

WORD LEARNING FROM CONTEXT:
RELATIONS WITH LANGUAGE ABILITY, SOCIOECONOMIC STATUS,
AND EXECUTIVE FUNCTION

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Chapter 1

Literature Review and Statement of the Problem

Introduction

Researchers and educators alike have long recognized the key role of vocabulary in student achievement, especially with regard to reading comprehension. Decades' worth of studies have revealed strong and reciprocal relations across the lifespan between vocabulary and reading ability. Evidence shows that skill in reading comprehension fosters the development of vocabulary, while a strong vocabulary enhances reading comprehension (Adlof & Perfetti, 2013). Biemiller (2006) emphasized the crucial importance of vocabulary to school success and pointed out that while neither fluent decoding nor adequate vocabulary is sufficient for reading comprehension, if either skill is deficient, comprehension—and learning—will suffer. Elaborating on the central role of vocabulary in reading comprehension, Hirsch (2003) argued that 90-95% of words in a passage must already be known for readers to achieve adequate levels of comprehension. Studies also show that targeted vocabulary intervention can boost reading comprehension. A meta-analysis by Elleman, Lindo, Morphy, and Compton (2009) found vocabulary instruction to be an effective strategy for improving reading comprehension, especially among students with reading difficulties.

There is evidence from prospective longitudinal studies that early vocabulary levels influence children's later reading comprehension ability (e.g., Cunningham & Stanovich, 1997; Muter, Hulme, Snowling, & Stevenson, 2004; Smith, Brooks-Gunn, & Klebanov, 1997). For example, Smith et al. (1997) found that receptive vocabulary at age three predicted children's reading skill in primary school. Muter et al. (2004) used

structural equation modeling to demonstrate a pathway from receptive vocabulary at age four to reading comprehension ability two years later. Cunningham and Stanovich (1997) reported that receptive vocabulary among first graders predicted reading comprehension skill a full ten years later in grade 11.

There is little doubt that reading is a major factor in children's vocabulary growth. Owing to the sheer scope and volume of vocabulary acquisition during the school-age years, there is general agreement that most word learning during this period occurs incidentally rather than through deliberate instruction, and that written context is the greatest source of new vocabulary (Nagy & Herman, 1987; Sternberg, 1987). For instance, Nagy, Anderson, and Herman (1987) estimated that a typically developing fifth-grader learns between 800 and 1200 words per year through reading. Although children may have access to a wide range of online and electronic media sources of written material, there is evidence that such outlets do not support vocabulary acquisition and may actually detract from students' overall word knowledge. Time spent reading traditional print sources—especially narrative text—remains the best predictor of children's vocabulary growth (Pfof, Dörfler, & Artelt, 2012).

Contemporary school curricula often include an explicit focus on reading as a key source of vocabulary acquisition. With the advent of Common Core state standards, there is an expanded emphasis, beginning in the earliest grades and continuing through high school, on the learning of content knowledge through reading (Common Core State Standards Initiative, 2015). To succeed academically, children must be able to acquire new vocabulary through written context.

Word Learning

Theories of word learning. Bloom (2000) offered a useful definition of word learning as an essentially two-step process: the learner must (a) acquire an underlying mental representation of a concept; and (b) associate a particular phonological form with that concept. Carey (1978) also conceived of word learning as a two-part process that involves constructing a mapping between the conceptual and lexical domains. According to Carey, word learning results in a restructuring of both domains. The conceptual domain must be restructured to create a “conceptual niche” for the concept encoded by the new word, and the lexical domain must be restructured to accommodate the new word. Importantly, Carey’s findings showed that a single encounter with a word may suffice to set such restructuring into motion. Information gathered during initial “fast mapping” often includes the knowledge that the new word actually *is* a word but may also involve a rough sense of the word’s phonological, orthographic, morphosyntactic, and semantic aspects. While fast mapping often occurs very quickly and efficiently, the process of acquiring more complete knowledge of a word—“full mapping”—requires a greater restructuring of the relevant conceptual and lexical domains and is thus far more time-consuming and laborious. The initial, incomplete hypotheses that are formed during fast mapping are tested, expanded, and further refined during subsequent encounters with the word. Many exposures to a word across a variety of contexts may be required for a learner to gain complete and stable word knowledge.

The *lexical quality hypothesis* (Perfetti & Hart, 2002) provides a somewhat different framework for understanding the word learning process. According to the lexical quality perspective, all words possess three constituents: phonology, orthography,

and semantics (the morphosyntactic aspects of words are subsumed under semantics). As learning proceeds, links are created between the form-related (phonological and orthographic) and meaning-related (semantic) aspects of words. Acquiring word knowledge is seen as a process of forming increasingly higher-quality lexical representations. Knowledge of each constituent accrues gradually over time with repeated exposure to a word across contexts. Relatedly, individual differences in vocabulary knowledge are also thought to occur because learners vary in the quality of their lexical representations. In support of the hypothesis, a computational model demonstrated how each type of constituent knowledge accumulated separately and gradually over time, for both morphologically simple and morphologically complex words (Reichle & Perfetti, 2003).

Nagy and Scott (2000) also described a series of word knowledge dimensions that are drawn together during the learning process. These dimensions include not only syntactic and semantic aspects but also socially appropriate word usage (pragmatics). Over time and with increased exposure learners also gather knowledge of a word's multiple meanings (polysemy) and an understanding of each word's semantic interrelatedness with other words in the lexicon.

Sternberg and Powell (1983) proposed a complex theory of word learning that focuses on three separate knowledge acquisition processes: (a) selective encoding, in which a word learner separates relevant from irrelevant information in the surrounding context; (b) selective combination, in which the learner combines relevant cues to form a working definition; and (c) selective comparison, in which new information is related to preexisting knowledge. Briefly, learners are thought to rely on a range of contextual cues

external to a word, such as class membership, along with internal contextual cues, such as morphology, as they generate hypotheses about word meaning. Gradually accumulating knowledge from either external or internal cues can help word learners to acquire more accurate definitions over time.

The more recent *instance-based learning* account (Bolger, Balass, Landen, & Perfetti, 2008) emphasizes the central role of context and draws a distinction among three general approaches to word learning: (a) incidental word learning that occurs spontaneously as learners are exposed to words across multiple contexts; (b) deliberate word learning that results from learners' purposeful efforts to derive meaning from context; and (c) a *passive resonance* process in which contexts activate related known words, and these words along with relevant contexts become associated with the new word. Each exposure to a word is thought to leave a memory trace of both the word itself and the surrounding context, and these memory traces affect processing of the word upon subsequent encounters. Over time, as learners gain experience with a word across varied contexts, a more refined sense of word meaning gradually develops.

Word learning during reading. As with word learning in general, vocabulary acquisition from written context is a gradual, cumulative process. Partial word knowledge gained through fast mapping is augmented over time as readers encounter new words in different contexts (Carey, 1978). Several decades ago, Trembly (1966) noted the incremental nature of word learning and described partially known words as occupying "the frontier region between the point where every word is known and the point where no words are known" (p. 229). More recently, Christ (2011) argued that word knowledge should not be viewed dichotomously as simply right or wrong but as

existing along a continuum that begins with no knowledge whatsoever and progresses through stages of context-dependent understanding to fully decontextualized word knowledge.

Modest yet significant gains in word knowledge are found after a first exposure to unfamiliar or novel words in narrative text (Biemiller & Boote, 2006; Swanborn & de Glopper, 1999). Among typically-developing kindergarten, first-, and second-grade children, Biemiller and Boote (2006) reported an average 12% improvement in word knowledge from pretest when children were exposed to unfamiliar words in read-aloud story contexts. Similarly, a meta-analysis of incidental word learning during reading by Swanborn and de Glopper (1999) found mean gains in word knowledge of 15% for novel or unfamiliar words encountered in written passages. This is not to imply that any word is learned completely after a single exposure. Rather, students are continually engaged in a process of accumulating partial knowledge of multiple words simultaneously. As Bloom (2000) noted, although overall gains in vocabulary may amount to an average of ten words per day, it is not the case that children fully learn ten words every day; “they might instead be learning one-hundredth each of a thousand different words” (p. 25).

Strategies readers use. Several studies have analyzed the strategies readers use when attempting to derive word meaning from written context (Fukkink, 2005; Fukkink, Blok, & de Glopper, 2001; Steele, 2012). Fukkink (2005) asked primary-school students to verbalize what they were thinking as they tried to understand the meanings of unfamiliar words in text. Children reported engaging in a range of strategies: inferring potential meanings, checking hypotheses against available facts, and accepting or rejecting provisional definitions. The process was quite flexible, and strategies were not

used in any particular order. In a study of word learning among typically developing second-, fourth-, and sixth-grade readers, Fukkink et al. (2001) described an incremental process that involved not only adding correct semantic attributes but also unlearning false attributes and acquiring greater de-contextualized understanding. The progression of word knowledge differed according to age, with sixth-graders generating more correct attributes, fewer false attributes, and more de-contextualized word definitions than second- or fourth-graders. Steele (2012) analyzed the errors made by typically developing nine- to 11-year-old readers as they generated definitions of novel words encountered in written passages. Among responses that were offered, the most common error was providing a false definition of a target word (indicating complete misunderstanding), followed by providing a correct definition of a different target word (indicating confusion about the meaning of individual target words). Some students generated incorrect definitions that were nevertheless phonologically or semantically related to the intended target word meaning, but these errors were less common.

Qualities of context. Some written contexts are more supportive than others in helping readers make inferences about unfamiliar words. Beck, McKeown, and McCaslin (1983) outlined a continuum of contextual support for word meaning, ranging from misdirective to highly directive. The more directive or constraining the context, the more successful readers are likely to be in deriving correct word meanings. A recent study found that school-age children were able to glean more semantic knowledge of novel words if they had been pre-exposed to those words in highly constraining contexts rather than in contexts that were relatively uninformative (Adlof, Frischkoff, Dandy, & Perfetti, 2016). A number of studies have found that texts manipulated to be more

“considerate” or “elaborated” were associated with higher rates of word knowledge growth (e.g., Gordon, Schumm, Coffland, & Doucette, 1992; Herman, Anderson, Pearson, & Nagy, 1987; Konopak, 1988a, 1988b). The position of informative context relative to target words may be a limiting factor, especially for readers with weaknesses in working memory (Cain, Oakhill, & Elbro, 2003; Cain, Oakhill, & Lemmon, 2004), although not all findings agree (Steele, 2015; Steele & Watkins, 2010). “Local context” that provides more immediate and specific cues to word meaning may also be more supportive of word knowledge growth than a passage’s broad, overall “global context” (de Leeuw, Segers, & Verhoeven, 2014). Finally, greater word learning is found when passages contain a lower density of unfamiliar words (Swanborn & de Glopper, 1999).

Age, background knowledge, and reading ability. Studies have shown that age and background knowledge both influence children’s word learning from written context (Fukkink et al., 2001; Kaefer, Neuman, & Pinkham, 2015; Swanborn & de Glopper, 1999). Swanborn and de Glopper’s (1999) meta-analysis found that across studies, gains in incidental word knowledge during reading increased steadily with age. As mentioned, Fukkink et al. (2001) reported that older students engaged in more advanced inferencing strategies while reading than their younger counterparts. As will be discussed more fully later, Kaefer et al. (2015) demonstrated that children’s level of background knowledge may also affect their ability to infer word meaning from context.

Aside from age, children’s reading abilities also account for individual differences in word knowledge growth during reading (Cain, Oakhill, & Elbro, 2003; Cain, Oakhill, & Lemmon, 2004; Ricketts, Bishop, Pimperton, & Nation, 2011; Swanborn & de Glopper, 1999, 2002). Swanborn and de Glopper (1999, 2002) reported that children’s

scores on reading assessments were significantly related to their scores on incidental word learning tasks. A pair of studies by Cain and colleagues (Cain et al., 2003, 2004) compared novel word learning during read-aloud tasks among seven- to eight-year-old children with poor reading comprehension to that of peers with typical reading comprehension skills. Results of both studies showed that when supportive context was placed immediately adjacent to target words, both groups performed similarly. However, when additional filler sentences were inserted between supportive context and target words, children with poor comprehension scored lower than their typically developing counterparts. The authors suggested that comprehension strategies, higher-level inferencing skills, and working memory constraints may all have played a role in the poorer performance of children with reading comprehension difficulties. More recently, Ricketts et al. (2011) studied novel word learning during a read-aloud task in sample of seven- to eight-year-old children of widely varying reading ability and found that decoding skill accounted for children's success in gleaning semantic information about target words.

Language ability. Fewer studies have focused on the influence of oral language ability on semantic word knowledge growth during reading (Steele & Watkins, 2010; Wagovich, Hill, & Petroski, 2015). Steele and Watkins (2010) examined novel word learning during silent reading among school-age children with language-learning disability (LLD) and same-age peers with typical language skills. Children with LLD gained significantly less syntactic and semantic knowledge of target words than their typically developing classmates. Wagovich et al. (2015) compared syntactic and semantic word knowledge growth during silent reading among students with lower

language skills (at least 1.0 standard deviation below the mean on receptive or expressive language) to that of peers with higher language skills. Both groups read narrative passages containing unfamiliar target words a total of three times, each several days apart. Students with lower language skills gained less overall knowledge of target words than their more-skilled age-mates. However, a subsequent analysis revealed that the rate of word knowledge growth was similar for both groups (Hill, Wagovich, & Manfra, 2017).

Word-level factors. Several word-level attributes may influence the likelihood that a word will be acquired during reading. For example, Fukkink et al. (2001) found that word knowledge growth was greater for concrete than abstract words. Ramey, Chrisykou, and Reilly (2013) reported that several factors—phonotactic probability, frequency, familiarity, imageability, and word length—all contribute to how difficult it may be for children to learn a given word. Although it is less clear how a word's grammatical class might affect word knowledge growth during reading, available evidence suggests that non-nouns (e.g., verbs, adjectives, adverbs) may be acquired more easily than nouns (Schwanenflugel, Stahl, & McFalls, 1997) or that that learning may occur similarly across grammatical classes (Steele & Watkins, 2010; Wagovich et al., 2015).

Relation of word learning to vocabulary. Although it may seem logical to expect children's performance on word learning tasks to be related to individual differences in measured vocabulary (or for children's vocabulary to predict their success on experimental word learning tasks), such connections do not always hold up in practice. Spencer and Schuele (2012) found that neither receptive nor expressive

vocabulary was related to performance on a fast-mapping task among preschool children from low-income homes. Likewise, Majerus and Boukebza (2013) reported that receptive vocabulary was not correlated with novel word learning among typically developing six- and seven-year-old children. As discussed more fully below, Burton and Watkins (2007) and Horton-Ikard and Ellis Weismer (2007) both found that although young children from low-income homes had significantly lower vocabulary scores than their more advantaged peers, their performance on experimental word learning tasks did not differ from that of children from middle-class homes.

Other researchers have found a positive association between vocabulary and children's experimental word learning performance (de Leeuw et al., 2014; Gathercole, Hitch, Service, & Martin, 1997; Ricketts et al., 2011; Shefelbine, 1990). Shefelbine (1990) reported that typically developing sixth-graders with higher vocabulary scores gained more word knowledge during reading than their peers with lower vocabulary. Similarly, Gathercole et al. (1997) found that both receptive and expressive vocabulary were related to novel word learning from context among typically developing five- and six-year-old children. More recently, Ricketts et al. (2011) found that expressive vocabulary predicted novel word learning in a read-aloud task among seven- to eight-year-old children with a wide range of reading and vocabulary skills. Likewise, de Leeuw et al. (2014) reported that general vocabulary knowledge was related to typically developing fifth-graders' performance on a measure of word learning during reading.

A few studies have yielded more nuanced findings regarding the relation between vocabulary and children's performance on word learning tasks (Hill et al., 2017; Kapa & Colombo, 2014; Steele & Watkins, 2010). Kapa and Colombo (2014) found that

receptive vocabulary was related to artificial language acquisition (primarily novel word learning) among adult participants, but not among four-year-old children. Steele and Watkins (2010) reported that receptive vocabulary was correlated with novel word learning among school-age children with LLD, but not among their counterparts with typical language skills. In an analysis of word knowledge growth during silent reading among students with a wide range of language abilities, Hill et al. (2017) found a moderate but significant bivariate correlation ($r = .41$) between receptive vocabulary and task performance. However, receptive vocabulary did not uniquely account for word knowledge growth beyond the effects of language ability and decoding skill.

A lack of association between measured vocabulary and experimental word learning performance could stem from two separate fundamental problems with validity. On the one hand, scores on relatively narrow or contrived experimental word learning tasks might not accurately reflect individual differences in children's broader ability to build vocabulary over time. On the other hand, standardized vocabulary tests might not be valid measures of children's skill in the actual process of word learning. There has been little research addressing the usefulness of experimental word learning tasks in predicting children's future real-world vocabulary growth. However, one longitudinal study by Gellert and Elbro (2013) did find that typically developing third graders' performance on a novel word learning task predicted their gains on a standardized test of receptive vocabulary over the following nine months.

Greater attention has focused on the issue of whether standardized vocabulary measures are valid indicators of children's underlying word learning ability. Scores on such tests may be unrelated to experimental word learning performance, particularly

among children of minority cultural or linguistic backgrounds or from low-income homes (e.g., Burton & Watkins, 2007; Horton-Ikard & Ellis Weismer, 2007; Spencer & Schuele, 2012). Moreover, minority or disadvantaged children may earn scores on standardized measures that place them below typical limits due solely to lack of specific content knowledge, even though no true psycholinguistic deficit exists (Campbell, Dollaghan, Needleman, & Janosky, 1997; Stockman, 2001). As a result, several researchers have questioned both the cultural fairness and prognostic value of standardized vocabulary tests for children of non-majority or non-middle-class backgrounds (Campbell et al., 1997; de Villiers, 2004; Johnson, 2010; Johnson & de Villiers, 2009; Stockman, 2001). In this regard, experimental word learning tasks have the potential to draw less heavily upon culture-specific content knowledge than most standardized tests and to provide a fairer and more accurate assessment of children's online processing of semantic information (de Villiers, 2004; Johnson, 2010; Johnson & de Villiers, 2009).

Socioeconomic Status

Children and poverty. According to the most recent statistics available, 19.7% of children in the United States live below the poverty line, which is defined as yearly household income below \$24,257 for a family of four (U.S. Census Bureau, 2015). Children living in poverty clearly face many developmental obstacles. In a comprehensive review of poverty-associated risk factors, Evans (2004) outlined numerous hazards, both physical and psychosocial, encountered by children growing up in families with low socioeconomic status (SES). Physical stressors include exposure to toxic waste and pollution, lead exposure, secondhand smoke, noise pollution, crowded and substandard housing, and inadequate municipal services. No less potentially

damaging are poverty-related psychosocial risk factors, which include exposure to neighborhood crime and domestic violence, family disruption, harsh and punitive parenting practices, inadequate intellectual stimulation, residential dislocation, and high mobility. The author suggested that accumulated exposure to numerous risk factors over time, rather than any single factor in isolation, may lead to adverse developmental outcomes for children living in poverty. In another influential review of poverty-related risks, McLoyd (1998) emphasized the impact of street violence, homelessness, illegal drug abuse, negative role models, and parental stress and depression on negative outcomes for children. Children of low-SES families with racial or ethnic minority status often face additional burdens of prejudice and discrimination, although these may be difficult to separate from the detrimental effects of poverty itself (Huston, McLoyd, & Garcia Coll, 1994).

It is also important to recognize that applying a blanket label such as “poverty” to all children and families of low income inevitably conceals many important distinctions and ignores the wide range of cultural diversity among families (Huston et al., 1994). For example, SES may exert different developmental effects depending not only on racial, cultural, or ethnic minority status but also on the particular demographic setting (urban or rural; Huston et al. 1994; Rhoades, Greenberg, Lanza, & Blair, 2011; Sirin, 2005). Moreover, a large-scale study of variability in home environments according to poverty status and ethnicity (Bradley, Corwyn, McAdoo, & Garcia Coll, 2001a) revealed that along with significant group differences for such factors as home learning stimulation, parental responsiveness, spanking, and father involvement, there was also great diversity within each income and ethnic group.

Timing of SES effects on cognitive outcomes. There is abundant evidence that a family's SES can have significant and long-lasting effects on children's verbal cognitive development, beginning very early in life (Hart & Risley, 1995; Hoff-Ginsburg, 1998; Horton-Ikard & Ellis Weismer, 2007; Smith, Brooks-Gunn, & Klebanov, 1997). In their classic longitudinal study of early vocabulary growth among young children from professional, working-class, and poor families, Hart and Risley (1995) found dramatic SES-related differences. Based on a series of regression analyses, the authors estimated that 40% of the variability in children's expressive vocabulary at age three could be traced to household SES. Smith et al. (1997) explored the detrimental effects of poverty on cognitive outcomes among young children and reported that SES-related differences in both verbal and nonverbal cognition were apparent by age two. Hoff-Ginsburg (1998) used child language samples to examine the influence of parental education, income, and occupation on the lexical development of toddlers (ages 18 to 29 months) and found a significant effect of SES on the number of object labels children produced. Likewise, Horton-Ikard and Ellis Weismer (2007) found significant SES-related differences in both receptive and expressive vocabulary among African American children who were between 30 and 40 months of age.

Findings indicate that SES continues to influence children's achievement outcomes during the school-age years. In a meta-analysis of 58 studies (representing data from 101,157 students) that examined relations between SES and children's academic achievement, Sirin (2005) reported a moderate overall correlation of .28 between SES and achievement. The size of the correlation increased across the school-age years, growing from .19 in kindergarten to a peak of .31 in middle school. Effects of SES were

strongest for verbal achievement outcomes. In a large-scale, prospective longitudinal study, Pungello, Kupersmidt, Burchinal, and Patterson (1996) found significant differences in math and reading achievement according to SES that were apparent by second grade. SES-associated disparities in reading persisted over the ensuing five years, while SES-related differences in math achievement grew larger.

The timing, depth, and duration of poverty that children experience may play key roles in the strength of SES effects on cognitive and achievement outcomes. For instance, a longitudinal study of SES-related differences in educational attainment with a large, nationally representative sample (Duncan, Yeung, Brooks-Gunn, & Smith, 1998) found that poverty occurring during early childhood had the greatest detrimental impact on later attainment. Smith et al. (1997) reported that both depth and duration of poverty are important predictors of children's cognitive development. Worse outcomes were found for children exposed to deeper poverty or with more years of poverty exposure.

Theories of SES influence. Differing theoretical interpretations of the relation between SES and children's developmental outcomes have been proposed. Two influential accounts are the parental investment model (Becker & Tomes, 1986) and the family stress model (Elder & Caspi, 1988). The developmental psychobiological model (Blair & Raver, 2012) and evolutionary life history theory (Belsky, Steinberg, & Draper, 1991) provide alternative accounts for the effects of SES on development.

Parental investment model. According to the parental investment model, SES-related limitations on access to resources serve to constrain parents' ability to invest in their children's development (Becker & Tomes, 1986; Haveman & Wolfe, 1994). An underlying assumption is that regardless of SES, parents have an abiding interest in the

optimal development of their offspring and will devote available resources in an effort to maximize their children's opportunities (Becker & Tomes, 1986). Such resources include educational opportunities, enriching activities, stimulating toys, and access to advantaged neighborhoods, as well as parents' capacity to invest time and attention in their children's development (Yeung, Linver, & Brooks-Gunn, 2002). As a result of limited parental access to important resources, children of low-SES households, especially those below the poverty line, are more likely to experience adverse outcomes (Haveman & Wolfe, 1994). An important implication of the parental investment model for children's verbal development is that parents' own educational background, as reflected in parental language use, can itself be viewed as a crucial limiting resource (Yeung et al., 2002). Studies have shown a reliable association between caregiver educational levels and the qualities of language to which children are exposed in their homes on an ongoing basis, as discussed further below (e.g., Hart & Risley, 1995; Hoff-Ginsburg, 1991; Huttenlocher, Waterfall, Vasilyeva, & Vevea, 2010).

Family stress model. An alternative framework, the family stress model (Elder & Caspi, 1988) places greater emphasis on the impact of economic hardship on caregiver mental or emotional health and resulting effects on caregiver-child interaction. In the family stress model, the chronic stress of coping with inadequate financial resources takes an emotional toll on parents, leading to psychological distress. Parental stress is thought to result in less-supportive parenting practices such as harsh and punitive parenting, lack of warmth, and diminished responsiveness (Bradley et al., 2001a). In turn, harsh parenting practices are hypothesized to lead to chronically elevated stress in

children, adversely affecting development and amplifying the impact of limited resources on child outcomes (Yeung et al., 2002).

Developmental psychobiological model. Relatedly, the developmental psychobiological model (Blair & Raver, 2012) posits that children's stress responses to adverse SES-related parenting practices result in suboptimal brain development. According to the model, chronically elevated stress hormones act to alter neural sensitivity and connectivity in key limbic and prefrontal areas of the developing brain, leading to unfavorable cognitive outcomes. Altered stress physiology is also central to the allostatic load hypothesis of Evans and colleagues (e.g., Evans, Schamberg, & McEwen, 2009). Allostatic load is defined as the cumulative wear-and-tear on the body, including a child's developing brain, resulting from long-term exposure to multiple sources of stress, such as those associated with poverty. The physiological stress response, although adaptive in the short term for overcoming isolated challenges, becomes maladaptive when stress is widespread and chronic and environmental demands are unrelentingly high. Over time and with accumulated exposure, SES-related stressors are thought to lead to a state of altered stress physiology in children, with resultant adverse effects on development (Evans et al., 2009; Evans & Kim, 2013).

Distal and proximal factors. According to both parental investment and family stress models, distal SES-related factors such as family income are thought to exert indirect rather than direct effects on child outcomes, by influencing more proximal factors such as household enrichment and parental interaction styles (Yeung et al., 2002). For example, a study by Nelson et al. (2015) examined whether proximal factors such as availability of learning materials and caregiver responsiveness would account for the

relation between a distal measure of parental financial resources and children's cognitive outcomes. Groups of typically developing three-year-olds from homes above and below the poverty line completed a series of cognitive tasks, and experimenters conducted structured observations of children's home environments. Structural equation modeling revealed that proximal measures associated with both the parental investment model (greater availability of learning materials, variety of enriching experiences, academic and language stimulation) and the family stress model (caregiver warmth and responsiveness) were significant predictors of cognitive performance for children from low-income homes. Moreover, proximal factors completely mediated the relation between SES and cognitive outcomes. As the authors noted, both parental investment- and family stress-related proximal factors may act together to influence children's cognitive development.

Life history perspective. A different perspective on the relation between SES and cognitive outcomes is based on evolutionary life history theory (Belsky et al., 1991). According to this view, SES-related adversity during childhood may be linked with certain adaptive changes. Rather than leading to widespread deficits in cognition, childhood adversity may instead result in specific adaptations that are useful for the environment in which an individual lives (Frankenhuis & de Weerth, 2013). In support of this perspective, a recent study by Mittal, Griskevicius, Simpson, Sung, and Young (2015) found that adults who had experienced childhoods high in unpredictability performed better on a task of cognitive flexibility than their counterparts who had experienced more predictable childhoods, but only when a general mindset of uncertainty had been experimentally induced immediately prior to the cognitive task. The authors

concluded that a history of adapting to unpredictable conditions might prepare individuals to deal more effectively with unpredictable situations in the future.

Role of separate aspects of SES. Another issue concerns which particular aspect(s) of SES are predictive of children's cognitive outcomes, and whether certain indicators are associated with greater or lesser effects. Over four decades ago, Duncan, Featherman, and Duncan (1972) proposed an SES framework that includes three key indicators—income, educational level, and occupation. This tripartite model of SES has been influential in guiding much of the subsequent literature (Hauser, 1994; Mueller & Parcel, 1981). Across several studies, researchers have compared the relative contribution of parental income, education, and occupation to overall SES effects on children's cognitive outcomes (e.g., Noble et al., 2015; Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005; Sirin, 2005; Smith et al., 1997). Smith et al. (1997) examined separately the influence of maternal education and household income on young children's cognitive development and found that education and income each had significant and independent effects. Sirin's (2005) meta-analysis of SES effects on school-age children's achievement reported similar moderate effect sizes (.28 - .30) for parental income, education, and occupation. In contrast, Noble et al. (2005) found that whereas parental educational level was uniquely predictive of young children's cognitive task performance, household income-to-needs ratio was not. In a similar finding, Noble et al. (2007) reported that among a range of SES variables, maternal education was the strongest predictor of several cognitive skills, including language. However, a more recent study exploring SES effects on cortical thickness and surface area in key brain areas by the same research group (Noble et al., 2015) produced more nuanced results.

Whereas parental education was linearly and positively related to cortical surface area for the entire range of participants, family income had more pronounced effects on cortical surface area among participants at the lower end of the income scale.

Role of context. To better understand the source of SES effects on development, researchers have also examined the relative contribution of various contexts to SES-related child outcomes (Aikens & Barbarin, 2008; Sampson, Sharkey, & Raudenbush, 2008; Taylor, Christensen, Lawrence, Mitrou, & Zubrick, 2013). According to bio-ecological theory (Bronfenbrenner, 1989) factors within multiple interconnected levels of context surrounding a child (e.g., family, school, neighborhood) may act together to influence development. Variables in the home environment might exert a relatively direct effect on children, while broader influences on a neighborhood or societal scale might affect children more indirectly.

With the bio-ecological framework in mind, researchers have explored the impact of different contexts on SES-related outcomes. For example, Aikens and Barbarin (2008) used a large, nationally representative database to model the separate effects of family, school, and neighborhood settings on reading achievement trajectories among school-age children. The family variables included such factors as home literacy environment, involvement in the child's school, and ratings of parental warmth. School variables included public/private and Title 1 status, teacher training, and classroom literacy activities. Neighborhood variables included ratings by parents, school administrators, and researchers of the prevalence of graffiti, boarded-up buildings, and people congregating. Results of hierarchical growth curve modeling, controlling for gender, race/ethnicity and age, showed significant differences in reading achievement according

to SES, with the greatest disparity occurring during first grade (the time of most rapid overall growth in reading skill). The model also revealed that each set of contextual variables contributed differentially to children's reading skills. Family context was related to initial pre-reading skills in kindergarten, but not to subsequent growth in reading ability. School context was related to both initial pre-reading level and growth in skill, while neighborhood context was related only to growth in reading skill across the years from kindergarten to third grade.

Neighborhood-level contextual factors may exert an especially strong influence on children's developing language skills. Two longitudinal studies (Sampson et al., 2008; Taylor et al., 2013) examined the contribution of neighborhood context to SES effects on children's verbal ability. Sampson et al. (2008) followed school-age African American children in Chicago for up to seven years to study the effects of living in neighborhoods of "concentrated disadvantage." Disadvantage was calculated based on a formula that included neighborhoods' rate of welfare receipt, poverty, unemployment, female-headed households, racial status, and density of children. The researchers found that living in a neighborhood with high scores on these variables, even temporarily, was associated with long-lasting detrimental outcomes for children's later verbal ability. Among children who had lived in the most disadvantaged neighborhoods, the effect was equivalent to missing an entire year of schooling. Similarly, Taylor et al. (2013) used multilevel growth curve modeling with a large, nationally representative sample of four- to eight-year-old children in Australia to analyze neighborhood-related SES effects on the development of receptive vocabulary. Findings indicated that vocabulary in children

living in areas of greater social and income disadvantage lagged behind that of their more affluent peers by an average of eight months.

Measuring SES. Several points are important to consider when attempting to measure SES. Sirin (2005) discussed a number of these issues in his meta-analysis of SES effects on achievement. One key question involves whether SES must be assessed for each participant's household individually, or whether aggregated measures at the school or neighborhood level (e.g., percentage of students receiving free or reduced-price lunch; percentage of residents with less than a high school degree) can suffice as an estimate of participants' SES. Although researchers commonly rely on such aggregated measures of SES, Sirin advised strongly against their use. Drawing on group data to make inferences or predictions about individuals introduces issues of "ecological fallacy" (p. 190) that can seriously compromise validity.

Additional assessment issues concern reliability and levels of measurement. Hauser (1994) pointed out the practical difficulty of accurately determining parental income (which is subject to response bias as well as being notoriously volatile over time) and recommended that researchers rely on parents' occupational status as a more valid and stable indicator of household SES. Relatedly, McLoyd (1998) suggested that a family's income ranking in relative terms (e.g., income-to-needs ratio) tends to be a more reliable indicator of SES than absolute income measures, which can change substantially even in the short term. With regard to levels of measurement, Sirin (2005) advised researchers against analyzing SES in a dichotomous or categorical fashion. Results of his meta-analysis showed that studies treating SES as a continuous variable produced higher correlations with student achievement than dichotomous SES measures did. Finally,

there is some evidence that parents' subjective self-ratings of their own SES may actually have greater predictive value than purely objective measures (Adler, Epel, Castellazzo, & Ickovics, 2000).

SES effects on vocabulary. The association between SES and vocabulary, in which children from low-income homes lag significantly behind their peers from more affluent homes, has been recognized for over 50 years (e.g., Deutsch, 1965; Templin, 1957). For instance, Templin (1957) noted a difference of about 5300 words between the vocabularies of eight-year-olds from higher and lower SES homes, and Deutsch (1965) reported significant class- and race-based differences in vocabulary among first- and fifth-grade children. More recently, researchers have found income-based disparities in vocabulary among toddlers (Hoff-Ginsburg, 1998; Horton-Ikard & Ellis Weismer, 2007), preschoolers (Dollaghan et al., 1999; Hart & Risley, 1995; Qi, Kaiser, Milan, & Hancock, 2006; U.S. DHHS, 2011; Washington & Craig, 1999), kindergarteners (Burton & Watkins, 2007; Campbell, Bell, & Keith, 2001), and school-age children (Farah et al., 2006; Hart & Risley, 1995; Noble et al., 2007). For example, Farah et al. (2006) compared performance on a range of cognitive tasks among 10- to 13-year-old African American children from low-SES homes to that of age- and gender-matched peers from middle-SES homes. The groups differed significantly on memory and working memory tasks, but the greatest group difference found was for language (a composite measure that included receptive vocabulary and grammar). Noble et al. (2007) likewise examined a wide range of skills, but in a racially and economically diverse sample of first graders. Regression analyses revealed that parental SES (a variable that included income,

education, and occupation) accounted for 43.9% of the variance in participants' receptive vocabulary scores.

SES effects on vocabulary growth. A number of studies have also reported SES-related differences in rates of vocabulary gain across the school-age years (e.g., Biemiller & Slonim, 2001; Chall, Jacobs, & Baldwin, 1990; Farkas & Beron, 2004; Rice & Hoffman, 2015; White, Graves, & Slater, 1990). While underlining the significance of both vocabulary and reading comprehension for acquiring new subject-related knowledge during reading, Chall et al. (1990) noted income-based disparities in both vocabulary and reading skill that persisted and grew wider as children progressed through elementary and middle school. A cross-sectional study with first- through fourth-grade students by White et al. (1990) compared vocabulary growth among children in a predominantly White, suburban middle-class school to that of their counterparts in two disadvantaged schools with large minority populations. The authors found SES-based disparities in first grade that grew wider across each ensuing grade. By fourth grade, the more affluent students had estimated vocabularies that were 50% larger than those of their less-advantaged peers. In another cross-sectional study with school-age children, Biemiller and Slonim (2001) reported conflicting findings. A relatively affluent group of private school students had vocabularies that were 20% larger, on average, than the less-advantaged "normative" group during second grade, but the between-group difference narrowed to only three percent in sixth grade. However, the study did not include many low-SES households; the normative group included participants with a wide range of SES that was representative of the population as a whole. In addition, the authors did not measure knowledge of morphologically complex or later-acquired words and suggested

that if such words had been included, between-groups differences would likely have been larger.

Two other studies (Farkas & Beron, 2004; Rice & Hoffman, 2015) used multilevel growth curve modeling to analyze SES-related differences in vocabulary growth. Farkas and Beron (2004) examined receptive vocabulary in a large, nationally representative sample and reported SES- and race-based disparities among children at age three that grew wider during the preschool period and then persisted through age 13. Observed home environmental variables together accounted for roughly 40% of the SES-related vocabulary gap. In a more recent longitudinal study, Rice and Hoffman (2015) modeled receptive vocabulary growth trajectories among participants between two and 21 years of age and found a modest but significant effect of maternal educational level on rates of vocabulary gain. Maternal education had a similar influence on vocabulary growth in participants with specific language impairment and participants with typical language development.

Pathways of SES influence on vocabulary: linguistic stimulation. According to family investment models of SES-related effects on development, differences in caregiver educational background can substantially constrain important characteristics of the language to which young children are continually exposed. Over time, these class-based disparities in children's linguistic environment are thought to contribute to measurable SES-associated differences in language development, including vocabulary. In support of such models, longitudinal studies have shown significant differences in caregiver speech according to SES that were, in turn, associated with disparities in children's vocabulary (Hart & Risley, 1995; Hoff-Ginsburg, 1991; Hoff-Ginsburg, 1998;

Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Pan, Rowe, Singer, & Snow, 2005; Weizman & Snow, 2001).

In their seminal longitudinal study of vocabulary development in children of professional, working-class, and welfare families, Hart and Risley (1995) observed dramatic class-based disparities in the amount and kind of language heard by young children. The authors reported a threefold difference in the sheer volume of words produced by caregivers in professional as compared with welfare households, amounting to an estimated difference of twenty million words by the time children were three years old. On a qualitative level, children in professional families heard a greater variety of different words, more positive feedback and encouragement, more responsive utterances, and more highly symbolic language. Conversely, children in welfare households received more negative feedback and discouraging comments, more imperatives, and more prohibitions. The authors found all of these features of caregiver language to be associated with SES disparities in children's expressive vocabulary at age three as well as with follow-up measures of receptive vocabulary in third grade. Regression analyses showed that overall, SES accounted for 40% of variance in expressive vocabulary at age three, 42% of variance in rate of vocabulary growth, and 30% of receptive vocabulary in third grade.

A number of additional studies have likewise found SES-related differences in linguistic stimulation that were related to children's vocabulary development. Hoff-Ginsburg (1991) observed several features of mothers' speech to their 18- to 29-month old children during daily caretaking activities among both working-class and upper-middle-class families. Whereas working-class mothers issued more behavior directives,

upper-middle-class mothers were more likely to give topic-continuing replies and engage their toddlers in conversation. In turn, children of upper-middle-class homes produced a greater number of object labels than the children of working-class families did (Hoff-Ginsburg, 1998). In a longitudinal study, Huttenlocher et al. (1991) found that the amount of parental speech input when children were 16 months old predicted toddlers' rate of vocabulary growth over the following 10 months.

There is also evidence that quality, rather than merely quantity, of caregiver speech may be an important factor in predicting young children's vocabulary growth. Pan et al. (2005) collected language samples from children of rural low-income families and used growth curve modeling to analyze gains in productive vocabulary from ages 14 to 36 months. Results showed that maternal educational level, diversity of mothers' speech, and measures of mothers' own vocabulary and literacy were all related to growth in children's vocabulary. Sheer quantity, or the overall amount of maternal speech, was not a predictive factor. Similarly, Weizman and Snow (2001) reported that the total amount of mothers' speech to their five-year-old children did not predict children's receptive vocabulary in either kindergarten or second grade. Rather, it was mothers' use of "sophisticated" words (words less common than the 3000 most common tokens), as well as contextual support for understanding such less-common words, that was related to children's concurrent and later receptive vocabulary.

Other studies have explicitly tested the hypothesis that characteristics of caregiver speech serve to mediate the relation between SES and child vocabulary (Hoff, 2003; Huttenlocher et al., 2010). Hoff (2003) collected mother/child language samples from middle- and high-income households to examine pathways of SES influence on toddlers'

developing vocabulary. Properties of maternal speech such as the number of utterances, number of word types and tokens, mean length of utterance, frequency of joint attention episodes, and number of topic-continuing replies were related to both SES and children's productive vocabulary. Regression analyses revealed that the SES-child vocabulary relation was completely mediated by the measured aspects of maternal speech.

Importantly, however, the study focused only on households of middle and high income and did not include participants at the poverty level. In likewise fashion, Huttenlocher et al. (2010) studied language development among 26- to 46-month-old children from households with SES that varied somewhat but did not include many low-income families. The authors used cross-lagged correlation to model longitudinal relations between aspects of caregiver input and child language. Results showed that diversity of caregiver language at the word, phrase, and clausal level predicted corresponding aspects of child productions four months later. Of note, the authors found that for vocabulary in particular, the reverse was also true: diversity of children's expressive vocabulary predicted diversity of caregivers' later input, suggesting at least some level of reciprocal influence between caregivers and children. Overall, SES was significantly related to diversity of children's productions, and analyses suggested that the effect was partially mediated by diversity of caregiver language.

Another aspect of the linguistic environment involves access to print resources, computers, and other information technology. On a neighborhood scale, SES has a profound influence on the quantity and quality of print and computer resources available to children (Neuman & Celano, 2001; Neuman & Celano, 2012). Research has demonstrated that exposure to print predicts oral language development, including

vocabulary, with the relation becoming stronger from early childhood to young adulthood (Mol & Bus, 2011). However, significant SES-related disparities exist in children's access to quality print resources (Neuman & Celano, 2001) as well as computers and information technology (Neuman & Celano, 2012). On a less tangible but no less important level, there are SES-associated differences in adults' attitudes toward reading and use of information technology that can act to reinforce and magnify the already wide income-based disparities (Neuman & Celano, 2012).

Pathways of SES influence on vocabulary: home environment. Studies focusing on SES-related aspects of family home environment have provided evidence for both parental investment and family stress models of SES influence on children's vocabulary (Bradley et al., 2001a; Bradley, Corwyn, Burchinal, McAdoo, & Garcia Coll, 2001b; Farah et al., 2008). In a large, nationally representative sample, Bradley et al. (2001a, 2001b) found significant differences according to SES in variables related to both parental investment (availability of stimulating materials, access to enriching experiences, frequency of informal teaching episodes) and family stress (parental sensitivity and responsiveness, frequency of spanking, father's level of involvement). Hierarchical regression analyses showed that both sets of variables, in turn, were significantly predictive of children's receptive vocabulary. In contrast, Farah et al. (2008) found differential effects of SES-related investment and stress variables for separate aspects of children's development. The authors followed groups of low- and middle-income African American children from age four to 11 and found that while levels of parental nurturance at ages four and eight predicted children's memory

performance during middle school, early home environmental stimulation predicted later language performance, including receptive vocabulary.

Summary: *SES and vocabulary.* There is broad agreement that family SES has a substantial influence on children's vocabulary development, with cascading effects on reading ability and academic achievement. SES-related differences in linguistic environment, home cognitive stimulation, and parental nurturance, as well as inequality in community-level access to print and information technology, may all play a role in SES-associated disparities in vocabulary. Less well-studied is whether SES-related discrepancies in other cognitive abilities (i.e., executive function) may also partially account for the association between SES and individual differences in children's vocabulary.

SES and word learning. Although a wealth of evidence indicates that SES is related to vocabulary, far fewer studies have examined the role of SES in the word learning process itself. One piece of indirect evidence comes from a meta-analysis of vocabulary interventions for young children by Marulis and Neuman (2010). While intervention was found to be generally effective for improving children's vocabulary, with a large and educationally significant overall effect size of .88, children from low-SES homes made significantly smaller gains with intervention than their counterparts from middle- and upper-class homes. As the authors pointed out, such SES-related disparities in response to intervention may result, over time, in widening rather than narrowing any SES-associated gaps in children's vocabulary. Compounding the problem is a trend for schools in predominantly low-SES neighborhoods to provide very little in the way of direct vocabulary instruction. Wright and Newman (2014) observed

kindergarten classes in neighborhoods of widely ranging SES and found that while scant time was set aside for direct teaching of vocabulary in any of the classrooms, teachers in low-SES schools were especially unlikely to devote class time to vocabulary instruction.

Two studies that directly examined the effect of SES on word learning in young children did not find an association between SES and young children's experimental task performance (Burton & Watkins, 2007; Horton-Ikard & Ellis Weismer, 2007). Horton-Ikard and Ellis Weismer (2007) compared novel word learning from context among low- and middle-income groups of African American toddlers. Although the groups differed significantly on standardized measures of receptive and expressive vocabulary, there were no between-group differences on a novel word learning task. Likewise, Burton and Watkins (2007) found that although a group of African American kindergarteners from lower-income homes performed more poorly on a test of receptive vocabulary than their peers from higher-SES homes, both groups earned similar scores on a fast mapping task. However, neither study encompassed a very wide range of SES levels. The lower-SES groups included participants from households with income below the poverty line, but the higher-SES groups on average had income and educational levels lower than what is considered typical for the middle class. Moreover, both studies involved oral fast mapping tasks with young children. The extent to which SES might influence word learning in the context of reading among school-age children remains unexplored.

If an SES-related disparity in word learning does exist, it may stem from discrepancies in background knowledge among children with varying levels of SES. Kaefer et al. (2015) compared novel word learning from narratives in children from low-income homes who were enrolled in Head Start to that of middle-class peers who

attended private preschools. When narrative passages were based on real-world background knowledge (about birds, in this instance), the Head Start group demonstrated both a lower level of background knowledge and less success at the novel word learning task than the private preschool group. However, when stories were altered to include only fictitious alien characters that were unfamiliar to both groups of children, the between-group difference in novel word learning disappeared. As the authors pointed out, children from low-SES backgrounds may be at a disadvantage in acquiring new vocabulary from context because of SES-related discrepancies in existing conceptual knowledge. Moreover, disparities in background knowledge are likely to become increasingly important as children get older and are expected to glean vocabulary knowledge through independent reading. Informational text typically includes a higher density of unfamiliar new terms and often assumes a level of background knowledge that children of lower-SES homes may not possess.

Executive Function

Although opinions differ as to the underlying structure of executive function (EF), there is broad agreement that EF comprises a set of higher order, top-down processes for regulating attention and engaging in purposeful, goal-directed behavior (Garon, Bryson, & Smith, 2008). EF skills are involved in numerous aspects of adaptive functioning, from goal selection and strategic planning to self-regulation and emotional control (Anderson, 2002). EF is generally associated with activity in particular brain areas, especially the dorsal anterior cingulate and portions of the prefrontal cortex (Best & Miller, 2010; Carter & van Veen, 2007; Ordaz, Foran, Velanova, & Luna, 2013; Shenhav, Botvinick, & Cohen, 2013; Spielberg et al., 2015). These brain areas, along

with the associated EF skills, are known to follow a protracted course of development throughout childhood and into adulthood (Romine & Reynolds, 2005). Though EF is related to IQ, studies have shown that EF is distinct from general intelligence (Huizinga, Dolan, & van der Molen, 2006; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Masten et al., 2012). Individual differences in EF are related to a wide range of outcomes across the lifespan, including academic and occupational attainment as well as aspects of both mental and physical health (Diamond, 2013).

Theories of executive function. A number of theories about the nature and structure of EF have been proposed (Garon et al., 2008). Theorists differ as to whether they view EF as a single unitary construct or as a set of related but separable factors. One of the most widely accepted models of EF emerged from a latent variable analysis of adults' performance on a range of EF tasks by Miyake and associates (Miyake et al., 2000). Results yielded three separate but correlated aspects of EF: updating, inhibition, and shifting. Updating involves the active manipulation, not merely passive storage, of information in working memory. Inhibition signifies the ability to suppress a dominant or prepotent response in favor of an alternative response. Shifting refers to the ability to flexibly switch from one mental set or rule to another. Structural equation modeling revealed that these three basic EF factors were each involved to varying degrees in more complex tasks of planning (Tower of Hanoi; Humes, Welsh, Retzlaff, & Cookson, 1997) and cognitive flexibility (Wisconsin Card Sorting Test; Berg, 1948). Miyake et al. suggested that the moderate correlations found among updating, inhibition, and shifting might stem from a shared underlying factor such as controlled attention.

Other theories conceive of EF as a unitary capacity. For example, the Cognitive Complexity and Control theory (Zelazo, Müller, Frye, & Marcovitch, 2003) emphasizes age-related changes in rule complexity that, with development, allow children to respond to challenges in an increasingly flexible and controlled manner. However, developmental trajectories may differ based on whether a task requires “hot” or “cool” EF; whereas “hot” tasks involve an emotionally or motivationally salient component, “cool” tasks rely on more abstract, affect-neutral cognitive processing (Prencipe et al., 2011; Zelazo & Müller, 2002). In contrast, Munakata’s (2001) graded representations theory views EF development as a unitary process in which children become capable of resolving conflict through a reliance on ever-strengthening cognitive representations.

Still other theories of EF posit a central role for attentional processes. Posner and Rothbart (2007) differentiate among three attention networks—alerting, orienting, and executive attention—and argue for the primary importance of executive attention in the development of EF throughout childhood. Executive attention is also seen as the foundation for the development of effortful control. Anderson (2002) proposes four interrelated EF domains: attentional control, information processing, cognitive flexibility, and goal setting. According to the model, attentional control is the most fundamental component, emerging during infancy and supporting the development of the other three domains. Although some research examining EF skills in children is grounded in attention-based theories of EF (e.g., González, Fuentes, Carranza, & Estévez, 2001; Harms, Zayas, Meltzoff, & Carlson, 2014; Mezzacappa, 2004; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005), the majority of recent studies have

conceptualized EF in terms of three separable but correlated latent factors (updating or working memory, inhibition, and shifting) as described by Miyake et al. (2000).

Structure of executive function in children. Evidence is mixed as to whether the structure of EF ability in children conforms to that reported by Miyake et al. (2000) in adults. Some studies suggest that, especially in younger children, EF may be organized as a single unitary construct. For example, Hughes and Ensor (2007) performed a principal components analysis of performance on a range of EF tasks among two- to four-year-old children and reported that the best-fitting model contained just one latent EF factor. Likewise, a confirmatory factor analysis by Willoughby, Blair, Wirth, and Greenberg (2010) yielded a single latent factor for EF ability in low-income preschoolers, and Wiebe, Espy, and Charak (2008) found that a single latent factor was best-fitting for two- to six-year-old children's performance on tasks of working memory and inhibition. Nevertheless, not all theorists agree with the view of children's EF as a singular ability, citing evidence of different developmental trajectories for performance on tasks targeting disparate aspects of EF (e.g., Garon et al., 2008) and neuroimaging evidence showing regional specialization of brain areas for the separate functions of working memory, inhibition, and shifting (Huizinga et al., 2006).

There is generally greater agreement that the structure of EF in school-age children and adolescents involves multiple interrelated latent factors (Best, Miller, & Jones, 2009), although uncertainty remains about the number of factors (Huizinga et al., 2006; Nigg, 2000; St. Thompson & Gathercole, 2006). For example, in a confirmatory factor analysis of performance on a battery of EF tasks by typically developing eight- to 13-year-old children, Lehto et al. (2003) found that the best-fitting model yielded the

same three interrelated factors—working memory, inhibition, and shifting—reported by Miyake et al. (2000) in adults. It is also important to note that each one of these broad factors may be comprised of multiple underlying abilities. In a review of inhibition effects, for example, Nigg (2000) differentiated eight separate and functionally distinct inhibitory skills involved in a range of behavioral tasks that all fall under the general category of “inhibition” measures.

Measurement issues. As a whole, the EF research literature has been beset by a number of troublesome methodological issues. First and perhaps most seriously, there is no universally-accepted definition of EF as a construct, nor is there agreement on a practical level as to how the EF construct, however defined, is best measured. In addition, researchers sometimes disagree about the particular underlying EF skill—e.g., inhibition, executive attention, cognitive flexibility—that a given experimental task purportedly measures, resulting in published articles that attribute performance on the same task to different underlying EF abilities (Best & Miller, 2010).

Beyond definitional issues, research into EF has been complicated by what Miyake et al. (2000) called the “task impurity problem.” However carefully measures are designed, they inevitably draw on multiple underlying skills, often in a hierarchical fashion. For example, many tasks of inhibition also place significant demands on working memory, and tasks of shifting or cognitive flexibility usually call on both working memory and inhibition (Garon et al., 2008). Not infrequently, experimental tasks of EF also rely heavily on verbal ability (Best & Miller, 2010).

Even when researchers agree about the underlying dimensions that are associated with an EF construct under consideration, thorny experimental design questions remain.

Miyake et al. (2000) advised great care in task selection, so that subjects' performance will actually reflect the dimension(s) a researcher intends. For example, they pointed out that working memory tasks must involve manipulation and not just passive storage of information. Miyake et al. also recommended that researchers be aware of the distinction between tasks of inhibition that merely require inhibition of a prepotent response and those that require execution of an alternative response. Finally, they cautioned that tasks of visual attention shifting most likely call on different underlying abilities than measures that require attentional shifting among multiple rules or mental sets.

Another methodological issue, and one that has received too little attention, is the problem of researchers' reliance on self-selected samples. The majority of EF studies have been conducted with convenience samples of participants from above-average educational and SES backgrounds (Willoughby et al., 2010). As a result, the generalizability of findings to the population at large is questionable. This is particularly problematic given the need to understand the role of EF skills in academic and other important outcomes among children at risk due to poverty or low SES.

Development of executive function. As mentioned, studies have shown that EF follows a lengthy developmental course throughout childhood and adolescence (Romine & Reynolds, 2005). Moreover, research indicates differing developmental trajectories for various aspects of EF, as well as for more complex tasks of planning and cognitive flexibility (Anderson, 2002; Best et al., 2009; Garon et al., 2008; Huizinga et al., 2006; Prencipe et al., 2011). Best et al. (2009) summarized both behavioral and neuroimaging evidence in a comprehensive review of the development of working memory, inhibition, shifting, and planning from age five to adulthood. The authors noted that working

memory performance develops in a linear fashion throughout childhood and adolescence, and that neuroimaging studies show both quantitative and qualitative changes with development. Inhibition, in contrast, develops rapidly in early childhood; further improvements in late childhood and adolescence primarily involve greater speed and efficiency. Shifting performance improves with development until early adolescence. However, in later childhood, as children come to rely increasingly on metacognitive strategies during shifting tasks, there can be a speed-accuracy tradeoff; response times become longer even as accuracy improves. Performance on complex planning tasks such as the Tower of Hanoi develops later, and studies show dramatic improvement during middle childhood and adolescence. In a study with typically developing participants between eight and 15 years of age, Prencipe et al. (2011) compared developmental trajectories for performance on a range of “hot” and “cool” EF tasks. Results showed scores on both sets of tasks improving with age, but with improvement occurring at earlier ages on affect-neutral “cool” tasks than on emotionally salient “hot” tasks.

Stability of executive function. To date, most research examining developmental change in children’s EF has been cross-sectional in nature. Few prospective longitudinal studies have explored the stability of individual differences in EF skills over time (Best & Miller, 2010). However, results of two such investigations suggest that EF skills are stable, both during the preschool years (Hughes & Ensor, 2007) and across middle childhood into preadolescence (Harms et al., 2014). Hughes and Ensor (2007) found that performance on a battery of tasks measuring working memory, inhibition, and shifting improved with age, and that individual differences were stable from ages two to four. In a similar finding with older children, Harms et al. (2014)

reported that performance on tasks of executive attention and cognitive flexibility at age eight predicted performance on those same tasks four years later.

Relation to self-regulation. Although the concepts are not synonymous, EF skills are related to children's capability for self-regulation. Self-regulation involves "the ability to control, direct, and plan behavior" (Sektnan, McClelland, Acock, & Morrison, 2010, p. 465). Self-regulation contributes to the capacity to focus and maintain attention on tasks, follow instructions, tune out distractions, and inhibit inappropriate behavior (Sektnan et al., 2010). Skill in self-regulation is associated with a host of developmental outcomes, including academic achievement, physical health, personal wealth, and criminal behavior (McClelland & Cameron, 2012; Moffitt et al., 2011). Usually assessed with the use of teacher or caregiver rating scales, self-regulation may also be evaluated through structured observation or behavioral tasks (McClelland & Cameron, 2012).

EF skills such as working memory, inhibitory control, and shifting are thought to contribute to children's ability for self-regulation (Best et al., 2009). In classroom settings, for example, working memory helps children remember instructions, inhibitory control helps them resist impulsive behavior, and shifting helps them transition from one lesson to the next (McClelland & Cameron, 2012). As measures of children's general adaptive functioning, experimental measures of EF skills and rating scales of self-regulation each have strengths and weaknesses. Whereas controlled, laboratory-based tasks enable researchers to focus on specific cognitive processes, parent or teacher rating scales tap into more global aspects of children's real-world use of EF skills in everyday contexts. While laboratory tasks are often considered a more "objective" measure of EF, rating scales can be subject to reporting bias. It may be most useful to consider EF tasks

and self-regulation scales as complementary measures of children's overall ability to control attention and direct behavior (Isquith, Crawford, Espy, & Gioia, 2005).

There is some empirical evidence that caregiver or teacher ratings of children's behavioral self-regulation are indeed related to concurrent (González et al., 2001) and later (Friedman et al., 2007) measured EF skills among school-age children and adolescents. González et al. (2001) reported that caregiver ratings of self-regulation were correlated with performance on experimental tasks of orienting and executive attention in typically developing seven-year-olds. Friedman et al. (2007) found that teacher-reported attention problems when students were between the ages of seven and 14 predicted subsequent performance on a battery of EF tasks at age 17. Results of confirmatory factor analyses yielded significant associations between teacher ratings and all EF factors. The relation was strongest for inhibition, intermediate for working memory (updating), and weakest for shifting.

Intervention to improve executive function skills. Results of numerous intervention studies indicate that at least some EF skills are malleable and show gains with targeted treatment (Diamond, 2012). Many of these interventions have focused specifically on improving participants' working memory (e.g., Dunning, Holmes, & Gathercole, 2013; Loosli, Buschkeuhl, Perrig, & Jaeggi, 2012), and findings have been mixed. In a recent meta-analysis of 23 working memory intervention studies including both typically developing and clinical samples and children as well as adults, Melby-Lervåg and Hulme (2013) found reliable short-term improvement but few lasting benefits. Further, there was little evidence to suggest that treatment-associated gains

were generalizable to other cognitive skills such as verbal or nonverbal ability or to greater academic achievement.

Dramatic treatment-related improvements in executive attention were reported by Rueda et al. (2005) in a study involving typically developing 4- and 6-year-old children. Five sessions of targeted executive attention training exercises were administered over the course of two to three weeks. Compared with control groups of children who either watched videos or received no treatment, the intervention group showed significant gains from pretest on a measure of executive attention; the authors equated the level of improvement to roughly one year of development. However, the study did not include a follow-up assessment to assess whether training benefits were maintained.

Intervention programs expressly targeted at improving EF skills in at-risk preschoolers have been associated with a number of treatment-related benefits (Blair & Raver, 2014; Diamond, Barnett, Thomas, & Munro, 2007; Raver et al., 2011). Diamond et al. (2007) examined outcomes for *Tools of the Mind*, a highly structured preschool curriculum that includes a focus on children's EF development. Preschoolers from low-income homes were randomly assigned to classrooms using either the *Tools* curriculum or the district's balanced literacy curriculum. Results showed that at the end of the year, children in *Tools* classrooms performed significantly better than children in control classrooms, with greater accuracy on tasks of working memory, inhibitory control, and cognitive flexibility. A more recent cluster randomized controlled trial examined effects of the *Tools* curriculum in kindergarten children from families with a wide range of SES (Blair & Raver, 2014). Children completed a battery of tasks measuring EF and attention in spring of the kindergarten year. Relative to children in control classrooms that

implemented the district's usual kindergarten curriculum, children exposed to the *Tools* curriculum had significantly better accuracy, faster response times, or both on most of the tasks. The effect was greatest in high-poverty schools. Raver et al. (2011) reported results of a cluster-randomized trial of the Chicago School Readiness Program (CSRП), an emotionally and behaviorally focused program targeting self-regulation skills among Head Start preschoolers. Compared with children in control classrooms, children receiving the CSRП intervention made significantly greater gains across the preschool year on measures of cognitive complexity, planning, and inhibitory control.

Relation of executive function to academic achievement. Similar to the findings on self-regulation and achievement already mentioned, research has shown that children's performance on behavioral measures of EF is associated with important achievement outcomes (Allan, Hume, Allan, Farrington, & Lonigan, 2014; Best, Miller, & Naglieri, 2011; Blair & Razza, 2007; Howse, Lange, Farran, & Boyles, 2003; Masten et al., 2012; St. Clair-Thompson & Gathercole, 2006). For instance, Howse et al. (2003) found that for kindergarteners enrolled in Title I classrooms as well as their more advantaged peers, children's ability to regulate attention (as measured by a distracting computerized task) explained unique variance in concurrent reading achievement. In a prospective study of mostly rural Head Start preschoolers, Blair and Razza (2007) reported that both inhibitory control and shifting, measured during preschool, were related to early math and literacy skills the following year in kindergarten. However, multiple regression analyses showed that only inhibitory control contributed uniquely to the prediction of kindergarten math and reading performance. Masten et al. (2012) administered a battery of EF tasks to kindergarten and first-grade children living in

homeless shelters—a population at greatly increased risk for both academic failure and behavioral problems—and reported that EF skills significantly predicted teacher ratings on a range of achievement and socioemotional outcomes. A recent meta-analysis by Allan et al. (2014) summarized the findings of 75 studies of the relation between inhibitory control and early academic achievement and found a moderate overall effect size of .27. Because measures of inhibition were related to both math and literacy skills, the authors suggested that inhibitory control exerts a domain-general influence on children's early achievement outcomes.

Although the majority of studies exploring associations between EF and achievement have been conducted with young children, research has also shown that EF skills are related to academic performance during middle childhood and adolescence. St. Clair-Thompson and Gathercole (2006) reported that 11- and 12-year-olds' scores on school-administered tests of reading, math, and science were correlated with performance on tasks of working memory, updating, inhibition, and shifting. In a large, nationally representative sample of participants five to 17 years of age, Best et al. (2011) found that speed and accuracy on a battery of EF tasks were related to scores on standardized measures of both reading and math. Similar to the pattern of results for preschoolers, findings with school-age children and adolescents point to an overall domain-general effect of EF on school achievement.

Relation of executive function to vocabulary. Beyond an association with achievement in general, research has shown that children's EF skills are related to individual differences in vocabulary. Both working memory and inhibitory control were correlated with receptive vocabulary in four-year-olds (Wolfe & Bell, 2004), inhibitory

control and shifting were correlated with receptive vocabulary in five- to eight-year-olds (Wilbourn, Kurtz, & Kalia, 2012), and planning skills were correlated with expressive vocabulary in Best et al.'s (2011) nationally representative sample of five- to 17-year-olds. Nicolay and Poncelet (2013) followed a group of typically developing children who were enrolled in second language immersion programs and found that auditory attention and flexibility skills at age five predicted gains in second language vocabulary over the following two years. Taken together, correlational findings such as these are suggestive but cannot speak to questions of causality in the EF-vocabulary relation. Indeed, the various theoretical interpretations that have been offered make fundamentally different assumptions about the direction of the effect.

Influence of language on executive function: self-directed speech. One perspective asserts a causal role, not for vocabulary specifically but for language skill more generally, in the development of EF. Based originally on the writings of L. Vygotsky (e.g., Vygotsky, 1978) the theory highlights the importance of self-directed or private speech in the development of self-regulation. According to the rationale, as young children develop, their overt egocentric speech becomes increasingly private and internalized; the growing capacity for private self-directed speech in turn results in continual improvement in children's ability to use language to regulate their emotions and behavior. For example, verbal skills may enable children to maintain rules in working memory, thus aiding in various aspects of problem-solving and decision-making (Marcovitch & Zelazo, 2009). Supporters of the argument point to empirical evidence from classroom settings which has shown that a greater reliance on private speech is indeed associated with higher levels of behavioral self-regulation (Zakin, 2007) and with

better performance on tasks requiring coordination of speech and motor activity (Winsler, Manfra, & Diaz, 2007). In the laboratory, studies have revealed correlations between children's use of private speech and performance on tasks of working memory (Fatzer & Roebbers, 2012), cognitive flexibility (Alarcón-Rubio, Sánchez-Medina, & Prieto-García, 2014), and planning skills (Fernyhough & Fradley, 2005). To test the effect of private speech on EF performance experimentally, researchers often incorporate an articulatory suppression condition in order to prevent participants from engaging in self-directed talk while completing a task. Along these lines, Lidstone, Meins, and Fernyhough (2010) reported that articulatory suppression resulted in poorer performance on a complex planning task among seven- to 10-year-old children. Considered together, the findings on private speech at least suggest a potentially causal role for children's overall language skills, perhaps including vocabulary, in the development of EF.

Influence of language on executive function: bilingualism. Another perspective on the causal relations between language or vocabulary and executive function stems from the literature on bilingualism. Although not all researchers agree (e.g., Hilchey & Klein, 2011), findings of several studies point to a significant EF advantage among children who speak more than one language. For example, young bilingual children have been shown to perform better than their monolingual peers on tasks of cognitive flexibility (Bialystok, 1999; Bialystok & Martin, 2004) and on tasks with conflicting attentional demands (Carlson & Meltzoff, 2008). Theorists have attributed the superior EF skills of bilingual individuals to the various demands inherent in learning a second language. To become proficient in two languages, learners must selectively attend to the sound structure, vocabulary, and grammar of one language while inhibiting attention to

the other. Being bilingual also provides ample practice in shifting or cognitive flexibility, as individuals learn to switch between languages according to situational demands (Bialystok, 2011). The relation between bilingualism and EF may also be seen in the function of the brain. A recent neuroimaging study (Stocco & Prat, 2014) used fMRI to explore the neural underpinnings of EF task performance in both monolingual and bilingual adults. Findings showed characteristic patterns of activation in the basal ganglia in bilingual participants that were specifically associated with better performance on a complex EF task. The authors likened the contrasting patterns of activation to a kind of enhanced “bandwidth” in bilingual persons. Although correlational results such as these can be compelling, they fail to solve the puzzle of directionality. Findings with regard to the bilingualism-EF relation have often been interpreted in terms of a causal role for bilingual experience on EF development (e.g., Bialystok, 2011), but the reverse is equally possible: greater EF skill may serve to enhance second-language learning.

Relation between self-regulation and vocabulary. Relatedly, some researchers (e.g., McClelland et al., 2007) have argued that EF exerts a causal influence on vocabulary development through children’s behavioral self-regulation. Some supportive evidence comes from studies showing that aspects of self-regulation predict vocabulary growth in young children (McClelland et al., 2007; Schmitt, Justice, & O’Connell, 2014), although other findings disagree (Cameron et al., 2012; Ponitz, McClelland, Matthews, & Morrison, 2009). Using a direct measure of behavioral self-regulation, the Head-to-Toes (HTT) task, with two groups of typically developing four-year-old children, McClelland et al. (2007) found that task performance at the start of preschool predicted both fall and spring expressive vocabulary. In addition, a hierarchical linear model controlling for age,

gender, and Spanish-speaking status showed that gains on the HTT task across the preschool year also predicted gains in vocabulary during the same period. However, a later study using an expanded version of the task (Head-Toes-Knees-Shoulders task; HTKS) yielded mixed results (Ponitz et al., 2009). Kindergarten children's performance on the task in the fall was correlated with vocabulary at the end of the year, but gains in HTKS scores across kindergarten did not significantly predict vocabulary growth. Likewise, Cameron et al. (2012) reported that although kindergarteners' scores on the HTKS in the fall were correlated with both spring and fall vocabulary, gains on the task across kindergarten failed to predict gains in vocabulary.

All of the above studies using the HTT and HTKS tasks were conducted with typically developing young children. In contrast, Schmitt et al. (2014) explored the influence of behavior regulation on growth in expressive vocabulary among kindergarten and first-grade children who were receiving school-based therapy for language disorders. Behavior regulation was assessed with a caregiver rating scale in fall of the school year, and expressive vocabulary was assessed in both fall and spring. A hierarchical linear regression analysis controlling for fall vocabulary scores revealed that caregiver ratings of behavior regulation significantly predicted vocabulary growth, accounting for nine percent of gains in vocabulary across the school year. The authors explained that children with greater behavior regulation may be more successful in therapy because they are better able to focus on therapy tasks and tune out irrelevant distractions. However, the researchers also suggested that the behavior regulation–vocabulary relation may be reciprocal in nature.

Influence of executive function on vocabulary: intervention studies. Even prospective longitudinal correlational studies demonstrating an influence of EF skills on subsequent vocabulary growth (e.g., McClelland et al., 2007; Nicolay & Poncelet, 2013; Schmitt et al., 2014) are not definitive proof of causality. Randomized controlled intervention studies provide stronger evidence of causal effects. Two such trials that have been reported in the literature (Barnett et al., 2008; Raver et al., 2011) examined the impact of training in self-regulation or EF on vocabulary development among at-risk preschoolers from low-income homes. Barnett et al. (2008) conducted a randomized trial comparing the *Tools of the Mind* curriculum to a control condition (the district's usual balanced literacy curriculum). Results showed that children in *Tools* classrooms made significantly greater improvement in teacher-rated behavioral self-regulation than children in control classrooms. Although *Tools* training also led to greater gains in receptive vocabulary across the preschool year when compared with the standard curriculum (effect size = .22), the difference was not statistically significant. In a related investigation, Raver et al. (2011) studied the effects of CSRP on preschoolers' receptive vocabulary and early academic skills. (As mentioned previously, CSRP is an emotionally and behaviorally focused school readiness intervention for young at-risk children from low-income homes.) Preschoolers were assigned in a cluster-randomized design to classrooms offering either CSRP or the usual Head Start curriculum. Tasks of planning and inhibitory control, along with standardized measures of vocabulary and early math and literacy skills, were administered in both fall and spring. Over the course of the school year, children in the CSRP classrooms made greater gains than children in control classrooms in EF task performance as well as in vocabulary and early math and reading.

Taken together, these two experimental studies provide a higher standard of evidence that at least suggests a causal role for EF skills in children's vocabulary growth.

Direction of effect: structural equation modeling. Another way to examine the causal relations between EF ability and vocabulary is through structural equation modeling (SEM). In SEM, latent variables representing EF and vocabulary skill are entered into path models and analyzed for directionality of effect. Two recent studies of the EF-vocabulary relation utilizing SEM (Fuhs & Day, 2011; Weiland, Barata, & Yoshikawa, 2014) produced conflicting results. Fuhs and Day (2011) administered measures of receptive and expressive vocabulary as well as tasks of inhibition and shifting in both fall and spring of the preschool year to children in Head Start classrooms. Results indicated a significant path from fall vocabulary to spring EF, suggesting a causal influence of vocabulary on EF growth, but no significant path from fall EF to spring vocabulary, suggesting no causal role for EF in vocabulary gains. In contrast, the SEM results reported by Weiland et al. (2014) with a larger and more diverse sample of preschoolers pointed to a causal role for EF skill but not vocabulary. Analyses showed a significant path from fall EF to spring receptive vocabulary but no significant path from fall vocabulary to spring EF. In explaining the discrepant results, Weiland et al. noted that the EF latent factor in each study encompassed a different range of EF abilities (Weiland et al. included a measure of working memory, but Fuhs and Day did not) and that the vocabulary latent factor included both receptive and expressive vocabulary in one study (Fuhs & Day) but only receptive vocabulary in the other (Weiland et al.).

Summary: EF and vocabulary. The conclusion that emerges most clearly from all of the disparate findings on the association between EF and vocabulary is that the

relation is decidedly complex. Findings from studies of self-directed speech and bilingualism suggest that verbal ability may play a causal role in the development of EF. On the other hand, some longitudinal studies indicate that EF (or at least behavioral self-regulation) predicts vocabulary growth, and intervention studies have demonstrated a benefit of EF-focused curricula for vocabulary gains. SEM results so far are equivocal. Plainly, much remains to be understood about directionality of effects. In all likelihood, as EF and vocabulary develop together in tandem over the course of childhood, the causal relations are both multifaceted and reciprocal.

Role of executive function in word learning. Although findings of significant associations between EF ability and vocabulary are suggestive, they can provide only indirect evidence as to how EF might influence word learning itself. Far fewer studies have specifically examined the role of EF ability in the word learning process. Drawing on Baddeley's (1986) model of working memory, numerous research findings have shown a positive correlation between children's phonological short-term memory storage capacity and their performance on experimental word learning tasks (e.g., Baddeley, Gathercole, & Papagno, 1998; Côté, Rouleau, & Macoir, 2014; Gathercole, 2006; Gathercole et al., 1997; Majerus & Boukebza, 2013; Michas & Henry, 1994). However, such studies do not address the contribution of the EF-related aspect of working memory—which involves not merely passive storage but manipulation of information (Gathercole, 1999; Miyake et al., 2000)—to the word learning process.

Although studies are few, there is some evidence that working memory may influence word learning. A pair of studies by Cain and colleagues (Cain, Oakhill, & Elbro, 2003; Cain, Oakhill, & Lemmon, 2004) explored the role of working memory in

word learning during reading among children with either average or poor reading comprehension skills. The first study (Cain et al., 2003) examined how the positioning of informative written context relative to target words might affect children's performance on a novel word learning task. Compared with their typically developing peers, seven- to eight-year-old children with poor reading comprehension skills learned fewer novel word meanings when informative context was placed further from target words. The authors suggested that the learning of children with poor comprehension was hampered when the task imposed greater working memory demands. In a later study with nine- to 10-year-old children (Cain et al., 2004), scores on a task of verbal working memory were significantly related to novel word learning performance, but only when informative context was positioned further from target words. Not all results agree, however. Steele and Watkins (2010) found that position of informative written context did not affect word learning performance for school-age children with language learning disability or their typically developing peers.

Skill in attentional control may also contribute to word learning. Yoshida, Tran, Benitez, and Kuwabara (2011) explored the relation between executive attention and novel adjective learning among groups of bilingual or monolingual two- to three-year-old children. Adjectives were chosen as target words rather than nouns because adjectives were expected to pose a greater learning challenge. Research has suggested that adjectives are more difficult for young children, because in order to map a novel word to an attribute of an object, children must overcome a prepotent tendency to interpret unfamiliar words as nouns (Gasser & Smith, 1998). Adjective learning may thus draw more heavily on children's capacity for inhibitory control. Yoshida et al. (2011) reported

that bilingual children were more accurate than their monolingual counterparts on an executive attention task and also outperformed their monolingual peers on a task of novel adjective learning. Regression analyses indicated that for bilingual but not monolingual children, performance on the adjective learning task was related to performance on the task of executive attention. Yoshida et al. interpreted their findings in terms of greater inhibitory control on the part of bilingual children. The authors suggested that because bilingual children are often required to inhibit one language in favor of another, they may be better equipped than their monolingual counterparts to inhibit any prepotent tendency to map novel word forms as nouns and thus better able to interpret unfamiliar words as adjectives.

EF skills have also been found to relate to word learning in the context of artificial language. Kapa and Colombo (2014) explored the relation between artificial language learning and performance on tasks of inhibitory control, attentional monitoring, and attention shifting among both adults and four- to five-year-old children. Participants, who were all monolingual, were introduced to both novel vocabulary (nouns and verbs) and novel grammar (simple word order rules). After training, a series of assessments measured participants' knowledge of both receptive and expressive aspects of the artificial language's vocabulary and grammar. However, principal components analysis showed all of the tasks loading onto a single factor, which the authors interpreted as primarily vocabulary-dependent due to the greatly simplified nature of the grammar. Hierarchical regression analyses controlling for both receptive vocabulary and digit span revealed that performance on the tasks of attention and inhibitory control were related to artificial language learning for both children and adults, but the patterns differed

according to age. Artificial language scores were associated with inhibitory control in adults and with attention shifting in children. For both age groups, full models including EF task performance as well as receptive vocabulary and digit span accounted for 36% of the variance in artificial language learning. Because none of the participants had significant prior experience with a second language, the authors reasoned that greater preexisting EF skills may facilitate vocabulary learning in a second language (whether artificial or not). They suggested that relatively higher EF ability may act to enhance learners' chances of becoming proficiently bilingual. Thus, the relation between EF and word learning may be bi-directional.

Neurophysiology of word learning. One relatively recent line of research hints at a possible connection between EF and word learning in the brain. Several studies, so far only in adults, have explored the neural mechanisms that might underlie the process of word knowledge growth during reading (Borovsky, Elman, & Kutas, 2012; Frischkoff, Pefetti, & Collins-Thompson, 2010; Mestres-Missé, Rodriguez-Fornells, & Münte, 2007). Using EEG methodology, researchers have focused on changes that occur during novel word learning in the N400, an event-related potential that is thought to index semantic integration of newly-learned words. Mestres-Missé et al. (2007) studied readers' neural activation patterns in response to novel words embedded in sentences and found that after three consecutive presentations, participants' N400 response to novel words was indistinguishable from their response to familiar words. Novel words inserted in sentences and familiar words both elicited an N400 pattern that differed significantly from the pattern that occurred in response to novel words presented in isolation. Variation in the level of contextual support also influences readers' neural response to

novel words, with more pronounced activity occurring when contextual support is low (Frischkoff et al., 2010). Moreover, there is evidence that the process of semantic integration of new vocabulary begins upon initial exposure to an unfamiliar word. Borovsky et al. (2012) found that even a single encounter with novel words in highly constraining written context was sufficient to induce significant changes in participants' N400 responses. Interestingly, all three studies found that when readers encountered novel words, neural activation was localized to areas of the dorsal anterior cingulate (dACC) or prefrontal cortex—the same areas that are thought to broadly underlie EF (Best & Miller, 2010; Carter & van Veen, 2007; Ordaz et al., 2013; Shenhav et al., 2013; Spielberg et al., 2015).

Such findings point to a relation between EF and word learning at the neural level. As Mestres-Missé et al. (2007) explained, it is not surprising that brain areas associated with EF are more likely to be activated early in the word learning process. When words are novel or unfamiliar, readers must rely on purposeful cognitive control in order to form and access new semantic associations. Along with word learning, tasks of working memory, inhibitory control, and cognitive flexibility are all associated with similar brain activation patterns in the dACC and dorsolateral prefrontal cortex (Carter & van Veen, 2007; Contini et al., 2013; Mansouri, Tanaka, & Buckley, 2009; Tsukiura et al., 2001; Zakzanis, Mraz, & Graham, 2005). It stands to reason that working memory plays a role in word learning during reading, because readers must hold surrounding context in memory while attempting to infer the meaning of a newly encountered word. As Cowan (2014) pointed out, working memory is heavily taxed when learners are asked to form new associations. Inhibitory control may also be essential to the word learning

process, as studies have shown that readers may discard many incorrect inferences while narrowing down potential word meanings (Fukkink et al., 2001). Cognitive flexibility may be central to word learning as well, as readers shift between multiple simultaneous tasks: generating potential meanings, discarding untenable ones, and maintaining overall text comprehension (Fukkink, 2005).

Effects of SES on executive function. As already discussed, the influence of SES on children's cognitive, academic, and socioemotional outcomes has been recognized for several decades (e.g., Deutsch, 1965; Huston et al., 1994; McLoyd, 1998; Templin, 1957). More recently, with growing awareness of the important contribution of EF to many aspects of children's development (Diamond, 2013), researchers have explored the impact of SES on children's EF skills. Numerous studies have documented SES effects on EF task performance in preschoolers and school-age children, as well as adolescents and adults (Hackman, Farah, & Meaney, 2010).

A series of studies by Noble and colleagues (Farah et al., 2006; Noble et al., 2007; Noble, Norman, & Farah, 2005) examined the influence of SES on children's neurocognitive task performance. Measures of EF included a spatial working memory task and a go-no go task to assess inhibitory control. Noble et al. (2005) found significant SES-related differences among typically-developing kindergarten children in EF task performance (better accuracy as well as fewer false alarms for children with higher SES). A subsequent study with older (10- to 13-year-old) children revealed significant SES-related disparities in working memory and a nonsignificant trend ($p = .06$) toward SES-related disparities in inhibitory control (Farah et al., 2006). A third study among typically developing first-graders with a wide diversity of racial, ethnic, and

SES backgrounds found significant SES-related gradients in performance on tasks of both working memory and inhibitory control (Noble et al., 2007).

There is also direct neuroimaging evidence of structural and functional SES-related differences in regions of the brain that are associated with EF (Lipina & Posner, 2012). A recent large-scale MRI study with a diverse sample of participants three to 20 years of age by Noble et al. (2015) revealed significant differences according to SES in both cortical thickness and cortical surface area, particularly for regions associated with language, reading, EF, and spatial skills. When the same participants performed a series of cognitive tasks, it was found that cortical surface area mediated the relation between SES and both inhibitory control and working memory. In an fMRI study of SES and EF with eight- to 12-year-old typically developing children, Sheridan, Sarsour, Jutte, D'Esposito, and Boyce (2012) reported both lower accuracy on an EF task and less efficient patterns of prefrontal neural recruitment among children from lower-SES homes. In a related two-year longitudinal fMRI study focusing on adolescents, Spielberg et al. (2015) found significant SES-related differences in inhibitory control and neural recruitment, but only for girls. Among girls from low-SES families, accuracy on a go/no-go task deteriorated with age, and the decrement in performance was accompanied by increased activity in the anterior cingulate cortex. These patterns were not found for boys or for girls from middle-SES homes. The authors suggested that adolescent girls may be particularly vulnerable to the damaging effects of low SES on inhibitory control, and that altered patterns of neural recruitment may represent a compensatory mechanism (albeit a relatively ineffective one) for responding to situations requiring inhibitory control.

The association between SES and EF is a robust empirical finding that is neither limited to children in Western industrialized countries nor dependent on a particular theoretical conceptualization of EF. For example, in a study with school-age children in Argentina, Arán-Filippetti and de Minzi (2012) found that SES explained between 10.7% and 55.7% of variance on a range of EF tasks. Notably, children in the low-SES group were exposed to conditions of far greater deprivation than that typically encountered in industrialized countries, including lack of public water supply and sanitation. For school-age children living in urban areas of Mexico and Colombia, Ardila, Rosselli, Matute, and Guajardo (2005) reported significantly better performance on a battery of EF tasks for children attending private rather than public schools. In the United States, Mezzacappa (2004) examined SES effects among five- to seven-year-old children on a series of EF tasks designed to measure the alerting, orienting, and executive aspects of attention as conceptualized by Posner and Rothbart (2007). Results showed that children from more socially advantaged homes benefited more from alerting cues and were less affected by interference cues (i.e., showed better executive attention) than children from lower-SES backgrounds.

Pathways of SES influence on executive function. Beyond the empirical evidence that SES affects children's EF development lie deeper questions about the possible mechanisms underlying SES effects on EF. As described earlier, models emphasizing the role of family investment in developmental outcomes (e.g., Becker & Thomes, 1986) describe SES-related disparities in a family's access to financial and educational resources as a major pathway by which SES constrains children's development. In contrast, family stress or psychobiological models (Elder & Caspi,

1988; Blair & Raver, 2012) place greater emphasis on the role of stress, either directly or indirectly through aspects of parent-child interaction (especially parental sensitivity and nurturance), as a principal mediator of the SES/EF relation. Similarly, Evans and colleagues (Evans & Kim, 2013; Evans et al., 2009) point to the cumulative impact of stress-related allostatic load as a key pathway for SES effects on cognitive development.

A number of studies have reported findings supporting the family stress model of SES influence on EF (Evans & Kim, 2013; Piccolo, Sbicigo, Grassi-Oliveira, & de Salles, 2014). In a large-scale longitudinal study of young White and Black children living in rural areas of the eastern U.S., Rhoades et al. (2011) found that for the sample as a whole, maternal positive engagement assessed at seven months of age mediated the relation between household SES-related risk factors and children's performance on tasks of working memory, inhibition, and shifting at age three. On the other hand, maternal negative intrusiveness at seven months mediated the SES/EF relation only for White children. Sarsour et al. (2011) conducted a cross-sectional study of the mediating role of home environment (including both access to educational resources and measures of parent-child interaction) in the association between SES and EF. Participants were eight- to 12-year-old typically developing children of widely varying racial and socioeconomic backgrounds. Multiple regression analyses revealed that while SES was significantly related to children's performance on all three aspects of EF that were assessed—working memory, inhibitory control, and shifting—home environment measures mediated the effect of SES only for inhibitory control. In line with the family stress model, caregiver-child interaction in particular contributed to the mediation. There was no support for the parental investment model; neither physical quality of the home environment nor

availability of learning materials mediated the association between SES and children's EF performance.

The parental investment and family stress pathways for SES effects on EF need not be mutually exclusive. The results of Sarsour et al. (2011) notwithstanding, some studies incorporating measures of both home educational resources and caregiver-child interaction have shown that both factors might mediate the relation between SES and children's developing EF. In a longitudinal study with a large national sample that followed children from birth to fifth grade, Hackman, Gallop, Evans, and Farah (2015) found that both home enrichment and maternal sensitivity mediated the relation between SES and children's overall EF task performance. More specific relations were also found for early childhood maternal sensitivity, which mediated the association between maternal education and children's performance on a complex planning task in third and fifth grade. Another set of findings suggesting separate roles for parental investment and family stress was reported by Farah et al. (2008). In a prospective longitudinal study of both EF and language development in low income African American children, regression analyses showed that the level of parental nurturance at ages four and eight was the strongest predictor of performance on a memory task in middle school, whereas the quality of home environmental stimulation at ages four and eight predicted middle school language skill (receptive vocabulary and grammar).

Heightened levels of allostatic load stemming from the experience of childhood poverty may also help explain the association between SES and EF. A composite measure that includes multiple physiological indicators of exposure to chronic stress, allostatic load is seen as an index of the cumulative wear and tear on the body—including

the brain—that can occur as a result of living in long-term poverty (Evans & Kim, 2013; Evans et al., 2009). In a study of the relations among poverty, allostatic load, and working memory, Evans et al. (2009) reported that young adults with a longer history of childhood poverty had both higher physiological levels of allostatic load and significantly shorter nonverbal working memory spans than their peers with less poverty exposure. In the sample as a whole, participants' levels of allostatic load were negatively correlated with working memory scores. Regression analyses revealed that allostatic load largely mediated the relation between childhood poverty and adult working memory. By way of explanation, the authors proposed that the development of key working memory-associated areas of the brain may be adversely affected by patterns of chronically altered stress physiology originating in childhood poverty.

Some researchers have examined the relations among SES, caregiver-child interaction, and EF or prefrontal cortex development more closely by directly analyzing measures of children's stress hormone reactivity. In a preliminary study with Head Start preschoolers, Blair, Granger, and Razza (2005) found that patterns of cortisol reactivity in response to experimental demands predicted performance on tasks of both inhibition and cognitive flexibility. A more recent study (Blair et al., 2011) investigated the role of stress in mediating the associations among family income, multiple aspects of parent-child interaction during infancy and toddlerhood, and children's performance on a battery of EF tasks at age three. Results showed that lower baseline cortisol levels during infancy were correlated with both positive parenting behaviors and stronger EF task performance. SEM revealed that negative parenting behaviors mediated the relation between household income and EF, and that both positive and negative parenting along

with baseline cortisol mediated the relation between maternal education and EF. In their fMRI investigation with eight- to 12-year old children, Sheridan et al. (2012) reported that in comparison with participants from higher-SES homes, participants from lower-SES homes demonstrated a pattern of relatively blunted cortisol reactivity in response to the demands of performing a complex EF task while undergoing scanning. This pattern of attenuated cortisol responsivity was associated, in turn, with both lower task accuracy and a less efficient pattern of neural activation. The authors hypothesized that the stress of living with low SES might exert damaging effects on stress physiology that interfere with development of prefrontal areas, leading to suboptimal patterns of prefrontal activation as well as reduced performance on tasks requiring EF.

Factors related to both family investment and stress may moderate the impact of exposure to early hardship on children's EF development. Research has shown that some individuals demonstrate remarkable resilience in the face of extended poverty or other childhood adversity (e.g., Miller & Chen, 2013). As described previously, a recent study by Nelson et al. (2015) compared the EF skills of two groups of three-year-old typically developing children: the "at-risk" group lived in households below the poverty line, while the "low-risk" group lived in households that were more affluent. The authors identified a subgroup of "resilient" children who, in spite of exposure to poverty, demonstrated EF skills that were similar to those of their low-risk peers. Analyses revealed that compared with at-risk children with poorer EF skills, the subgroup of resilient children were provided with a greater number of learning materials at home, more extensive language and academic stimulation, and a wider variety of cognitively enriching experiences. Caregivers of the resilient children also demonstrated interaction styles characterized by

higher levels of warmth and responsiveness. The resilient children thus benefited from both greater investment of resources and more positive interactions with caregivers. The authors suggested that together, these protective factors served to moderate or buffer the effects of poverty on the development of EF skills.

Summary. In sum, research indicates that SES-related factors have a significant impact on children's EF. Evidence from a variety of sources—structural and functional neuroimaging studies as well as performance on behavioral tasks—has demonstrated that for preschoolers as well as school-age children and adolescents, EF skills are influenced by parental SES. The possible pathways by which poverty or lower SES constrains children's EF development may involve a variety of factors, including resource limitations, maladaptive caregiver interaction patterns, and altered stress physiology. It is likely that all of these factors act in combination to affect the development of EF skills.

Mediating role of language. There is evidence to suggest that language ability might also serve as a means for SES to influence the development of EF (i.e., language might mediate the SES-EF relation). With the use of regression analysis, researchers have examined whether the relation between SES and EF performance is reduced or eliminated when language skill is added to the model, indicating a significant mediating role for language (Baron & Kenny, 1986; Holmbeck, 1997).

Analyses reported by Noble and colleagues (Noble et al., 2005, 2007) demonstrated a pathway from SES to children's EF through language ability. As previously described, Noble et al. (2005) examined performance on a variety of cognitive tasks among typically developing kindergarten children from low- and middle-SES homes. Participants from middle-class homes earned higher scores than their peers from

low-SES homes on tasks of language (receptive vocabulary and phonological awareness) and EF (inhibitory control). A series of multiple regression analyses revealed that whereas SES and EF both independently explained language task performance, the relation between SES and EF was completely mediated by children's language scores. A later study (Noble et al., 2007) explored the relations among SES, language ability, and EF among typically developing first graders from a wide range of SES backgrounds. Children of higher-SES homes performed better than their counterparts from lower-SES homes on tasks of language (receptive vocabulary and grammar) and on two tasks of EF (working memory and inhibitory control). As with the earlier study, analyses showed a mediating role for language skill: controlling for receptive vocabulary eliminated the relation between SES and inhibitory control and reduced the relation between SES and working memory. Taken together, these findings suggest that language ability may account, at least in part, for the association between SES and EF.

Mediating role of executive function. Conversely, it is also possible that EF serves to mediate the relation between SES and other cognitive outcomes, including language ability. Several research findings have implicated pathways from SES to achievement through children's EF skills during both early and middle childhood. For example, two studies with preschoolers (Fitzpatrick, McKinnon, Blair, & Willoughby, 2014; NICHD Early Child Care Research Network, 2003) demonstrated a role for attention or EF in partially mediating the relation between SES and school readiness. The NICHD (2003) study was a large-scale longitudinal investigation of cognitive outcomes in young children from homes with a wide range of SES. Results showed that at 54 months of age, children's family environment (an SES-related composite of home

and maternal characteristics) was significantly related to language skill and to early math and reading ability. Statistical analyses revealed that the associations were partially mediated by children's performance on a task of sustained attention. More recently, Fitzpatrick et al. (2014) compared young children (mean age 57 months) enrolled in needs-based preschool programs (low-SES group) to their counterparts in private preschools (high-SES group). The groups differed significantly on both parental educational level and household income. Results showed that children in the low-SES group performed more poorly than their high-SES peers on a battery of EF tasks assessing working memory, inhibitory control, and shifting, as well as on measures of school readiness (expressive vocabulary and early math and reading skills). A series of regression analyses controlling for age, speed of processing, and nonverbal cognition revealed that the relation between SES and school readiness was partially mediated by children's EF task performance.

Studies with school-age children also suggest a mediating role for attention or EF skills in the association between SES and achievement (Crook & Evans, 2014; Howse et al., 2003). Howse et al. (2003) examined performance on a distracting sustained attention task in kindergarten children from at-risk (Title I) and not-at-risk (middle class) classrooms. Although the authors did not employ a formal mediation analysis, findings showed that SES was related to scores on the distracting task, which were in turn correlated with performance on a test of reading achievement. In a recent large-scale longitudinal study of cognitive outcomes among children of diverse backgrounds, Crook and Evans (2014) examined relations over time among SES, planning ability, and school achievement. Results showed that household income-to-needs ratio during infancy was

related to children's performance on a complex planning task in third grade and to reading and math achievement in fifth grade. A structural equation model controlling for IQ indicated a pathway from income to achievement, with a significant mediating effect of planning ability. Considered together, these studies suggest a potential contributing role for children's EF skills in the relation between SES and a range of cognitive outcomes, including language.

Mediated or Moderated Effects on Word Learning

Language-word learning relations: mediation by EF. Empirical findings indicate that language skill has an overall significant impact on children's word learning during reading (Steele & Watkins, 2010; Wagovich et al., 2015). Evidence also suggests that language ability may influence the development of children's EF (e.g., Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Fuhs & Day, 2011; Lidstone et al., 2010), and that EF skills may in turn be related to children's performance on word learning tasks (Cain et al., 2003, 2004; Kapa & Colombo, 2014; Yoshida et al., 2011). Thus, it is possible that children's EF ability accounts, at least in part, for the relation between language and word learning skill. However, because research has not yet addressed mediation by EF in the association between language skill and word learning during reading, any such hypotheses remain speculative.

EF-word learning relations: mediation by language. As noted, there is evidence to suggest an overall effect of EF on children's word learning ability (Cain et al., 2003, 2004; Kapa & Colombo, 2014; Yoshida et al., 2011). In addition, findings have shown that EF skill may influence the development of language (e.g., Raver et al., 2011; Weiland et al., 2014) and that language ability may in turn be related to children's

word learning performance (Steele & Watkins, 2010; Wagovich et al., 2015). Thus, it is possible that language accounts, at least in part, for the association between EF and word learning. As with mediation by EF, in the absence of empirical findings indicating a mediational role for language, such a pathway remains largely hypothetical.

Moderation by language, SES, or EF. Previous findings have failed to demonstrate a significant direct association between SES and experimental fast mapping performance (e.g., Burton & Watkins, 2007; Horton-Ikard & Ellis Weismer, 2007). Exploring any mediation by language or EF on a hypothetical SES-word learning relation makes sense only if a significant overall SES-word learning relation is found (Baron & Kenny, 1986; Holmbeck, 1997). However, even in the absence of such a relation, it is possible that SES moderates the effect of other variables on word learning through an interaction with either language ability or EF. Furthermore, it is possible that language plays a similar moderating role. For example, EF ability may influence word learning differently, depending on the level of SES or language ability. Children of higher-SES homes or with higher language skill may be buffered from any negative effects of lower EF ability on word learning. On the other hand, children of lower-SES homes or with lower language skill may perform disproportionately more poorly on word learning tasks in spite of higher EF ability. Either of these findings would suggest significant moderation (by SES or language, respectively) on the relation between EF and word learning (Baron & Kenny, 1986; Holmbeck, 1997). Any potential moderating effects of language, SES, or EF on children's word learning during reading remain speculative, however, since no such associations have been examined empirically.

Summary and Statement of the Problem

Word learning is a process that requires children to form new mappings between the lexical and conceptual domains (Bloom, 2000; Carey, 1978). Despite the central importance of vocabulary acquisition for children's overall academic success (e.g., Adlof & Perfetti, 2013; Biemiller, 2006; Cunningham & Stanovich, 1997) and widespread requirements for students of all ages to gain curriculum-related knowledge through reading (Common Core State Standards Initiative, 2015), the process of word learning during reading remains poorly understood. Findings indicate that word knowledge growth from written context is a slow and incremental process (Swanborn & de Glopper, 1999). Some research suggests that text- and word-level factors may affect the likelihood of word learning from written context (e.g., Beck et al., 1983; Cain et al., 2003, 2004; de Leeuw et al., 2014; Herman et al., 1987; Hill et al., 2017). In addition, learner-related characteristics such as age, background knowledge, and reading ability may influence students' skill in inferring new word meanings from written context (Fukkink et al., 2001; Kaefer et al., 2015; Ricketts et al., 2011; Swanborn & de Glopper, 2002). Available findings suggest that language ability also contributes to individual differences in word learning during reading (Steele & Watkins, 2010; Wagovich et al., 2015).

Numerous empirical findings have demonstrated a profound impact of socioeconomic status (SES) on children's vocabulary (e.g., Farah et al., 2006; Hart & Risley, 1995; Noble et al., 2007) and vocabulary growth over time (e.g., Chall et al., 1990; Farkas & Beron, 2004; Rice & Hoffman, 2015). SES, a construct that includes but is not limited to such factors as family income, parental education, and occupational prestige, is a continuous variable on which individual households may vary substantially

(Duncan et al., 1972; Sirin, 2005). SES is thought to influence children's development by several pathways: through financial constraints on parental investment in offspring (Becker & Tomes, 1986; Haveman & Wolfe, 1994), through differences in qualities of caregiver-child interaction (e.g., low maternal warmth, harsh and punitive parenting; Bradley et al., 2001a; Elder & Caspi, 1988), and through stress-related processes that affect brain development (Blair & Raver, 2012; Evans et al., 2009). Studies have shown positive associations between SES and children's vocabulary that could be traced to SES-related disparities in linguistic stimulation (e.g., Hart & Risley, 1995; Hoff, 2003; Huttenlocher et al., 2010), availability of cognitively stimulating materials and activities (Farah et al., 2008), and qualities of caregiver-child interaction (Bradley et al., 2001b).

Despite the robust association between SES and children's vocabulary, studies have not shown corresponding SES-related discrepancies in children's performance on experimental word learning tasks (Burton & Watkins, 2007; Horton-Ikard & Ellis Weismer, 2007). SES-related differences in performance on standardized vocabulary measures may stem from disparities in culture-specific content knowledge rather than from fundamental differences in word learning ability (Campbell et al., 1997; Stockman, 2001). Some researchers have suggested that processing-dependent measures such as experimental word mapping tasks might be a more culturally fair means of assessing word learning ability than standardized vocabulary tests, especially among children of cultural or linguistic minority backgrounds (Campbell et al., 1997; de Villiers, 2004; Johnson, 2010; Johnson & de Villiers, 2009). Indeed, one recent study found that when background knowledge was held constant, SES-related disparities in word learning disappeared (Kaefer et al., 2015).

Executive function (EF) involves a set of higher-level processes that enable individuals to set goals, monitor performance, and regulate emotions and behavior (Anderson, 2002; Garon et al., 2008). EF is generally associated with prefrontal and dorsal anterior cingulate areas of the brain (Best & Miller, 2010) and follows a lengthy course of development into young adulthood (Romine & Reynolds, 2005). One of the most influential theories of the structure of EF (Miyake et al., 2000) describes EF in terms of three distinct yet correlated abilities: working memory, inhibitory control, and cognitive flexibility. Working memory (also known as updating) involves the capacity to hold and manipulate information for short periods of time. Inhibitory control involves the ability to suppress a dominant or prepotent response in favor of a chosen subdominant response. Cognitive flexibility (also known as shifting) calls on the ability to flexibly switch from one rule or mental set to another.

Just as SES affects children's language development, findings demonstrate that SES also has a significant impact on the development of EF (Hackman et al., 2010). SES disparities have been found on tasks of working memory (Farah et al., 2006; Noble et al., 2005, 2007) and inhibitory control (Noble et al., 2005, 2007). In addition, neuroimaging studies have shown SES-related differences in brain areas associated with EF (Lipina & Posner, 2012). SES disparities in EF task performance have been linked with SES-related differences in brain structure (Noble et al., 2015) and patterns of neural activation (Sheridan et al., 2012; Spielberg et al., 2015).

Individual differences in EF and language are correlated across childhood into adolescence, and findings suggest that any effects are probably bidirectional. On the one hand, language ability may influence the development of EF (e.g., Bialystok, 1999;

Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Fuhs & Day, 2011; Lidstone et al., 2010). Conversely, skill in EF may also affect the development of language (e.g., Raver et al., 2011; Weiland et al., 2014). Beyond language ability in general, vocabulary in particular is related to a range of EF skills. Working memory, inhibitory control, shifting, and planning have all been shown to correlate with children's vocabulary (Best et al., 2011; Nicolay & Poncelet, 2013; Wilbourn et al., 2012; Wolfe & Bell, 2004). Less is known about the effect of EF ability on the word learning process, but there is evidence to suggest that EF skills may influence children's word learning performance (Cain et al., 2004; Kapa & Colombo, 2014; Yoshida et al., 2011). In addition, neuroimaging studies indicate that EF and word learning may share a neural substrate (Borovsky et al., 2012; Frischkoff et al., 2010; Mestres-Missé et al., 2007).

Because language, SES, and EF are all related across development, a number of different functional relationships may exist among them. Any proposed pathway is essentially speculative, as none of the potential relations have been explored empirically. Based on the literature, however, two potential mediated pathways seem plausible. One possibility is that SES affects EF development through language ability (e.g., Fuhs & Day, 2011; Lidstone et al., 2010). On the other hand, SES may influence language development through skill in EF (e.g., Raver et al., 2011; Weiland et al., 2014). With regard to any effects on word learning during reading, moderated relations among the independent variables are also possible. Language ability and EF might interact, so that EF influences children's word learning performance differently depending on the level of language skill. Although SES has not been found to relate directly to performance on experimental word learning tasks (Burton & Watkins, 2007; Horton-Ikard & Ellis

Weismer, 2007), it is possible that SES, like language, may moderate the effects of EF on children's word learning.

Proposed Study

There are many significant gaps in the literature concerning the joint contributions of language ability, SES, and EF to the process of vocabulary acquisition from written context. The proposed study aims to address these gaps by examining the relations among language, SES, and EF as they combine to influence school-age children's word learning from context. Specifically, the study will address the following questions:

1. Relations among independent variables:

- Are language ability and EF significantly related? (Hypothesis: yes)
- Is SES related to language ability? (Hypothesis: yes)
 - If so, is the relation between SES and language ability mediated by EF? (Exploratory)
- Is SES related to EF? (Hypothesis: yes)
 - If so, is the relation mediated by language ability? (Exploratory)

2. Factors associated with semantic word learning from context:

- Does language ability explain word learning from context? (Hypothesis: yes)
 - If so, is the relation mediated by EF? (Exploratory)
- Does SES explain word learning from context? (Hypothesis: no)
 - But if a relation is found: is there mediation by language ability? By EF? (Exploratory)
- Do EF skills (working memory, inhibitory control, and cognitive flexibility) explain word learning from context? (Hypothesis: yes)
 - If so, is the relation mediated by language ability? (Exploratory)
 - Does EF interact with SES in explaining word learning? (Exploratory)
 - Does EF interact with language ability in explaining word learning? (Exploratory)

Chapter 2

Method

Participants

Fifty children between the ages of 9;0 and 11;11 (years;months) took part in the study (mean age = 10.4 years, $SD = .93$; 19 nine-year-olds, 15 10-year-olds, 16 11-year-olds; 19 girls, 31 boys). According to parent report, 80% of children were White and of non-Hispanic ethnicity, six percent were White and of Hispanic ethnicity, two percent were Black or African American, 10% were of Asian ancestry, and two percent were of mixed race. Because the experimental procedure involved reading as well as listening, an age range was chosen to maximize the likelihood that participants had mastered the basics of beginning reading. For example, nine- to 11-year-old typically developing readers are expected to be proficient at decoding, to have an extensive sight vocabulary, and to read fluently at approximately 80 to 110 words per minute (Fountas & Pinnell, 1996). By the age of nine, typically developing children are expected to be able to gain new knowledge, including knowledge of word meanings, through independent reading (Chall, 1983). Based on the results of a statistical power analysis (80% power to detect medium-to-large effects at an alpha level of .05), 50 children were a sufficient sample size for the current study. Participants were recruited with electronic advertisements and with flyers posted in mid-Missouri.

All included participants had normal hearing per parent report and passed a bilateral hearing screening administered as part of the study. All had normal or corrected-to-normal vision per parent report. Participants had no history of neurological impairment, developmental or acquired, and no diagnosis of learning disability or receipt

of special educational services per parent report. Participants were not disqualified based on an articulation-related diagnosis, which was rarely reported. Parents of only three children reported that their children received treatment for an articulation disorder. All participants were native speakers of English, per parent report and examiner observation. Participants were not excluded based on bilingual status, and parents of seven children reported that a second language in addition to English was spoken in the home. According to parents, all children were making satisfactory progress in school. Forty-eight of the 50 participants demonstrated skills no lower than 1.0 *SD* below the population mean on norm-referenced measures of oral language, decoding, and nonverbal cognition, as described below. One participant, though not an outlier, scored 1.33 *SD* below the population mean on language (standard score of 80). The same child along with one other participant also scored 1.13 *SD* below the population mean on nonverbal cognition (standard scores of 83). However, neither participant was excluded from the study based on two considerations: (a) parents of both children indicated that they were developing normally and progressing satisfactorily in school, and (b) analyses excluding both participants resulted in the same pattern of results as analyses including both participants.

Procedures

Each participant took part in two sessions of 60-75 minutes each that were held in a quiet room in the experimenter's laboratory. In Session 1, after obtaining informed consent from caregivers and assent from participants, standardized measures of language, nonverbal cognition, and decoding were administered, along with a hearing screening, to verify that participants qualified for the study. Caregivers were asked to complete a

parent questionnaire with questions about their children's developmental history and caregiver education and occupation. Participants also completed a set of computerized multiple-choice items as a pretest during Session 1 to assess pre-existing knowledge of target words.

Participants returned for Session 2 after an average interval of 7.8 days (range = 5 to 14 days). During Session 2, participants completed three pairs of EF tasks and a test of receptive vocabulary. In addition, participants were asked to read and listen to two short stories, one at a time, with order randomized across participants. Each story was presented by visual and auditory routes simultaneously on a desktop computer, at an average rate of 108 words per minute. At the end of each story, participants took part in an oral definition task for target and common words occurring in that story. After both stories with the two oral definition tasks were completed, the computerized multiple-choice items were re-administered as a posttest.

Measures

Parent questionnaire. A questionnaire was completed by caregivers during Session 1 to obtain information about children's developmental history along with age, gender, and race/ethnicity. Questionnaire responses were also used to derive a numerical estimate of each family's SES. The questionnaire inquired about primary caregivers' current occupation and educational attainment. This information was sought from only those caregivers who resided in the same household with the participant. Caregivers were not asked directly about their income for several reasons: (a) to respect their privacy, (b) because occupation has been found to be a more stable indicator than current income for estimating household financial status (Hauser, 1994), and (c) because a

measure of income may not be necessary, given that parental education, income, and occupation have been found equally predictive in terms of children's achievement-related outcomes (Sirin, 2005). Each family's SES was measured individually rather than drawing on an aggregate measure such as the percentage of students receiving free or reduced-price lunch at a participant's school. Aggregate measures of SES may not accurately reflect a particular child's circumstances and thus may not provide a valid estimate of individual household SES (Sirin, 2005).

Information obtained from parents about occupation and education allowed for the calculation of a continuous SES variable. Analyses involving SES in the present sample included this continuous variable, rather than a dichotomous or categorical scoring scheme, to maximize statistical power (Sirin, 2005). Specifically, the computation of SES was based on the scaling formula provided by the Hollingshead Four Factor Index of Social Status (Hollingshead, 1975). The Hollingshead scale, which draws on respondents' educational attainment and occupational status, has been in widespread use in educational and behavioral research for 40 years. The scale is flexible, in that scores can be calculated for households with either one or two primary caregivers.

Estimation of SES based on the Hollingshead scale derives from an established formula. Respondents' level of educational attainment is scored as follows: less than seventh grade = 1; junior high school (ninth grade) = 2; partial high school (tenth or eleventh grade) = 3; high school graduate = 4; partial college (at least one year) or specialized training = 5; standard college degree = 6; graduate or professional degree = 7. A score for occupational status is based on the following categories: farm laborers and menial service workers = 1; unskilled workers = 2; machine operators and semiskilled

workers = 3; skilled manual workers, craftsmen, and tenant farmers = 4; clerical and sales workers, small farm and business owners = 5; technicians, semiprofessionals, and smaller business owners = 6; smaller business owners, farm owners, managers, and minor professionals = 7; administrators, lesser professionals, proprietors of medium sized businesses = 8; higher executives, proprietors of large businesses, and major professionals = 9. Scores for educational attainment are multiplied by a factor of three, and scores for occupation are multiplied by a factor of five, to yield a continuous measure with a minimum value of eight and a maximum value of 66.

Efforts were made to recruit children from families with the widest possible range of SES. Including participants with a restricted range of SES may lead to attenuated correlations between SES and other variables (Baron & Kenny, 1986) and may partially explain why previous studies have not found significant associations between SES and word learning in children (Burton & Watkins, 2007; Horton-Ikard & Ellis Weismer, 2007). However, for various practical reasons, it was challenging to recruit participants from very low-income households, as discussed further below.

Standardized tests. As mentioned, standardized tests of oral language, decoding, and nonverbal cognition were administered during Session 1 as screening measures to determine whether participants' skills fell within the typical range. The following sections describe all standardized tests that were administered in the study.

Oral language. The *Clinical Evaluation of Language Fundamentals-5* (CELF-5; Wiig, Semel, & Secord, 2013) is an individually-administered test of oral language ability that takes approximately 30 minutes to complete and is appropriate for examinees between the ages of 5;0 and 21;11. Subtests comprising the Core Language composite

were administered: Word Classes, Formulated Sentences, Recalling Sentences, and Semantic Relationships. The Word Classes subtest measures the test-taker's receptive understanding of the semantic relationships between words. For each item, a series of three or four words are presented orally, and the examinee is asked to indicate the two words that are related in some way (e.g., synonyms, antonyms). The Formulated Sentences subtest assesses the test-taker's ability to generate grammatically and semantically correct sentences. A series of illustrations are presented, and the examinee is asked to formulate a sentence that contains one or two target words to describe the scene depicted in each illustration. The Recalling Sentences subtest measures the test-taker's ability to repeat spoken sentences of increasing length and complexity. Sentences are presented orally, and the examinee is asked to repeat each sentence verbatim. The Semantic Relationships subtest evaluates the test-taker's ability to interpret spoken sentences that include comparisons such as time or serial order as well as sentences expressed in passive voice. The examinee chooses two correct responses from among four written choices. The Core Language composite has a mean of 100 and a standard deviation of 15.

Information about reliability and validity were furnished by the developers of the CELF-5 (Wiig et al., 2013). For subtests included in the Core Language composite, split-half reliability ranged from .80 to .95, and test-retest reliability ranged from .73 to .89. To demonstrate convergent validity with other tests of oral language ability, the CELF-5 was compared with an earlier version of the test (CELF-4; Semel, Wiig, & Secord, 2003) and with the Expressive Vocabulary Test (EVT; Williams, 2007). Core Language scores on the CELF-5 were correlated .74 with Core Language scores on the CELF-4, and .73

with scores on the EVT. In addition, the discriminant validity of the CELF-5 was high, with an excellent level of diagnostic accuracy for identifying language impairment. With a cutoff of 1.3 *SD* below the mean, sensitivity and specificity were both reported to be .97. In the current study, scores on the CELF-5 were used to screen participants for typical language skill. CELF-5 Core Language scores were also included in analyses of the association between language, SES, and EF skills and as an independent variable in analyses of children's experimental word learning performance.

Decoding. The Basic Skills cluster of the *Woodcock Reading Mastery Test, Third Edition* (WRMT-III Basic Reading; Woodcock, 2011) was administered during Session 1 to determine whether participants possessed decoding skills in the typical range. The Basic Skills cluster consists of two subtests: Word Identification and Word Attack. The examinee is asked to pronounce orthographically-presented words and nonwords of increasing difficulty. The Basic Skills cluster has a mean of 100 and a standard deviation of 15.

Reliability and validity data for the WRMT-III were furnished by the author (Woodcock, 2011). Test-retest reliability at intervals of 20.5 days for participants in the age range of the current study were as follows: .95 for Letter-Word Identification, .89 for Word Attack, and .95 for the Basic Skills cluster. As evidence of discriminant validity, the author reported that clinical samples earned lower mean scores than the normative sample; students with diagnosed reading disorders earned average standard scores of 76.8 on the Basic Skills cluster, while an age-matched sample of students with typical development earned average standard scores of 97.9.

Nonverbal cognition. The *Test of Nonverbal Intelligence-4* (TONI-4; Brown, Sherbenou, & Johnsen, 2010) was also administered during Session 1 as a screening measure to verify that participants' nonverbal cognitive skills were within the typical range. The TONI-4 is an individually-administered test of nonverbal fluid intelligence, abstract reasoning, and problem solving. The test is appropriate for ages 6;0 to 89;11 and takes approximately 15 minutes to complete. Test-takers are presented with a sequence of abstract figures with one item in the sequence missing and are asked to indicate, either verbally or by pointing, the item (of four possible) that best completes each sequence. Figures include a range of attributes including shape, position, direction, shading, and size. Sequences become progressively more difficult as more attributes are added to the figures. The test has a mean of 100 and a standard deviation of 15.

Authors of the TONI-4 provided reliability and validity data (Brown et al. 2010). Internal reliability coefficients ranged from .93 to .97, and alternate-form reliability ranged from .67 to .89. Test-retest reliability after intervals of one to two weeks among a group of school-age children ranged between .88 and .93. As evidence of construct validity, the TONI-4 was compared with the *Comprehensive Test of Nonverbal Intelligence, Second Edition* (CTONI-2; Hammill, Pearson, & Wiederholt, 2009) and with the *Test of Nonverbal Intelligence, Third Edition* (TONI-3; Brown, Sherbenou, & Johnsen, 1997). Scores on the TONI-4 were correlated .73 to .79 with scores on the CTONI-2 and .74 with scores on the TONI-3.

Receptive vocabulary. To assess receptive vocabulary, participants completed the *Peabody Picture Vocabulary Test-4* (PPVT-4; Dunn & Dunn, 2007) during Session 2. The PPVT-4 is an individually-administered assessment that takes approximately 10-15

minutes to complete and is appropriate for evaluation of children and adults ages 2;6 and older. For each item, the examinee is presented with a page containing four illustrations and is asked to indicate the illustration corresponding to a word spoken by the examiner. Items increase progressively in difficulty, and testing continues until the examinee fails to answer eight out of 12 items correctly. The PPVT-4 has a mean of 100 and a standard deviation of 15.

Authors of the PPVT-4 furnished reliability and validity data for the test (Dunn & Dunn, 2007). For the age range of children included in the current study, split-half reliability ranged from .90 to .95, internal consistency (coefficient alpha) ranged from .94 to .98, alternate form reliability was .83, and test-retest reliability was .91. As evidence of convergent validity, scores on the PPVT-4 were found to correlate .80 to .83 with scores on the EVT (Williams, 2007) and .77 with both the Lexical/Semantic composite of the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999) and the Core Language scale of the CELF-4 (Semel et al., 2003). For the current study, there was no lower cutoff for scores on the PPVT-4, and the test was not used as a screening measure. Rather, PPVT-4 scores were included in bivariate correlation analyses to evaluate the relation of receptive vocabulary to children's experimental word learning outcomes and key predictor variables.

EF measures. During Session 2, participants completed three pairs of tasks to assess individual differences in working memory, inhibitory control, and cognitive flexibility. Each pair of tasks took approximately five to ten minutes to administer.

Working memory. The Number Memory Forward and Number Memory Reversed subtests of the *Test of Auditory Processing Skills, Third Edition* (TAPS-3;

Martin & Brownell, 2005) were used to assess participants' working memory. The TAPS-3 is an individually-administered measure appropriate for use with ages 4;0 to 18;11. Digit lists of increasing length are presented orally at a rate of one digit per second, and the test-taker is asked to repeat each list in either the same (Number Memory Forward) or reversed (Number Memory Reversed) order. A greater decrement in performance on Number Memory Reversed relative to Number Memory Forward indicates greater difficulty with manipulating information in working memory, beyond simple storage capacity. To derive an estimate of EF-related working memory that is separate from simple short-term memory (Miyake et al., 2001), Number Memory Forward scores were entered as covariates in all analyses of participants' Number Memory Reversed performance. Raw scores on both tasks were converted to T-scores (mean = 50, $SD = 10$), in keeping with generally accepted scoring procedures (Vakil, Blachstein, Sheinman, & Greenstein, 2009).

Authors of the TAPS-3 provided reliability and validity data for the test (Martin & Brownell, 2005). Reliability (internal consistency; coefficient alpha) was reported to be between .85 and .90. Concurrent validity values, as measured by correlations between the Number Memory Forward and Number Memory Reversed subtests with the Forward and Backward Digit Span tests, respectively, of the *Wechsler Intelligence Scale for Children – Third Edition* (WISC-III; Wechsler, 1991) were .38 and .36.

Inhibitory control. The Stroop color word interference task (Stroop, 1935) has seen widespread use as a measure of inhibitory control for 80 years. The *Stroop Color and Word Test, Children's Version* (Stroop task; Golden, Freshwater, & Golden, 2003) is appropriate for use in children ages five to 14 years. The task includes three pages with

100 items each. The first page presents a series of color words (e.g., *red*, *blue*) printed in black ink, and the child is asked to read the words, in order, as quickly as possible. The second page presents a series of nonwords printed in various colors of ink, and the child is asked to name the colors, in order, as quickly as possible. The third page presents a series of color words, each printed in a contrasting color of ink (e.g., *blue* in red ink), and the child is asked to name the ink colors of each word, in order, as quickly as possible. For all three pages, the child's score is the number of words read correctly (page 1) or colors named correctly (pages 2 and 3) within 45 seconds. Less deterioration in performance from page 2 to page 3 is taken as evidence of greater inhibitory control, while more deterioration in performance from page 2 to page 3 is taken as evidence of poorer inhibitory control (Miyake et al., 2000). All raw scores were converted to T-scores, and participants' T-scores on the baseline page 2 measure (no interference) were included as covariates in all analyses of page 3 performance (interference present).

A study of test-retest reliability for the Stroop Color-Word Interference Test, with a one-month interval between testing occasions, yielded correlations of .90 for word reading performance, .83 for color naming performance, and .91 for the interference effect (Baron, 2004). Neuroimaging studies examining neural substrates of the Stroop interference effect consistently point to the role of EF-related prefrontal brain areas, particularly the dorsolateral prefrontal cortex and dorsal anterior cingulate cortex (Carter & van Veen, 2007; Mansouri, Tanaka, & Buckley, 2009).

Cognitive flexibility. The *Comprehensive Trail Making Test* (CTMT; Reitan & Wolfson, 1992) is a measure of cognitive flexibility appropriate for individuals between eight and 74 years of age. The examinee is first given a sheet of paper (Trail 1) with the

numerals 1 through 25 scattered around the page in random order and is asked to draw a line connecting the numerals, in order, as quickly as possible. A second page (Trail 5) has both numerals and letters, and the examinee is asked to draw a line, alternating between letters and numbers (i.e., 1-A-2-B and so on) as quickly as possible. Any errors are corrected by the examiner as they occur. The raw score on each portion of the task is the time taken to connect all items in the correct order. According to the generally accepted interpretation (e.g., Vakil et al., 2009), lower scores on Trail 5 relative to Trail 1 indicate greater difficulty with the increased cognitive flexibility demands of Trail 5. All raw scores were converted to T-scores, and T-scores on Trail 1 were included as covariates in all analyses of children's Trail 5 performance.

A study investigating the psychometric properties of the CTMT in participants ages nine to 14 with learning disabilities or typical development was reported by Stanczak and Triplett (2003). Test-retest reliabilities after an interval of one month were .55 for Form A and .72 for Form B, while coefficients of internal consistency were .84 and .86, respectively. Factor analysis yielded a single factor for both forms. Participants in the group with learning disabilities scored significantly lower than participants in the group with typical development, and a discriminant function analysis to predict group membership yielded an overall correct classification rate of 72.6%.

Experimental stimuli. Rare words. Twelve rare target words were chosen from online GRE word lists (majortests.com, 2015). All words are two syllables in length and conform to standard English orthographic patterns (i.e., no exception words). Four of the words are nouns, four are verbs, and four are adjectives. A list of the target words is provided in Table 1, and a list of target words with definitions is presented in

Appendix B. Based on information available in online psycholinguistic databases (Brysbaert, Warriner, & Kuperman, 2014; Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012; Vaden, Halpin, & Hickock, 2009; Washington University Speech & Hearing Lab Neighborhood Database, 2016), target words were found to have the following lexical characteristics: age of acquisition, mean = 13.52 ($SD = .77$); frequency, mean = .27 per million ($SD = .25$); familiarity, mean = 4.15 ($SD = 1.38$); concreteness, mean = 1.80 ($SD = .50$); number of phonemes, mean = 5.64 ($SD = .81$); neighborhood density, mean = 1.45 ($SD = 1.81$); phonotactic probability (biphoneme), mean = .003 ($SD = .002$). These characteristics do not differ between target nouns and verbs ($t = .17 - .96$, $p = .39 - .88$); between target nouns and adjectives ($t = .21 - .80$, $p = .44 - .88$); or between target verbs and adjectives ($t = .04 - 1.0$, $p = .40 - .84$).

Table 1.
Target Words.

Nouns:	Verbs:	Adjectives:
Carping	Delude	Abstruse
Censure	Forestall	Adroit
Kudos	Purloin	Maudlin
Largesse	Supplant	Vapid

Six target words (two nouns, two verbs, two adjectives) were inserted into each of two stories (described below). A target word density of approximately one target word per 150 words of text was chosen to maximize participants' word knowledge growth. Swanborn and de Glopper's (1999) meta-analysis found that the likelihood of semantic

word learning was greatest when the density of target words was held to one in 150 words or lower. Target words were distributed as evenly as possible within each story, and the text of the stories was altered as necessary to provide contextual support for target word meaning. Target words in each story were highlighted in bold, colored font to draw participants' attention to the words. Definitions of target words are provided in Appendix B.

Common words. In addition to rare target words, three two-syllable common words (one noun, one verb, one adjective) that are presumably already familiar to the participants were highlighted in bold, colored font in the stories. These words are *morning*, *review*, and *early*. The common words have an average age of acquisition of 6.05 ($SD = 2.5$) and a mean frequency of 187.28 per million ($SD = 222.9$). Target and common words do not differ significantly on any other lexical characteristic ($t = .01 - .86$, $p = .41 - .99$). Participants' responses to common words were examined to confirm their overall attentiveness and understanding of task demands. The common words along with their definitions are provided in Appendix B.

Stories. Two stories, of 835 and 925 words, respectively, were presented during Session 2 to serve as context for the target words (ReadWorks.org, 2015). Both stories contain themes thought to be of general interest among nine- to 11-year-old children (a student plays a practical joke on his classmates and teacher; a girl tries to avoid a summer activity she dislikes). Lexile levels for the two stories are between 500 and 600 (i.e., third-grade reading level). The stories were chosen from an original pool of four stories based on the results of pilot testing, as described in Appendix A. In presenting the stories, the intent was twofold: (a) to maximize the likelihood that the text had been

decoded accurately and (b) to minimize the effort needed for decoding and allow greater cognitive resources to be available for comprehending text and inferring word meaning (Just & Carpenter, 1992; Perfetti, 1985, 2010). Therefore, children heard the text of the stories while simultaneously following along with visually-presented verbatim text on a computer screen. The two stories, with target words highlighted, can be found in Appendix C.

As described in Appendix A, and based on a procedure outlined by Beck et al. (1983), a cloze task was used to evaluate how well the story contexts serve to support target word meaning. Sentences containing target words from the stories were presented to a group of 46 college undergraduate volunteers, but with target words blanked out. Volunteers were asked to read the sentences and supply a word they thought would best complete each sentence. It was not expected that volunteers would supply the actual target words, because these words are relatively rare. However, common synonyms of target words were supplied by volunteers an average of 85% of the time ($SD = .23$). In a similar study with adult participants, Beck et al. found that correct target words (or synonyms) were supplied 86% of the time in contexts that were intended to be highly directive or supportive of word meaning and 49% of the time in contexts that were generally supportive but not as highly directive. Therefore, it was concluded that the stories provide good overall contextual support for target word meaning.

Oral definition task. During Session 2, an oral definition task assessed participants' ability to generate semantic information about target words. Following the procedure of Steele and Watkins (2010), participants were presented with the orthographic forms of target words from each story and were asked to pronounce and

define each word. Any incorrect pronunciations were corrected by the examiner. If participants did not supply a correct or complete definition, follow-up questions were asked, as necessary, to elicit further responses. If participants could not offer any definition, they were asked if the target word reminded them of anything. If participants offered a vague response (for example, “large” in response to *largesse*), they were asked for a specific example. If participants offered an incomplete definition (e.g., “taking something” in response to *purloin*), they were asked if they could give any additional information. The most complete definition provided for each word was coded on a four-point scale: 0 (no response or incorrect definition); 1 (vague response); 2 (correct but incomplete definition); 3 (complete, correct definition).

Multiple-choice items. A set of 12 four-option multiple-choice items assessed participants’ receptive understanding of target word meanings, and three multiple-choice items assessed participants’ receptive understanding of common words. The stem for each item was presented both visually and auditorily by computer, with target word highlighted (e.g., “The word **vapid** means something like . . .”). Participants selected one response from among four options presented on the computer screen via text only. Correct answer choices occurred an equal number of times in first, second, third, and fourth position among the available answer choices. The order in which items were presented was randomized across participants, and different randomizations were administered at pretest and posttest for each participant. An initial practice item was presented to familiarize participants with the procedure, but responses to the practice item were not included in analyses. Responses to all other items were coded as either 1

(correct) or 0 (incorrect). A list of all 15 multiple-choice items plus the practice item is provided in Appendix D.

Analyses

Initial inspection of data. As a reliability check, responses of 20% of participants on the oral definition task (selected randomly) were independently scored by a graduate research assistant to determine that responses were recorded and coded accurately by the author during data collection as described by Steele and Watkins (2010). To avoid issues of bias in scoring, the research assistant was not informed of any scores assigned by the author.

As a first step in analysis, bivariate scatterplots were constructed to allow visual inspection of the data, and variables were examined to determine that relevant statistical assumptions were not violated. The presence of multivariate outliers was explored with the Mahalanobis distance statistic. Linearity, normality, and homoscedasticity were evaluated with plots of standardized residuals. If substantial violations of normality or homoscedasticity were found, a Box-Cox procedure would guide the choice of an appropriate transformation (e.g., squaring the scores in the event of negatively skewed data).

Bivariate correlations. Zero-order correlations between variables were calculated to evaluate bivariate relations among the independent variables (SES, language ability, working memory, inhibitory control, and cognitive flexibility), receptive vocabulary, and the outcome variables (multiple-choice posttest and oral definition scores).

Relations among independent variables. A first set of multiple regression analyses examined the relation of SES and measures of EF (working memory, inhibitory control, and cognitive flexibility) to language ability. A second set of multiple regression analyses explored the relation of language ability and SES to working memory, inhibitory control, and cognitive flexibility. Age was controlled in all analyses. As previously noted, each participant's scores on baseline measures EF were included in models as appropriate (e.g., scores on the Number Memory Forward task of the TAPS-3 were controlled in analyses focusing on TAPS-3 Number Memory Reversed scores). In addition, all potential mediating and moderating effects were explored when appropriate, using the Baron and Kenny (1986) approach described below. An alpha level of $p = .05$ was used for all analyses.

Factors associated with word learning. The next step was to evaluate factors contributing to word learning. Adjusting for age, separate multiple regression models were used to explain (a) posttest scores on the multiple-choice measure and (b) scores on the oral definition task. Scores for each participant on baseline measures of EF were included as covariates when appropriate. In addition, pretest scores on the multiple-choice measure were included in all models to account for pre-existing knowledge of target words, and total multiple-choice scores on common words were included in analyses of the multiple-choice measure to account for participants' attention to the task. An alpha level of $p = .05$ was used for all analyses.

Mediation analyses. For each analysis of potential mediation in the explanation of word learning, procedures recommended by Baron and Kenny (1978) were followed: (1) a regression equation with independent variable predicting mediator (e.g., language

predicting EF skill); (2) a regression equation with independent variable predicting dependent variable (e.g., language predicting oral definition scores); (3) a regression equation with both independent variable and mediator predicting dependent variable (e.g., both language and EF skill predicting oral definition scores). A significant relation between independent and dependent variables that becomes nonsignificant with the addition of a mediator indicates complete mediation. If the independent-dependent variable relation were reduced but not eliminated, Sobel tests would be used to evaluate whether the observed reduction is significant, indicating partial mediation.

Moderation analyses. For each analysis of potential moderation in explaining word learning, interaction terms were examined. For example, to assess moderation by language in the relation between an EF skill and word learning, a language x EF term was included in the model. If interaction terms account for significant variance in a dependent variable (e.g., oral definition scores) above and beyond other independent variables, a significant moderation effect can be inferred (Baron & Kenny, 1986). To minimize problems associated with multicollinearity, variables included in interaction terms were first centered. Simple slopes analyses were used to examine in more detail the nature of any significant interactions.

Chapter 3

Results

Initial Inspection of Data

As a reliability check, responses of 20% of participants on the oral definition task were independently scored by both the experimenter and a graduate research assistant to verify accuracy in recording and coding. The research assistant was unaware of the

scores originally assigned by the experimenter. Average inter-rater agreement was 87% and ranged from 70% to 100% for individual participants. Ratings for individual items differed by at most one point on the zero- to three-point scale. Any disagreements were resolved through discussion between the experimenter and the research assistant. Based on these discussions, scores for six participants were adjusted. The average adjustment was one point per participant (range = zero to three points).

As an initial step in analysis, bivariate scatterplots were constructed, and variables were examined to verify that relevant statistical assumptions had been met. No substantial violations of linearity, normality, or homoscedasticity were found, and analyses revealed no evidence of either univariate or bivariate outliers. Few data were missing; multiple-choice posttest scores for one participant were lost due to computer malfunction, and baseline working memory scores for another participant were lost due to error in administration by a research assistant. Both instances were random and accidental. A series of two-way ANOVAs revealed no significant differences for any of the independent or dependent variables based on gender or race/ethnicity. Therefore, all analyses were collapsed across gender and race/ethnicity.

Descriptive Statistics

Standardized test scores. There was a wide range of performance within the typical range on standardized measures of language, decoding, and nonverbal cognition. Standardized test scores are displayed in Table 2. As previously mentioned, one child scored more than 1.0 *SD* below the population mean on language (standard score of 80). The same child and one additional participant scored more than 1.0 *SD* below the population mean on nonverbal cognition (standard scores of 83). Receptive vocabulary

scores also ranged widely, with two children scoring more than 1.0 *SD* below the population mean (standard scores of 72 and 78).

Table 2.

Descriptive Statistics for Standardized Tests.

Test or Composite	Mean	Standard Deviation	Range
CELF ^a Core Language	109	11.2	80-125
WRMT ^b Basic Reading	109	12.1	86-132
TONI ^c	107	10.8	83-136
PPVT ^d	113	15.5	72-142

Note. Standard scores, $M = 100$, $SD = 15$. ^aClinical Evaluation of Language Fundamentals, Fifth Edition (Wiig et al., 2013). ^bWoodcock Reading Mastery Test, Third Edition (Woodcock, 2011). ^cTest of Nonverbal Intelligence, Fourth Edition (Brown & Sherbenou, 2010). ^dPeabody Picture Vocabulary Test, Fourth Edition (Dunn & Dunn, 2007).

Executive function measures. Scores also ranged widely on the tasks of working memory, inhibitory control, and cognitive flexibility. T-scores (population mean = 50, $SD = 10$) for all measures are displayed in Table 3. As previously described, each EF measure required children to complete two versions of a task, with one task in each pair designed to be more challenging in terms of the underlying EF skill, thus isolating EF-related performance from fine motor ability or general cognitive factors such as simple short-term memory.

Table 3.

Descriptive Statistics for Executive Function Measures.

Measure	Mean	Standard Deviation	Range
TAPS ^a Numbers Forward	47.1	8.0	27-67
TAPS ^a Numbers Reversed	49.4	10.3	27-73
Stroop ^b Color Score	48.5	5.3	34-60
Stroop ^b Color-Word Score	44.3	7.1	29-62
CTMT ^c Trail 1	51.4	11.6	38-85
CTMT ^c Trail 5	48.7	11.4	25-72

Note. T-Scores, $M = 50$, $SD = 10$. ^aTest of Auditory Processing Skills, Third Edition (Martin & Brownell, 2005). ^bStroop Color and Word Test, Children's Version (Golden et al., 2003). ^cComprehensive Trail Making Test (Reynolds, 2002).

Parent questionnaire. As described, caregivers completed a questionnaire to verify that all children were typically developing and without any history of language impairment or other developmental disorders. As previously mentioned, children were not excluded based on treatment for an articulation disorder. Parents were also asked to provide information about educational attainment and occupation, to derive estimates of family SES. The mean score for SES on the Hollingshead (1975) scale was 53.7 ($SD = 10.4$), which roughly corresponds to minor professional, medium business, and technical occupations. Household SES in the current sample ranged from 30.0 (skilled craftsmen, clerical and sales workers) to 66.0 (major business and professional occupations). Efforts were made to obtain permission from community organizations serving children from lower-SES families (e.g., the public schools, city-run after-school and recreation facilities) to recruit participants with a wider range of family SES and to recruit children

from low-income households especially. However, because permission was not granted by these organizations, it proved difficult to recruit participants from lower-SES families. This limitation may have influenced the results of analyses focusing on SES, as described in the Discussion section.

Word learning tasks. Performance ranged widely on both the multiple-choice measure and the oral definition task. Descriptive statistics for the multiple-choice and oral definition tasks are displayed in Table 4. Overall scores on the multiple-choice pretest were higher than chance, $t(49) = 20.1, p < .001$, suggesting that participants had at least some pre-existing familiarity with target words. Mean target word knowledge also increased significantly after exposure to the words in stories, $t(48) = 4.63, p < .001, d = 0.67$, demonstrating that significant learning had taken place. Average multiple-choice scores increased by 29.5% from pretest to posttest (range = -70 - 500, $SD = 81.1$). Most children responded correctly to five or six of the six common words on both testing occasions.

On the oral definition task, children earned an average score of 26.2% correct (range = 0.0 – 80.6, $SD = 20.4$). Results showed that scores on the multiple-choice pretest were correlated with scores on the multiple-choice posttest, $r(49) = .55, p < .001$ and with scores on the oral definition task, $r(50) = .38, p = .007$, suggesting that for both outcome measures, children with greater pre-existing target word knowledge earned higher scores than their peers with less pre-existing knowledge.

Table 4.
Descriptive Statistics for Word Learning Measures.

Score	Mean	SD	Range
Multiple-Choice Pretest ^a	4.84	1.71	1–9
Multiple-Choice Posttest ^a	6.27	2.48	2–10
Gain, Pretest to Posttest ^a	1.39	2.10	-4–6
Common Words ^b	5.71	.65	3–6
Oral Definition Task ^c	9.42	7.33	0–29

Note. ^aMaximum score = 12. ^bMaximum score = 6. ^cMaximum score = 36.

Bivariate Correlations

Zero-order Pearson correlations were calculated among all independent and dependent variables to examine bivariate relations. Correlations among variables are displayed in Table 5. The two dependent variables, multiple-choice posttest scores and oral definition scores, were highly intercorrelated. Both measures were significantly correlated with language and receptive vocabulary but not with any of the EF tasks. SES was significantly correlated with multiple-choice posttest scores but not with any other variable. Among the other predictor variables, language was significantly correlated with receptive vocabulary, working memory, and cognitive flexibility, but not with inhibitory control. Working memory was correlated with language and cognitive flexibility. Inhibitory control was not significantly correlated with any other variable. Cognitive flexibility was correlated with language and working memory.

Table 5.

Pearson Correlations Among Variables (two-tailed).

Variable	SES ^a	CELF ^b	PPVT ^c	TAPS ^d	Stroop ^e	CTMT ^f	MC Score ^g
Oral Def. ^h	.26 [†]	.44**	.49***	.15	.05	.15	.76***
MC Score ^g	.39**	.53***	.54***	.08	.13	.17	
CTMT ^f	.08	.40**	.22	.29*	.26 [†]		
Stroop ^e	.05	.03	.05	.15			
TAPS ^d	.14	.30*	.08				
PPVT ^c	.12	.57***					
CELF ^b	.09						

Note. [†] $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$. ^aFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^bCore Language Composite of Clinical Evaluation of Language Fundamentals, Fifth Edition (Wiig et al., 2013). ^cPeabody Picture-Vocabulary Test, Fourth Edition (Dunn & Dunn, 2007). ^dTest of Auditory Processing Skills, Third Edition (Martin & Brownell, 2005), Number Memory Reversed scores. ^eStroop Color and Word Test, Children's Version (Golden et al., 2003), Color-Word scores. ^fComprehensive Trail Making Test (Reynolds, 2002), Trail 5 scores. ^gMultiple-choice posttest score. ^hOral definition score.

Relations Among Independent Variables

Explanation of language by SES and working memory. The first major aim of the study was to explore the structural relations among language ability, SES, and the EF skills of working memory, inhibitory control, and cognitive flexibility. The first analysis examined the relation of SES and working memory to language. A regression equation controlling for age and the baseline TAPS-3 measure was used to explore whether SES or working memory would explain significant variance in children's language ability. Coefficients for the explanation of language ability by SES and working memory are

presented in Table 6. The overall model was not significant, $F(5, 43) = 1.39, p = .25$, and explained only 13.9% of variance in language ability. The hypothesis that SES would relate to children's language ability was not supported. There was no significant main effect of SES on language and no significant interaction of SES with working memory. Despite the bivariate correlation between language and working memory and the hypothesis that language and EF measures would be associated, working memory was likewise not significantly related to language. Because no significant overall association between language and SES was found, it was neither necessary nor appropriate to examine mediation by working memory (Baron & Kenny, 1986).

Table 6.

Explanation of Language Ability by SES and Working Memory.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	70.45	23.54		2.99	.01
Age	1.41	1.79	0.12	0.79	.44
SES ^a	0.01	0.17	0.01	0.06	.96
TAPS-F ^b	0.33	0.26	0.23	1.22	.23
TAPS-R ^c	0.16	0.36	0.15	0.45	.65
SESxTAPS	0.00	0.02	-0.01	-0.02	.99

Note. Dependent variable: Standard score on Core Language Composite of CELF-5. ^aFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^bTAPS-3 Number Memory Forward T-score (baseline short-term memory task). ^cTAPS-3 Number Memory Reversed T-score (working memory task).

Explanation of language by SES and inhibitory control. In likewise fashion, a regression equation controlling for age and the baseline Stroop measure was used to examine whether SES and inhibitory control would explain significant variance in

children's language ability. Coefficients for the explanation of language ability by SES and inhibitory control are presented in Table 7. The overall model was not significant, $F(5, 44) = 1.02, p = .42$, and explained only 10.3% of variance. SES was nonsignificant, both as a main effect and in interaction with inhibitory control. Inhibitory control also failed to explain significant variance in language skill. Because SES had no main effect on language, no analysis of mediation by inhibitory control was performed.

Table 7.

Explanation of Language Ability by SES and Inhibitory Control.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	57.87	25.91		2.23	.03
Age	2.43	1.84	0.20	1.32	.19
SES ^a	0.20	0.22	0.18	0.91	.37
Stroop-C ^b	0.73	0.41	0.34	1.79	.08
Stroop-CW ^c	-0.45	0.38	-0.29	-1.20	.24
SESxStroop	0.01	0.02	0.10	0.41	.69

Note. Dependent variable: Standard score on Core Language Composite of CELF-5. ^aFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^bStroop Color T-score (baseline rapid naming task). ^cStroop Color-Word T-score (inhibitory control task).

Explanation of language by SES and cognitive flexibility. A regression equation controlling for age and the baseline CTMT measure was used to explore whether SES and cognitive flexibility would explain significant variance in children's language ability. Coefficients for the explanation of language ability by SES and cognitive flexibility are presented in Table 8. The overall model was not significant, $F(5, 44) = 1.99, p = .10$, and explained 18.5% of variance. There were no significant main effects of either SES or cognitive flexibility and no significant interaction between SES

and cognitive flexibility. Because no significant relation between SES and language was found, no analysis of mediation by cognitive flexibility was performed.

Table 8.

Explanation of Language Ability by SES and Cognitive Flexibility.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	69.83	18.67		3.74	.001
Age	1.38	1.76	0.11	0.78	.44
SES ^a	-0.01	0.16	-0.01	-0.03	.98
CTMT-1 ^a	0.04	0.16	0.05	0.27	.79
CTMT-5 ^c	0.46	0.26	0.47	1.78	.08
SESxCTMT	-0.01	0.01	-0.12	-0.48	.63

Note. Dependent variable: Standard score on Core Language Composite of CELF-5. ^aFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^bCTMT Trail 1 T-score (baseline trail-drawing task). ^cCTMT Trail 5 T-score (cognitive flexibility task).

Explanation of working memory by SES and language ability. A regression analysis was then used to examine whether participants' SES or language ability would explain their working memory skill, as measured by the TAPS-3 Number Memory Reversed task, after adjusting for age and scores on the TAPS-3 Number Memory Forward task. Coefficients for the explanation of working memory by SES and language ability are presented in Table 9. The overall model was significant, $F(5, 43) = 6.12, p < .001$, and explained 41.6% of variance in working memory. However, despite the hypotheses that SES and language would both relate to children's working memory skill, and despite the bivariate correlation between language and working memory, no significant effects were found for SES, language, or their interaction. Because there was

no significant main effect of SES on working memory, no analysis of mediation by language was performed.

Table 9.

Explanation of Working Memory by SES and Language Ability.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-1.92	31.82		-0.06	.95
Age	0.11	1.36	0.01	0.08	.94
TAPS-F ^a	0.77	0.16	0.59	4.75	<.001
SES ^b	0.06	0.15	0.07	0.44	.66
CELF ^c	0.10	0.26	0.11	0.38	.70
SESxCELF	-0.00	0.01	-0.01	-0.05	.96

Note. Dependent variable: TAPS-3 Number Memory Reversed T-score (working memory task). ^aTAPS-3 Number Memory Forward T-score (baseline short-term memory task). ^bFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^cCELF-5 Core Language Composite.

Explanation of inhibitory control by SES and language ability. A regression equation controlling for age and scores on the Stroop Color task likewise examined the effects of SES and language ability on children's inhibitory control as measured by the Stroop Color-Word task. Coefficients for the explanation of inhibitory control by SES and language ability are presented in Table 10. The overall model was significant, $F(5, 44) = 7.68, p < .001$, and explained 46.6% of variance in inhibitory control. However, results showed no main effects of SES or language and no significant interaction between language and SES. Because no main effect of language was found, no analysis of mediation by language in the relation between SES and inhibitory control was conducted.

Table 10.

Explanation of Inhibitory Control by SES and Language Ability.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-37.82	25.12		-1.51	.14
Age	1.42	0.92	0.18	1.55	.13
Stroop-C ^a	1.00	0.17	0.72	5.94	<.001
SES ^b	0.20	0.11	0.28	1.85	.07
CELF ^c	0.09	0.18	0.14	0.52	.61
SESxCELF	-0.01	0.01	-0.34	-1.14	.26

Note. Dependent variable: Stroop Color-Word T-score (inhibitory control task). ^aStroop Color T-score (baseline rapid naming task). ^bFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^cCELF-5 Core Language Composite.

Explanation of cognitive flexibility by SES and language ability. Regression analyses controlling for age and CTMT Trail 1 scores examined the contribution of SES and language to children's cognitive flexibility as measured by the CTMT Trail 5 task. Coefficients for the explanation of cognitive flexibility by SES and language ability are presented in Table 11. The overall model was significant, $F(5, 44) = 6.84, p < .001$, and explained 43.7% of variance in cognitive flexibility. Results showed a significant interaction between SES and language. The interaction between language and SES in explaining cognitive flexibility is illustrated in Figure 1. The interaction accounted for six percent of variance in cognitive flexibility, representing a small effect (Cohen's $f^2 = 0.11$).

To explore the nature of the interaction, two sets of simple slopes analyses were performed. The first set of analyses examined whether the effect of language ability on children's cognitive flexibility might differ according to household SES. The effect of

language ability on cognitive flexibility was compared for children with SES at the sample mean to that of children with lower SES (1.0 *SD* below the sample mean) and higher SES (1.0 *SD* above the sample mean). Results showed that for all three SES groups, language had a significant and positive effect on cognitive flexibility: $\beta = 1.13$, $t(44) = 2.76$, $p = .008$, for children with lower SES; $\beta = 0.82$, $t(44) = 2.97$, $p = .005$, for children with SES at the sample mean; $\beta = 0.52$, $t(44) = 3.20$, $p = .003$, for children with higher SES, respectively. Thus, children's language ability was positively related to their cognitive flexibility regardless of household SES.

A set of post-hoc pairwise comparisons, with Bonferroni correction, were then used to examine whether the magnitude of language effects on cognitive flexibility might differ according to SES level. No significant pairwise differences were found. Results were as follows: lower SES compared with SES at the sample mean, $t(96) = 0.62$, $p = .54$; SES at the sample mean compared with higher SES, $t(96) = 0.96$, $p = .34$; lower SES compared with higher SES, $t(96) = 1.39$, $p = .17$. Thus, there was no evidence to indicate that language ability had either a weaker or a stronger influence on children's cognitive flexibility at different levels of household SES.

A second set of simple slopes analyses examined whether the effect of SES on cognitive flexibility might differ according to children's language ability. The effect of SES on cognitive flexibility was compared for children with language ability at the sample mean to that of children with lower language ability (1.0 *SD* below the sample mean) and higher language ability (1.0 *SD* above the sample mean). It should be noted that for this relatively high-scoring sample, language ability 1.0 *SD* below the sample mean corresponded to a standard score of about 97, still quite well within the typically

developing range. Results showed no significant effect of SES on cognitive flexibility for children with higher language ability, $\beta = -0.12$, $t(44) = -0.92$, $p = .37$, for children with language ability at the sample mean, $\beta = 0.18$, $t(44) = 1.29$, $p = .21$, nor for children with lower language ability, $\beta = 0.49$, $t(44) = 1.94$, $p = .06$. Thus, SES was not significantly related to cognitive flexibility, regardless of children's level of language ability.

None of the foregoing follow-up analyses explained the significant interaction that was found between SES and language in relation to children's cognitive flexibility. Therefore, one final simple slopes analysis was performed to examine whether the effect of SES on cognitive flexibility might differ for children with more extreme differences in language ability. The effect of SES on cognitive flexibility was compared for children with language ability at the sample mean to that of children with even lower language ability (1.5 *SD* below the sample mean) and even higher language ability (1.5 *SD* above the sample mean). Language ability 1.5 *SD* below the sample mean corresponded to a standard score of about 91, again still well within the typically developing range. Results showed no significant effect of SES on cognitive flexibility for children with language ability 1.5 *SD* above the sample mean, $\beta = -0.27$, $t(44) = -1.57$, $p = .13$, nor for children with language ability at the sample mean, $\beta = 0.18$, $t(44) = 1.29$, $p = .21$. However, for children with language ability 1.5 *SD* below the sample mean, SES had a significant positive effect on cognitive flexibility, $\beta = 0.64$, $t(44) = 2.03$, $p = .04$. Thus, there was evidence of a relation between SES and cognitive flexibility among children with language ability substantially below the sample mean, but not for children with language ability at the sample mean or higher. Among children with weaker language ability (at least 1.5 *SD* below the sample mean), lower SES was associated with poorer cognitive

flexibility performance, while higher SES was associated with better cognitive flexibility performance.

No significant main effect of SES on cognitive flexibility was found. Therefore, no analysis of mediation by language was performed.

Table 11.

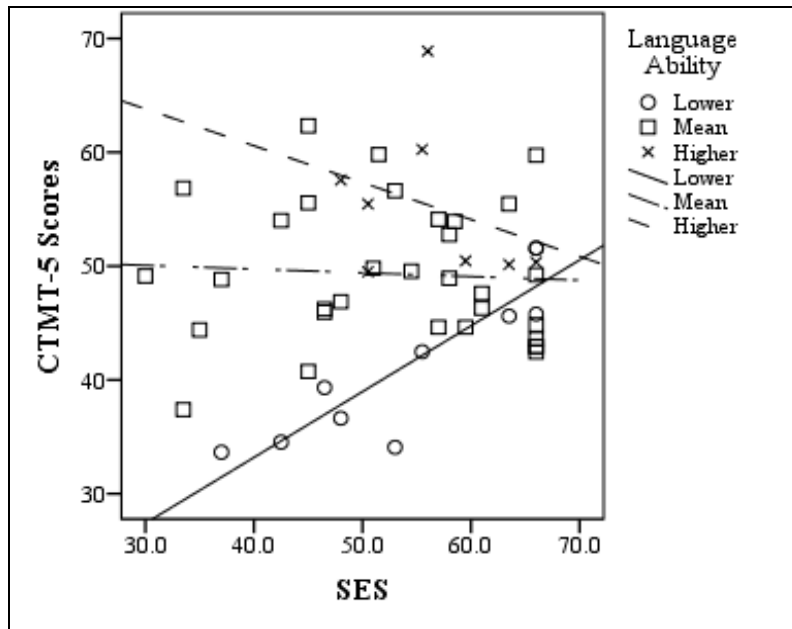
Explanation of Cognitive Flexibility by SES and Language Ability.

Model	B	SE	β	<i>t</i>	<i>p</i>
(Constant)	-67.56	34.06		-1.98	.05
Age	-0.42	1.46	-0.03	-0.29	.78
CTMT-1 ^a	0.46	0.12	0.47	3.99	<.001
SES ^b	0.20	0.16	0.18	1.29	.21
CELF ^c	0.84	0.28	0.82	2.97	.005
SESxCELF	-0.03	0.01	-0.63	-2.17	.04

Note. Dependent variable: CTMT Trail 5 T-score (cognitive flexibility task). ^aCTMT Trail 1 T-score (baseline trail-drawing task). ^bFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^cCELF-5 Core Language Composite.

Figure 1.

Language-SES Interaction in Explaining Cognitive Flexibility.



Note. CTMT-5 = CTMT Trail 5 T-score (cognitive flexibility task). SES = Family socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). Lower language ability = 1.5 *SD* below sample mean. Higher language ability = 1.5 *SD* above sample mean.

Factors Associated with Word Learning

The second major aim of the study was to explore the relation of language ability, SES, and EF to children's word learning performance. Multiple regression analyses were used to examine the variables associated with children's scores on both the multiple-choice posttest measure and the oral definition task. Age and multiple-choice pretest scores were included as covariates in all analyses. Baseline EF scores were included as appropriate, and scores on common words were also included in analyses of multiple-choice posttest scores. Coefficients for the multiple-choice measure are provided in Table 12. The most parsimonious model with significant predictors for the multiple-choice measure was significant, $F(7, 41) = 9.16, p < .001$, and accounted for 61.0% of total variance in posttest scores. Coefficients for the oral definition task are provided in

Table 13. The most parsimonious model with significant predictors for the oral definition task was also significant, $F(6, 43) = 7.30, p < .001$, and accounted for 50.4% of total variance in oral definition scores. For brevity, only the most parsimonious models with significant predictors are shown in Tables 12 and 13. All pertinent findings are described in the sections that follow, and full results for all tested models are provided in Appendix E.

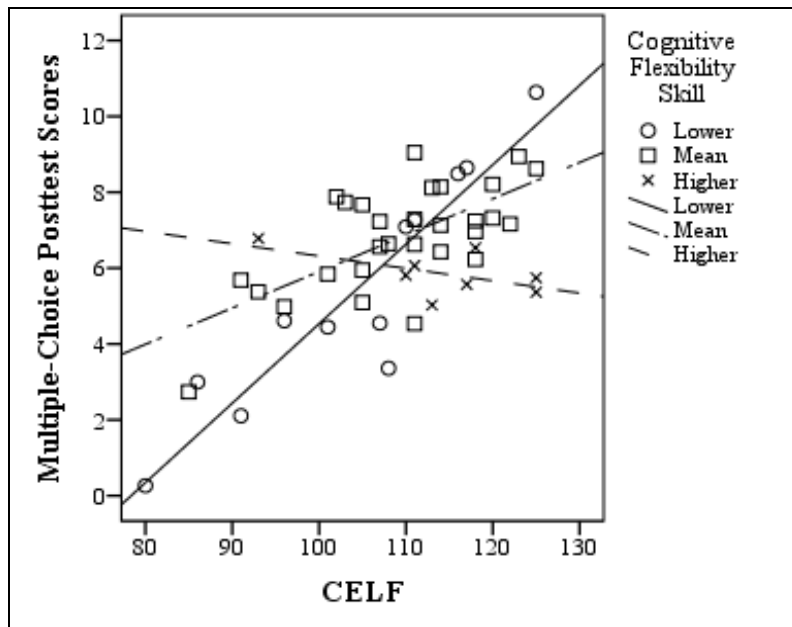
Language. Results of regression analyses showed a significant interaction between language and cognitive flexibility for both word learning outcome measures. The moderating role of cognitive flexibility in the relation between language ability and posttest scores is illustrated in Figure 2, and the moderating role of cognitive flexibility in the relation between language ability and oral definition scores is illustrated in Figure 3. The interaction represented a medium effect in the case of the multiple-choice posttest (8.1% of total variance; Cohen's $f^2 = 0.21$) and a small effect in the case of the oral definition task (5.7% of total variance; Cohen's $f^2 = 0.11$).

To explore the nature of the interaction between language and cognitive flexibility in explaining word learning performance, a series of simple slopes analyses were performed. The first set of analyses examined whether the contribution of language ability to multiple-choice posttest scores might differ according to children's skills in cognitive flexibility. The effect of language ability on posttest scores was compared for children with cognitive flexibility, as measured by CTMT Trail 5 scores, at the sample mean to that of children with lower cognitive flexibility (CTMT Trail 5 scores 1.0 *SD* below the sample mean) and higher cognitive flexibility (CTMT Trail 5 scores 1.0 *SD* above the sample mean). The effect of language for children with lower cognitive

flexibility was positive and significant, $\beta = 0.52$, $t(41) = 4.01$, $p < .001$. However, the effect of language was not significant for children with cognitive flexibility at the sample mean, $\beta = 0.25$, $t(41) = 2.02$, $p = .05$, or for children with higher cognitive flexibility, $\beta = -0.01$, $t(41) = -0.04$, $p = .97$. Thus, language ability made a positive contribution to posttest scores among children with lower cognitive flexibility, but not among children with cognitive flexibility at the sample mean or higher.

Figure 2.

Effect of Language on Posttest Scores: Moderation by Cognitive Flexibility.



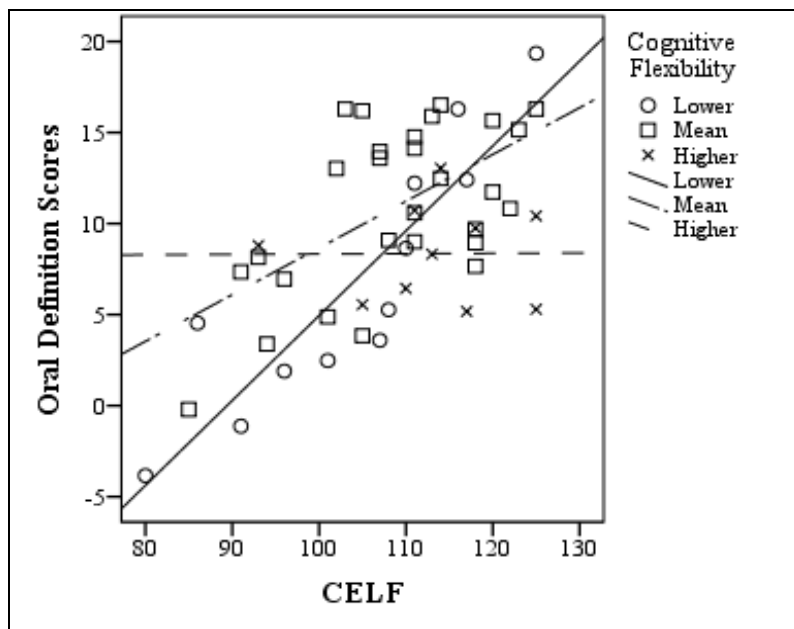
Note. CELF = CELF-5 Core Language Composite standard score. Lower cognitive flexibility = CTMT Trail 5 score 1.0 *SD* below sample mean. Higher cognitive flexibility = CTMT Trail 5 score 1.0 *SD* above sample mean.

To explore the extent to which oral definition performance also followed this pattern, another set of simple slopes analyses examined whether the contribution of language ability to oral definition scores might differ according to children's cognitive flexibility skills. The effect of language ability was compared for children with cognitive flexibility (i.e., CTMT Trail 5 scores) at the sample mean to that of children with lower

cognitive flexibility (CTMT Trail 5 scores 1.0 *SD* below the sample mean) and higher cognitive flexibility (CTMT Trail 5 scores 1.0 *SD* above the sample mean). The effect of language for children with lower cognitive flexibility was positive and significant, $\beta = 0.46$, $t(43) = 3.19$, $p = .003$. In contrast, the effect of language was not significant for children with cognitive flexibility at the sample mean, $\beta = 0.24$, $t(43) = 1.77$, $p = .08$, nor for children with higher cognitive flexibility, $\beta = 0.02$, $t(43) = 0.12$, $p = .91$. Thus, language ability made a positive contribution to oral definition performance among children with lower cognitive flexibility skills but not among children with cognitive flexibility at the sample mean or higher.

Figure 3.

Effect of Language on Oral Definitions: Moderation by Cognitive Flexibility.



Note. CELF = CELF-5 Core Language Composite standard score. Lower cognitive flexibility = CTMT Trail 5 score 1.0 *SD* below sample mean. Higher cognitive flexibility = CTMT Trail 5 score 1.0 *SD* above sample mean.

There were no significant interactions between language and the other EF skills in relation to either word learning measure. Results were as follows: language in interaction

with working memory for multiple-choice posttest scores, $\beta = -0.13$, $t(37) = -0.94$, $p = .35$; for oral definition scores, $\beta = -0.17$, $t(39) = -1.12$, $p = .27$; language in interaction with inhibitory control for multiple-choice posttest scores, $\beta = 0.05$, $t(38) = 0.37$, $p = .71$; for oral definition scores, $\beta = -0.08$, $t(40) = -0.47$, $p = .64$. The lack of significant interaction between language and either of these EF skills suggests that any contribution of language ability to children's word learning performance was independent of their skills in working memory and inhibitory control. Similarly, language was not involved in significant interaction with SES in relation to either word learning measure: for multiple-choice posttest scores, $\beta = -0.19$, $t(42) = -0.66$, $p = .52$; for oral definition scores, $\beta = 0.35$, $t(44) = 1.16$, $p = .25$, suggesting that any influence of language ability on children's scores was independent of SES. Because neither SES nor EF showed significant main effects on posttest scores (see below), no analyses of mediation by language were performed.

Receptive vocabulary. The relation of receptive vocabulary to word learning was not a primary focus of the current study. However, because receptive vocabulary was significantly correlated with scores on both the multiple-choice posttest and the oral definition task, a pair of post hoc regression analyses were performed to evaluate whether receptive vocabulary would still relate to word learning measures once age, prior knowledge of target words, and scores on common words were taken into account. Results showed that after controlling for age, pretest scores, and scores on common words, receptive vocabulary was significantly related to multiple-choice posttest scores, $\beta = 0.38$, $t(44) = 3.36$, $p = .002$, and accounted for 11.2% of total variance (medium effect size; Cohen's $f^2 = 0.26$). Receptive vocabulary was also significantly related to

scores on the oral definition task after controlling for age and pretest scores, $\beta = 0.43$, $t(46) = 3.99$, $p < .001$, accounting for 16.4% of total variance (large effect size; Cohen's $f^2 = 0.35$).

Socioeconomic status. It was hypothesized that SES would not relate significantly to children's word learning performance, and this hypothesis was supported. Although SES had a significant bivariate correlation with the multiple-choice posttest, there were no main effects of SES on posttest or oral definition scores after age, pretest performance, and scores on common words were controlled. SES did not explain scores on the multiple-choice posttest, $\beta = 0.14$, $t(44) = 1.08$, $p = .29$, nor the oral definition task, $\beta = 0.06$, $t(46) = 0.44$, $p = .66$. As previously mentioned, SES was not involved in significant interaction with language in explaining scores on either word learning measure. In addition, there were no significant interactions between SES and working memory for the multiple-choice posttest, $\beta = -0.01$, $t(37) = -0.05$, $p = .96$, nor oral definition task, $\beta = 0.09$, $t(39) = 0.37$, $p = .72$. Likewise, SES did not interact significantly with inhibitory control in explaining multiple-choice scores, $\beta = 0.27$, $t(38) = 1.19$, $p = .24$, nor scores on the oral definition task, $\beta = 0.02$, $t(40) = 0.07$, $p = .94$. Finally, SES did not interact significantly with cognitive flexibility in explaining multiple-choice scores, $\beta = -0.01$, $t(41) = -0.05$, $p = .96$, nor oral definition scores, $\beta = -0.07$, $t(43) = -0.31$, $p = .76$. Because there were no significant main effects of SES on children's scores on either word learning task, no analyses of mediation by language or EF were performed.

Executive function. It was hypothesized that children's EF skills would relate to their experimental word learning performance. However, after adjusting for control

variables, no significant main effects were found for either working memory or inhibitory control on either the multiple-choice measure or the oral definition task. Results were as follows: main effect of working memory on multiple-choice posttest scores, $\beta = -0.16$, $t(42) = -1.04$, $p = .30$; main effect of working memory on oral definition scores, $\beta = -0.06$, $t(44) = -0.36$, $p = .72$; main effect of inhibitory control on multiple-choice posttest scores, $\beta = 0.10$, $t(43) = 0.71$, $p = .48$; main effect of inhibitory control on oral definition scores, $\beta = -0.11$, $t(45) = -0.67$, $p = .50$.

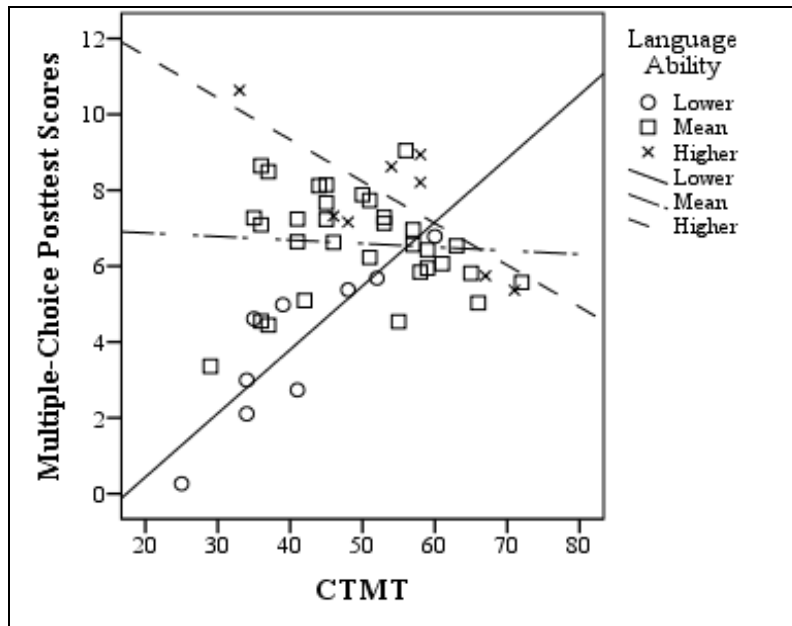
As previously mentioned, there was a significant interaction between cognitive flexibility and language ability for both the multiple-choice posttest and the oral definition task. To examine moderation by language in the relation between cognitive flexibility and word learning measures, a series of simple slopes analyses were performed. The first set of analyses evaluated whether the contribution of cognitive flexibility to multiple-choice posttest scores might differ according to children's language ability. The moderating role of language ability in the relation between cognitive flexibility and posttest scores is illustrated in Figure 4. The effect of cognitive flexibility on posttest scores for children with language ability at the sample mean was compared to that of children with lower language ability (1.0 *SD* below the sample mean) and higher language ability (1.0 *SD* above the sample mean). Again, it is important to note that in the current sample, language ability 1.0 *SD* below the sample mean corresponded to a standard score still well within the typical range. Results showed that the effect of cognitive flexibility for children with lower language ability was significant and positive, $\beta = 0.50$, $t(41) = 2.23$, $p = .03$. In contrast, there were no significant effects of cognitive flexibility for children with higher language ability, $\beta = -0.04$, $t(41) = -0.26$, $p = .80$, nor

for children with language ability at the sample mean, $\beta = 0.23$, $t(41) = 1.43$, $p = .16$.

Thus, cognitive flexibility made a significant positive contribution to posttest scores for children with relatively lower language ability, but not for children with language ability at the sample mean or higher.

Figure 4.

Effect of Cognitive Flexibility on Posttest Scores: Moderation by Language.



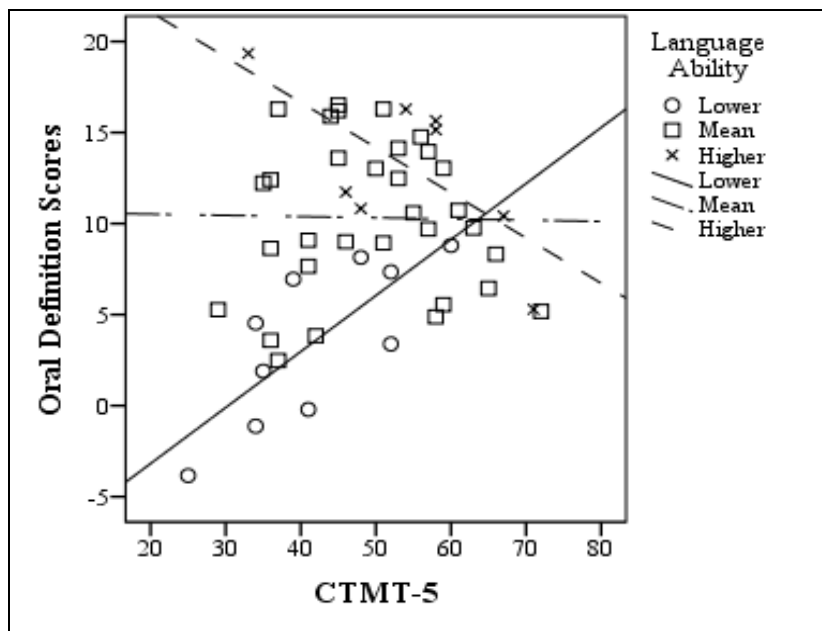
Note. CTMT = CTMT Trail 5 T-score (cognitive flexibility task). Lower language ability = 1.0 *SD* below sample mean. Higher language ability = 1.0 *SD* above sample mean.

Another set of simple slopes analyses examined whether the contribution of cognitive flexibility to oral definition scores might differ according to children's language ability. The relation of cognitive flexibility to oral definition scores according to language ability is illustrated in Figure 5. The effect of cognitive flexibility on oral definition scores for children with language ability at the sample mean was compared to that of children with lower language ability (1.0 *SD* below the sample mean) and higher language ability (1.0 *SD* above the sample mean). The effect of cognitive flexibility was

not significant for any level of language ability: for children with lower language ability, $\beta = 0.33$, $t(43) = 1.45$, $p = .16$; for children with language ability at the sample mean, $\beta = 0.11$, $t(43) = 0.68$, $p = .50$; for children with higher language ability, $\beta = -0.11$, $t(43) = -0.80$, $p = .43$. Thus, there was no evidence that cognitive flexibility contributed to oral definition scores, regardless of children's language ability.

Figure 5.

Effect of Cognitive Flexibility on Oral Definitions, by Language Ability.



Note. CTMT = CTMT Trail 5 T-score (cognitive flexibility task). Lower language ability = 1.0 *SD* below sample mean. Higher language ability = 1.0 *SD* above sample mean.

No other significant interactions involving any of the EF measures with language or SES were found. Because there were no significant main effects for any of the EF tasks on either word learning measure, no analyses of mediation by EF skills were performed. A final set of analyses explored three-way interactions involving language, SES, and the three EF skills; no three-way interactions emerged as significant.

Table 12.

Coefficients for Multiple-Choice Model.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-13.10	3.91		-3.35	.002
Age	0.73	0.27	0.27	2.68	.01
Pretest ^a	0.39	0.17	0.27	2.32	.03
Common ^b	0.50	0.44	0.13	1.14	.26
CELF ^c	0.06	0.03	0.25	2.02	.05
CTMT-1 ^c	-0.02	0.03	-0.11	-0.96	.34
CTMT-5 ^f	0.05	0.04	0.23	1.43	.16
CELFxCTMT-5	-0.01	0.00	-0.37	-2.91	.006

Note. Dependent variable: Multiple-choice posttest score. ^aMultiple-choice pretest score.

^bMultiple-choice score on common words. ^cCELF-5 Core Language Composite. ^dCTMT Trail 1 T-score (baseline trail-drawing task). ^fCTMT Trail 5 T-score (cognitive flexibility task).

Table 13.

Coefficients for Oral Definition Model.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-53.10	11.27		-4.71	<.001
Age	3.63	0.89	0.46	4.10	<.001
Pretest ^a	0.26	0.54	0.06	0.48	.63
CELF ^b	0.16	0.09	0.24	1.77	.08
CTMT-1 ^c	0.07	0.08	0.11	0.87	.39
CTMT-5 ^d	0.07	0.10	0.11	0.68	.50
CELFxCTMT-5	-0.01	0.01	-0.30	-2.22	.03

Note. Dependent variable: Multiple-choice posttest score. ^aMultiple-choice pretest score. ^bCELF-5 Core Language Composite. ^cCTMT Trail 1 T-score (baseline trail-drawing task). ^dCTMT Trail 5 T-score (cognitive flexibility task).

Chapter 4

Discussion

This study was undertaken to examine factors related to the acquisition of new word meanings from context among typically developing school-age children. There were two major aims: (a) to explore the structural relations among language ability, SES, and EF; and (b) to examine the contribution of language ability, SES, and EF to word learning from context. Results revealed that both language ability and the EF skill of cognitive flexibility may play a direct role in the word learning process. Findings also suggest that children may rely more heavily on either language or cognitive flexibility in the word learning process to compensate for relative weakness in either of the two skills. There was no evidence to indicate that SES is directly involved in word learning, but SES may play an indirect role through its influence on cognitive flexibility. In this chapter each of these findings will be discussed in light of the extant literature.

Relations Among Language, SES, and Executive Function

Language and executive function. The first major aim of the study was to examine the structural relations among language ability, SES, and the EF skills of working memory, inhibitory control, and cognitive flexibility. First, it was hypothesized that children's language ability would relate to their performance on tasks of the three EF skills. Previous studies have found a significant association between EF and language-related academic achievement outcomes among school-age children (e.g., Best et al., 2009; St. Clair-Thompson & Gathercole, 2006). Some findings suggest that language ability may influence the development of EF (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Fuhs & Day, 2011; Lidstone et al., 2010), whereas others

suggest that skill in EF impacts the development of language (e.g., Raver et al., 2011; Weiland et al., 2014). This hypothesis was only partially supported by the present findings. Although language and working memory were moderately correlated, neither working memory nor inhibitory control was significantly related to children's tested language ability once age and scores on baseline EF measures were controlled. There were no significant main effects of working memory or inhibitory control on language ability and no significant interactions between SES and working memory or inhibitory control in relation to language ability. In addition, there was no evidence of significant language influence, either as a main effect or in interaction with SES, on children's working memory or inhibitory control. Moreover, of the three EF skills that were measured, only working memory and cognitive flexibility were significantly intercorrelated, a finding that conflicts with results of previous studies (e.g., Miyake et al., 2000; Sarsour et al., 2011).

The lack of association between language and working memory or inhibitory control in the current study is difficult to explain, given the findings of previous studies. It is unlikely that restricted range of either language or EF task performance could be to blame, because there was a wide range of performance on language ability as well as on all three measures of EF. One possibility is that the two-part assessments of each EF skill did not adequately estimate children's underlying abilities in working memory or inhibitory control. To demonstrate relations between EF and language or other abilities, it may be necessary to administer a greater assortment of EF tasks or to employ latent factor analysis, as discussed below (Kaushanskaya, Park, Gangopadhyay, Davison, & Ellis Weismer, 2017; Yang & Gray, 2017).

Of the three EF skills, only cognitive flexibility showed evidence of a relation to language ability. Language and cognitive flexibility were moderately correlated, and after adjusting for control variables, language ability had a significant positive main effect on cognitive flexibility that was independent of household SES. Moreover, the magnitude of language effects on cognitive flexibility did not differ according to SES. Although speculative, one explanation of the language-cognitive flexibility relation seems plausible. Cognitive flexibility was arguably the most complex and multifaceted of the three EF skills included in the current study. It has been suggested that cognitive flexibility is a higher-order skill than either working memory or inhibitory control and that tests of cognitive flexibility such as the CTMT necessarily place demands on both working memory and inhibitory control in addition to shifting (Miyake et al., 2000). Perhaps it was this complexity that resulted in cognitive flexibility showing a relation to language ability in the current sample when working memory and inhibitory control did not. As a multidimensional measure itself, the CELF-5 language assessment may have required participants to draw on multiple EF skills in a manner at least somewhat compatible with the demands inherent in the CTMT. An additional explanation for the association between language and cognitive flexibility in the current study involves the relation of both sets of skills to cognitive processing speed, as discussed below.

Language and SES. Second, it was hypothesized that children's tested language ability would be related to household SES. Previous studies have found SES-related disparities among school-age children on standardized measures of receptive vocabulary (e.g., Farah et al., 2006; Farkas & Beron, 2004; Rice & Hoffman, 2015), receptive grammar (Farah et al., 2006), and morphosyntax (Reynolds & Fish, 2010). However,

there was no significant bivariate correlation between SES and language in the current study and no significant relation between SES and language when age was controlled. It is possible that the relatively narrow range of SES in this fairly affluent sample served to weaken any relation between language ability and SES that might otherwise have emerged (Baron & Kenny, 1986). In addition, there may have been issues with the way SES was measured, as discussed below.

Executive function and SES. Finally, it was hypothesized that children's performance on measures of working memory, inhibitory control, and cognitive flexibility would be related to household SES. EF skills exhibit a gradual and lengthy course of development throughout childhood and adolescence and as a result may be especially vulnerable to environmental influences such as those associated with family SES (Romine & Reynolds, 2005). Moreover, previous studies have found evidence of significant relations between SES and EF across development (e.g., Hackman et al., 2010). Researchers comparing high- and low-SES groups of children based on composite measures of SES (parental education and occupation along with household income-to-needs ratio) have reported SES-related disparities on tasks of working memory (Farah et al., 2006; Noble et al., 2005, 2007) as well as inhibitory control (Noble et al., 2005, 2007). With another group of typically developing school-age children, Sarsour et al. (2011) found significant associations between SES and performance on the same tasks of working memory, inhibitory control, and cognitive flexibility used in the current study. However, no significant bivariate correlations were found in the present sample of children between SES and any of the three EF measures. Likewise, no significant main

effects of SES on any of the EF tasks were found when age and scores on baseline EF measures were controlled.

The current study's failure to replicate the results of Sarsour et al. (2011), who found a significant association between household SES and all three EF skills in similarly-aged children using the very same tasks, is a puzzling finding. However, two explanations seem plausible. First, the range of SES in the current sample (lower middle class to upper class) was relatively narrow compared with that of Sarsour et al.; one-third of participants in the earlier study were from families below the federal poverty line, and 28% were from families with household income of \$100,000 or higher. Secondly, the discrepancy in results may also stem from differences in how family SES was measured in the two studies. Whereas the current study relied on the parental education and occupational status formula from the Hollingshead (1975) scale, Sarsour et al. (2011) derived a composite SES index for each participant based on income-to-needs ratio, family wealth, occupational status from the Hollingshead scale, and maternal education. For the present study, the decision about how to measure SES was made on both empirical and privacy grounds. Results of a meta-analysis by Sirin (2005) demonstrated that parental education, income, and occupation are all equally valid indicators of household SES that can be used interchangeably. Arguably, occupation may be a more stable indicator than current income as an estimate of overall household financial status (Hauser, 1994). Thus, it was judged that asking caregivers about income would be both unnecessary and undesirable; it was decided to respect caretakers' privacy by not questioning them about income. Nevertheless, it may be the case that broader measures

including all three aspects of SES are optimal when analyzing the influence of family SES on child outcomes.

Results showed no interaction between language ability and SES in relation to working memory or inhibitory control, but a significant SES-language interaction did emerge in relation to cognitive flexibility. Follow-up analyses showed that while there was no significant relation between SES and cognitive flexibility among children with higher language ability, SES was positively related to cognitive flexibility among children with language ability at least 1.5 *SD* below the sample mean (i.e., a standard score of 91). For these children, whose language skills were weaker but still well within the typically developing range, lower SES was associated with lower cognitive flexibility scores.

Broad generalizations may not be appropriate, given the relatively high levels of both language ability and SES in the current sample. Nevertheless, the pattern of results suggests that children with weaker language ability may be particularly vulnerable to any deleterious influence of low SES on cognitive flexibility. Indeed, prior studies have shown significant SES-related disparities in children's developing EF skills, due perhaps to limited household resources, maladaptive caregiver-child interaction patterns, altered stress physiology, or most likely some combination of several factors (e.g., Hackman et al., 2015; Sheridan et al., 2012). The current sample did not include participants from families below the poverty line. However, the findings suggest that children of poverty might be at an especially greater risk of SES-related disparities in cognitive flexibility if language skills are relatively weak.

On the other hand, the findings suggest that stronger language ability might help protect children against SES-related disparities in cognitive flexibility, perhaps due to the overlap between cognitive flexibility and language. As mentioned, language and cognitive flexibility scores were related among the current study's participants, and the two sets of abilities most likely share some of the same underlying skills. As a result, children with relatively strong language proficiency may be at a simultaneous advantage in terms of cognitive flexibility. Thus, greater language ability may serve an important buffering or protective role in helping to shield children from the potentially harmful impact of lower SES on the development of cognitive flexibility. In any case, the current findings can serve to inform future research on the intersecting roles of SES and language ability for children's developing cognitive flexibility.

Factors Associated with Word Learning

The second major aim of the study focused on the influence of language ability, SES, and EF skills on children's word learning performance. It should be noted at the outset that the current study differed from many previous investigations of contextual word learning among school-age children in one important respect: children were exposed to target words and their surrounding context by two routes simultaneously. Participants were asked to read along silently from a computer screen while also listening as stories containing target words were read aloud. Thus, any gains in word knowledge that occurred may have resulted from reading, listening, or both. This method was chosen in order to maximize the chances that children would glean significant semantic information about target words. Contextual word learning is a slow and incremental process; at best, only modest word knowledge gains may accrue upon initial exposure to

unfamiliar words in context (Carey, 1978; Wagovich & Newhoff, 2004). Floor effects in word learning during silent reading are a common problem in the literature, with the meta-analysis by Swanborn and de Glopper (1999) reporting an average word knowledge gain of only eight percent among typically developing fourth graders from incidental word learning tasks.

Results of the current study's multiple-choice measure showed that after reading and listening to target words in context, participants demonstrated significant and practically meaningful gains in word knowledge, with an average gain of 29.5% over pretest. Moreover, it is reasonable to infer that the increase in scores from pretest to posttest in the current study resulted specifically from children's encounters with target words in context in the stories, rather than from mere repeated exposure to the words on the multiple-choice measure. Previous studies have failed to show that multiple encounters with unfamiliar words, in the absence of meaningful context, resulted in significant semantic learning (e.g., Adlof et al., 2016; Wagovich et al., 2015).

The oral definition task was challenging for many participants. Indeed, 12% of children were not able to offer even one partial definition for any of the target words. On average, children earned scores of 9.4 points out of 36 points possible (i.e., 26.2%). This percentage is lower than those reported by Steele (2015) and Steele and Watkins (2010) for typically developing school-age participants. However, both earlier studies employed somewhat different methods that included shorter, one-syllable target nonwords and a dynamic assessment procedure with contextual cues.

Language. It was hypothesized that children's language ability would relate to their performance on experimental word learning measures. Verbal short-term memory

capacity, along with the ability to comprehend semantic relationships and to produce grammatically correct and semantically appropriate sentences, as assessed by the CELF-5, should, at least in theory, aid children in inferring new meanings from surrounding context. Previous studies of semantic word learning during reading have found that children with higher language skills outperform their peers with lower language ability on experimental word learning tasks (Steele, 2015; Steele & Watkins, 2010; Wagovich et al., 2015). However, prior studies have not taken EF skills such as cognitive flexibility into account.

Findings of the current study suggest that for children with language development in the typical range, the contribution of language ability to the word learning process may vary according to children's cognitive flexibility skills. Among children with lower cognitive flexibility (1.0 *SD* or more below the sample mean), language ability was positively related to word learning performance. For these children, greater language ability was associated with higher scores on both word learning tasks. In contrast, results showed no significant relation between language ability and word learning scores among children with cognitive flexibility at the sample mean or higher. Thus, language ability may be especially critical to the word learning process for children with weaker cognitive flexibility skills and may play an important compensatory role in supporting word learning from context if cognitive flexibility is lacking.

In contrast, no significant interactions were found between language and SES, working memory, or inhibitory control in relation to scores on either word learning measure. At least for this sample of typically-developing children from relatively affluent homes, language ability was positively related to word learning performance

regardless of household SES or children's level of working memory or inhibitory control. Whether this result would hold for children of lower-SES families, especially children of poverty, or for children with development outside the typical range is uncertain and deserves further study.

Receptive vocabulary. The role of receptive vocabulary in the word learning process is controversial. Some authors have argued that standardized vocabulary tests primarily measure crystallized, culturally-specific knowledge and, as such, may not fairly or accurately represent children's actual word learning abilities (Campbell et al., 1997; de Villiers, 2004; Johnson, 2010; Johnson & de Villiers, 2009; Stockman, 2001). The empirical evidence is also mixed. Several studies, mostly with young children, have not found significant relations between children's scores on standardized vocabulary measures and their performance on experimental word learning tasks (Burton & Watkins, 2007; Horton-Ikard & Ellis Weismer, 2007; Majerus & Boukebza, 2013; Spencer & Schuele, 2012). However, other researchers have reported significant relations between standardized vocabulary measures and experimental word learning among typically developing school-age children (de Leeuw et al., 2014; Ricketts et al., 2011; Shefelbine, 1990).

Although the relation of receptive vocabulary to word learning was not a primary focus of the current study, results showed that receptive vocabulary was moderately to strongly correlated with children's scores on both experimental word learning tasks. After adjusting for age, pre-existing knowledge of target words, and scores on common words, receptive vocabulary had a medium effect on multiple-choice posttest scores and a large effect on oral definition scores. These results confirm those of other researchers

who have likewise found a relation between receptive vocabulary and performance on word learning measures among typically developing school-age children (de Leeuw et al., 2014; Ricketts et al., 2011; Shefelbine, 1990). It should be noted that because the current results are only correlational, no claims can be made as to the direction of effect between receptive vocabulary and the word learning process. Although it is certainly plausible that a larger pre-existing vocabulary could facilitate children's word learning, it is also likely that children with greater skill in word learning amass larger vocabularies over time (and thus earn higher scores on standardized vocabulary measures; Gellert & Elbro, 2013).

Socioeconomic status. It was hypothesized that SES would not relate to word learning performance in the current study. Although numerous studies have found SES-related disparities in children's vocabulary (e.g., Farah et al., 2006; Hart & Risley, 1995; Noble et al., 2007), there is no evidence to indicate that SES influences the word learning process itself. Two previous studies with young children did not find SES-related disparities on experimental word learning tasks (Burton & Watkins, 2007; Horton-Ikard & Ellis Weismer, 2007). A more recent study with preschoolers (Kaefer et al., 2015) found SES-related effects on word learning that disappeared when relevant background knowledge was experimentally controlled. These findings were largely confirmed in the current study. Although SES was significantly correlated with children's scores on the multiple-choice posttest measure and marginally correlated with scores on the oral definition task, SES became nonsignificant when age, prior knowledge of target words, and scores on common words were taken into account. Admittedly, the lack of significant SES effects could have stemmed from the relatively limited range of SES

among the current set of participants. Future studies with children of lower SES backgrounds might shed further light on this question.

It is also worth mentioning that SES was correlated with performance on the multiple-choice posttest but not with scores on the standardized tests of language or receptive vocabulary. Thus, the experimental word learning task may have been more sensitive to subtle SES-related disparities in language learning than the standardized tests of language and receptive vocabulary. Finally, although SES did not relate directly to word learning in the current study, SES may nevertheless play an indirect role in word learning through its influence on cognitive flexibility, particularly among children whose language skills are relatively weak.

Executive function. It was hypothesized that the EF skills of working memory, inhibitory control, and cognitive flexibility would relate to children's performance on experimental measures of word learning. On a theoretical level, it was expected that working memory might aid children in remembering contextual semantic information about target words, that inhibitory control might assist children in suppressing irrelevant information, and that cognitive flexibility might enable children to switch between comprehending text and making inferences about word meaning. Although empirical studies are few, previous findings suggest that children's EF skills may predict performance on experimental word learning tasks (e.g., Cain et al., 2003, 2004; Côté et al., 2014; Kapa & Colombo, 2014; Majerus & Boukebza, 2013; Yoshida et al., 2011). However, this hypothesis was only partially supported. Results showed no significant relation between working memory or inhibitory control and word learning outcomes, either as main effects or in interaction with language or SES.

Again, it is possible that the tasks chosen to assess EF in the current study were not adequately representative of children's skills in working memory or inhibitory control. In addition, any effects of EF abilities on word learning might be revealed more effectively through direct manipulation of the EF demands inherent in experimental word learning tasks. For example, children's performance could be compared across contexts designed to be relatively more or less demanding in terms of working memory (e.g., by including helpful context that is relatively near or far from target words; Cain et al., 2003). Likewise, the effects of inhibitory control on word learning might be studied by varying the level of extraneous or irrelevant information included in the context surrounding target words.

Of the three EF skills included in the current study, only cognitive flexibility was shown to relate to children's word learning performance, and only for the multiple-choice measure. In addition, the relation of cognitive flexibility to multiple-choice posttest scores differed according to language ability. Cognitive flexibility made a positive contribution to posttest scores among children whose language ability, though still well within the typical range, was relatively weaker (1.0 *SD* or more below the sample mean). For these children, greater cognitive flexibility was associated with better word learning performance. However, no relation between cognitive flexibility and word learning was found among children with stronger language ability. Thus, cognitive flexibility may be especially crucial to the word learning process for children with lower language ability and may serve in a compensatory role when language is relatively weak. These findings mirror the results, already discussed, suggesting a greater impact of language ability on word learning for children with lower cognitive flexibility skills. Either language or

cognitive flexibility may, in parallel fashion, support the word learning process when the other set of skills is relatively limited.

In contrast, cognitive flexibility was not significantly related to children's oral definition scores, regardless of their level of language ability. Although speculative, one explanation seems most plausible. Skill in cognitive flexibility may not have proven very useful when children were asked to generate expressive definitions of target words. For such a task, language ability or vocabulary may have been more beneficial for explaining the meaning of a word. On the other hand, it is easier to see how cognitive flexibility may have boosted performance on the receptive multiple-choice posttest. For this measure, children were required to choose among alternative definitions presented on the computer screen. Greater skill in cognitive flexibility may well have aided children in shifting between comprehending the presented alternatives, eliminating obviously wrong answers, and remembering the context in which each target word had been presented.

Practical and Theoretical Implications

The current study's findings suggest that language ability and cognitive flexibility may share, at least in part, a common set of underlying skills. One possibility, supported by recent research findings, is that individual differences in both cognitive flexibility and vocabulary development may stem from individual differences in cognitive processing speed that emerge very early in life (Cuevas & Bell, 2014; Fernald & Marchman, 2012; for a review of early influences on EF, see Hendry, Jones, & Charman, 2016). For instance, Cuevas and Bell (2014) found that processing speed measured at the age of five months predicted later performance on tasks of EF, especially cognitive flexibility, at ages 24, 36, and 48 months. With regard to language development, Fernald and

Marchman (2012) reported that lexical processing efficiency at 18 months of age predicted growth in expressive vocabulary from ages 18 to 40 months in both typically developing and late-talking toddlers. Thus, it is possible that processing speed, as measured by tasks that are either primarily nonverbal or verbal, may at least partially account for the relation between cognitive flexibility and language that was found in the current study.

SES-related individual differences in processing speed may also help explain SES-associated disparities in vocabulary development among young children (Fernald, Marchman, & Weisleder, 2013; Weisleder & Fernald, 2013). In a prospective longitudinal study, Fernald et al. (2013) found significant SES-related disparities in both lexical processing efficiency and expressive vocabulary that were evident at 18 months of age, with a six-month gap in development between lower- and higher-SES groups by 24 months of age. A further longitudinal study comparing young children from lower- and higher-SES homes found that SES-related disparities in child-directed speech predicted group differences in subsequent vocabulary growth; SES-associated differences in lexical processing speed were found to mediate the relation between child-directed speech and vocabulary development. The authors suggested that young children's direct experience with language may facilitate faster processing speed and that discrepancies in vocabulary development among children from lower-SES homes may stem from SES-related differences in processing efficiency that are traceable to lower levels of child-directed speech from parents and caregivers.

The current results, though only correlational, suggest that the effects of language and cognitive flexibility are bidirectional. Just as language may support the development

of cognitive flexibility among school-age children, so too may cognitive flexibility support the development of language. Even so, language may be of paramount importance among children of lower-SES homes. Although speculative, it is possible that for these children especially, stronger language ability may serve to buffer any deleterious effects of low SES on cognitive flexibility. Therefore, educational efforts that emphasize the development of improved language skills for children of less-privileged backgrounds may result in benefits not only for enhanced language development but also for the development of complex EF skills such as cognitive flexibility.

Regarding SES and its impact on child developmental outcomes, the current findings also highlight some difficult issues regarding how SES is conceived and measured. Indicators such as parental education, occupation, and income are only useful to the extent that they index the level of daily SES-related stress and deprivation that children face in their daily lives. Even among families below the poverty line, there is considerable heterogeneity in the level of daily poverty-related stressors that children encounter, as well as individual differences in the coping strategies employed by caregivers (Ackerman, Brown, & Izard, 2003; Brown, Seyler, Knorr, & Garnett, 2016). Perhaps instead of evaluating household SES based on generic indicators such as education, occupation, or income, it would be useful to evaluate more proximal factors such as children's daily SES-related stress and coping directly. Such an approach might be especially helpful when examining the contribution of SES to children's persistence on challenging experimental tasks such as the word learning measures in the current study. A recent study with Head Start preschoolers demonstrated that daily poverty-related stress, but not family income-to-needs ratio, predicted children's persistence on a

challenging puzzle task (Brown et al., 2016). Moreover, there is recent longitudinal evidence that persistence at least partially accounts for the relation between SES and educational outcomes (Whipple, Genero, & Evans, 2016). Studies that include measures of persistence as well as SES-related daily stress might shed more light on the underlying processes involved in SES's impact on children's development.

The current study's findings suggest that for the word learning process, there might be some trade-off between language ability and cognitive flexibility. Children with language abilities that are relatively lower, though still within the typical range, might rely more heavily on cognitive flexibility in learning the meanings of target words, while children with weaker cognitive flexibility might rely more on language ability. At a basic level, this pattern of results suggests that children may naturally draw upon those abilities that come more easily to them and thereby self-compensate for areas which may be weak. A further implication is that children with limitations in both language ability and cognitive flexibility may be at particular risk in terms of contextual word learning and may require additional ongoing and focused support from educators or speech-language pathologists to develop strong vocabularies.

Limitations

There were several limitations to the current study. As with any correlational design, findings can point to patterns of association among variables but cannot provide any definitive evidence of causality. As mentioned, the relatively narrow range of SES in the study, perhaps exacerbated by the methods used to estimate household SES, may have attenuated any association between SES and other factors. In addition, a greater variety of EF measures may have better gauged participants' EF skills (Yang & Gray,

2017). Furthermore, some researchers have recently suggested that to demonstrate more convincing relations between language ability and domain-general cognitive skills such as EF, studies should incorporate visually-based, non-linguistic EF tasks (e.g., Kaushanskaya et al., 2017; Yang & Gray, 2017). However, the visual/linguistic dichotomy may not be an entirely valid distinction, because all experimental EF measures necessarily involve a certain verbal component. At the very least, participants must comprehend, remember, and follow verbally-presented instructions and prompts when performing EF tasks.

Although the current study's sample size was not large, power analyses indicated that the sample was adequate for detecting clinically- and educationally-relevant medium to large effects. Admittedly, the sample was not balanced in terms of either gender or race/ethnicity; more boys than girls took part in the study, and the great majority of participants were White and non-Hispanic. However, analyses showed no significant differences in any of the independent or dependent variables based on either gender or race/ethnicity. In addition, because it was decided to include rare but real target words in the current study rather than experimental nonwords, some participants were able to demonstrate a significant level of pre-existing target word knowledge. Although this may be viewed as a design flaw, studies that include naturally occurring variability in children's pre-existing word knowledge can also allow researchers to explore the effects of such pre-existing knowledge in relation to other variables. Lastly, there were no follow-up sessions included in the current study, because the intent was only to examine children's initial learning of word meanings from context (i.e., fast mapping). Further

studies might include additional follow-up sessions to evaluate children's short- or long-term retention of newly-acquired word meanings.

Future Directions

The present study focused only on typically developing children. Future studies should be extended to special populations of children to examine the joint contribution of EF skills and language ability to the contextual word learning process among children with development outside the typical range. For example, a recent study found that young children with language disorders performed more poorly on several EF measures than peers with typical language development (Yang & Gray, 2017). However, it is still unknown whether such differences exist among school-age children or whether the contribution of EF skills to the word learning process might differ between children with language disorders and children with typical development. Current findings suggest that for typically developing children, cognitive flexibility might serve to compensate for relatively weaker language skills in the word learning process. Future studies could shed light on whether interventions targeted to improve cognitive flexibility skills might also support contextual word learning for children with language impairment.

Future studies might also focus on word learning among children with neurodevelopmental disorders. For example, children with autism spectrum disorders and attention deficit disorders often show deficits in various EF skills (Craig et al., 2016), but how such EF skills might contribute to the word learning process among children with these disorders has yet to be explored. Future research efforts could examine the relative contribution of EF and language ability to the word learning process among children with neurodevelopmental disorders and ultimately enable clinicians to design

more effective EF- or language-focused interventions to promote word learning among individual children.

Future research should also explore the word learning process among children with proficiency in more than one language. Research has shown that young typically developing children who are bilingual may exhibit EF skills that are more advanced than those of their monolingual peers, and that these differences may translate into better word learning among bilingual children (Yoshida et al., 2011). Further studies should focus on the word learning process among school-age bilingual children to examine whether fluency in more than one language might confer an advantage in both EF and word learning. Ultimately, a clearer understanding of the interplay between bilingualism, EF, and word learning could help clinicians and educators provide more effective learning experiences to enhance vocabulary development among bilingual or multilingual children as well as their monolingual peers.

The current findings also underline some problematic methodological issues regarding the assessment of children's EF skills. A lack of association between EF measures and other variables may derive from random error inherent in the measures themselves or from the use of single measures rather than from any real lack of relatedness among the skills those measures were intended to assess. Factor analysis can be a potent tool for circumventing such problems with measurement error. Though not new, factor analytic methods are increasingly utilized in studies of child language. For instance, a recent study using latent variable analysis found significant relations between EF skills and latent factors representing lexical-semantic and syntactic abilities among typically developing school-age children (Kaushanskaya et al., 2017).

Future studies should also incorporate longitudinal methods to explore changes in the word learning process as children grow older. Although age was treated in the current study as a control variable, results showed that children's performance on both word learning measures improved greatly with age. Whereas nine-year-old children responded correctly to about 41% of multiple-choice posttest items on average, 11-year-old children responded correctly on average to almost 61%. Even greater age-related differences were found on the oral definition task, with nine-year-old participants earning an average score of only 14% but 11-year-old participants earning an average score of 40%. Longitudinal studies might further our understanding of how age-related improvements in vocabulary, language ability, morphological analysis, EF, or other cognitive skills might act singly or together in support of contextual word learning.

A final point concerns poverty-related effects on learning. The present investigation included children from relatively affluent families. It is imperative that future studies of the word learning process be extended to lower-SES populations and especially to children living in poverty. Research has shown that the harmful effects of low SES on brain structure and function may be markedly more severe among the most disadvantaged children (Noble et al., 2015). A better understanding of how SES, EF skills, and language ability interact in the word learning process among children of poverty will ultimately enable the design of more effective and targeted interventions to support vocabulary development among these most vulnerable children.

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Appendix A

Pilot Study

Chapter 1 outlines the theoretical rationale for the proposed study and poses a series of questions that the study was intended to address. However, before commencing the main study, a pilot study was conducted to address methodological issues of design, stimuli, and procedure. The pilot study had several specific aims: (a) to verify that target words were indeed relatively unfamiliar to participants at pretest; (b) to explore whether the experimental word learning task would result in practically significant gains in word knowledge; (c) to discover the level of semantic information about target words that participants would express immediately after exposure to the words in stories; (d) to analyze differences, if any, according to the lexical form class of target words; and (e) to select the two (out of four possible) stories that were most supportive of word knowledge growth. In light of the multiple assessments and tasks to be administered to each participant, and with a view toward minimizing participant fatigue and maximizing attention to the experimental word learning task, it was judged that two stories would provide an optimal learning opportunity. Results of the pilot study allowed for a strengthening of the study as originally conceived and led to the methods described in Chapter 2.

Method

Participants. The pilot study included 10 children (four boys, six girls) with typical development and normal hearing between the ages of 9;0 and 11;7 (years;months; M age = 10;3, SD = .9 years). Because the experimental procedure involved reading as well as listening, this age range was chosen to maximize the likelihood that participants would have mastered the basics of beginning reading. For example, typically developing readers in this age range are expected to be proficient at decoding, to have an extensive

sight vocabulary, and to read fluently at approximately 80-110 words per minute (Fountas & Pinnell, 1996). By the age of nine, typically developing children are expected to be capable of gaining new knowledge, including knowledge of word meanings, through independent reading (Chall, 1983).

A questionnaire was administered to caregivers to obtain information about children's developmental history along with age, gender, and race/ethnicity. According to parent report, all participants had language, reading, and nonverbal cognitive skills in the typical range. Questionnaire responses were also used to derive a numerical estimate of each family's SES (Hollingshead, 1975). Estimates of household SES ranged from 38 (skilled craftsmen, clerical and sales workers) to 61 (major professionals), with most families falling in the major professional range. All parents were compensated for their children's participation.

Experimental stimuli. *Rare words.* Twenty-four rare target words were chosen from GRE word lists (majortests.com, 2015). All words are two syllables in length and conform to standard English orthographic patterns (i.e., no exception words). Eight of the words are nouns, eight are verbs, and eight are adjectives. A list of the target words is provided in Table A1, and a list of target words with definitions is presented in Appendix B. Based on information available in online psycholinguistic databases (Brybaert, Warriner, & Kuperman, 2014; Kuperman, Stadthagen-Gonzalez, & Brybaert, 2012; Vaden, Halpin, & Hickock, 2009; Washington University Speech & Hearing Lab Neighborhood Database, 2016), target words were found to have the following lexical characteristics: age of acquisition, mean = 13.86 ($SD = 1.21$); frequency, mean = .28 per million ($SD = .25$); familiarity, mean = 4.42 ($SD = 1.27$); concreteness, mean = 2.10 (SD

= .79); number of phonemes, mean = 5.71 ($SD = .86$); neighborhood density, mean = 1.74 ($SD = 2.0$); phonotactic probability (biphoneme), mean = .004 ($SD = .002$). These characteristics do not differ between nouns and verbs ($t = .44 - .92, p = .37 - .67$); between nouns and adjectives ($t = .06 - .93, p = .37 - .95$); or between verbs and adjectives ($t = .04 - 1.0, p = .33 - .97$).

Table A1.

Pilot Target Words.

Nouns:	Verbs:	Adjectives:
Carping	Assuage	Abstruse
Censure	Delude	Adroit
Cyborg	Discern	Banal
Foible	Forestall	Bereft
Greenhorn	Nettle	Inured
Kudos	Purloin	Maudlin
Largesse	Quibble	Replete
Pittance	Supplant	Vapid

Six target words (two nouns, two verbs, two adjectives) were inserted into each of four stories (described below). An average target word density of one target word per 150 words of text was chosen in order to maximize participants' word knowledge growth. Swanborn and de Glopper's (1999) meta-analysis found that the likelihood of word learning was greatest when the density of target words was held to one in 150 words or lower. Target words were distributed as evenly as possible within each story, and the text of the stories was altered as necessary to provide contextual support for target word

meaning. Target words in each story were highlighted in bold, colored font to draw participants' attention to the words.

Common words. In addition to rare target words, six two-syllable common words (two nouns, two verbs, two adjectives) that were presumably already familiar to the participants were highlighted in bold, colored font. These words are *early*, *decide*, *kitchen*, *morning*, *review*, and *second*. The common words have an average age of acquisition of 5.29 ($SD = 2.34$) and a mean frequency of 159.19 per million ($SD = 167.03$). Target and common words do not differ significantly on any other lexical characteristic ($t = 0 - .63, p = .53 \rightarrow .99$). Participants' responses to common words were examined in order to confirm their overall attentiveness and understanding of task demands.

Stories. Four stories, averaging 900 words each, served as context for the target words (ReadWorks.org, 2015). All of the stories contain themes thought to be of general interest among nine- to 11-year-old children (e.g., a student plays a practical joke on his classmates and teacher; two friends try out for the school basketball team). Lexile levels for the four stories range from 500 to 600 (i.e., third-grade reading level). In presenting the stories, the intent was twofold: (a) to ensure that the text would be decoded accurately and (b) to minimize the effort needed for decoding and allow greater cognitive resources to be available for comprehending text and inferring word meaning (Just & Carpenter, 1992; Perfetti, 1985, 2010). Therefore, children heard the text of the stories while simultaneously following along with visually presented verbatim text on a computer screen. The four stories, with target words highlighted, can be found in Appendix C.

Based on a procedure described by Beck et al. (1983), a cloze task was used to evaluate how well the story contexts serve to support target word meaning. Sentences containing target words from the stories were presented to a group of 46 college undergraduate volunteers, but with target words blanked out. Volunteers were asked to read the sentences and supply a word they thought would best complete each sentence. It was not expected that volunteers would supply the actual target words, because these words are relatively rare. However, common synonyms of target words were supplied by volunteers 85% of the time, on average ($SD = .23$). In a similar study with adult participants, Beck et al. found that correct target words (or synonyms) were supplied 86% of the time in contexts that were worded to be highly directive or supportive of word meaning and 49% of the time in contexts that were generally supportive but not as highly directive. Therefore, it was concluded that the stories provide good overall contextual support for target word meaning.

Oral definition task. An oral definition task assessed participants' ability to generate semantic information about target words. Following the procedure of Steele and Watkins (2010), participants were presented with the orthographic forms of target words from each story and were asked to pronounce and define each word. Any incorrect pronunciations were corrected by the examiner. If participants did not supply a correct or complete definition, follow-up questions were asked, as necessary, to elicit further responses. If participants could not offer any definition, they were asked if the target word reminded them of anything. If participants offered a vague response, they were asked for a specific example. If participants offered an incomplete definition, they were asked if they could give any additional information. The most complete definition

provided for each word was coded on a four-point scale: 0 (no response or incorrect definition); 1 (vague response); 2 (correct but incomplete definition); 3 (complete, correct definition).

Multiple-choice measure. A set of 24 four-choice multiple-choice items assessed participants' receptive understanding of target word meanings, and six multiple-choice items assessed participants' receptive understanding of common words. The stem for each item was presented both visually and auditorily by computer, with target word highlighted (e.g., "The word **vapid** means something like . . ."). Participants chose from among four responses presented on the computer screen via text only. Correct answer choices occurred an equal number of times in first, second, third, and fourth position among the available answer choices. Each foil was a correct definition for a different target or common word. Care was taken in constructing the items so that participants would be less likely to confuse the multiple target words within each story. An error analysis of Steele and Watkins' (2010) word learning study found that some participants tended to err by choosing a correct definition for a different target word in a story (Steele, 2013). Therefore, each of the three foils in every item is a definition of a target or common word from one of the other three stories. The order in which items were presented was randomized across participants, and participants were administered a different randomization at each experimental session. An initial practice item was presented to familiarize participants with the procedure, but responses to the practice item were not included in analyses. Responses to all other items were coded as either 1 (correct) or 0 (incorrect). A list of all 30 multiple-choice items plus the practice item is provided in Appendix D.

Procedures. Each participant took part in two sessions, one week apart. During the first session, after obtaining parental consent and child assent, participants were administered the multiple-choice measure as a pretest to assess prior knowledge of target words. A hearing screening was also administered during Session 1, and caregivers completed the parental questionnaire.

During Session 2, one week later, participants read and listened to the four stories (order randomized across participants). Stories were presented visually and auditorily by computer at an average rate of 114.4 words per minute. At the end of each story, the oral definition task was administered. After the fourth story and accompanying oral definition task, participants again completed the multiple-choice measure as a posttest.

Results

Common words. Participants' pre- and posttest responses to common words were examined first, to verify general attentiveness and understanding of task demands. On average, participants' responses on common words were correct 96.7% of the time at pretest ($SD = 8\%$, range = 80 – 100%) and 95% of the time at posttest ($SD = 8\%$, range = 80 -100%). This result suggests that overall, participants did understand and attend to the experimental task.

Pretest word knowledge. On average, participants responded correctly to 11 of the 24 target words at pretest ($SD = 2.1$, range = 8 – 15), representing a 45.8% mean level of correct responding. Although pretest performance did not differ significantly from chance, or 25% correct responding ($t = .000004$, $p > .99$) due to the small sample size, results suggest that participants had at least partial knowledge of some target words. On a descriptive level, 18 of the target words were associated with better-than-chance

performance at pretest. Of these, five were from the story “Davy is Absent,” three were from “Lizzie Escapes,” five were from “Making the Team,” and five were from “World’s Greatest Robot.”

Growth in word knowledge. The majority of participants demonstrated gains in word knowledge from pretest to posttest, with wide variability among participants in posttest scores and pretest-posttest gains. On average, participants scored 14.14 points out of 24 possible at posttest ($SD = 4.1$, range = 9 - 22), or a mean level of 58.9% correct. Percent change from pretest ranged from a decrease of 15.4% to an increase of 100% ($M = \text{gain of } 32.4\%$, $SD = 41.1\%$). Although pretest and posttest scores did not differ significantly ($t = .055$, $p = .96$), again owing to large variability and small sample size, overall gains at posttest were associated with a large effect size (Cohen’s $d = 0.96$).

Oral definition task. Participants also ranged widely in expressive word knowledge as assessed by the oral definition task. The mean total score was 21.67 points out of 72 possible ($SD = 10.32$, range = 6 - 36), or 30% of complete and correct word knowledge.

Lexical form class analysis. Because the target words included an equal number of nouns, verbs, and adjectives, performance for each lexical form class was compared. Table A2 presents mean scores at pretest and posttest, mean word knowledge gains, and mean oral definition scores for target words in each class.

Although on a descriptive level participants earned higher scores on nouns at pretest, there were no statistically significant differences at pretest between nouns and verbs ($t = .08$, $p = .93$), between nouns and adjectives ($t = .06$, $p = .95$), or between verbs and adjectives ($t = .87$, $p = .39$). Likewise, although scores were higher on nouns and

verbs at posttest, there were no significant differences between lexical classes at posttest ($t = .03 - 1.0, p = .32 - .98$) and no significant differences in gain scores ($t = .22 - .36, p = .44 - .83$). For expressive word knowledge as assessed by the oral definition task, performance was best for nouns and worst for adjectives, with intermediate performance for verbs. However, these differences were not statistically significant ($t = .0007 - .17, p = .87 - .99$).

On a practical level, the gain score advantage for verbs was associated with a small effect size when compared with both nouns (Cohen's $d = 0.20$) and adjectives (Cohen's $d = 0.25$). For expressive word knowledge, the advantage for nouns was associated with a small effect size when compared with verbs (Cohen's $d = 0.36$) and a medium effect size when compared with adjectives (Cohen's $d = 0.58$). Expressive knowledge of verbs and adjectives was similar, with a Cohen's d effect size of only 0.19.

Table A2.

Mean scores by lexical form class.

	Nouns	Verbs	Adjectives
Pretest	.55 (.50)	.41 (.50)	.40 (.49)
Posttest	.64 (.48)	.64 (.48)	.45 (.50)
Gain	.09 (.62)	.23 (.73)	.05 (.69)
Expressive	.44 (.49)	.27 (.45)	.19 (.37)

Note: Scores represent mean proportion correct (SD in parentheses).

Story comparison. Performance on target words in each of the four stories was compared to analyze which stories might be most supportive of children's word

knowledge growth. Table A3 presents mean pretest and posttest scores, mean word knowledge gains, and mean oral definition scores for target words in each story.

There were no statistically significant differences between any of the stories in average pretest performance ($t = .38 - .92, p = .38 - .81$), average posttest performance ($t = .44 - .93, p = .37 - .67$), average gains ($t = .09 - .91, p = .38 - .93$), or expressive word knowledge ($t = .01 - .86, p = .41 - .99$). On a descriptive level, however, when analyzing percent gain for posttest over pretest, there were gains of 19% for “Davy is Absent” and 67% for “Lizzie Escapes” but only nine percent for “Making the Team” and 15% for “World’s Greatest Robot.”

Table A3.

Mean scores by story.

	Davy	Lizzie	Team	Robot
Pretest	.48 (.19)	.40 (.24)	.42 (.25)	.52 (.33)
Posttest	.57 (.24)	.67 (.27)	.45 (.31)	.60 (.35)
Gain	.09 (3.22)	.27 (1.22)	.03 (.66)	.08 (.93)
Expressive	.17 (.10)	.44 (.12)	.28 (.15)	.31 (.35)

Note: Scores represent mean proportion correct (SD in parentheses). Davy = “Davy is Absent,” Lizzie = “Lizzie Escapes,” Team = “Making the Team,” Robot = “World’s Greatest Robot.”

Discussion

Results of this pilot study were informative with respect to five separate issues: (a) participants’ preexisting level of semantic word knowledge of target words; (b) overall word knowledge gains after reading and listening to stories containing target words; (c) expressive word knowledge after exposure to the stories; (d) differences, if

any, according to the lexical form class of target words; and (e) the selection of stories most conducive to word knowledge growth.

Preexisting word knowledge. The finding that participants, as a group, demonstrated some semantic knowledge of target words is perhaps not surprising, given the educational level of caregivers (most households had at least one parent with a graduate degree and with occupational status in the “major professional” category). Although it remains to be seen whether such strong pretest performance will be found among participants from families with more diverse educational backgrounds in the main phase of the study, this result nevertheless makes clear the importance of choosing stories with fewer target words showing better-than-chance performance at pretest. As a pair, “Davy is Absent” and “Lizzie Escapes” had fewer such words than “Making the Team” and “World’s Greatest Robot.”

Word knowledge gains. As a group, participants ranged widely in word knowledge gain from pretest to posttest. Although gains were not statistically significant for this small pilot sample, the average gain was positive and associated with a large effect size. Thus, it can be concluded that overall, participants did demonstrate practically meaningful gains in word knowledge after exposure to target words in stories. Moreover, the wide variability in word knowledge growth among participants suggests that further investigation to account for such individual differences is warranted.

Expressive word knowledge. There was also great variability in the level of semantic knowledge expressed by participants on the oral definition task. The mean level of expressive word knowledge (30%) was somewhat lower than that reported by Steele and Watkins (2010) for a similar word learning task with nine- to 11-year-old typically

developing children. Although Steele and Watkins found average oral definition scores of 43%, their study differed from the current study in several respects. For example, Steele and Watkins' narrative passages were shorter, and target words, which were novel rather than real words, were both fewer and shorter than the target words in this pilot study. In addition, Steele and Watkins' participants read the passages silently rather than reading along as passages were presented visually and auditorily.

Lexical form class. Although there were no statistically significant differences among words in different classes for pretest, posttest, gain scores, or oral definition scores, some differences may be of practical significance. Gains from pretest to posttest were greater for verbs than for nouns or adjectives. For expressive word knowledge, performance was best on nouns, intermediate on verbs, and worst on adjectives. These effects were associated with small to medium effect sizes.

Story selection. In consideration of the multiple assessments and experimental tasks that participants will be asked to complete in the course of two sessions, it was judged that two (rather than four) stories would be optimal for the purposes of minimizing fatigue, maintaining attention to task, and maximizing performance. Although there were no statistically significant differences between stories for this small pilot sample, some practically significant differences did emerge. In combination, target words in "Davy is Absent" and "Lizzie Escapes" showed both lower average pretest scores and greater average percent gains at posttest than target words in "Making the Team" and "World's Greatest Robot." Therefore, a decision was made to retain "Davy is Absent" and "Lizzie Escapes" for inclusion in the main phase of the study.

Appendix B

Target Words with Definitions

Nouns:

1. **Carping:** constant nagging
2. **Censure:** strong disapproval or blame
3. Cyborg: a human-like machine
4. Foible: a minor weakness
5. Greenhorn: a beginner
6. **Kudos:** strong praise
7. **Largesse:** a valuable gift
8. Pittance: a very small amount

Verbs:

1. Assuage: to soothe or relieve
2. **Delude:** to trick or mislead
3. Discern: to see or notice something
4. **Forestall:** to delay or prevent
5. Nettle: to annoy or provoke
6. **Purloin:** to steal
7. Quibble: to argue about minor things
8. **Supplant:** to switch one thing for another

Adjectives:

1. **Abstruse:** difficult to understand
2. **Adroit:** skillful
3. Banal: common or ordinary
4. Bereft: sadly going without
5. Inured: hardened or tough
6. **Maudlin:** tearful or overly emotional
7. Replete: filled
8. **Vapid:** dull or unexciting

Common Words:

1. Decide: to put together or construct
2. **Early:** before others
3. Kitchen: a room where food is prepared
4. **Morning:** the early part of the day
5. **Review:** to go over something, such as a lesson
6. Second: after first and before third

Note: All of the above words were used in the pilot study, but only words in bold font will be included in the study's main phase.

Appendix C

Stories with Target Words Highlighted

Story 1

Davy Is Absent

“Can anyone tell me where Davy is?” Miss Mastiff asks.

“I saw Davy last night,” says Lolly. “My family went to his house for dinner.”

“But today his seat is empty,” says Miss Mastiff. “Marcos, maybe you know where your twin brother is. Can you tell the class where Davy is?”

“Certainly, Miss Mastiff. Easy as pie,” says Marcos. “Davy is here in class.”

The entire classroom bursts into laughter.

Marcos laughs along with the rest of the class. No one is surprised, because everyone knows how good-natured he is. Marcos has the best sense of humor in the class.

But Miss Mastiff is not amused. “We can all see Davy’s seat is empty, Marcos. Davy must be absent.”

“You may be right, Miss Mastiff,” says Marcos with a smile. “But maybe not.”

“How odd,” says Miss Mastiff, but she begins the lesson anyway. The class has a math exam at the end of the week, and there is a lot of material to review.

Later in the lesson, Miss Mastiff asks, “If there are twenty-seven students and twenty-eight chairs in a classroom, how many chairs are there for every student? Marcos, since you’re so **adroit** at math, would you please answer?”

No one is surprised that Miss Mastiff calls on Marcos. Everyone in the class knows how good he is in math.

“Certainly!” says Marcos. “Easy as pie. Every student has one chair. Sure as my name’s Marcos!”

“You may be right,” Miss Mastiff smiles. “But maybe not.”

It's recess. Marcos walks by Ella, who is talking with Miss Mastiff. Ella says, "Say Marcos, where's your brother really? I know he isn't playing hooky because Davy never lies. Is he sick?"

"No sicker than you, Ella. No sicker than Miss Mastiff, either."

"But I am sick," Miss Mastiff says. "I've had a terrible cold for weeks. Can't you hear how hoarse my voice is?" She does sound awful.

"Oh, that's right," says Marcos. "I forgot. Isn't it odd the way you can forget a thing like that? When something has been odd for long enough, it starts to seem ordinary. On the other hand, something can be completely obvious and easy to understand, but everyone thinks it's totally **abstruse!**" Marcos laughs happily and runs off after Lolly.

"Well, I sure don't get it . . . there **must** be something odd going on!" says Ella. "Wouldn't you say so, Miss Mastiff?"

"Odd indeed, Ella. Sure as my name's Miss Mastiff!" Miss Mastiff sneezes.

"Next, we'll practice a word problem," says Miss Mastiff, later that afternoon. She passes out a photocopied sheet of paper. "Lolly, would you please read it aloud?"

Lolly reads: "Papa has cut the pie so that everyone will get an even-sized slice. There are four members of Papa's family, and five members of the family Papa invited over. But before dinnertime, the two naughty brothers decide to **purloin** the pie and split the whole thing between them. How many slices do the two brothers each eat?"

"Marcos, you're so good at math," says Miss Mastiff, giving Marcos more **kudos** for his math skill. "Maybe you'd like to show the class how to solve the problem."

"Certainly. Easy as pie! Four members of my family plus five members of Lolly's family means nine people altogether, nine slices of pie. Now, nine slices of pie between

my brother and me means we each get . . . uh . . . we each get . . .” Marcos’ voice trails off, and his face turns red.

“You see,” says Miss Mastiff, “nine is an odd number and so it cannot be evenly divided between two people. One of the brothers must have had four slices of pie, while the other one had five. The one who ate five is sick. Perhaps that is why he is absent from class.” There is a twinkle in Miss Mastiff’s eye.

“You’re wrong!” says Marcos loudly. “Davy only ate four slices.”

“Precisely!” says Ella. “Marcos ate five slices. Marcos is absent. You’ve been trying to **delude** us all along! *You’re* Davy. Marcos is good at math. He must’ve known that nine divided by two is four and one half. He let you think it was four, so that he could eat five slices. Davy, you’re not so good at math, but you’re always honest. You said, ‘Davy is in class,’ and ‘Davy isn’t sick.’ You never once lied. That’s how I knew it was you.”

“It’s true!” cries Davy. “I’m so sorry! It’s all my fault, and I’m the one who deserves **censure**! If I had only been better at fractions, Marcos and I would have eaten the same amount, and poor Marcos wouldn’t be sick. It’s because of me that Marcos is absent. If only I had been better with fractions! Oh, Miss Mastiff! I promise to study for the test!”

“I’m sure you’ll do just fine,” says Miss Mastiff with a wink. “Just remember, Davy: Fractions are as easy as pie.”

Story 2

Lizzie Escapes

Lizzie vowed that she would not return to summer camp. The first year at camp had been awful. The next year had been even worse. And last year had been the absolute pits. She just had to find a way out.

“Now, Sugar Plum,” her mother said. “I know you don’t want to go back to camp, but think how much fun you’ll have. All your friends from last year will be there.”

“What friends?” asked Lizzie. “I don’t have friends at camp.” All Lizzie’s mother ever did was criticize her. Sometimes Lizzie got tired of her mother’s carping.

“What about Brittany? She was so nice.”

“Mom, Brittany was just my bunkmate. She didn’t choose to live with me. We had nothing in common.”

“Nothing?” Her mother frowned. “But she seemed so outgoing.”

“Nothing. She hadn’t even heard of Saul Bellow.”

Her mother frowned again.

Lizzie’s idea of an exciting summer was sitting in the cool of the library and devouring a high stack of novels one by one. Ever since summer vacation started, she’d been showing up at the library early every morning. As soon as the doors opened, she’d sprint to a table on the second floor, right next to the big window. For the next eight hours, she’d sit at the table and read. It was heavenly.

“I heard the camp added knitting as a new activity this year,” her mother said brightly. “And archery.”

Lizzie scowled. “Aren’t kids supposed to stay away from weapons?”

“Archery is a sport, dear.”

“Sure,” said Lizzie. “So is bowling. And croquet. And baseball.”

Her mother sighed.

As they drove to camp, Lizzie sat staring out the window. Her suitcase was beside her. She’d packed it last night, but her mother got mad when she found out Lizzie hadn’t packed any clothes. Lizzie had tried to argue that a pair of flip-flops and fifteen novels were all you really needed for three weeks of camp, but her mom wouldn’t listen. She made Lizzie take out most of her favorite books and **supplant** them with bug spray and T-shirts.

“Sweetie, look,” her mom said, giving Lizzie a pleading expression. “I love that you’re such a little bookworm. I do. I really do. But being outside and making friends with people your own age is really important, too.”

“Why?” asked Lizzie.

“Because it makes you well-adjusted and happy.”

“Yeah, well.”

As they pulled up to the camp entrance, Lizzie strained her mind for last-minute strategies that could free her. In a panic, she briefly considered faking a severe illness, but figured that if it were severe enough to **forestall** camp, then it would be severe enough for her mother to keep her home from the library. The thought of spending all day with her mom was more than she could stand.

As her mother pulled to a stop, she turned to look at Lizzie. Her mother’s forehead had the little lines it got when she was worried.

“Promise me you’ll make a friend,” her mother said.

“Mom...”

“Please? Promise me.” Her mother suddenly sounded quite **maudlin**. Lizzie worried she might start crying.

“OK,” Lizzie sighed. “I’ll make a friend.”

“I love you, Sugar Plum.”

“I know.”

The camp director, Mr. Scott, stepped out of the lodge.

“Hello, Lizzie. And hello, Ms. Lockwood. Nice to see you again.”

“And nice to see you again, Mr. Scott,” said her mother, blushing. “Lizzie, say hi to Mr. Scott.”

Lizzie shrugged. It was hopeless – there was no point in trying to escape.

“Lizzie, it’s wonderful to have you back,” said Mr. Scott.

Lizzie hugged her mother goodbye. Her mother blew her a kiss.

“Have fun, Sugar Plum.”

Fun – fat chance. She’d be lucky not to die of boredom. Everything about camp was so **vapid**.

Mr. Scott picked up her suitcase and walked her to her cabin.

“Now, I remember how much you like to read,” Mr. Scott said as they walked.

“So, I was wondering if you might do a special job for me this summer.”

Lizzie cocked an eye at the camp director. “What kind of job?”

“I want you to be the camp librarian.”

Lizzie stopped in her tracks. “The camp has a library?”

“It’s brand new. One of our former campers died and left us his library in his will. It’s quite a collection — thousands of books in all. We were surprised by such **largesse**, it really was a very generous gift. He was over 80, but he tried hard to keep up with the hot new talent. Do you think you could sort it?”

Lizzie was excited. “I can do that.”

“Excellent,” Mr. Scott smiled. “Let me lead you to it.”

Mr. Scott, still carrying Lizzie’s bag, led her to a small building behind the dining room. He opened the door.

“Now, you can arrange them anyway you like, but — oh, hello, Jenny. I didn’t know you were in here.”

Lizzie walked through the doorway to find several heaping piles of books and, at the bottom, a girl her age. The girl was wearing glasses and a baseball jersey and reading a worn-out copy of Don DeLillo’s *Underworld*.

“Hey, Mr. Scott,” said Jenny. She turned to Lizzie. “What’s your name?”

“Lizzie.”

“Do you like Don DeLillo?” Jenny asked.

For a moment, Lizzie was too surprised to speak. Then she gathered herself. “I like early DeLillo.”

“Me too. The early novels are funnier than the big, long, serious ones.” She held up *Underworld*. “But this one has some good parts.”

Lizzie sat down next to Jenny.

“Do you want to help me sort these?” she asked quietly.

Story 3

Making the Team

Tick-tock. Tick-tock.

Andre watched the clock. It seemed to be moving very slowly. This was his last class of the day – biology. Usually, Andre liked biology. He liked learning about all of the different plants. He liked understanding how animals survived in the wild. Usually, Andre didn't want biology class to end. But today was different. Today there were tryouts for the basketball team after school.

There was only one thing that Andre liked more than science: basketball. Andre wasn't a **greenhorn** at the game, either – he'd been playing as long as he could remember. His parents had put a basketball hoop in the backyard. Every night after dinner, Andre went outside and practiced his shots until it got dark. He loved the feeling of the basketball in his hands and the sound the ball made when it sailed through the net. Swish! Andre thought it was the best sound in the world.

“Psst! Andre!”

Andre's best friend, Tyrell, was trying to get his attention.

“I feel like this class will never end,” said Tyrell. Unlike Andre, Tyrell didn't care even a **pittance** about science.

“I know,” said Andre. “And I'm so nervous.”

“You shouldn't be nervous,” said Tyrell. “You're the tallest kid in fourth grade.”

“Height doesn't matter,” said Andre. “What matters is if you can play the game. You're a much better shooter than I am.”

Tyrell and Andre had been best friends since kindergarten. Tyrell loved basketball, too, but his favorite team was the New York Knicks. Andre's favorite team was the Chicago Bulls. Tyrell and Andre hardly ever argued – the only time they would **quibble** was when the Knicks were playing the Bulls. Tyrell was also trying out for the basketball team that afternoon. Andre was glad he'd have his best friend by his side.

Suddenly the bell rang and class was over. Andre and Tyrell walked quickly down to the gym. When they got there, Andre's heart sank. They didn't expect to see so many other kids. As their eyes swept the gym, they could count at least 60 boys crowded onto the bleachers.

“Oh no,” said Tyrell. “I never imagined there would be so many kids trying out for the basketball team.”

Andre knew the basketball team only had room for 20 people. That meant two-thirds of the kids there wouldn't make the team. Andre and Tyrell looked at each other. What if only one of them made the team? It would feel awful if he had to play **bereft** of Tyrell. That would be worse than not making the team at all.

The coach blew a whistle and the tryouts began. Andre and Tyrell were separated into different groups. First Andre ran sprints across the gym, over and over until his legs felt weak, and he was out of breath.

Then, the coaches divided them into teams to play against one another. As soon as he felt his hands on the basketball, Andre felt better. This was why he loved the game. All the nights of practicing paid off as he took shots from the 3-point line. Swish! Swish! Not all of the shots went in, but a lot of them did.

Tyrell was waiting outside when the tryouts were over.

“How did it go?” Andre asked.

“I don’t know . . . I think it went all right,” said Tyrell. “The coach said he’s posting a list of who made the team tomorrow before school. So I guess we’ll find out soon enough.”

Andre felt his stomach tighten. He knew he had played well, but was it good enough? He wasn’t so sure. He didn’t know how to **assuage** the nagging fear that he hadn’t made it.

“It’s okay,” said Tyrell. Tyrell had known Andre for so long that he could see when Andre was upset. “I’m sure you made it. I just don’t know if I did.”

“Playing on the basketball team wouldn’t be any fun without you,” said Andre.

They walked the rest of the way home in silence.

The next morning Andre couldn’t eat any of his breakfast. “Can we go to school early today?” he asked his mother. “I can’t wait anymore.”

Andre’s mother could sense his nervousness – she was never **inured** to his feelings. She nodded and reached for the car keys. Five minutes later, Andre was standing in front of the gym. He looked up at the list. Tyrell’s name was at the very top – he had made it!

Andre stared at the list, slowly reading every name. His eyes began to sting. He didn’t see his name anywhere.

“Andre!” He heard Tyrell’s happy voice. “We made it!”

“What do you mean?” asked Andre sadly. “My name’s not on there.”

“Yes it is! Didn’t you look at the second sheet?” asked Tyrell.

Andre looked back at the list. Tyrell was right; there was a second sheet of paper underneath. Andre lifted up the first sheet, and his heart gave a giant leap. There was his name, at the very top! He turned and gave Tyrell a high-five. They were going to be on the basketball team together.

Note: This story was used in the pilot study but was not included in the study's main phase.

Story 4

World's Greatest Robot

"I want it to have six heads," said Carlos.

"No," said Marisol. "It only needs two heads. One to breathe fire, and one to spray water. That way, if he starts a fire he shouldn't, he can put it out – much safer."

"What about his arms? His right hand should be a chainsaw, and his left should be a hammer. And maybe there should be a claw sticking out of his chest."

"Are you nuts? What's he going to do with a chainsaw and a hammer?"

"Saw stuff. Hammer stuff."

"I think he'll be much better with plain old ordinary hands."

Carlos looked at his sister like *she* had just grown five extra heads. "Ordinary hands? We don't want ordinary *anything*. Who wants a **banal** robot? We're going to build the greatest robot the universe has ever seen."

They were sitting outside of school, waiting for their mother to pick them up. While the other kids ran around and played, Carlos and Marisol hunched over a notebook. Its cover said "TOP SECRET", and one look inside made the need for secrecy clear. The entire notebook was **replete** with robot plans. Every page was covered with careful drawings of rockets, laser guns, cannons and slingshots, like the blueprints for a superweapon. There were plans for robot arms, robot legs, robot bodies, and robot heads – with eight whole pages of designs for robot eyes. Should it have laser eyes or X-ray eyes? Heat-ray eyes or ice-blaster eyes? The children were going to have to decide.

These are the sorts of decisions faced by children whose parents buy them a “Build Your Own Robot Kit.” Carlos first saw the ad for the kit in the back of a comic book. Right away he began asking his parents to buy it for him.

“Please, please, please, please, please?” he asked. “This can count for my birthday and Christmas and Easter and Halloween and—”

“No,” said his father firmly. “You don’t need to build a robot.”

Carlos begged for weeks, but got nowhere. Then, one day, he had an idea. All parents have their little flaws, and Carlos knew what his father’s **foible** was. Maybe – just maybe – Carlos could take advantage of it.

“Dad,” he said. “I want you to get me that robot kit.”

“I know,” said his father in a tired voice.

“But not just for me!”

“Oh?” Suddenly his father sounded interested.

“For me and Marisol. We can design it together. As brother and sister.”

Fathers like when their sons and daughters do things together. Carlos’ plan worked! His father agreed to order the kit. And ever since that day, Carlos and Marisol had done nothing but work on their plans. It was not going well.

“This robot is going to be ugly,” Marisol would say. “It has too many rocket launchers.”

“You can never have enough rocket launchers!” Carlos would shout. Marisol was so annoying. She always said things just to **nettle** him.

“What if it gets hot in the sun?”

“Robots don’t get hot.”

“But what if it goes to the beach? We should give it an umbrella.”

“Robots don’t need umbrellas. They need flamethrowers and tank treads and grenade launchers and . . .”

“It could get sunburned.”

“Fine,” said Carlos. He erased the fifth rocket launcher and replaced it with an umbrella. “I guess that’s okay. Nobody wants a sunburnt **cyborg**.”

For weeks, they had been compromising, until they had a robot that was part warrior, part leisure machine. Next to the machine guns was a window box, where Marisol insisted the robot would want to grow flowers. In between the laser eyes was a unicorn horn, which she thought looked pretty. And above the flamethrower was something she called a “rainbow cannon.”

“What’s a rainbow cannon?” Carlos asked.

“Duh,” she said. “It shoots rainbows.”

The robot kit was arriving that day, and Carlos and Marisol were nearly ready. They only had to decide about the hands. Finally they settled on a chainsaw and a flyswatter, because “nobody likes flies,” said Marisol.

Carlos closed the notebook. “We’re finished,” he said, just as their mother’s car pulled up. “Can you believe it?”

“This robot is going to be amazing,” said Marisol. “Now all we have to do is build it.”

“That’s going to be the hard part. Like, really hard. I’ve never built a robot before.”

“It’ll be worth it. It’s going to shoot so many rainbows.”

Carlos and Marisol burst through the front door, ready to start building.

“Where is it?!” Carlos shouted. He looked all around the living room for a ten-foot tall box of flamethrower parts and unicorn horns, but he didn’t **discern** any sign of the package. “Where could it be?”

“Silly goose,” said Marisol. “It must be outside. Something this big couldn’t fit in the living room.”

But the backyard was empty too. So was the kitchen, the garage, the basement, and the living room. There was no ten-foot tall cardboard box anywhere. Had the postman been delayed?

“Mom,” said Carlos. “Did the mail come?”

“Yep,” said Mom from the kitchen. “It’s on the coffee table. I think there’s a package for you.”

She was right. There was a package – a six-inch cardboard box with “Build Your Own Robot!” written on it in sad little letters.

Carlos opened it slowly, and inside found a few metal rods and wheels, and plans to build something that looked like a cockroach, but uglier.

“This robot is terrible,” he said. “Where are the rocket launchers? Where are the chainsaws? Where are the tank treads?”

“It doesn’t even have a rainbow cannon,” said Marisol.

Carlos was about to throw the kit away when Marisol grabbed his wrist.

“Wait,” she said. “It may not be as good as our robot, but it’s still a robot. Let’s build it together.”

Note: This story was used in the pilot study but was not included in the study’s main phase.

Appendix D

Multiple-Choice Items

Practice item:

The word **happy** means something like

1. tired
2. sad
3. angry
4. glad

Target and common words:

The word **abstruse** means something like

1. difficult to understand
2. before others
3. tearful or overly emotional
4. after first and before third

The word **adroit** means something like

1. dull or unexciting
2. skillful
3. sadly going without
4. hardened or tough

The word **assuage** means something like

1. to soothe or relieve
2. to annoy or provoke
3. to switch one thing for another
4. to choose

The word **banal** means something like

1. common or ordinary
2. skillful
3. before others
4. sadly going without

The word **bereft** means something like

1. skillful
2. sadly going without
3. common or ordinary
4. filled

The word **carping** means something like

1. constant nagging
2. a minor weakness
3. a room where food is prepared
4. a human-like machine

The word **censure** means something like

1. the first part of the day
2. a beginner
3. strong disapproval or blame
4. a minor weakness

The word **cyborg** means something like

1. the first part of the day
2. a human-like machine
3. a very small amount
4. a room where food is prepared

The word **decide** means something like

1. to trick or mislead
2. to switch one thing for another
3. to choose
4. to delay or prevent

The word **delude** means something like

1. to argue about minor things
2. to choose
3. to see or notice something
4. to trick or mislead

The word discern means something like

1. to go over something, such as a lesson
2. to argue about minor things
3. to annoy or provoke
4. to see or notice something

The word **early** means something like

1. difficult to understand
2. before others
3. common or ordinary
4. hardened or tough

The word foible means something like

1. a minor weakness
2. strong praise
3. a valuable gift
4. constant nagging

The word **forestall** means something like

1. to steal
2. to argue about minor things
3. to delay or prevent
4. to choose

The word **greenhorn** means something like

1. strong disapproval or blame
2. a valuable gift
3. a beginner
4. a minor weakness

The word **inured** means something like

1. difficult to understand
2. before others
3. after first and before third
4. hardened or tough

The word **kitchen** means something like

1. strong disapproval or blame
2. a room where food is prepared
3. a beginner
4. a very small amount

The word **kudos** means something like

1. strong praise
2. a valuable gift
3. constant nagging
4. a human-like machine

The word **largesse** means something like:

1. strong praise
2. a beginner
3. a room where food is prepared
4. a valuable gift

The word **maudlin** means something like

1. tearful or overly emotional
2. after first and before third
3. common or ordinary
4. filled

The word **morning** means something like

1. strong disapproval or blame
2. the first part of the day
3. a very small amount
4. a human-like machine

The word **nettle** means something like

1. to steal
2. to soothe or relieve
3. to annoy or provoke
4. to see or notice something

The word **pittance** means something like

1. a very small amount
2. strong praise
3. the first part of the day
4. constant nagging

The word **purloin** means something like

1. to switch one thing for another
2. to steal
3. to delay or prevent
4. to soothe or relieve

The word quibble means something like

1. to steal
2. to argue about minor things
3. to go over something, such as a lesson
4. to delay or prevent

The word replete means something like

1. difficult to understand
2. tearful or overly emotional
3. dull or unexciting
4. filled

The word **review** means something like

1. to annoy or provoke
2. to see or notice something
3. to go over something, such as a lesson
4. to trick or mislead

The word second means something like

1. tearful or overly emotional
2. dull or unexciting
3. after first and before third
4. filled

The word **supplant** means something like

1. to trick or mislead
2. to go over something, such as a lesson
3. to switch one thing for another
4. to soothe or relieve

The word **vapid** means something like

1. skillful
2. hardened or tough
3. sadly going without
4. dull or unexciting

Note: All of the above items were used in the pilot study, but only items with target words in bold font were included in the study's main phase.

Appendix E

Model Results for Word Learning Measures

Table E1.

Multiple-Choice Posttest: Effects of SES, Language, and Working Memory.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-19.22	7.58		-2.54	.02
Age	0.66	0.31	0.25	2.14	.04
Pretest ^a	0.41	0.21	0.28	2.01	.05
Common ^b	0.39	0.44	0.10	0.88	.38
SES ^c	0.06	0.04	0.25	1.70	.10
CELF ^d	0.11	0.06	0.51	1.93	.06
TAPS-F ^d	0.01	0.04	0.03	0.24	.82
TAPS-R ^e	-0.02	0.06	-0.10	-0.38	.71
SESxCELF	-0.00	0.00	-0.19	-0.65	.52
SESxTAPS-R	0.00	0.00	-0.01	-0.06	.96
CELFxTAPS-R	-0.00	0.00	-0.13	-0.94	.35

Note. Dependent variable: Multiple-choice posttest score. ^aMultiple-choice pretest score.

^bMultiple-choice score on common words. ^cFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^dCELF-5 Core Language Composite. ^eCTMT Trail 1 T-score. ^fCTMT Trail 5 T-score.

Table E2.

Oral Definition Task: Effects of SES, Language, and Working Memory.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-33.97	23.51		-1.45	.16
Age	3.73	0.98	0.47	3.82	<.001
Pretest ^a	0.07	0.65	0.02	0.10	.92
SES ^b	0.03	0.11	0.04	0.24	.81
CELF ^c	0.01	0.19	0.02	0.07	.94
TAPS-F ^d	0.04	0.14	0.05	0.30	.77
TAPS-R ^e	-0.04	0.20	-0.05	-0.19	.85
SESxCELF	0.01	0.01	0.34	1.09	.29
SESxTAPS-R	0.00	0.01	0.09	0.37	.72
CELFxTAPS-R	-0.01	0.01	-0.17	-1.12	.27

Note. Dependent variable: Oral definition score. ^aMultiple-choice pretest score. ^bFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^cCELF-5 Core Language Composite. ^dTAPS-3 Number Memory Forward T-score. ^eTAPS-3 Number Memory Reversed T-score.

Table E3.

Multiple-Choice Posttest: Effects of SES, Language, and Inhibitory Control.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-8.04	8.55		-0.94	.35
Age	0.62	0.31	0.23	2.01	.05
Pretest ^a	0.21	0.22	0.15	0.96	.34
Common ^b	1.01	0.52	0.26	1.95	.06
SES ^c	0.04	0.04	0.18	1.01	.32
CELF ^d	0.07	0.06	0.32	1.19	.24
Stroop-C ^e	-0.18	0.08	-0.39	-2.35	.02
Stroop-CW ^f	0.01	0.07	0.03	0.14	.89
SESxCELF	0.00	0.00	0.16	0.49	.63
SESxStroop-CW	0.01	0.00	0.27	1.19	.24
CELFxStroop-CW	0.00	0.00	0.05	0.37	.71

Note. Dependent variable: Multiple-choice posttest score. ^aMultiple-choice pretest score.

^bMultiple-choice score on common words. ^cFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^dCELF-5 Core Language Composite. ^eStroop Color T-Score T-score. ^fStroop Color-Word T-score.

Table E4.

Oral Definition Task: Effects of SES, Language, and Inhibitory Control.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-23.38	27.89		-0.84	.41
Age	3.81	1.01	0.48	3.78	.001
Pretest ^a	0.06	0.70	0.01	0.09	.93
SES ^b	-0.02	0.14	-0.03	-0.14	.89
CELF ^c	-0.01	0.18	-0.02	-0.05	.96
Stroop-C ^d	-0.18	0.24	-0.13	-0.73	.47
Stroop-CW ^e	0.04	0.20	0.04	0.18	.86
SESxCELF	0.01	0.01	0.41	1.16	.25
SESxStroop-CW	0.00	0.01	0.02	0.07	.94
CELFxStroop-CW	-0.01	0.01	-0.08	-0.47	.64

Note. Dependent variable: Oral definition score. ^aMultiple-choice pretest score. ^bFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^cCELF-5 Core Language Composite. ^dStroop Color T-Score T-score. ^eStroop Color-Word T-score.

Table E5.

Multiple-Choice Posttest: Effects of SES, Language, and Cognitive Flexibility.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-17.70	7.25		-2.44	.02
Age	0.67	0.29	0.25	2.31	.03
Pretest ^a	0.33	0.19	0.23	1.75	.09
Common ^b	0.46	0.46	0.12	0.99	.33
SES ^c	0.05	0.03	0.22	1.59	.12
CELF ^d	0.09	0.06	0.43	1.55	.13
CTMT-1 ^e	-0.03	0.03	-0.12	-0.97	.34
CTMT-5 ^f	0.03	0.05	0.14	0.58	.56
SESxCELF	-0.00	0.00	-0.17	-0.59	.56
SESxCTMT-5	0.00	0.00	0.05	0.28	.78
CELFxCTMT-5	-0.01	0.00	-0.35	-2.72	.01

Note. Dependent variable: Multiple-choice posttest score. ^aMultiple-choice pretest score.

^bMultiple-choice score on common words. ^cFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^dCELF-5 Core Language Composite. ^eCTMT Trail 1 T-score. ^fCTMT Trail 5 T-score.

Table E6.

Oral Definition Task: Effects of SES, Language, and Cognitive Flexibility.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-33.23	22.58		-1.47	.15
Age	3.58	0.96	0.45	3.72	.001
Pretest ^a	-0.10	0.63	-0.02	-0.15	.88
SES ^b	-0.01	0.11	-0.02	-0.11	.91
CELF ^c	-0.04	0.20	-0.06	-0.21	.84
CTMT-1 ^d	0.07	0.09	0.11	0.83	.41
CTMT-5 ^e	0.14	0.16	0.21	0.86	.39
SESxCELF	0.01	0.01	0.34	1.07	.29
SESxCTMT-5	-0.00	0.01	-0.04	-0.20	.85
CELFxCTMT-5	-0.01	0.01	-0.34	-2.38	.02

Note. Dependent variable: Oral definition score. ^aMultiple-choice pretest score. ^bFamily socioeconomic status based on Hollingshead four-factor index (Hollingshead, 1975). ^cCELF-5 Core Language Composite. ^dCTMT Trail 1 T-score. ^eCTMT Trail 5 T-score.

Table E7.

Multiple-Choice Posttest, Final Model ANOVA Results

	Sum of Squares	Df	Mean Square	<i>F</i>	<i>p</i>
Regression	180.28	7	25.76	9.16	<.001
Residual	115.27	41	2.81		
Total	295.55	48			

Note. Dependent variable: Multiple-choice posttest score. Predictors: Age, Multiple-choice pretest score, Multiple-choice score on common words, CELF-5 Core Language Composite, CTMT Trail 1 T-score, CTMT Trail 5 T-score, CELF \times CTMT-5.

Table E8.

Multiple-Choice Posttest, Final Model Coefficients.

Variable	b	SE	β	<i>t</i>	<i>p</i>
(Constant)	-13.10	3.91		-3.35	.002
Age	0.73	0.27	0.27	2.68	.01
Pretest ^a	0.39	0.17	0.27	2.32	.03
Common ^b	0.50	0.44	0.13	1.14	.26
CELF ^c	0.06	0.03	0.25	2.02	.05
CTMT-1 ^c	-0.02	0.03	-0.11	-0.96	.34
CTMT-5 ^f	0.05	0.04	0.23	1.43	.16
CELF \times CTMT-5	-0.01	0.00	-0.37	-2.91	.006

Note. Dependent variable: Multiple-choice posttest score. ^aMultiple-choice pretest score.

^bMultiple-choice score on common words. ^cCELF-5 Core Language Composite. ^dCTMT Trail 1 T-score. ^fCTMT Trail 5 T-score.

Table E9.

Oral Definition Task, Final Model ANOVA Results

	Sum of Squares	Df	Mean Square	<i>F</i>	<i>p</i>
Regression	1317.94	6	219.66	7.08	<.001
Residual	1333.84	43	31.02		
Total	2651.78	49			

Note. Dependent variable: Oral definition score. Predictors: Age, Multiple-choice pretest score, CELF-5 Core Language Composite, CTMT Trail 1 T-score, CTMT Trail 5 T-score, CELF \times CTMT-5.

Table E10.

Oral Definition Task, Final Model Coefficients.

Variable	<i>b</i>	SE	β	<i>t</i>	<i>p</i>
(Constant)	-53.10	11.27		-4.71	<.001
Age	3.63	0.89	0.46	4.10	<.001
Pretest ^a	0.26	0.54	0.06	0.48	.63
CELF ^b	0.16	0.09	0.24	1.77	.08
CTMT-1 ^c	0.07	0.08	0.11	0.87	.39
CTMT-5 ^d	0.07	0.10	0.11	0.68	.50
CELF \times CTMT-5	-0.01	0.01	-0.30	-2.22	.03

Note. Dependent variable: Multiple-choice posttest score. ^aMultiple-choice pretest score. ^bCELF-5 Core Language Composite. ^cCTMT Trail 1 T-score. ^dCTMT Trail 5 T-score.

VITA

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