Relationships between socioeconomic status and reading development: Cognitive outcomes and neural mechanisms

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Learning to read is one of the most important achievements of early childhood, and sets the stage for future success. Even prior to school entry, children's foundational literacy skills predict their later academic trajectories (Duncan et al., 2007; La Paro & Pianta, 2000; Lloyd, 1969; Lloyd, 1978). Children learn to read with differing levels of ease, with an estimated 5-17% of school-age children who struggle with reading acquisition (Shaywitz, 1998). The individual variation in children's reading skills can be predicted by genetic, environmental, academic and socio-demographic factors (for review, see Peterson & Pennington, 2015). This chapter focuses on the relationship between reading development and socioeconomic status (SES), with attention to both cognitive outcomes and neural mechanisms. First, we describe SES and its relation to academic achievement in general, and reading development in particular. Second, we examine environmental factors that can potentially give rise to socioeconomic disparities in reading, such as early language/literacy exposure and access to books. Next, we explore the link between SES and reading disability (RD), including a focus on intervention approaches and treatment response. Finally, we summarize remaining questions and propose future research priorities.

Socioeconomic status: Definition and measurement

An individual's socioeconomic status (SES) refers to their social and economic resources, and the consequent social status that arises from these resources (Bradley & Corwyn, 2002). SES is a complex, multi-faceted, and intangible construct, with multiple measurement tools that aim to capture distinct aspects. Objective measurement of SES typically combines a three-pronged assessment of an individual's educational attainment, income, and occupation (Bradley & Corwyn, 2002; Duncan & Magnuson, 2012; Ensminger & Fothergill, 2003; Green, 1970; U.S. Bureau of the Census, 1963; White, 1982). Perhaps the best known measure is the Hollingshead

Index, which combines a weighted sum of all householders' education and occupation ratings (Hollingshead, 1975). Other measures include neighborhood SES (Minh, Muhajarine, Janus, Brownell, & Guhn, 2017), income-to-needs ratios (Duncan, Brooks-Gunn, & Klebanov, 1994), and principal component analysis of multiple factors (e.g., Noble, Farah, & McCandliss, 2006; Noble, Wolmetz, Ochs, Farah, & McCandliss, 2006). In contrast to objective measures of SES, subjective assessments of social status measure *perceived* financial and social standing with respect to local and national communities (Adler, Epel, Castellazzo, & Ickovics, 2000; Cundiff, Smith, Uchino, & Berg, 2013). Pediatric research relies on caregivers in the home (e.g., parents) to offer information on SES through one or more of these approaches to measuring SES.

In practice, one or a few measures typically serve as a proxy for socioeconomic index, though SES is not a unitary construct with a simple unidirectional influence on child outcomes. SES correlates with many intertwined developmental influences including stress, nutrition, toxin and violence exposure, access to and quality of healthcare and educational resources. Associations between SES and child development are best understood within a wider social, physical, and environmental context.

The "achievement gap"

The "achievement gap" refers to the disparity in academic performance and/or educational attainment between students from disparate backgrounds, typically by either racial background or socioeconomic determinants (Reardon, 2011). The achievement gap has been of great interest to researchers since the 1960s, when a sweeping review of American education, as a part of the War on Poverty, revealed that the strongest determinant of a child's educational success was his/her family background (Coleman et al., 1966). Specifically, white and higher-income students performed several grade levels higher in both reading and math than black and lower-income students (Coleman et al., 1966).

Evidence for the achievement gap has accumulated since the early recognition in educational disparities. While the racial achievement gap has shrunk significantly over the last half century, the income achievement gap has more than doubled. This increase in the achievement gap translates to scores 1.25 standard deviations higher on standardized tests, on average, for wealthier students compared to their lower SES peers (Reardon, 2011; U.S. Department of Education). Similar gaps favoring higher SES students are found in other academic measures including grade point averages (Sirin, 2005; White, 1982), high school completion rates (Brooks-Gunn & Duncan, 1997; Duncan & Magnuson, 2011), and college entry and completion (Bailey & Dynarski, 2011).

Despite its wide-reaching consequences across educational outcomes, the impact of SES is not uniform across all domains. While SES is significantly correlated with memory, cognitive control, and executive functioning, the greatest effects appear in language and reading skills (Farah et al., 2006; Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005). Specifically, SES explains nearly a third (32%) of the variance in the language skills of first graders (Noble et al., 2007), nearly twice that of all other cognitive domains studied. Meta-analyses over several decades of studies reveal that SES also explains 30-35% of the variance in broadly defined academic reading measures (Sirin, 2005; White, 1982), which makes it one of the strongest predictors of academic performance.

Socioeconomic disparities are also apparent in individual sub-domains of reading and pre-reading skills. Higher SES background is associated with more positive outcomes in important skills including phonological awareness (Bowey, 1995; Lonigan, Burgess, Anthony, & Barker, 1998; McDowell, Lonigan, & Goldstein, 2007; Raz & Bryant, 1990), early print knowledge (Hecht, Burgess, Torgesen, Wagner, & Rashotte, 2000; Smith & Dixon, 1995), decoding and early word reading (Hecht et al., 2000; Molfese, Modglin, & Molfese, 2003; Share, Jorm, Maclean, Matthews, & Waterman, 1983; White, 1982), fluency and automaticity (Haughbrook, Hart, Schatschneider, & Taylor, 2017; Stevenson, Reed, & Tighe, 2016), and reading comprehension (Hart, Soden, Johnson, Schatschneider, & Taylor, 2013; Hecht et al., 2000; MacDonald Wer, 2014). Lower SES is also associated with a slower trajectory of literacy growth throughout elementary school (Hecht et al., 2000), and as children transition in later elementary school from “learning to read” to “reading to learn” (Chall, 1983; Chall, Jacobs, & Baldwin, 1990), disparities in reading often snowball into disparities in other academic domains, which rely on analysis and comprehension of complex texts.

Achievement gaps in language and literacy appear to begin very early in childhood, before children enter school (Ginsborg, 2006; Lee & Burkam, 2002; Ramey & Ramey, 2004). Consequently, higher-SES children begin Kindergarten better prepared and with a stronger foundation on which to build literacy skills (described below). Indeed, achievement gaps continue to widen throughout the elementary grades, creating a Matthew effect (“the rich get richer while the poor get poorer”) in which good readers improve more rapidly, while struggling readers fall further behind their peers (Chall et al., 1990; Stanovich, 1986).

One phenomenon contributing to these widening gaps occurs outside of the traditional school year. The "summer slump" or "summer slide" refers to the trend in which lower-SES children are vulnerable to academic regression during the summer months between school years; meanwhile, higher-SES students tend to maintain or even gain academic skills (Alexander, Entwisle, & Olson, 2007; Cooper, Nye, Charlton, Lindsay, & Greathouse, 1996; McCoach, O'Connell, Reis, & Levitt, 2006). By the ninth grade, more than half of the income-achievement gap can be explained by differential summer learning during the elementary school years (Alexander et al., 2007), with significant summer learning disparities in reading (Cooper et al., 1996).

Neuroimaging and SES

Neuroimaging research has revealed the neural correlates of SES and academic achievement gaps as well. A study on adolescents aged 13-15 year old from diverse backgrounds showed that the thickness of cortical gray matter in temporal and occipital lobes was associated with both SES and performance on standardized tests, and that cortical differences in these regions accounted for almost half of the income achievement gap (Mackey et al., 2015). Another study of children aged 4-22 years found that differences in the cortical volume of frontal and temporal gray matter explained as much as 20% of test score gaps (Hair, Hanson, Wolfe, & Pollak, 2015). Other studies have confirmed similar relationships between SES, neuroanatomy, and a variety of cognitive domains and/or academic achievement (for reviews, see Brito & Noble, 2014; Farah, 2017; Johnson, Riis, & Noble, 2016).

Several studies have investigated the neural *mechanisms* underlying SES disparities in reading skills. A common neuroimaging tool is functional magnetic resonance imaging (fMRI), which tracks blood flow to brain regions most active during a cognitive task such as rhyming judgments or reading words and/or pseudowords. These studies have found significant relationships between SES and brain activation related to phonological awareness in left perisylvian regions in pre-reading 5 year-olds (Raizada, Richards, Meltzoff, & Kuhl, 2008) as well as in 8-13 year-olds (Demir, Prado, & Booth, 2015; Demir-Lira, Prado, & Booth, 2016). Another study of 6-9 year-olds revealed that SES modulated the relationship between phonological awareness skills and brain activity in left fusiform and perisylvian regions during reading (Noble, Wolmetz, et al., 2006). Lower-SES children exhibited a stronger brain-behavior relationship than their higher-SES peers, who exhibited higher fusiform activation and higher reading scores regardless of their phonological awareness scores (Noble, Farah, et al., 2006; Noble, Wolmetz, et al., 2006). This suggests that low SES multiplies the effect of low phonological awareness to result in weaker decoding skills, while some aspect of higher-SES children's early environments may have buffered the effects of low phonological skill, resulting in increased fusiform recruitment and better reading outcomes.

These cognitive and neuroimaging studies show that the socioeconomic achievement gap is particularly pervasive in language and literacy skills, and these disparities arise long before children arrive at school. These findings raise questions of *how* SES differences in children's language skills arise in the first several years of life, and which aspects of higher and lower SES environments influence linguistic and neural development. Answers to these questions require a deeper examination of children's early language environments.

Environmental contributions to SES reading gaps

Given that SES is a multifaceted construct, encompassing both economic resources and sociocultural backgrounds, many aspects of higher and lower SES environments likely contribute to early learning. Indeed, the bioecological model of development suggests that SES is a *distal* factor that presumably affects children's neurocognitive outcomes via more immediate, *proximal* environmental influences (Bronfenbrenner & Ceci, 1994; Bronfenbrenner & Morris, 1998). Two proximal influences that have been frequently found to relate to reading outcomes are children's early exposure to oral language and experience with literacy and reading practices.

The home literacy environment (HLE) characterizes children's early exposure to literacy-related resources, interactions, and attitudes (Shapiro, 1979). HLE encompasses the availability of books in the home, the frequency/quality of storybook reading with young children, caregivers' efforts to teach print-related concepts (e.g., the alphabet), and family members' modeling of reading practices and attitudes toward literacy (Payne, Whitehurst, & Angell, 1994; Sénéchal & LeFevre, 2002). Children's early HLE is associated with their later development of oral and written skills, including receptive and expressive vocabulary, listening comprehension and grammatical knowledge, phonological awareness, early letter and print knowledge, and comprehensive reading skills later in school (Bracken & Fischel, 2008; Burgess, Hecht, & Lonigan, 2002; Bus, van Ijzendoorn, & Pellegrini, 1995; Frijters, Barron, & Brunello, 2000; Hood, Conlon, & Andrews, 2008; Levy, Gong, Hessels, Evans, & Jared, 2006; Martini & Sénéchal, 2012; Payne et al., 1994; Scarborough & Dobrich, 1994; Scarborough, Dobrich, & Hager, 1991; Sénéchal & LeFevre, 2002; Sénéchal, LeFevre, Hudson, & Lawson, 1996; Sénéchal & LeFevre, 2014;

Sénéchal, Pagan, Lever, & Ouellette, 2008; Storch & Whitehurst, 2001). HLE can reflect SES through specific home environment practices and resources. For example, lower SES is associated with reduced access to reading materials in the home and at libraries (Feitelson & Goldstein, 1986; Neuman & Celano, 2001), or less frequent teaching of print concepts or reading to young children (Burgess et al., 2002; Chaney, 1994; Feitelson & Goldstein, 1986; Harris & Smith, 1987; Karrass, VanDeventer, & Braungart-Rieker, 2003; Leseman & Jong, 1998; McCormick & Mason, 1986; Phillips & Lonigan, 2009).

However, there is also great variability within SES factions, with certain lower SES families reading to children more often than some higher SES families (Chaney, 1994; Farver, Xu, Eppe, & Lonigan, 2006; Senechal, 2006; Smith & Dixon, 1995; Storch & Whitehurst, 2001; Van Steensel, 2006). This within-group variability allows for statistical analysis of the factors most strongly linked to reading outcomes, and several studies have found that HLE predicts children's literacy achievement over and above SES alone (Bracken & Fischel, 2008; Christian, Morrison, & Bryant, 1998; Gottfried, Schlackman, Gottfried, & Boutin-Martinez, 2015; Payne et al., 1994; Rodriguez & Tamis-LeMonda, 2011; Smith & Dixon, 1995). Moreover, mediation analyses reveal that individual differences in HLE partially or fully explain relationships between SES and literacy development (Chazan-Cohen et al., 2009; Foster, Lambert, Abbott-Shim, McCarty, & Franze, 2005; Hamilton, Hayiou-Thomas, Hulme, & Snowling, 2016; Kiernan & Huerta, 2008; Krishnakumar & Black, 2002). Yet these need not be static phenomena; intervention studies reveal that programs targeting parents' literacy activities can have a significant effect on children's reading development (for review, see Sénéchal & Young, 2008).

Oral language exposure is another salient aspect of HLE, which shows even earlier socioeconomic disparities. In a landmark study, Hart and Risley (1992, 1995) followed 42 socioeconomically diverse children from 7 months to 3 years of age. They found that children from the lowest-SES families heard fewer than a third of the words per hour heard by higher-SES children early on, which aggregated to a gap of thirty million word by age three (Hart & Risley, 1995). Disparities were not only evident in the *quantity* of linguistic input, but also the *quality*. Higher SES parents also used more diverse vocabulary, more affirmatives and fewer prohibitions, more questions, and more linguistically beneficial responses such as repetitions, expansions, and extensions of child utterances, and they were generally more responsive, affirmative, and encouraging (Hart & Risley, 1995). The combination of these qualitative variables explained over 60% of the variance in children's IQs at 3 years of age.

More recent studies have found socioeconomic differences in a number of other qualitative aspects of language exposure. Higher SES has been associated with more favorable outcomes in aspects of language including the mean length of utterance (Hoff, 2003; Hoff & Naigles, 2002; Hoff-Ginsberg, 1991; Rowe, 2008), syntactic complexity and diversity (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Naigles & Hoff-Ginsberg, 1998), contingency and contiguity (Conway et al., 2018; Goldstein, King, & West, 2003; Hirsh-Pasek et al., 2015; Hoff-Ginsberg, 1991; Hoff-Ginsberg, 1998; Reed, Hirsh-Pasek, & Golinkoff 2016; Smith et al., 2018; Tamis-LeMonda, Kuchirko, & Song, 2014), and decontextualized references (Rowe, 2012). In addition, SES disparities have been shown regarding conversational exchanges (Hirsh-Pasek et al., 2015; Romeo et al., 2018; Zimmerman et al., 2009) and nonverbal gestures and referents (Cartmill et al., 2013; Iverson, Capirci, Longobardi, & Cristina Caselli, 1999; Pan, Rowe, Singer, & Snow, 2005; Rowe & Goldin-Meadow, 2009; Rowe, Özçalişkan, & Goldin-Meadow, 2008).

However, as with HLE, there is also considerable variation in language exposure within socioeconomic factions (Gilkerson et al., 2017; Hirsh-Pasek et al., 2015; Rowe, Pan, & Ayoub, 2005; Weisleder & Fernald, 2013). Quantity and/or quality of children's language exposure predict unique variance in children's language skills above and beyond SES (Romeo et al., 2018; Rowe, 2012; Weisleder & Fernald, 2013), and even mediate the SES achievement gaps in language skills (Hoff, 2003; Huttenlocher et al., 2002; Romeo, Leonard, et al., 2018; Romeo, Segaran, et al., 2018; Rowe & Goldin-Meadow, 2009). Upon school entry, these differences in early oral language skills often persist and transform into disparities in literacy acquisition, explaining a large proportion of the achievement gaps in reading, spelling, and other cognitive and academic skills in elementary school (Durham, Farkas, Hammer, Bruce Tomblin, & Catts, 2007; Marchman & Fernald, 2008; Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015; Walker, Greenwood, Hart, & Carta, 1994).

While many studies have investigated neural correlates of SES, comparatively few have investigated mechanistic relationships between proximal environmental influences—such as HLE and oral language exposure—and neural development. Research with 3-5 year-olds asked parents about their children's access to books, frequency of shared reading, and variety of books read, and found that greater reading exposure was associated with great activation during a story-listening fMRI task in the left parietal-temporal-occipital association cortex, a region involved in mental imagery and narrative comprehension (Hutton et al., 2015). A similar study measured the real-world language exposure of 4-6 year-old children over the course of two days, including the number of words spoken by adults and the number of dialogic conversational turns between adults and the enrolled children. While the sheer number of adult words was not associated with neural measures, the number of conversational turns correlated positively with activation in known language areas in left lateral prefrontal region during story listening (Romeo et al., 2018), as well as with the structural connectivity between this region and left posterior temporal regions known to subserve language processing (Romeo et al., under review). Furthermore, both structural and functional measures mediated SES disparities in children's language skills, indicating both environmental and neural mechanisms underlying the linguistic achievement gaps preceding literacy.

Relationship between SES and reading disability

Reading disability (RD) is a language-based learning disability characterized by persistent difficulty in reading acquisition and development (Peterson & Pennington, 2015; Shaywitz, Morris, & Shaywitz, 2008). RD is the most prevalent specific learning disability (Lerner, 1989); about 80% of children with learning disabilities struggle in reading (Lyon, Shaywitz, & Shaywitz, 2003). Despite average cognitive skills, children with RD may exhibit deficits in word recognition, decoding, text-level fluency, reading comprehension, or multiple sub-domains of reading (Lyon, Shaywitz, & Shaywitz, 2003). Etiologically, RD runs in families, and exhibits a high degree of heritability (Harlaar, Spinath, Dale, & Plomin, 2005).

The prevalence of reading challenges differs across the SES continuum however. For example, low-income fourth and eighth graders have scored at "below basic" reading levels at more than twice the rate of their higher-income peers (U.S. Department of Education). Additionally, lower-income students are diagnosed with specific learning disabilities at significantly higher rates (Shifrer, Muller, & Callahan, 2011), and exhibit a disproportionately higher risk of being diagnosed with developmental dyslexia (Peterson & Pennington, 2015), although reduced access to diagnostic care may prevent many lower-SES parents from seeking diagnoses of reading disability for their children.

Indeed, several studies have revealed gene by environment interactions in the heredity of RD, whereby SES modulates the risk for developing reading difficulties in children with familial risk (for review, see Becker et al., 2017). In most cases, the genetic contribution is greatest and environmental contribution lowest at the higher end of the SES spectrum, while the reverse is true at the lower end, with a greater influence of environmental factors in lower SES circumstances (Friend, DeFries, & Olson, 2008; Mascheretti et al., 2013). This suggests that, in low SES environments, reduced HLE and oral language exposure may intensify a genetic predisposition for RD and/or may prevent children with low genetic risk from achieving their full reading potential. Indeed, low HLE better predicts diminished reading skills over and above a familial risk of dyslexia (Dilnot, Hamilton, Maughan, & Snowling, 2017). Neuroanatomically, in children with RD, SES is more strongly correlated with the cortical structure of reading related brain regions than clinical reading scores (Romeo et al., 2017). This etiological and neurological heterogeneity in RD suggest that the effectiveness of treatment programs may vary based on differences in children's environmental backgrounds.

Given the wealth of literature focused on the predictors of success in various reading interventions, surprisingly few studies have investigated socioeconomic differences in treatment response. According to recent reviews of studies aiming to predict children's response to literacy interventions (Barquero, Davis, & Cutting, 2014; Lam & McMaster, 2014), fewer than 30 percent of behavioral studies and only two neuroimaging studies have examined SES as a predictive factor. These reveal mixed results—two smaller studies find that *higher* SES predicts better treatment response (Hatcher et al., 2006; Morris et al., 2012), while one finds that *lower* SES predicts better treatment response and commensurate neuroanatomical changes (Romeo et al., 2017). These opposite results may arise as result of fundamental differences in the treatment programs themselves, such as the content and domain of focus, and/or to the format, such as treatment timing. For example, higher-SES children with RD may benefit more from school-based programs with distributed phonologically-focused sessions over a longer duration, whereas lower-SES children with RD may respond best to intensive, short-term interventions with an orthographic focus during non-academic summers. Whatever the reason, these results suggest that the efficacy of certain treatment approaches may depend on the etiology of the reading struggle amongst various other environmental factors.

The future of SES and reading research

The last half century has seen a dramatic increase in research on academic achievement gaps between students from higher- and lower-income backgrounds, finding a disproportionate effect of SES on the development of children's reading skills. Since then, numerous studies have identified early language and literacy exposure as proximal influences driving these disparities, both independently and in confluence with genetics. The identification of neural mechanisms by which the environmental factors may contribute to academic and cognitive development has also advanced understanding of SES and reading. The juncture of education and neuroscience fields invites exciting opportunities for both basic and translational research, with the following areas requiring particular attention.

Perhaps the most pressing issue is the continuing investigation into the heterogeneity of etiologies of reading difficulties. While there are both genetic and environmental contributions to variation in children's language and reading skills, it is clear that environmental factors have a particularly strong influence early in life, during sensitive periods when the brain is most plastic (Hayiou-Thomas, Dale, & Plomin, 2012; Logan et al., 2013; Tierney & Nelson, 2009). Socioeconomic disparities in early language and literacy environments suggest that the etiology of reading disabilities may vary by socioeconomic background, such that RD in lower-SES children may be triggered by limitations in resources in the environment, while RD in higher-SES children may have a greater genetic basis (Haughbrook et al., 2017). Such etiological differences may give rise to different cognitive and neural phenotypes of the disorder, which in turn may respond differently to specific treatments. Educational neuroscience is just beginning to utilize such "precision medicine" techniques, using behavioral, demographic, neural markers to predict individualized treatment outcomes and employ the most effective programs for each child (Gabrieli, Ghosh, & Whitfield-Gabrieli, 2015). Future research should consider investigating biomarkers that can inform educational practice and RD treatment on an individualized level.

Relatedly, future RD studies of both baseline neurocognitive descriptors and treatment response should investigate SES as a variable of interest and enroll participants across a wide range of diverse demographic variables. The vast majority of research on reading development, and most of cognitive development at large, has relied on “convenience samples,” of participants that frequently skew toward higher-income and more highly educated individuals who both have an awareness/appreciation of research and the time to participate. These samples are often referred to as “WEIRD” (Western, Educated, Industrialized, Rich, and Democratic) (Henrich, Heine, & Norenzayan, 2010), and these psychology and neuroscience findings achieved with restricted populations may not generalize more broadly (LeWinn, Sheridan, Keyes, Hamilton, & McLaughlin, 2017; Nielsen, Haun, Kartner, & Legare, 2017). Although adopting more representative sampling approaches will likely not overhaul all of the fundamental findings in reading research, it certainly has the potential to alter our understanding of reading development and the treatment of reading disabilities.

Finally, as research on the neuroscience of poverty continues to expand, researchers must take great care in streamlining measurement of SES and related factors. Parental education and family income are not interchangeable measures; nor are they universally meaningful across cultures, or the best index of the psychosocial stressors and/or buffers present in adverse situations. Future research expand beyond these broad, distal measures of sociocultural context, by delving deeper into proximal factors that presumably act directly on cognitive development, such as home literacy and language exposure. With improved understanding on which precise environmental variables contribute meaningfully to language and literacy development, as well as the underlying neural mechanisms, the field can build more effective interventions for at-risk children.

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