved by research ethics boards at two universities and at the local school district. Furthermore, children's verbal assent was required for participation.

SES measurement was obtained through the completion of an adapted version of Hollingshead Four-Factor Index of Social Status (Hollingshead, 1975; Bornstein et al., 2003) which delivered a composite index including residential area quality, parental occupation, and parental education. The highest occupation of either parent was rated using the Hollingshead categories 9-1, ranging from 'higher executives' to 'labourers/menial workers.' Education was scored on a 7-point scale ranging from graduate professional training to less than seventh grade. Initially, all SES indicator scores were transformed to ranks across individuals so as to equate the rank structure of the four-factor SES categories. Then, the Hollingshead's algorithm was used to weigh and aggregate the measures. On the composite SES scale (highest I, lowest V; note that by convention the original Hollingshead index used reversed scales), the higher-SES parents ranked II, the middle-SES parents ranked III, whereas the lower-SES parents

ranked IV. The SES indices of the three groups of children are provided in Table 1 in raw and z-scores.

Table 1 summarizes the vulnerability scores from The Early Development Instrument scale for the three groups of children. The scores were obtained from the first wave (2004) of a large longitudinal population-based study conducted in BC on early childhood development and geodemographic variables such as socioeconomic status (Kershaw, Irwin, Trafford, & Hertzman, 2005). The regions selected reflected, at the population level, the demographics of the three groups of children involved in our study. Measures of vulnerability for physical health and well-being, social competence, emotional maturity, language and cognitive development, and communication skills and general knowledge were obtained for each representative group. Each scale details the percent of vulnerable children along with Z-scores of these domains, shown in Figure 1.

Figure 1. Graph representing the z-score values for the three groups of children based on regional information obtained on the EDI (Kershaw et al., 2005).

Vulnerability scores on the EDI reflect three broad areas of child development that are known to influence outcomes in adulthood, including: physical, social-emotional, and language/cognitive development (Kershaw et al., 2005). The quality of residential area (neighborhood) was assessed by developmental vulnerability taken from *The BC Atlas of Child Development* (Kershaw et al., 2005). The percentage of vulnerable children in the lower-SES neighborhood was 43.8% compared with 25% in the middle-SES neighbourhood and 9.6% in the higher-SES neighborhood.

In order to address our hypothesis that SES is linked with early childhood experience, we examined the relationship between early indicators of vulnerability on the EDI and indicators of SES rank, comparing the three groups of children. . Indeed, the two variables coincide a linear model with EDI as the predictor variable and the ranked and raw total scores from the adapted version of the Hollingshead Four Factor Social Index (Bornstein et al., 2003) as the dependent variables confirmed this expected relationship (Total Hollingshead: $R^2 = .92$; $F(2,51) = 293.72$, $MSE = 53.99$, $p < .05$; SES Rank: $R^2 = .88$; $F(2,51) = 187.38$, $MSE = 30.73$, $p < .05$) indicating that contextual measures of SES are interconnected with population-level vulnerability measures during early childhood as reflected by the EDI.

2.3 Experimental procedure

2.3.1 Stimuli

Children were tested for hearing impairments using a portable Maico Diagnostics air conduction audiometer, model MA 27 (William Demant Holdings, Berlin, Germany). Children had pure-tone thresholds of 20dB or lower from 250-8000Hz in both ears. The experimental stimuli involved four pure tones generated by STIM2 sound editor function

program (Compumedics Neuroscan, Sterling, VA, USA) at two frequencies (800 Hz and 1200 Hz) and each at two durations (100 ms and 250 ms). A 250 ms Hanning window with 10% taper (5 ms rise/fall) was structured at the beginning and end of the tone.

Children were asked to attend to either a tone at 800 Hz or 1200 Hz at 250ms while ignoring all other tones. For example, if the child was asked to attend to the 1200 Hz tone, then the 800 Hz tone became the unattended stimulus. For the attended stimuli, children were asked to respond to the longer duration (250ms) which was rarer (target deviant). Previous research indicated that there was no significant difference between responses to the shorter or longer duration tones (D'Angiulli et al., 2012). They were told to withhold responses to all other tones whether these were attended (standards) or unattended (deviant).

The block was comprised of an intermixed sequence of 30 rare (10% occurrence) target tones (attended deviant), 30 rare (10% occurrence) target-duration unattended tones having the same duration but different frequency to the target tone (unattended deviant), 120 (40% occurrence) non-target duration attended tones having a different duration but the same frequency to the target tone (attended standard), and 120 (40% occurrence) target-duration unattended tones having a different duration and a different frequency to the target tone (unattended standard). Children responded to the attended deviant tone by thumb-pressing a button in the centre of a hand-held response pad.

The four types of tones were presented binaurally through insert earphones at 84 dB SPL, with an interstimulus interval of 1 s. The presentation of the tones was controlled via an Audio System interfaced with the STIM2 program. Stimulus presentation was counterbalanced and pseudo-randomized; the order was preselected so

that an attended deviant tone would not appear twice in a row in a given sequence. Children were asked to press the button as fast and as accurately as possible to the attended deviant tones of one of the two presented frequencies at the beginning of each recording block. Children completed two blocks of 300 trials. For half of each SES group, the attended tone in the first block was 800 Hz whereas in the second block it was 1200 Hz. The order was reversed for the other half. Refer to Figure 2 (D'Angiulli et al., 2012) for a visual description.

Figure 2. Adapted from D'Angiulli et al. (2012): Layout of the auditory selective attention task and electrode positions (adapted from the international 10-20 system of electrode placement) shown from the right side (left picture) and the left side (right picture) of child's head. As an example, this figure represents a child asked to press a button to the 800-Hz, 100 ms tone (target tone). Thus, the *attended* standard tone was 800-Hz, 250 ms tone (red) and the *unattended* standard tone was the 1200-Hz, 100ms tone (blue).

Correct trials required withholding manual responses for three types of tones: the attended standards, the unattended standards, and the unattended deviants. Reaction times and accuracy were measured for manual responses to correct attended deviants. The expected overall accuracy was about 75% based on previous data (Bartgis, Lilly,

Thomas, 2003; Berman & Friedman, 1995) and on previous pilot work which eliminated the need for extra individual adaptive testing.

2.3.2 ERP Data Acquisition and Recording Procedures

The EEG data was processed using the software package EEGLAB from The University of California at San Diego which runs on the proprietary MATLAB software (Delorme, and Makeig, 2004). All statistical analyses were run using SPSS v.20.0. Each participant had seven Ag-AgCl electrode sites (F3, F4, Fz, FC3, FC4, Cz, Pz) applied according to the 10-20 system of electrode application (Harner & Sannit, 1974) and participated in a modified version of a standard selective attention task (Hillyard, Hink, Schwent & Picton, 1973). The selection and number of electrodes was based on previous research and extensive pilot work (Herdman et al, 2006; D'Angiulli, 2008a, 2008b; 2012; 2013).

All electrodes were average referenced and impedances were kept below 5 kOhms. The vertical electrooculogram (VEOG) was recorded from a split bipolar electrode on the left supraorbital ridge (VEOGU) and the left zygomatic arch (VEOGL). The signal from the electrodes was amplified and digitized by a SynAmps2 and a SCAN™ 4.3 EEG system (Neurosoft, Inc., Sterling, VA, USA) with filter settings at 0.15 Hz (high pass) and 100 Hz (low pass). The data from all channels were digitized online at a sampling rate of 1,000 Hz. The EEG recordings were conducted in a sound-proof, shielded EEG mobile lab between 1:15 and 1:45 p.m.

Ocular artifact reduction was based on the eye movement reduction algorithm devised by Semlitsch, Anderer, Schuster and Presslich (1986) which consists of

constructing an average artifact response and then subtracting it from the EEG channels on a sweep-by-sweep, point-by-point basis.

The EEG was epoched from 100 ms prestimulus to 900 ms poststimulus and then averaged with respect to the onset of each tone for each participant. Averages were computed for attended and unattended standard and deviant tones, for 800 Hz and 1200 Hz separately. Since the results of the first ANOVA indicated no significant differences as a function of type of pure tone, the ERPs were re-averaged across the two frequencies to yield attended and unattended pure-tone averages for standards and deviants for each participant.

The N200 ERP component was measured at the maximum value with latency range 250-300ms. The maximum amplitude and latency of the P300 ERP component was measured at the maximum value within the latency range 350-500 ms. Negative difference waveforms were computed on children of comparable ages to determine the effect of selective attention (Bartgis et al., 2003; Berman & Friedman, 1995; Loisel, Stamm, Maitinsky, & Whipple, 1980). ERP negative differences were calculated for attended standards (AS) and unattended standards (US) and, similarly, for attended deviants (AD) and unattended deviants (UD) for each electrode. Only valid trials corresponding to correct responses were submitted to the ERP analysis.

3 Chapter: Results

3.1 Analytic Design

All analyses were set at a significance threshold of $p < .05$, therefore all significant results reported use this significance level. We used GLM through either ANOVAs, focused contrasts, or regressions. Multiple comparisons were adjusted with the

Bonferroni procedure, and the repeated-measures ANOVA models involved Greenhouse-Geisser adjustment.

3.2 Behavioural data

3.2.1 Accuracy

The task was found to be relatively easy with all children performing at over 85% accuracy. Despite the simplicity of the task, there were significant differences between the groups for accuracy and reaction times (Table 2).

We compared the groups of children across levels of accuracy using a 3 (low, mid, high SES) x 4 (percent of hits, false alarms, correct rejections, misses) ANOVA, which revealed a significant quadratic trend ($p < .05$). A significant effect of group was seen for percent hits, $F(2, 49) = 13.70$, $MSE < .01$, $p < .05$, and percent misses, $F(2, 49) = 12.83$, $MSE < .01$, $p < .05$. Multiple comparisons showed a significant difference between the middle-SES group and the other two SES groups for percent of hits ($p < .05$) demonstrating that children from the middle-SES group had a lower percent of hits ($M = 6.48$, $SD = 1.11$) compared with children in the low- ($M = 8.01$, $SD = 1.31$) and high- ($M = 8.45$, $SD = 1.19$) SES groups. Children from the middle-SES group also showed a significantly higher percent of misses ($M = 3.83$, $SD = 1.26$) than the low- ($M = 2.15$, $SD = 1.42$) and high- ($M = 1.68$, $SD = 1.30$) SES groups. The results for correct rejections (CR) and false alarms (FA) showed a similar pattern with the middle group demonstrating a lower percent of CR and a higher percent of FA compared with the other two groups, however, this did not reach significance.

Despite ceiling effects for accuracy on the task for low- ($M = 95.84$, $SD = 3.49$), middle- ($M = 92.83$, $SD = 2.18$) and high-SES groups ($M = 96.63$, $SD = 3.06$), a

significant effect for percent total correct (accurate response to attended deviant added with CR to the remaining 3 tones) was revealed when comparing the middle-SES children with the other two groups of children ($p < .01$). Furthermore, the percent total for incorrect (withheld response to attended deviant added with response to all other tones) was significantly higher ($p < .05$) for the middle-SES group ($M = 7.17\%$, $SD = 2.18\%$) compared with the low- ($M = 4.16\%$, $SD = 3.49\%$) and high- ($M = 3.37\%$, $SD = 3.06\%$) SES groups.

3.2.2 Reaction Times

We performed a general linear model with reaction times to hits and false alarms as the dependent variable and groups (low-, middle-, high-SES) as the independent variable. The reaction times to hits between low- ($M = 559.99$, $SD = 63.95$), middle- ($M = 509.64$, $SD = 46.28$) and high- ($M = 569.84$, $SD = 50.82$) SES groups, and reaction times to false alarms ($M = 493.01$, $SD = 74.02$; $M = 473.40$, $SD = 46.63$; $M = 506.72$, $SD = 71.26$, respectively) revealed a significant quadratic pattern ($p < .05$) with the middle-SES group showing lower reaction times. A significant mean difference for combined reaction times was found between the middle- and high-SES group ($p < .05$).

Next we conducted one way ANOVAs for reaction times to hits and false alarms separately with group as the independent variable. Children in the middle-SES group had significantly lower reaction times for hits when compared with children in the low- and the high-SES groups ($p < .05$). A similar quadratic pattern was seen for reaction times to false alarms, but was not found to be significant.

3.2.3 Signal Detection Analysis

The effects for correct and incorrect accuracy responses reported above accounted both for a quarter of the variance ($R^2 = 0.25$), and the effects relative to hits and misses were even larger ($R^2 = 0.35$, for hits, and $R^2 = 0.34$ for misses). Thus, even though at high performance levels these differences indicate important differences in the underlying processes. Hence, a closer look at performance measures through signal detection theory was warranted.

Based on our preliminary behavioural findings, we decided to conduct a signal detection analysis to determine why children from the middle-SES group showed a higher percent of misses and a lower percent of hits on the task, despite responding more quickly. Standard Detection Theory (SDT) posits that the level of sensitivity to the signal (relative to noise) can be observed by looking at the difference between hits (response to signal) and false alarms (response to noise). This is presented in the statistic d-prime (d') which is the difference between the z-scores of false alarms subtracted from hits ($d' = z(H) - z(F)$). Secondly the strategy applied when making a decision is captured in the criterion (c), which assesses whether the individual is more liberal and more inclined to respond resulting in more hits (and possibly more false alarms), or more conservative and less inclined to respond resulting in fewer false alarms (and possibly fewer hits) (Stanislaw & Todorov, 1999). The analysis was performed using an online detection theory calculator (ComputerPsyc LLC, 2004-2011) developed from Macmillan and Creelman (2005).

We performed a general linear model analysis with SDT measures (d' and c) as our dependent variable and SES group (low, mid, high) as our independent variable.

There was a significant interaction for SDT measures by group demonstrating a quadratic relationship ($F(2, 49) = 11.726, MSE = .39, p < .05$). Pairwise comparisons revealed a greater mean difference for the middle SES group compared with the low and high SES groups ($p < .05$).

Next we performed separate ANOVAs on the two measures of SDT, and discovered a significant quadratic relationship for d' driven by the middle-SES group ($M = 2.19, SD = 0.42$) when compared with the low- ($M = 3.10, SD = 0.93$) and high- ($M = 3.38, SD = 0.86$) SES groups; the middle group showed significantly lower d' scores, which suggests a lower sensitivity to the signal. There was also a significant quadratic relationship for criterion ($p < .05$) with the middle-SES group showing higher scores ($M = 0.75, SD = 0.21$) compared with the low- ($M = 0.59, SD = 0.29$) and high- ($M = 0.57, SD = 0.25$) SES groups, indicating a more conservative approach to the task. However, the differences between the three groups for c did not reach significance. All significant results are detailed in Table 2.

Table 2. Behavioural profiles of the three groups of children for performance during the auditory selective attention task.

Socioeconomic Status				$F_{(2, 49)}$	MSE	p
Low ($n = 18$)	Mid ($n = 20$)	High ($n = 14$)				
Accuracy %						
Hits	8.01 (1.31)	6.48 (1.11)	8.45 (1.19)	13.17	0.000	<.001
Misses	2.15 (1.42)	3.83 (1.26)	1.68 (1.30)	12.83	0.000	<.001
CR*	87.83 (2.77)	86.35 (1.80)	88.18 (2.34)			
FA*	2.01 (2.70)	3.34 (1.68)	1.69 (2.21)			
Correct Total	95.84(3.49)	92.83 (2.18)	96.63 (3.06)	8.40	0.007	.001
Incorrect Total	4.16 (3.49)	7.17 (2.18)	3.37 (3.06)	8.40	0.007	.001
Reaction Time in ms						
Hits	559.99 (63.95)	509.64 (46.28)	569.84 (50.82)	12.74	2934.66	.001
FA	493.01 (74.02)	473.40 (46.63)	506.72 (71.26)			
Standard Detection Analysis						
D prime (d')	3.10 (0.93)	2.19 (0.42)	3.38 (0.86)	23.90	0.567	<.001
Criterion (c)	0.59 (0.29)	0.75 (0.21)	0.57 (0.35)	5.281	0.062	<.026

Note. Values represent group means (values in parentheses represent standard deviations) collapsed across tone frequency conditions which did not reveal significant differences on preliminary analyses ($F < 1$). F statistics, MSE , and p values are only indicated for significant findings. Unreported statistics had an $F < 3.12$, $p > .05$. Accuracy is in percentage; reaction times are in milliseconds.

*CR = Correct Rejections, FA = False Alarms

3.3 ERP Results

For the ERP analyses, we included the two children who had underperformed on the auditory selection task (both from high-SES group), since they did not differ significantly in ERP response from the ERP waves of any of the groups. We performed a winsorization of means procedure (replacement of observed outlier means with predicted mean at 3 SDs, Wilcox & Keselman, 2003) for mean ERP responses corresponding to two electrodes (Cz and Pz) in one child. Because the pattern of results in the analysis with and without the two underperforming children was substantially similar, but

statistical power was slightly improved, the following analyses involved 16 children from the high-SES group

3.3.1 Visual Inspection of ERP Waveforms

A visual inspection across the seven electrodes for the averages of the three groups involved an examination of early potentials (N2), and later potentials (P3) when comparing neural response to the attended versus the unattended stimuli. It is critical to notice here that the timing of occurrence or latency for N2 and P3 can be different or delayed in children as compared to adults (for example see Berman & Friedman, 1995). Therefore, the time windows are to be taken as relative pointers of the ERP activity, which should mainly reflect a similar morphology to adult ERP waveforms (deflections), with the possibility of rather large latency shifts from the typical mean latency ranges shown by adult samples. This was again observed in our results in a qualitative analysis of the data according to standard guidelines (Luck, 2005), which we describe next.

3.3.2 Deviant: Attended vs. Unattended

The high-SES group showed slightly greater amplitudes on the N2 (approximately from 250 to 300 ms) and visibly greater, sustained amplitudes on the P3 (approximately from 350 to 500 ms) to the attended deviant compared with the unattended deviant across electrodes; whereas there was very little difference between attended and unattended responses to the deviants for the middle-SES group. However, the middle-SES group showed greater P3 and late potentials (LPs: from 500 ms onwards) amplitude for the attended deviant at FC3 and Pz. In contrast, the low-SES group showed differences in early potentials with greater amplitude on the N2 to the unattended deviant for right frontal and central electrodes (Fz, F4, Cz, FC4). Furthermore, the P2 showed greater

amplitude to the attended deviant for the middle-SES group. Differences on the P3 and LPs between the attended and unattended deviants was limited to Cz, FC4 (P3 only), and Pz indicating greater amplitude for the attended deviant in the middle-SES group. Figure 3 illustrates the deviant ERP waveforms at the midline electrodes for the three SES groups.

Figure 3. ERP activation in response to deviants at midline for the three groups, from left to right: high-, middle-, and low-SES.

3.3.3 Standard: Attended vs. Unattended

There was very little difference in ERPs between standard attended and unattended across groups. However, the high-SES group showed greater amplitude for the N2 for the unattended standard at electrode F3. Furthermore, the right frontal and

central electrodes showed a greater amplitude for unattended standard for the P3 (Fz, F4, Cz, FC4) in this group. There was no difference between the attended and unattended standard on LPs for the high-SES group. The middle-SES group did not show a differential response across electrodes when comparing conditions. The low-SES group did not show differences between the two conditions other than greater amplitude for the P3 to the unattended standard at electrode Cz. Figure 4 illustrates the deviant ERP waveforms at the midline electrodes for the three SES groups.

Figure 4. ERP activation in response to standards at midline for the three groups, from left to right: high-, middle-, and low-SES.

3.4 ERP Statistical Analyses

For each SES group, amplitudes relative to all seven electrodes were examined focusing on the time windows corresponding to the negative and positive ERP deflections identified during the visual inspection and based on the fact that the following windows were not contaminated by motor response processes since they did not overlap with the confidence intervals of the correct RTs observed in any of the three groups. Specifically, we examined: 1) a first time window corresponding to children's equivalent of N2, over the interval between 250 ms and 300 ms; and 2) a second time window corresponding to the children's equivalent of P3, over the interval between 350 ms and 500 ms.

Preliminarily, we examined the effects of tone duration relative to any other factor. Tone duration – long (250 ms) vs. short (100 ms) – did not yield main effects or interactions ($F < 1$) in any univariate or multivariate ANOVA model explored and was therefore collapsed across conditions in order to reduce the complexity of the factorial analysis. Successively, we examined, separately for each time window, the general relationships between one between-subjects factor, SES group (low, middle, high), and three within-subjects factors: Condition (attended vs. unattended), Tone type (deviant vs. standard) and Electrode (FC3, Cz, FC4, Pz, F4, Fz, F3) using a 3 X 2 X 2 X 7 mixed model 4-way ANOVA.

3.4.1 Analysis of negative (N2) waveform (250-300 ms)

For the N2, the global ANOVA revealed a significant interaction between Tone type and Electrode ($F(2, 51) = 5.93$; $MSE = 114.00$, $p < .05$) and another significant interaction between Condition and Electrode ($F(2, 51) = 12.00$; $MSE = 181.00$, $p < .05$).

Post hoc comparisons revealed midline electrodes – Fz, Cz, Pz – having similar ERP patterns in that the amplitudes associated with the attended tones showed a significantly more negative-going than the amplitudes associated with the unattended tones. In addition, in these electrodes response to the attended deviant was significantly different from the all other three condition types (attended standard, unattended deviant, unattended standard). However, there was no difference or interaction due to SES. Hence, although the differences found confirmed the manipulation of the selective attention task, in the present time window the attention effects observed did not vary as a function of SES.

3.4.2 Analysis of positive (P3) waveform (350-500 ms)

For the P3, a main effect of Tone type ($F(2, 51) = 10.62$; $MSE = 257.56$; $p < .05$) showed again that response to the attended deviant was also significantly different from all other three condition types (attended standard, unattended deviant, unattended standard). However, because this factor was not involved with any interaction with SES, and the 4-way highest level interaction was not significant, we dropped this variable from the factorial analysis. In the reduced 3-way mixed model ANOVA, the SES X Condition X Electrode interaction was significant ($F(2, 51) = 4.84$, $MSE = 12.56$, $p < .05$) as was the interaction between Condition and SES ($F(2,51) = 11.77$, $MSE = 126.33$, $p < .05$). Furthermore, we found a linear main effect of SES ($F(2, 51) = 2.22$; $MSE = 1.04$; $p < .05$), showing a linear gradient in the ERP amplitudes across groups. To further clarify how the SES differences were related in changes of ERP responses we further reduced the analysis by considering waveform differences between the three groups (thereby, reducing the degree of the factorial analysis).

3.4.3 Negative wave differences (attended versus unattended)

A subtraction of the response to unattended stimuli from the response to attended stimuli (negative difference, Nd) provides a measure of how children are allocating their focus with a greater difference reflecting more discrimination between condition types. Figures 5 and 6 show the difference waves for the three SES groups in response to deviants and standards, respectively. Linear regressions were performed to determine the relationship between SES, attention to stimuli and midline electrodes. We first examined the relationship between Nd for standards across the three groups (low, middle, high) and discovered a significant linear relationship ($F(2,51) = 6.55$, $MSE = 35.40$, $p > .05$). The same analysis was conducted using the Nd for deviants across the three groups, which revealed a significant linear effect ($F(2,51) = 3.74$, $MSE = 51.92$, $p > .05$). Next we replaced group with each child's SES rank and compared it with Nd for standards across the seven electrodes, all of which showed a significant linear association ($F(2,51) > 4.48$, $p < .05$). The strongest effect was seen at the midline electrodes (Table 3). Based on previous research demonstrating significant differences between lower-SES and higher-SES children at the midline (D'Angiulli et al., 2012), we decided to narrow our focus to three electrodes: Fz, Cz, Pz. The same analysis on the Nd for deviant trials in relation to SES rank was not significant across electrodes ($F < 3.60$).

We next examined the relationship between negative wave differences for standards with the total score from the adapted version of Hollingshead. A significant linear relationship was reflected across electrodes with the greatest effect seen at the midline (Table 3). We performed the same analysis with the negative difference waves

for deviants, which showed a marginally significant linear relationship for electrode F4 ($p = .051$).

To distinguish the effect of Nd for standards and deviants between the three groups, we ran one-way ANOVAs on each midline electrode, which showed a significant linear effect across electrodes. Multiple comparisons between the three SES groups revealed a significant difference between the middle- ($M = -0.83$, $SD = 3.51$) and the high- ($M = 9.16$, $SD = 2.29$) SES groups, as well as the low- ($M = 0.53$, $SD = 5.04$) and the high-SES groups for Nd for standards at Fz. A significant difference between the low- ($M = 0.53$, $SD = 5.04$) and the high- ($M = 9.60$, $SD = 12.85$) SES groups, and the middle- ($M = 1.83$, $SD = 3.34$) and the high-SES groups for Nd standards at Pz. A significant difference was also seen between the low- ($M = -0.24$, $SD = 4.70$) and high- ($M = 7.58$, $SD = 11.99$) SES groups, and between the middle- ($M = .33$, $SD = 4.10$) and the high-SES groups at Cz. Similarly, we examined Nd for deviants for each midline electrode across groups, and discovered a significant difference at Pz between the middle ($M = 6.42$, $SD = 9.68$) and the high ($M = 17.43$, $SD = 13.35$) groups and a significant difference between the middle ($M = 3.40$, $SD = 9.37$) and the high ($M = 16.48$, $SD = 13.94$) groups at Cz. All significant effects are listed in Table 3.

Table 3. Results of regression models for examining relationship between negative difference waves at midline electrodes and SES rank, Hollingshead Total, and SES group

MODEL SUMMARY Nd Standards								
Model	Electrode	R	R ²	Adjusted R ²	Std. error of the estimate	ANOVA		
						F _(1, 51)	MSE	p
1 ^a	Fz	0.34	0.12	0.10	6.48	6.86	41.94	.012
	Cz	0.35	0.12	0.10	7.69	7.13	59.09	.010
	Pz	0.34	0.12	0.10	8.16	6.99	66.59	.011
2 ^b	Fz	0.38	0.15	0.13	6.37	8.94	40.52	.004
	Cz	0.39	0.15	0.13	7.57	9.02	57.25	.004
	Pz	0.38	0.15	0.13	8.04	8.79	64.62	.005
3 ^c	Fz	0.35	0.13	0.11	6.44	7.47	41.51	.009
	Cz	0.38	0.14	0.13	7.59	8.68	51.51	.005
	Pz	0.42	0.17	0.16	7.91	10.81	62.55	.002
MODEL SUMMARY Nd Deviants								
3 ^c	Cz	0.28	0.08	0.06	11.70	4.27	136.80	.044

^aPredictors: (Constant), SES Rank

^bPredictors: (Constant), Hollingshead Total

^cPredictors: (Constant), Group

Figure 5. Graph depicting the negative difference waves of deviants for the three groups. The differences between the three groups are highlighted in the blown-up peaks at Cz from 350-500ms.

Figure 6. Graph depicting the negative difference waves of standards for the three groups. The differences between the three groups are highlighted in the blown-up peaks at Cz from 350-500ms.

3.4.4 EDI scores, SES, and ERPs

To effectively demonstrate the relationship between EDI vulnerability scores, SES measures and neural response, we performed a GLM with the Nd for standards of the midline electrodes as the repeated measure, and EDI total scores as the between-subjects variable. Figure 7 shows the negative linear trend that as the percent of vulnerable children increases the difference in neural activation between attended and unattended stimuli decreases from high- to low-SES. Figure 8 demonstrates the relationship between SES group and Nd for standards at the midline electrodes (using Cz as an example) indicating a positive linear trend: as SES increases, the difference in neural activation between attended and unattended stimuli increases as well. These findings extend on past research demonstrating the differential response to attended (relevant) versus unattended (irrelevant) stimuli across SES by illustrating the link with early childhood experience.

Figure 7. Graph representing the negative linear relationship between the percentage of vulnerable children and ERP response to attended versus unattended stimuli.

Figure 8. Scatterplot depicting the linear relationship between SES and ERP activation (particular example is Nd for standard at Cz).

4 Chapter: Discussion

This study examined the relationships between socioeconomic status and the neural correlates of attention in pre-adolescence linking neural and behavioural outcomes on a selective attention task to measures of family socioeconomic background and vulnerability in early childhood. As expected, ERP correlates of selective attentional processes reflected a linear trend supporting our hypothesis of a socioeconomic neurogradient of attention. An example of this type of socioeconomic gradient is shown

in Figure 8, which, to the writer's knowledge, is the first graphic representation of a genuine socioeconomic gradient relative to neuroimaging data, in other words as defined earlier, a socioeconomic neurogradient (Schibli & D'Angiulli, 2013).

The regression line showed in the figures resembles the ones replicated many times over the past 50 years across a plethora of health and social determinants outcomes, from cardiovascular disease to obesity (see Wilkinson & Pickett, 2006). What is impressively striking is that the effects size reported for many of the other health gradients just mentioned is very similar to the one found in our regression analyses.

In support of past research (D'Angiulli et al., 2012), we found that children from higher-SES showed a greater difference in ERP activation between attended (relevant) and unattended (irrelevant) stimuli along midline electrodes in comparison to children from lower-SES. Extending on this research, we discovered a linear trend indicating a gradual intensification in ERP activation to attended stimuli as SES increases. Furthermore, this relationship corresponded with contextual experience across a broad domain of SES, which was inextricably linked to early childhood experience. Our findings indicate the necessity to include an extensive measure of contextual experience when comparing groups of children.

Despite a significant linear trend in ERP activation, differences between the low- and middle-SES children were not significant suggesting that the pattern was driven by disparities with the high-SES group. This finding contrasts with past research indicating a clear dichotomy between low- and middle-SES children in relation to neuronal activation, and emphasizes the need to include a variety of measures to account for contextual experience. For example, Stevens et al. (2009) relied solely on maternal education to

support their categorization of SES, however, we were unable to differentiate this variable between the low and middle group.

One possible interpretation for the lack of differences in the neurobehavioural outcomes of low- and middle-SES may be that these similarities reflect the known notion that middle income is gradually slipping in to the low income as support for the social welfare state has been declining since the 1980s (Bryant, Raphael, Schrecker, & Labonte, 2011). Despite a distinct difference in annual income and residential quality, it is possible that the strain parents experience trying to remain in a middle social position is impacting how children experience their neighbourhood/household. Whereas children from low-SES may have learned to pay equal attention to relevant and irrelevant information as an adaptive response to experiencing less predictable living environments (D'Angiulli et al., 2012), perhaps for children from middle-SES this is a response to a changing environment reflecting the uncertainty of the family living conditions. Families in the middle-SES range are increasingly faced with financial/occupational insecurity (Sauvé, 2005; Ivanova, 2014), which may impact their interactions and/or time spent with their children. Our behavioural findings support this interpretation as children from the middle-SES group showed inconsistent responses to the task in comparison to the other two groups (i.e fewer hits and more misses in combination with faster reaction times).

Despite nearly ceiling performance on the auditory selective attention task among the three groups of children, there were distinct differences when comparing the middle with the other two groups. We discovered through signal detection analysis that children in the middle-SES group were less sensitive to the target tone and leaned more towards a conservative approach which one would expect if there was a sense of uncertainty –

difficulty recognizing the signal would logically be coupled with tentativeness. However, the puzzling aspect is that children in the middle group were significantly quicker at responding. Furthermore, one would expect a greater variation in response across the different levels of accuracy (hits, misses, CR, FA) if there was a sense of uncertainty, however, the standard deviations for the middle-SES group were in fact lower than what was seen in the low- and high-SES groups.

An alternative explanation may be that children from the low-SES group received some form of intervention in the early years and have learned how to perform on tasks assessing ability, such as the auditory selective attention task used in this study. Considering the purpose of the EDI is to identify school districts and neighbourhoods in need of support, it is highly possible that these children received guidance and instruction in the classroom. Despite a relatively high percentage of children from the middle-SES region showing vulnerabilities in the early years (25%), the focus for the need to intervene would be targeted to regions with the most drastic percentage of children at risk for difficulties. Therefore, children in the middle-SES group may have “slipped through the cracks” and not received the guidance for learning needed to effectively complete tasks targeting executive function.

It is difficult to interpret these behavioural differences given all children showed very high performance levels on the task (>85% accuracy). A more challenging task might provide insight regarding behavioural performance, and help clarify reasoning for the differences. However, the finding that the low- and high-SES groups performed similarly on the task despite different neuronal activation indicates that performance cannot be directly tied to neuroimaging underpinnings. Furthermore, our examination of

the socioeconomic neurogradients validates the necessity of incorporating a multidimensional measure of SES in comparative research.

Despite incorporating stringent selection criteria to ensure there was no overlap between the three groups studied, there are other factors that may have influenced children's contextual experience (i.e. family size, extended family responsibilities, the increasing cost of living, and accumulated debt). Regardless of these discrepancies in our measure, we effectively demonstrated that vulnerabilities in early childhood are confounded with SES and predict different ERP activation to attentional processes in preadolescence. However, we also demonstrated that assumptions associated with ability and levels of income must be challenged and interventions targeting children need to recognize the child's individual experience taking into consideration both neurobiological and social influences.

There appears to be an interest in computer-based interventions that focus at the individual level with the aim to target scholastic underachievement. These programs are attractive as they provide an affordable solution to enhance children's cognition and are often commercially available and directed to parents and teachers. Our findings illustrate the complexity of neurocognitive development, and the importance of recognizing the role of experience-dependent outcomes. However, the vast majority of commercially available cognitive training programs entail a broad-based approach that is expected to work for all children (Logie, 2012). Cogmed is an example of a cognitive training program that has received mixed findings regarding its validity.

4.1 Implications for neurocognitive training

The goal of Cogmed training programs is to increase working memory (WM) capacity leading to improvement in cognition and academic achievement. Emphasis is placed on short-term memory span as children are expected to recall a sequence and repeat it in reverse (Shipstead, Hicks, & Engle, 2012). The website delivering the training program targets consumers, educators, and health care professionals with a detailed description of scientific research demonstrating the validity of Cogmed programs for improving WM as “an evidence-based intervention” (p. 3, Ralph, n.d.). However, these claims are controversial with other researchers expressing reservations with the validity of these findings (Shipstead et al., 2012; Logie, 2012; Morrison & Chein, 2012).

In their review, Shipstead et al. (2012) outline several examples concerning the validity of research supporting Cogmed’s claims, including: the inability to replicate findings, limited construct validity (measures used to assess WM incorporate similar training paradigms found in Cogmed programs), concern over demand characteristics and experimenter bias, ineffective control samples due to unbalanced motivation to attend to scientific testing and in some studies no control sample at all (Shipstead et al., 2012). Whether these training programs increase WM is still debatable given no studies to date have incorporated measures of WM that differ dramatically from those applied in Cogmed training programs (Morrison & Chein, 2012).

Logie (2012) explains that individual differences in studies assessing cognition can be lost as the score observed is interpreted to reflect the desired outcome (i.e. increased working memory capacity) and argues that the focus should be on the cognitive mechanisms driving the outcome, for example it is possible that some individuals rely on

visual processing to recall information whereas others might engage the auditory system. What appears to be lacking in the studies examining Cogmed is a theoretical cognitive framework to determine the extent of the impact and why cognitive training might promote learning in some individuals and not others. Furthermore, it is difficult to determine whether skills learned under artificial settings (i.e. from a computer screen) can translate into real-life contexts putting into question Cogmed's ecological validity.

4.2 Community-Based Interventions

Community-based interventions have the potential to overcome social barriers by incorporating strategies that address the needs of families from that particular neighbourhood. The recognition of regional differences as reflected by measures of vulnerability on the EDI, indicate the significance of interventions aimed at understanding the child's experience and support communal initiatives that focus on early child development. Successful interventions, such as The Perry Preschool Project (Schweinhart & Weikart, 1980) and The Carolina Abecedarian Project (Barnett & Masse, 2007) incorporated social early childhood education programs and health assessments for vulnerable populations. The effect of these interventions lasted into adulthood as children who had received the intensive early childhood education were more likely to enter college and hold a full-time position for an extended period of time when compared with a control group (Campbell et al., 2012). However, these types of interventions have the potential to stigmatize already marginalized populations.

Lipina and Posner (2012) explain how different aspects of socioeconomic status (i.e. education, occupation, income) may influence neuroplasticity in different ways, and that an assessment to measure different brain networks would contribute to our

understanding of how context-specific experience influences cognitive development. Given the multidimensional nature of SES, interventions should be geared at addressing a wide range of social factors implicated with children's neurocognitive development (Lipina & Colombo, 2009). For example, having a child participate in an online attention training program is ineffective if the child hasn't had a substantial, nutritious meal. Interventions should reflect the needs of children by exploring the ecological factors influencing development while being sensitive to the cultural and ethnic backgrounds of families (Ungar, 2011). Despite evidence for neuroplastic changes throughout the lifespan (May, 2011), neuronal sensitivity to experience is especially prevalent during critical periods of early childhood (Lipina & Colombo, 2009).

4.3 Socioeconomic Neurogradients, Public Policy and the Shrinking Middle Class

Shifts in the political economy over the past three decades have led to greater health disparities between the rich and the poor. Canada is moving away from a focus on social welfare to neoliberal ideology which emphasises the importance of capitalism and privatization (Bryant et al., 2011). In the year 2003 (the year prior to our data collection), negative saving was most evident in BC in comparison to other Canadian provinces, meaning that the majority of families were spending beyond their means. Approximately 60% of Canadian households were relying on savings or loans to pay for everyday needs, with those at the very high end of the socioeconomic spectrum saving an average of \$16,000 annually (Sauvé, 2005). Therefore, the financial stress for families was high, especially for those in the low-mid range of the socioeconomic gradient.

Conditions in BC for families in this income range do not appear to be improving with fewer job opportunities, lower-paying positions and a reduction in permanent

positions leading to job insecurity (Ivanova, 2014). The impact this has on families and communities may influence interactions with children resulting in a higher percentage of vulnerabilities in a broad range of developmental skills. One of the greatest social determinants of health is early child development as experience in the early years has been shown to influence health in adulthood (Poulton et al., 2002). Children's development may be impacted as more parents are working longer hours and feeling the strain of a competitive workforce, coupled with a limited access to affordable and regulated early childhood education.

The increase of commercially available interventions targeting individual children to enhance neurocognition may limit our ability to effectively recognize the social factors influencing children's development (D'Angiulli, Lipina & Olesinska, 2012). Research in developmental neuroscience should incorporate a more comprehensive understanding of the social and environmental factors influencing early experience and recognize how public policy influences child ecology (Collins, 2012).

4.4 Conclusion and Limitations

There are a few limitations in the present study that are worth mentioning. We recruited our sample from a region in BC with a significantly higher proportion of families at the lower range of socioeconomic backgrounds (in comparison to the provincial socioeconomic median) which impeded our ability to include an equal, representative number of participants in each category. Due to the unequal number of families within each category, we were unable to effectively differentiate between the low- and middle-SES groups for education on the adapted version of the Hollingshead scale ($t < 1$). Despite including a comprehensive measure of SES, there are contextual measures not accounted

for (family size, debt accumulation) that may have helped clarify our findings. Furthermore, we did not control for HPA reactivity following task participation which has been associated with SES (Fernald & Gunbar, 2009), although D'Angiulli et al. (2012) discovered that stress and motivation were not implicated with differences in ERP activation among a low- and high-SES group of children who completed the same auditory selective attention task we use in the current study.

In spite of these limitations, our findings expand on past research demonstrating differences in ERP activation between children from varying levels of income by demonstrating a linear socioeconomic neurogradient of attention: as income increases so does children's selective focus between attended and unattended stimuli. As expected the neural responses vary according to a pattern reflecting the ordinal differences in SES, however, contradictory to our hypothesis, this linear trend was mediated by a disparity between the high SES group in comparison with the low- and middle-SES groups.

In support of past research, behavioural performance did not coincide with ERP differences as children from the low- and high-SES groups showed a similar behavioural profile. Despite ceiling performance across groups (>90% mean accuracy), children from the middle-SES group showed a different behavioural pattern reflecting less sensitivity to the attended stimuli and leaning towards a more conservative approach to the task. A more challenging task would help elucidate these differences.

Furthermore, we illustrated a direct link between early child experience and SES by demonstrating how scores obtained on the EDI predicted ERP differences between the three groups. This study highlights the role of developmental neuroscience in critically

examining intervention practices with children by incorporating a theoretical perspective that recognizes the child's socio-ecological experience.

References

- Alexander, A. L., Lee, J. E., Lazar, M., & Field, A. S. (2007). Diffusion Tensor Imaging of the Brain, *4*(July), 316–329.
- Ansary, N. S., & Luthar, S. S. (2009). Distress and academic achievement among adolescents of affluence: a study of externalizing and internalizing problem behaviors and school performance. *Development and Psychopathology*, *21*(1), 319–41. doi:10.1017/S0954579409000182
- Asami, T., Hayano, F., Nakamura, M., Yamasue, H., Uehara, K., Otsuka, T., Roppongi, T., Nihashi, N., Inoue, T., & Hirayasu, Y. (2008). Anterior cingulate cortex volume reduction in patients with panic disorder. *Psychiatry and Clinical Neurosciences*, *62*(3), 322–30. doi:10.1111/j.1440-1819.2008.01800.x
- Asherson, P. (2012). ADHD across the lifespan. *Medicine*, *40*(11), 623–627. doi:10.1016/j.mpmed.2012.08.007
- Barger, M. K. (2010). Maternal Nutrition and Perinatal Outcomes. *Journal of Midwifery & Women's Health*, *55*(6), 502–511. doi:10.1016/j.jmwh.2010.02.017
- Bari, A., Dalley, J. W., & Robbins, T. W. (2008). The application of the 5-choice serial reaction time task for the assessment of visual attentional processes and impulse control in rats. *Nature Protocols*, *3*(5), 759–67. doi:10.1038/nprot.2008.41
- Barker, D. J. (1997). Fetal nutrition and cardiovascular disease in later life. *British Medical Bulletin*, *53*(1), 96–108. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/9158287>
- Barnett, W. S., & Masse, L. N. (2007). Comparative benefit-cost analysis of the Abecedarian program and its policy implications. *Economics of Education Review*, *26*, 113-125.
- Bartgis, J., Lilly, A. R., & Thomas, D. G. (2003). Event-related potential and behavioral measures of attention in 5-, 7-, and 9-year-olds. *J. Gen. Psychol.* *130*, 311-335.
- Berger, L. M., Paxson, C., & Waldfogel, J. (2009). Income and Child Development. *Children and Youth Services Review*, *31*(9), 978–989. doi:10.1016/j.chilyouth.2009.04.013
- Berman, S., & Friedman, D. (1995). The development of selective attention as reflected by event-related brain potentials. *J. Exptl. Child Psychol.* *59*, 1-31.
- Bornstein M. H., Hahn C. S., Suwalsky J. T. D., Haynes O. M. (2003). Socioeconomic status, parenting, and child development: The Hollingshead Four-Factor Index of

- Social Status and the Socioeconomic Index of Occupations. In *Socioeconomic Status, Parenting, and Child Development* (eds.) M. H. Bornstein and R. H. Bradley (Mahwah, NJ: Lawrence Erlbaum Associates) 29-82.
- Bryant, T., Raphael, D., Schrecker, T., & Labonte, R. (2011). Canada: a land of missed opportunity for addressing the social determinants of health. *Health Policy*, 101, 44-58.
- Bush, G. (2011). Cingulate, frontal, and parietal cortical dysfunction in attention-deficit/hyperactivity disorder. *Biological Psychiatry*, 69(12), 1160–7. doi:10.1016/j.biopsych.2011.01.022
- Buss, C., Poggi, E., Shahbaba, B., Pruessner, J. C., Head, K., & Sandman, C. A. (2012). Maternal cortisol over the course of pregnancy and subsequent child amygdala and hippocampus volumes and affective problems, 109(20). doi:10.1073/pnas.1201295109/-/DCSupplemental.www.pnas.org/cgi/doi/10.1073/pnas.1201295109
- Calderón-Garcidueñas, L., & Torres-Jardón, R. (2012). Air Pollution, Socioeconomic Status, and Children's Cognition in Megacities: The Mexico City Scenario. *Frontiers in Psychology*, 3(July), 217. doi:10.3389/fpsyg.2012.00217
- Campbell, F. A., Pungello, E. P., Burchinal, M., Kainz, K., Pan, Y., Wasik, B. H., Sparling, J. J., Barbarin, O. A., & Ramey, C. T. (2012). Adult outcomes as a function of an early childhood educational program: An Abecedarian project follow-up. *Developmental Psychology*, 48(4), 1033-1043.
- Canadian Human Rights Tribunal. (2013, August 1). *Final written submissions of the Canadian Human Rights Commission on retaliation*. Retrieved from: <http://www.fncaringociety.ca/sites/default/files/Final%20Written%20Submissions%20-%20Retaliation%20%28August%201%2C%202013%29.pdf>
- Cherry, E. C., (1953). Some experiments on the recognition of speech, with one and with two ears*. *The Journal of the Acoustical Society of America*, 25(5), 975-979.
- Collins, T. M. (2012, August). Improving research of children using a rights-based approach: A case study of some psychological research about socioeconomic status. *Frontiers in Psychology*, 3(293), doi: 10.3389/fpsyg.2012.00293.
- ComputerPsyc LLC (2004-2011). *Online detection theory calculator*. Retrieved from: https://www.computerpsych.com/Research_Software/NormDist/Online/Detection_Theory
- D'Angiulli, A., Herdman, A., Stapells, D., and Hertzman, C. (2008a). Children's event-related potentials of auditory selective attention vary with their socioeconomic status. *Neuropsychology* 3, 293-300.

- D'Angiulli, A., Weinberg, J., Grunau, R., Hertzman, C., and Grebenkov, P. (2008b). Towards a Cognitive Science of Social Inequality: Children's Attention-related ERPs and Salivary Cortisol vary with their Socioeconomic Status. *Proceedings of the 30th Cognitive Science Society Annual Meeting*, 211-216.
- D'Angiulli, A., Lipina, S. J., & Olesinska, A. (2012). Explicit and implicit issues in the developmental cognitive neuroscience of social inequality. *Frontiers in Human Neuroscience*, 6(September), 254. doi:10.3389/fnhum.2012.00254
- D'Angiulli, A., Van Roon, P. M., Weinberg, J., Oberlander, T. F., Grunau, R. E., Hertzman, C., & Maggi, S. (2012). Frontal EEG/ERP correlates of attentional processes, cortisol and motivational states in adolescents from lower and higher socioeconomic status. *Frontiers in Human Neuroscience*, 6(November), 306. doi:10.3389/fnhum.2012.00306
- Davis, D. W., Chang, F., Burns, B., Robinson, J., & Dossett, D. (2004). Lead exposure and attention regulation in children living in poverty. *Developmental Medicine and Child Neurology*, 46(12), 825–31. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/15581156>
- De Coster, S., Heimer, K., & Wittrock, S. M. (2006). *Neighborhood Disadvantage, Social Capital, Street Context, and Youth Violence. The Sociological Quarterly* (Vol. 47, pp. 723–753). doi:10.1111/j.1533-8525.2006.00064.x
- Delorme A, Makeig S (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *J Neuro. Methods* 134, 9–21.
- Désert, M. (2009). So young and already victims of stereotype threat : Socio-economic status and performance of 6 to 9 years old children on Raven 's progressive matrices, *XXIV*, 207–218.
- Du Boisgueheneuc, F., Levy, R., Volle, E., Seassau, M., Duffau, H., Kinkingnehun, S., Samson, Y., Zhang, S., & Dubois, B. (2006). Functions of the left superior frontal gyrus in humans: a lesion study. *Brain : A Journal of Neurology*, 129(Pt 12), 3315–28. doi:10.1093/brain/awl244
- Dupéré, V., Lacourse, E., Willms, J. D., Leventhal, T., & Tremblay, R. E. (2008). Neighborhood poverty and early transition to sexual activity in young adolescents: a developmental ecological approach. *Child Development*, 79(5), 1463–76. doi:10.1111/j.1467-8624.2008.01199.x
- Dupéré, V., Leventhal, T., & Lacourse, E. (2009). Neighborhood poverty and suicidal thoughts and attempts in late adolescence. *Psychological Medicine*, 39(8), 1295–306. doi:10.1017/S003329170800456X

- Evans, G. W., Gonnella, C., Marcynyszyn, L. A., Gentile, L., & Salpekar, N. (2005). The role of chaos in poverty and children's socioemotional adjustment, *Psychological Science*, 16(7), 560-565. doi:10.1111/j.0956-7976.2005.01575.x
- Farah, M. J., Shera, D. M., Savage, J. H., Betancourt, L., Giannetta, J. M., Brodsky, N. L., Malmud, E. K., & Hurt, H. (2006). Childhood poverty: specific associations with neurocognitive development. *Brain Research*, 1110(1), 166–74. doi:10.1016/j.brainres.2006.06.072
- Fernald, L. C. H., & Gunbar, M. R. (2009). Poverty-alleviation program and salivary cortisol in very low-income children. *Social Science & Medicine*, 68, 2180-2189.
- Forget-Dubois, N., Lemelin, J.-P., Boivin, M., Dionne, G., Séguin, J. R., Vitaro, F., & Tremblay, R. E. (2007). Predicting early school achievement with the EDI: a longitudinal population-based study. *Early Education & Development*, 18(3), 405–426. doi:10.1080/10409280701610796
- Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. *Psychological Bulletin*, 134(1), 31–60. doi:10.1037/0033-2909.134.1.31
- Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, a C., ... Thompson, P. M. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences of the United States of America*, 101(21), 8174–9. doi:10.1073/pnas.0402680101
- Graf, W. D., Nagel, S. K., Epstein, L. G., Miller, G., & Nass, R. (2013). Pediatric neuroenhancement, 1251–1260.
- Guhn, M., Gadermann, A., & Zumbo, B. D. (2007). Does the EDI Measure School Readiness in the Same Way Across Different Groups of Children? *Early Education & Development*, 18(3), 453–472. doi:10.1080/10409280701610838
- Guhn, M., Janus, M., & Hertzman, C. (2007). The Early Development Instrument: Translating School Readiness Assessment Into Community Actions and Policy Planning. *Early Education & Development*, 18(3), 369–374. doi:10.1080/10409280701610622
- Harner, P. F., and Sannit, T. (1974). *A Review of the International Ten-Twenty System of electrode Placement*. Quincy, MA: Grass Instruments Co.
- Hegarty, C. E., Foland-Ross, L. C., Narr, K. L., Townsend, J. D., Bookheimer, S. Y., Thompson, P. M., & Altshuler, L. L. (2012). Anterior cingulate activation relates to local cortical thickness. *Neuroreport*, 23(7), 420–4. doi:10.1097/WNR.0b013e3283525a95

- Herdman, A., D'Angiulli, A., Stapells, D., & Hertzman, C. (2006). Children's brains and socioeconomic status: a selective-attention ERP study. *Proceedings of the 28th Cognitive Science Society Annual Meeting*, 2505.
- Hillyard, S. A., Hink, R. F., Schwent, V. L., and Picton, T. W. (1973). Electrical signs of selective attention in the human brain. *Science* 182, 177-180.
- Hollingshead, A. A. (1975). Four-factor index of social status. Unpublished manuscript, Yale
- Human Early Learning Partnership (2013). EDI mapping - wave 2 . Retrieved from: http://earlylearning.ubc.ca/media/mapsets/w2/bc_w2_edimapset.pdf
- Ivanova, I. (Spring 2014). BC jobs plan reality check: The first two years. *BC Commentary: A review of provincial, social, economic and environmental trends*, 17(2), 1.
- Janus, M., & Offord, D. (Autumn 2000). Readiness to learn at school. *ISUMA Canadian Journal of Policy Research*, 71-75.
- Kishiyama, M. M., Boyce, W. T., Jimenez, A. M., Perry, L. M., & Knight, R. T. (2009). Socioeconomic disparities affect prefrontal function in children. *Journal of Cognitive Neuroscience*, 21(6), 1106–15. doi:10.1162/jocn.2009.21101
- Kohen, D. E., Leventhal, T., Dahinten, V. S., & McIntosh, C. N. (2008). Neighborhood disadvantage: pathways of effects for young children. *Child Development*, 79(1), 156–69. doi:10.1111/j.1467-8624.2007.01117.x
- Lambert, S. F., Ialongo, N. S., Boyd, R. C., & Cooley, M. R. (2005). Risk factors for community violence exposure in adolescence. *American Journal of Community Psychology*, 36(1-2), 29–48. doi:10.1007/s10464-005-6231-8
- Lawson, G. M., Duda, J. T., Avants, B. B., Wu, J., & Farah, M. J. (2013). Associations between children's socioeconomic status and prefrontal cortical thickness. *Developmental Science*, 16(5), 641–52. doi:10.1111/desc.12096
- Lee, A. K. C., Larson, E., Maddox, R. K., & Shinn-Cunningham, B. G. (2014). Using neuroimaging to understand the cortical mechanisms of auditory selective attention. *Hearing Research*, 307, 111–20. doi:10.1016/j.heares.2013.06.010
- Li, J., D'Angiulli, A., & Kendall, G. E. (2007). The Early Development Index and children from culturally and linguistically diverse backgrounds. *Early Years*, 27(3), 221–235. doi:10.1080/09575140701594384

- Li, J., D'Angiulli, A., & Kendall, G. (2009). Response to "Reply to Li, D"Angiulli, and Kendall: The Early Development Index and children from culturally and linguistically diverse backgrounds' by Janus, Hertzman, Guhn, Brinkman, and Goldfeld. *Early Years*, 29(1), 89–92. doi:10.1080/09575140802689240
- Lipina, S. J., & Colombo, J. A. (2009). *Poverty and brain development during childhood: an approach from cognitive psychology and neuroscience*. Washington, D.C.: American Psychological Association.
- Lipina, S. J., & Posner, M. I. (2012). The impact of poverty on the development of brain networks. *Frontiers in Human Neuroscience*, 6(August), 238. doi:10.3389/fnhum.2012.00238
- Lipina, S., Segretin, S., Hermida, J., Prats, L., Fracchia, C., Camelo, J. L., & Colombo, J. (2013). Linking childhood poverty and cognition: environmental mediators of non-verbal executive control in an Argentine sample. *Developmental Science*, 16(5), 697–707. doi:10.1111/desc.12080
- Logie, R. H. (2012). Cognitive training: Strategies and the multicomponent cognitive system. *Journal of Applied Research in Memory and Cognition*, 1(3), 206–207. doi:10.1016/j.jarmac.2012.07.006
- Loiselle, D. L., Stamm, J. S., Maitinsky, S., and Whipple, S. C. (1980). Evoked potential and behavioral signs of attentive dysfunctions in hyperactive boys. *Psychophysiology* 17, 193–201.
- Luck, S.J. (2005). *An Introduction to the Event-Related Potential Technique*. Cambridge, MA: MIT Press.
- Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2000). Child's stress hormone levels correlate with mother's socioeconomic status and depressive state. *Biological Psychiatry*, 48(10), 976–980. doi:10.1016/S0006-3223(00)00965-3
- Luthar, S. S., & Latendresse, S. J. (2005). Children of the Affluent: Challenges to Well-Being. *Current Directions in Psychological Science*, 14(1), 49–53. doi:10.1111/j.0963-7214.2005.00333.x
- Macmillan, N. A., & Creelman, C. D. (2005). *Detection theory* (2nd ed.). U.S.: Lawrence Erlbaum Associates.
- Maggi, S., Irwin, L. J., Siddiqi, A., & Hertzman, C. (2010). The social determinants of early child development: an overview. *Journal of Paediatrics and Child Health*, 46(11), 627–35. doi:10.1111/j.1440-1754.2010.01817.x
- Magnusson, D. (2003). The person approach: concepts, measurement models, and research strategy. *New Directions for Child and Adolescent Development*, (101), 3–23. doi:10.1002/cd.79

- Mani, A., Mullainathan, S., Shafir, E., & Zhao, J. (2013). Poverty impedes cognitive function. *Science (New York, N.Y.)*, 341(6149), 976–80. doi:10.1126/science.1238041
- Melchior, M., Chastang, J., Lauzon, B. De, & Galéra, C. (2012). Maternal depression , socioeconomic position , and temperament in early childhood : The EDEN mother – child cohort. *Journal of Affective Disorders*, 137(1-3), 165–169. doi:10.1016/j.jad.2011.09.018
- Mistry, R. S., Benner, A. D., Biesanz, J. C., Clark, S. L., & Howes, C. (2010). Family and social risk, and parental investments during the early childhood years as predictors of low-income children’s school readiness outcomes. *Early Childhood Research Quarterly*, 25(4), 432–449. doi:10.1016/j.ecresq.2010.01.002
- Moren-Cross, J. L., Wright, D. R., LaGory, M., & Lanzi, R. G. (2006). Perceived neighborhood characteristics and problem behavior among disadvantaged children. *Child Psychiatry and Human Development*, 36(3), 273–94. doi:10.1007/s10578-005-0003-4
- Morrison, A. B., & Chein, J. M. (2012). The controversy over *Cogmed*. *Journal of Applied Research in Memory and Cognition*, 1, 208-210.
- Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science*, 8(1), 74–87. doi:10.1111/j.1467-7687.2005.00394.x
- Noble, K. G., Grieve, S. M., Korgaonkar, M. S., Engelhardt, L. E., Griffith, E. Y., Williams, L. M., & Brickman, A. M. (2012). Hippocampal volume varies with educational attainment across the life-span. *Frontiers in Human Neuroscience*, 6(November), 307. doi:10.3389/fnhum.2012.00307
- Patchin, J. W. (2006). Exposure to Community Violence and Childhood Delinquency. *Crime & Delinquency*, 52(2), 307–332. doi:10.1177/0011128704267476
- Petterson, S. M., & Albers, A. B. (2014). Effects of Poverty and Maternal Depression on Early Child Development, 72(6), 1794–1813.
- Picton, T. W., Bentin, S., Berg, P., Donchin, E., Hillyard, S. A., Johnson, R., Jr., Miller, G. A., Ritter, W., Ruchkin, D. S., Rugg, M. D., & Taylor, M. J. (2000). Guidelines for using human event-related potentials to study cognition: recording standards and publication criteria. *Psychophysiology*, 37(2), 127–52. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/10731765>
- Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology*, 58, 1–23. doi:10.1146/annurev.psych.58.110405.085516

- Poulton, R., Caspi, A., Milne, B. J., Thomson, W. M., Taylor, A., Sears, M. R., & Moffitt, T. E. (2002). Association between children's experience of socioeconomic disadvantage and adult health: a life-course study. *The Lancet*, 360, 1640-1645.
- Pujol, J., López, A., Deus, J., Cardoner, N., Vallejo, J., Capdevila, A., & Paus, T. (2002). Anatomical variability of the anterior cingulate gyrus and basic dimensions of human personality. *NeuroImage*, 15(4), 847–55. doi:10.1006/nimg.2001.1004
- Raizada, R. D. S., & Kishiyama, M. M. (2010). Effects of socioeconomic status on brain development, and how cognitive neuroscience may contribute to levelling the playing field. *Frontiers in Human Neuroscience*, 4(February), 3. doi:10.3389/neuro.09.003.2010
- Ralph, K. (n.d.) *Cogmed research claims & evidence*. Retrieved from: <http://www.Cogmed.com/published-research>
- Rapport, M. D., Orban, S. a, Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review*, 33(8), 1237–52. doi:10.1016/j.cpr.2013.08.005
- Ruiz, R. J., & Avant, K. C. (2005). Effects of Maternal Prenatal Stress on Infant Outcomes A Synthesis of the Literature, 28(4), 345–355.
- Russell, G., Ford, T., Rosenberg, R., & Kelly, S. (2013). The association of attention deficit hyperactivity disorder with socioeconomic disadvantage: alternative explanations and evidence. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*. doi:10.1111/jcpp.12170
- Sauvé, R. (2005, January). The current state of Canadian family finances - 2004 report. *Contemporary Family Trends*. Retrieved from: <http://www.vanierinstitute.ca/modules/news/newsitem.php?ItemId=298#.U9fq-vldWSo>
- Schweinhart, L. J., & Weikart, D. P. (1980). *Young Children Growing Up: The Effects of the Perry Preschool Program on Youths Through Age 15*. Ypsilanti, MI: The High/Scope Educational Research Foundation.
- Schibli, K., & D'Angiulli, A. (Spring 2011). The neuroscience of poverty: Implications for teaching. *Education Canada*, 51(1), 17-20.
- Schibli, K., & D'Angiulli, A. (2013). The social emotional developmental and cognitive neuroscience of socioeconomic gradients: laboratory, population, cross-cultural and community developmental approaches. *Frontiers in Human Neuroscience*, 7(November), 788. doi:10.3389/fnhum.2013.00788

- Semlitsch, H., Anderer, P., Schuster, P., and Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology* 23, 695–703.
- Sheridan, S. M., Knoche, L. L., Kupzyk, K. A., Pope, C., & Marvin, C. A. (2011). A randomized trial examining the effects of parent engagement on early language and literacy : The Getting Ready intervention. *Journal of School Psychology*, 49(3), 361–383. doi:10.1016/j.jsp.2011.03.001
- Stanislaw, K., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers*, 31(1), 137-149.
- Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). *Cogmed* working memory training: Does the evidence support the claims? *Journal of Applied Research in Memory and Cognition*, 1, 185-193.
- Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: an event-related brain potential study. *Developmental Science*, 12(4), 634–46. doi:10.1111/j.1467-7687.2009.00807.x
- Strenze, T. (2007). Intelligence and socioeconomic success: a meta-analytic review of longitudinal research. *Intelligence*, 35(5), 401–426. doi:10.1016/j.intell.2006.09.004
- Talge, N. M., Neal, C., & Glover, V. (2007). Antenatal maternal stress and long-term effects on child neurodevelopment: how and why? *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 48(3-4), 245–61. doi:10.1111/j.1469-7610.2006.01714.x
- Tremonti, A. (2012, October 16). Prescribing ADHD medication to children. *CBC Radio, The Current Podcast*. Retrieved from <http://www.cbc.ca/thecurrent/episode/2012/10/16/prescribing-adhd-medication-to-children/>
- Ungar, M. (2011). The social ecology of resilience: addressing context and cultural ambiguity of a nascent construct. *American Journal of Orthopsychiatry*, 81(1), 1-17.
- University, New Haven, CT.Human Early Learning Partnership. (2013). *EDI mapping - wave 2*. Retrieved from: http://earlylearning.ubc.ca/media/mapsets/w2/sd73_w2_edimaps.pdf
- Van der Molen, M. W. (2000). Developmental changes in inhibitory processing: evidence from psychophysiological measures. *Biological Psychology*, 54(1-3), 207–39. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/11035224>

- Vohs, K. D. (2013). Psychology. The poor's poor mental power. *Science (New York, N.Y.)*, 341(6149), 969–70. doi:10.1126/science.1244172
- Walker, J., Crawford, K., & Taylor, F. (2008). Listening to children : gaining a perspective of the experiences of poverty and social exclusion from children and young people of single-parent families Correspondence, 16, 429–436. doi:10.1111/j.1365-2524.2008.00781.x
- Wilcox, R.R.; Keselman, H.J. (2003). "Modern robust data analysis methods: Measures of central tendency". *Psychological Methods* 8 (3): 254–274
- Wilkinson RG, Pickett KE. Income inequality and population health: a review and explanation of the evidence. *Soc Sci Med* 2006;62:1768-84.
- Wilson, C. a, Schade, R., & Terry, a V. (2012). Variable prenatal stress results in impairments of sustained attention and inhibitory response control in a 5-choice serial reaction time task in rats. *Neuroscience*, 218, 126–37. doi:10.1016/j.neuroscience.2012.05.040
- Xue, Y., Leventhal, T., Brooks-Gunn, J., & Earls, F. J. (2005). Neighborhood residence and mental health problems of 5- to 11-year-olds. *Archives of General Psychiatry*, 62(5), 554–63. doi:10.1001/archpsyc.62.5.554