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Research Article

Differences in the Performance of Children With Specific Language Impairment and Their Typically Developing Peers on Nonverbal Cognitive Tests: A Meta-Analysis

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Purpose: This study used meta-analysis to investigate the difference in nonverbal cognitive test performance of children with specific language impairment (SLI) and their typically developing (TD) peers.
Method: The meta-analysis included studies (a) that were published between 1995 and 2012 of children with SLI who were age matched (and not nonverbal cognitive matched) to TD peers and given a norm-referenced nonverbal cognitive test and (b) that reported sufficient data for an effect size analysis. Multilevel modeling was used to examine the performance of children with SLI relative to their typically developing, age-matched peers on nonverbal IQ tests.
Results: Across 138 samples from 131 studies, on average children with SLI scored 0.69 standard deviations below their TD peers on nonverbal cognitive tests after adjusting for the differences in the tests used, the low-boundary cutoff scores, the age of the participants, and whether studies matched the two groups on socioeconomic status.
Discussion: The lower performance of children with SLI relative to TD children on nonverbal IQ tests has theoretical implications for the characterization of SLI and clinical and political implications regarding how nonverbal cognitive tests are used and interpreted for children with this disorder.

Key Words: assessment, cognition, children, meta-analysis, specific language impairment, language disorders

Specific language impairment (SLI) is defined as a disorder in which children present with oral language difficulties that cannot be attributed to hearing loss, frank neurological deficits, or poor cognitive functioning (Leonard, 1998; Tallal, Ross, & Curtiss, 1989; Tomblin, Records, & Zhang, 1996). Consequently, verbally based cognitive assessments are not appropriate for these children, as demonstration of their intellectual capacity would likely be hindered by their poor linguistic skills. The normal range of cognition is typically verified through the use of scores on nonverbal cognitive tests (e.g., Leonard, 1998; Plante, Bahl, Vance, & Gerken, 2011; Stark & Tallal, 1981). However, a large body of research has documented a range of nonverbal cognitive deficits in children with SLI (e.g., Archibald & Gathercole, 2006b; Kemény & Lukács, 2010; Spaulding, Plante, & Vance, 2008). Prior work has suggested that such deficits manifest as lower scores than their typically developing (TD) peers on tests of nonverbal cognition (e.g., Cole, Mills, & Kelley, 1994; Miller & Gilbert, 2008). This investigation is designed to evaluate whether existing evidence supports preliminary data suggesting that children with SLI perform more poorly than their TD peers on nonverbal IQ tests by capitalizing on the benefits of meta-analysis, a statistical method involving the integration of data across studies to form a general conclusion (Borenstein, Hedges, Higgins, & Rothstein, 2009).

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Theoretical Accounts of SLI

There are two competing theoretical frameworks for the characterization of children with SLI, which broadly

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fall under either linguistic-based or cognitive-based theories. Linguistic-based theories propose that the cause of SLI originates from a specific impairment in the linguistic system and results in deficits that are isolated to language. For example, some posit a grammar-specific deficit, suggesting that the difficulty children with SLI face is due to an impairment with the grammatical system (e.g., Clahsen, 1989; Crago & Gopnik, 1994; Gopnik & Crago, 1991; Rice & Oetting, 1993; Rice & Wexler, 1996; Rice, Wexler, & Cleave, 1995; van der Lely, 1994; van der Lely & Marshall, 2011; van der Lely, Rosen, & McClelland, 1998; van der Lely & Stollwerk, 1997; Wexler, 1994). A deficient grammatical system does account for many of the deficits observed in children with SLI. For example, they produce grammatical markers less frequently than do younger TD children matched on mean length of utterance (e.g., Rice & Wexler, 1996). Children with SLI exhibit particular difficulties with inflectional markers and functional words, as they tend to omit or fail to consistently produce obligatory tense and agreement inflections (e.g., Leonard, Eyer, Bedore, & Grela, 1997; Miller & Leonard, 1998; Rice & Wexler, 1996). Grammatical deficits have also been documented in children with SLI who speak languages other than English (e.g., Clahsen, 1995; Fukuda & Fukada, 2001; Leonard et al., 1992). However, many children with SLI exhibit deficiencies that are not isolated to the grammatical system, including syntax (e.g., Hansson & Nettelbladt, 1995; Kamhi & Koenig, 1985; Leonard, 1998; Thordardottir & Weismer, 2002; van der Lely & Battell, 2003), word learning (e.g., Alt & Plante, 2006; Gray, 2003b, 2004; Rice, Buhr, & Nemeth, 1990), and phonology (e.g., Fee, 1995; Marshall & van der Lely, 2007; Rice, 2004). An impaired grammatical system that sets inaccurate parameters for language may still account for the disruption in these nongrammatical language domains (Marshall & van der Lely, 2007). However, an alternative perspective, based on the assumption that children match the speech that they hear to innate rules in order to identify and learn the grammar of the language to which they are exposed, proposes that children with SLI have difficulty processing speech and/or exhibit a deficiency in their innate rule system that leads to deficits in language acquisition more broadly.

In addition to deficits in language, a number of researchers have found that many children with SLI also present with subtle deficits in nonverbal cognition, including but not limited to auditory and visual attention (e.g., Finneran, Francis, & Leonard, 2009; Noterdaeme, Amorosa, Mildenberger, Sitter, & Minnow, 2001; Spaulding et al., 2008), visuospatial working memory (e.g., Archibald & Gathercole, 2006b; Bavin, Wilson, Maruff, & Sleeman, 2005; Hick, Botting, & Conti-Ramsden, 2005), serial reaction time learning (e.g., Kemény & Lukács, 2010; Tomblin, Mainela-Arnold, & Zhang, 2007), and deductive reasoning (e.g., Newton, Roberts, & Donlan, 2010). In contrast to linguistic-based theories, which isolate the deficits of SLI to the linguistic system, cognitive-based theories attempt to account for both the linguistic and the nonlinguistic cognitive difficulties of children with SLI by positing that they both stem from a nonlinguistic cognitive or processing deficiency. Some propose that these deficits originate from a specific cognitive or processing mechanism, such as phonological working memory (Gathercole & Baddeley, 1990), procedural memory (Ullman & Pierpont, 2005), or perceptual processing (e.g., Tallal, 1980; Tallal & Piercy, 1974, 1975). Others suggest that the source of these difficulties is more general in nature, proposing that the difficulties children with SLI encounter are because they have reduced processing capacity. Stemming from this perspective, it has been argued that children with SLI are slower to process information whether it is linguistic or not, that they have less space available for processing incoming information, and/or that they are less efficient or have less energy available to facilitate processing relative to TD children (e.g., Bishop, 1994; Hayiou-Thomas, Bishop, & Plunkett, 2004; Kail, 1994; Leonard et al., 2007; Norbury, Bishop, & Briscoe, 2001). Both general slowing and processing limitations can account for the linguistic and nonlinguistic deficits observed in children with SLI, although Ullman and Pierpont (2005) have argued that they lack adequate specificity for robust empirical testing.

Assuming that nonverbal IQ tests tap nonverbal cognition ability, whether children with SLI perform similarly to or more poorly than their TD peers on nonverbal IQ tests is important to theoretical models of SLI. If children with SLI perform similarly to their TD peers on nonverbal IQ tests, this provides strong support for the linguistic-based theoretical perspective on the nature of SLI. In contrast, poor performance of children with SLI on these tests would be consistent with nonlinguistic processing accounts of SLI. In addition, if children with SLI perform poorly relative to their TD peers on nonverbal IQ tests, there are implications on the very definition of SLI, as the classic definition of SLI specifically excludes “low nonverbal IQ” as a characteristic of the disorder (Leonard, 1998; Stark & Tallal, 1981).

Given the growing body of research documenting a wide variety of nonverbal cognitive difficulties on experimental tasks for children with SLI (e.g., Archibald & Gathercole, 2006b; Bavin et al., 2005; Finneran et al., 2009; Hick et al., 2005; Kemény & Lukács, 2010; Noterdaeme et al., 2001; Spaulding et al., 2008), we would predict that children with SLI would perform poorly relative to their TD peers on norm-referenced tests of nonverbal IQ. Indeed, a handful of investigations have found that children with SLI do tend to perform poorer on such tests relative to TD controls (Cole et al., 1994; Miller & Gilbert, 2008). However, additional data are needed to verify that this is the case, to determine the extent to which they score lower than their TD peers on such tests, and to determine whether children with SLI consistently obtain poorer scores than their peers on these tests.

If children with SLI do perform worse than their peers on nonverbal IQ tests, there are important political and clinical implications. Historically, a comparison of children’s language skills to scores on nonverbal intelligence tests had been used to assist in determining whether a child qualifies for language intervention (Casby, 1992). This practice, referred to as "cognitive referencing" (Cole, Dale, & Mills, 1992), was based on the assumption that children are deemed to have "cognitive potential" for additional language growth only when their language abilities fall behind their nonverbal cognitive functioning (see Krassowski & Plante, 1997). This stemmed, in part, from Cromer's (1974) strong cognitive hypothesis, which purported that language skills could not exceed cognitive skills. Consequently, if children's language skills were similar to their nonverbal cognitive skills, the assumption is that they would not be able to benefit from language intervention. However, there is mounting evidence that language skills can exceed nonverbal cognitive skills (e.g., Annaz et al., 2009; Dethorne & Watkins, 2006). In addition, children who do not have a discrepancy between language and cognition have similar rates of language learning and similar long-term outcomes as children who qualify for services under the cognitive referencing criterion (Cole et al., 1992; Tomblin, 2008). Both of these findings provide evidence against the assumptions underlying cognitive referencing. At one time, cognitive referencing was common practice (Casby, 1992). However, the 2004 amendment to the Individuals with Disability Education Improvement Act (IDEA) eliminated cognitive referencing as a required procedure for eligibility determinations. The 2004 amendment to IDEA states that "a local educational agency shall not be *required* [emphasis added] to take into consideration whether a child has a severe discrepancy between achievement and intellectual ability in oral expression, listening comprehension, written expression, basic reading skill, reading comprehension, mathematical calculation, or mathematical reasoning" (IDEA, 2004, Section 1414(b)(6)). It is important to note that, as a result of this legislation, cognitive referencing was no longer mandated; however, it is still permitted. If the results of this meta-analysis provide evidence that children with SLI perform poorly relative to their TD peers on nonverbal IQ tests, this, when combined with prior work in this area, would provide a strong basis for amending the legislation to prevent the use of cognitive referencing in the case of children with SLI for use in determining eligibility for intervention. In addition, this finding would provide evidence for modifying state and/or school district eligibility criteria that are based on the cognitive referencing assumption.

The current study is designed to capitalize on the large number of studies investigating children with SLI in order to determine how they perform relative to similar-aged TD peers on nonverbal IQ tests. Specifically, we compared the nonverbal IQ test scores of the children with SLI with the nonverbal IQ test scores of TD children. To isolate the relative contribution of language impairment to nonverbal IQ test scores, it is important to consider four factors that may influence children's nonverbal IQ scores. These include the test selected for administration, the low-boundary cutoff score used, the age of the participants, and whether the researchers matched the SLI and TD groups for socioeconomic status (SES).

Study-Level Moderator Variables: Nonverbal IQ Test, Nonverbal IQ Cutoff Score

There is some evidence that children with SLI perform differently depending on the norm-referenced nonverbal cognitive test used (Cole et al., 1994; Miller & Gilbert, 2008). For example, Miller and Gilbert (2008) assessed the nonverbal cognitive performance in several groups of adolescents, including those with SLI and those with TD language skills. They compared each group's performance on the Wechsler Intelligence Scale for Children—Third Edition (WISC–III; Wechsler, 1992) with their performance on the Universal Nonverbal Intelligence Test (UNIT; Bracken & McCallum, 1998). The researchers found that the nonverbal IQ scores of the children with language impairment were significantly different between these two tests, while the scores of the TD children were not. When comparing across groups, the authors found that there was a greater difference between the SLI and control groups on the WISC–III relative to the UNIT. Another study by Cole and colleagues (1994) compared the performance of preschool children with language disorders on three other nonverbal cognitive measures, the Perceptual Performance and General Cognitive Indices of the McCarthy Scales of Children's Abilities (McCarthy, 1972) and the Columbia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972). These investigators also found significant differences in how children with language impairment performed on these tests. Consequently, there is some evidence that the magnitude of the difference between children with SLI and TD controls appears to vary according to the test selected for use. Therefore, to isolate the relative contribution of SLI to nonverbal IQ test performance, it is important to take into account variability attributable to the different tests used by research investigators.

When investigating this population of children, researchers administer nonverbal IQ tests to exclude children with lower cognitive functioning from their participant pool. There are differing opinions on what the criterion should be to ensure normal-range nonverbal intelligence, an inclusionary criterion for both children with SLI and TD children. Some researchers presume that unless a child has an intellectual disability, he or she has "normal range" nonverbal IQ (e.g., Alt, 2011; McArthur & Bishop, 2005; Perona, Plante, & Vance, 2005). According to the *Diagnostic and Statistical Manual of Mental Disorders* (4th edition; American Psychiatric Association, 1994), a standard score of 69 or below (when the mean is 100 and the standard deviation is 15) is consistent with intellectual disability. To rule out intellectual disability, most investigations take into account children's test scores in light of the standard error of the test. For example, the Nonverbal Cognitive Index of the Kaufman Assessment Battery for Children—Second Edition (KABC–II: Kaufman & Kaufman, 2004a) has a standard error of 5. Taking a conservative stance to ensure that children with intellectual disabilities are not represented in their TD or SLI samples, researchers using this assessment typically require their participants to score 75 or higher, assuming that children with intellectual disability may obtain a standard score of 74 (69, the maximum score consistent with intellectual disability, plus 5, the standard error of the test; e.g., Alt, 2011; Perona et al., 2005).

In contrast to those who interpret "normal range" nonverbal cognition as consistent with the lack of intellectual disability, others equate "normal range" nonverbal cognition as synonymous with scoring within the average range. On a norm-referenced test with a mean of 100 and a standard deviation of 15, children scoring within one standard deviation of the mean (or a standard score between 85 and 115) are considered to have performed within the average range. Finally, other investigators take less of a firm stance. In an apparent compromise between these two extremes, a number of researchers are choosing a cutoff criterion lower than one standard deviation below the mean but higher than that consistent with ruling out intellectual disability (e.g., Bishop, Hardiman, & Barry, 2010; Conti-Ramsden, Durkin, Simkin, & Knox, 2009; Newman & McGregor, 2006). Clearly, having a higher low-boundary standard cutoff score would restrict the between-group difference that could be apparent when lower low-boundary cutoff scores are used in the participant selection criteria. Because variability in the performance of children with SLI relative to TD children on nonverbal IQ tests may be attributable to the different cutoff scores used across research investigations, it is important to take this factor into account to ensure that the results are an accurate estimate of the true effect size.

Participant-Level Moderator Variables: Age, SES

Nonverbal IQ tests are designed to measure fluid intelligence, as opposed to crystalized intelligence, which is typically measured by verbal IQ or vocabulary tests. *Fluid intelligence* refers to the ability to solve problems in new situations by using logic as opposed to previously acquired knowledge (Cattell, 1941, 1963). Nonverbal IQ tests or subtests of IQ tests that are nonverbal in nature may assess pattern recognition, abstract reasoning, and problem solving, for example. Relative to verbal IQ tests or vocabulary tests that rely on one's general knowledge, nonverbal IQ tests should produce stable scores across time for the same child, with consideration to the standard error of measurement of the test. This is because nonverbal IQ tests are constructed to be stable indicators of ability as opposed to a measure of the child's current knowledge or skill.

For children with language impairment in particular, there is some evidence suggesting a lack of stability in nonverbal IQ test scores with age (e.g., Aram et al., 1984; Botting, 2005). Prior work has demonstrated a strong, complex, and bidirectional relationship between language and cognition (e.g., Dijk & Kintsch, 1983; Dixon & Salley, 2006; Just & Carpenter, 1992). Therefore, we might not expect the nonverbal IQ test performance of children with SLI to remain stable as they age. First, their poor language skills may inhibit cognitive skill development, which in turn would inhibit further development in their language skills. Supporting this possibility, Botting (2005) conducted a longitudinal study and found that the nonverbal IQ scores of children with SLI fell by 20 points, on average, between testing at 7 and 14 years of age. However, it is difficult to determine whether this is a true age effect because the nonverbal IQ test administered at 14 was not the same as the nonverbal IQ test administered to the children when they were 7. In contrast, improved ability in language resulting from treatment might facilitate improved performance on nonverbal cognitive tests. Krassowski and Plante (1997) suggested that the variable performance of children with SLI on nonverbal IQ tests over a 3-year period found in their study may have been because the children were all enrolled in language intervention services. Because it is currently unclear whether the nonverbal IQ skills of children with SLI change with age, it is important to control for this variable to isolate the relative contribution of SLI status to nonverbal IQ test scores.

Prior work has found a significant relationship between SES and nonverbal cognition in children (e.g., Brooks-Gunn, Klebanov, & Duncan, 1996; Suzuki & Valencia, 1997). Children with SLI are likely to come from families with lower SES than TD children (Bishop & McDonald, 2009). Failing to match children with SLI and TD children for SES may lead to disproportionately lower SES in the SLI group relative to the TD group and potentially large differences in nonverbal IQ test scores for these two groups of children. In contrast, matching children with SLI and TD children on SES would likely decrease between-group disparities in nonverbal IQ test scores. Therefore, whether studies matched children with SLI and TD children for SES may contribute to variability in nonverbal IQ effect sizes across studies.

Purpose of Present Study

The purpose of this investigation was to use meta-analysis to provide a quantitative summary of the difference in performance between children with SLI and their TD peers on norm-referenced tests of nonverbal cognition. The central questions are (a) do children with SLI obtain lower scores on nonverbal IQ tests relative to their TD age peers, and (b) if so, to what extent? If variability in the nonverbal IQ effect size across studies is found, study-level factors likely to influence the results will be controlled in order to obtain a more accurate estimate of the difference in performance between these two groups of children on nonverbal IQ tests. These include differences in the nonverbal IQ test used, the nonverbal IQ cutoff score criterion for participant inclusion, participants' age, and whether the studies matched the SLI and TD groups for SES. On the basis of prior work demonstrating subtle nonverbal cognitive deficits in children with SLI (e.g., Archibald & Gathercole, 2006b; Kemény & Lukács, 2010; Spaulding et al., 2008) and a handful of studies suggesting that children with SLI obtain lower nonverbal IQ test scores than their TD peers (Cole et al., 1994; Miller & Gilbert, 2008), we expected that the children with SLI would score significantly lower than their TD peers on nonverbal IQ tests.

Method

Literature Search Procedures

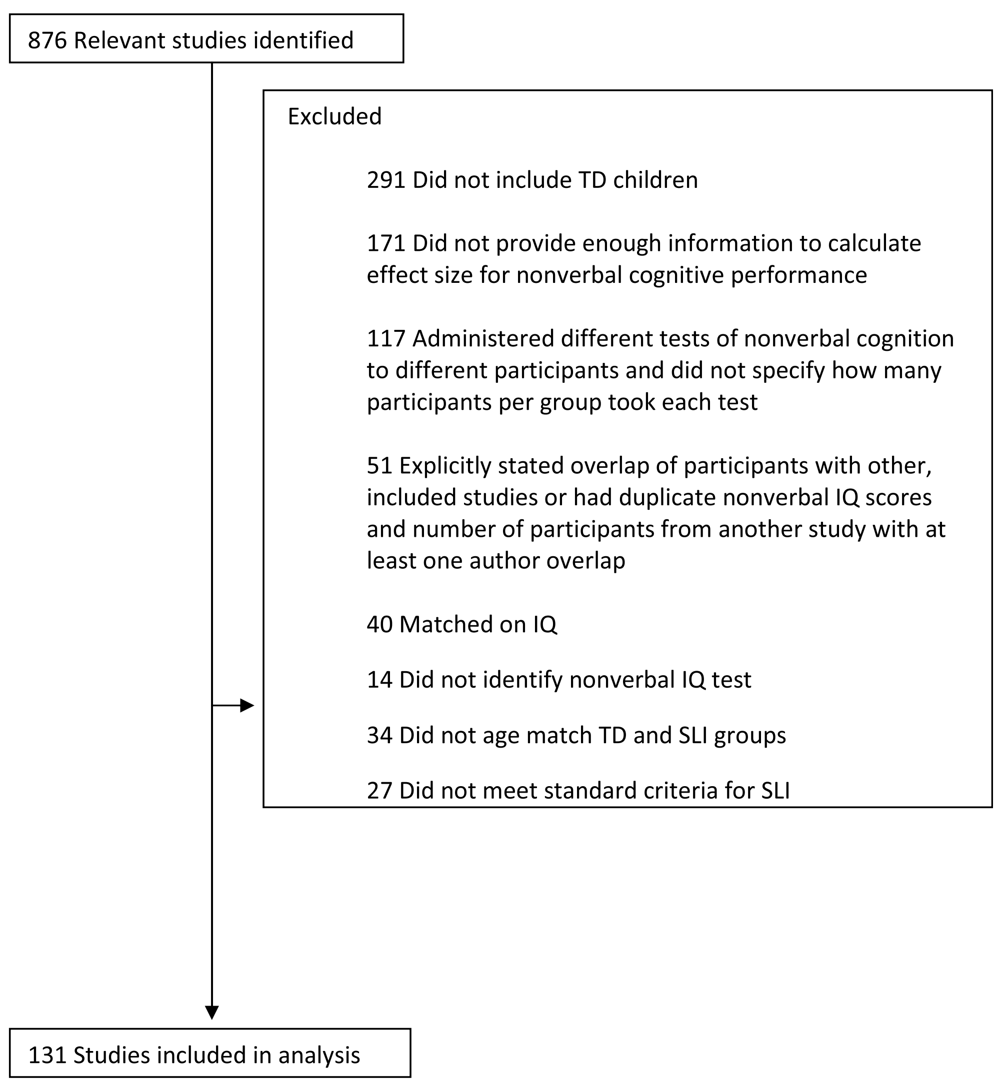
Figure 1 provides a flow chart illustrating the selection of the final studies included in the meta-analysis. The studies used for this meta-analysis were found using an electronic search of five databases: PsycINFO, PubMed, ERIC, Web of Science, and Dissertation Abstracts Online. To identify relevant studies published between January 1995 and December 2012, the following search terms were used in each database: "language impairment" or "specific language impairment" or "SLI" or "primary language impairment" or "language disorder" or "language delay" and "children." In four of the databases, PsycINFO, PubMed, ERIC, and Web of Science, all parameters were searched; however, in Dissertation Abstracts Online, all parameters other than full text were searched because of an excessive number of irrelevant studies in the search results when full text search was conducted. This search strategy yielded 6,370 studies.

Study Inclusion and Exclusion Criteria

Each study identified from the electronic search was reviewed to assess the appropriateness of the study for inclusion. Included studies were required to meet the following criteria: (a) contained a conventional operational definition or a clinical diagnosis of specific language impairment; (b) examined monolingual, English-speaking children; (c) were written in English; (d) were grouped to distinguish between SLI and TD groups; (e) matched the SLI and TD groups for chronological age; and (f) administered a nonverbal IQ test to the SLI and TD participants.

Studies were excluded if they individual- or group-matched children with SLI and TD children for nonverbal intelligence, did not specify which nonverbal IQ test was

Figure 1. Flow chart for the selection of eligible studies. TD = typically developing; SLI = specific language impairment.



administered to the participants, administered only subtests or portions of a nonverbal cognitive test, administered a different nonverbal IQ test to the SLI and the TD children, or administered more than one nonverbal IQ test to both the SLI and TD groups but did not report separate scores on each IQ test and the number of participants in each group who took each test.

A total of 5,494 studies were excluded on the basis of information in the abstracts. Reasons for exclusion included that they were duplicates, book chapters, reviews, or case studies or that they did not present any new data. Additional reasons for exclusion included that they were written in a language other than English or involved non-English-speaking or bilingual children only. After excluding these studies, full text copies of 876 articles were obtained for a more detailed review.

Included Studies

Of the remaining studies, a total of 745 were excluded at this stage because they failed to meet both the inclusionary and exclusionary criteria; because they did not report sufficient data for calculating the effect size, either by not reporting empirical data on nonverbal IQ test scores or by not reporting both means and standard deviations for each group; or because they reported that the participants or a proportion of the participants were from a sample in another study that met our inclusionary and exclusionary criteria. In the cases in which the participants overlapped between studies, the studies with the larger sample size were included and the studies with the smaller sample size were excluded. This resulted in 131 relevant studies, which included 138 samples of children with SLI and 138 samples of TD children.

Study Coding

For each study, we coded the authors, year of publication, number of participants in the SLI and TD groups, the mean age of the participants in each group, the nonverbal cognitive test administered, the low-boundary cutoff performance criterion used by the study authors on the nonverbal cognitive test, the SLI and TD group means and standard deviations for the nonverbal IQ test, and whether the two groups were matched for SES. See Table 1.

Reliability

The first author extracted and coded the data from the included studies. Thirty-six samples from 36 studies (26.09% of total samples [36/138] from 27.48% of total studies [36/131]) were randomly selected and coded by an undergraduate student trained by the second author on the coding procedures. This second coder was provided with an Excel sheet of the authors and year of publication, along with a copy of each of the articles. With the authors and year of publication provided, this left 396 opportunities for agreement across the 36 studies. Intercoder discrepancies were determined by the second author and were found in five instances (3.68%). Each of the discrepancies was resolved by conferring among the first author (initial coder), undergraduate student (second coder), and second author. In each case, the first author was determined to have coded the data correctly.

Effect Size Computations

Effect size (d) was used in this study as a standardized basis to compare group differences in performance between SLI and TD groups on measures of nonverbal cognition. The calculation of effect size is determined by subtracting the mean of the SLI group from the mean of the TD group and dividing by the average pooled standard deviation. The effect size formula was converted to Hedges's g using a correction factor, referred to as J (Hedges, 1981). Multiplying d, calculated from the effect size formula above, by the J correction factor corrects for bias that may occur when using smaller samples (Borenstein et al., 2009). This correction factor is based on the assumption that when multiple studies are combined while disregarding sample size, studies with relatively smaller samples are given too much weight in the averaging process using the traditional effect size formula. Through the Hedges's g correction, each individual study's effect size contributes proportionally to the combined average effect size based on the individual study's sample size. In this manner, studies with more participants are given more weight within the analyses than studies with fewer participants.

Statistical Procedure

We used multilevel modeling to examine the performance of children with SLI relative to their age-matched TD peers on nonverbal IQ tests. If the results were consistent across studies, the average effect size would be an accurate estimate for summarizing the results. In contrast, if there was significant heterogeneity across studies, a single average effect size would ignore important sources of variability across studies and may be biased (Light, 1983). If heterogeneity was documented, multilevel modeling would be used to account for the heterogeneity across studies and to obtain a more accurate estimate of the effect size. In our meta-analysis, groups of participants were regarded as nested within studies, and studies were regarded as nested within nonverbal IQ tests. Consequently, there were two potential sources of variation, namely, heterogeneity across studies within the test type as well as heterogeneity between different tests. The multilevel model accounted for these two sources of heterogeneity and also allowed for an adjustment of the covariates simultaneously. Specifically, the Level 1 model obtained estimates of the effect size within the same test type, accounting for the covariates of cutoff score, participants' age, and whether the studies matched the SLI and TD participants on SES. The Level 2 model took into account the heterogeneity between different tests in order to obtain a less biased estimate of the overall effect size.

Table 1. Characteristics of included studies.

Study	N		Age (months)		Nonverbal IQ Scores				IQ test	Cutoff	SES match
	TD	SLI	TD	SLI	TD *M*	TD *SD*	SLI *M*	SLI *SD*			
Ahmed et al. (2008)	19	19	115	113	78.2	20.3	53.7	31.6	KABC–II	75	No
Alt (2011)	20	20	94	91.3	103.8	13.74	95.35	13.34	KBIT–II	75	Yes
Alt & Plante (2006)	23	23	58	57.9	110.7	11.3	97.47	12.2	KABC	85	No
Alt et al. (2004)	26	26	61	60.5	102.9	11.6	97	13.4	KABC	75	No
Anderson (2006)	15	15	55	54	103	7	107	18	KBIT	85	Yes
Archibald & Gathercole (2006a)	12	12	117	116	114	9.09	102.8	10.37	RCM	85	No
Archibald & Gathercole (2006b)	15	15	116	116	112.7	11.01	103.5	9.76	RCM	85	No
Archibald & Gathercole (2007)	16	13	122	125	110	11.31	102.9	9.93	RCM	—	No
Bishop (2001)	172	120	111	99.8	99.72	12.72	99.48	13.55	RCM	—	No
Bishop et al. (2000)	76	54	—	—	101.4	8.03	90.2	9.91	RCM	80	No
Bishop et al. (2010)	16	16	117	118	102.3	9.86	98.38	9.22	WASI	80	No
	16	16	166	169	101.4	12.15	100.8	9.35	WASI	80	No
Bishop & Norbury (2005)	18	17	103	112	110.8	10.38	98.94	11.56	RCM	80	No
Boynton, Hauerwas & Stone (2000)	51	22	72	70.8	111.3	12.9	97.7	10.3	CMMS	85	Yes
Briscoe et al. (2001)	20	14	102	108	107.4	12.84	105.4	14.15	RCM	80	No
Clarke & Adams (2007)	31	19	115	115	72.9	22.7	53.29	31.1	RCM	—	No
Coady et al. (2007)	21	21	121	123	107.1	10.8	96.9	9.5	LIPS–R	85	No
Collisson (2010)	13	13	50	49.2	116.7	11.84	109.9	6.53	TONI–II	85	Yes
Conti-Ramsden et al. (2009)	121	120	208.8	208.8	100	15.9	83.9	19.6	WISC–III	80	Yes
Corriveau, Pasquini, & Goswami (2007)	21	21	117	122	97.29	10.08	92.14	11.75	WISC–III	80	No
Creusere et al. (2004)	26	26	61	61	104.8	10.43	96.54	13.44	KABC	75	No
Crosbie et al. (2004)	15	15	111	107	99.6	10.4	93.7	9.4	WISC–III	—	No
De Fossé et al. (2004)	11	9	125	119	110.6	11	95.7	14.6	WISC–III	80	No
Deevy et al. (2010)	47	29	60	60	118	10	106	13	CMMS	85	No
Donlan et al. (2007)	55	48	98	99.6	104.6	11.6	103	12.3	RCM	—	No
Durkin et al. (2011)	47	47	204	205	107	9.2	99.8	10.1	WASI	80	Yes
Fazio (1998)	10	10	59	62	101	9.56	98	8.91	CMMS	85	No
Fazio (1999)	11	10	113	119	98	4.9	93	4.6	CMMS	85	No
Finneran et al. (2009)	13	13	63	62.1	120	11	108	13	CMMS	85	No
Fisher et al. (2007)	30	30	61	59	109.2	12.5	94.8	11.7	KABC	70	Yes
Ford & Milosky (2003)	12	12	68	69	113.1	10.1	98.1	10.4	KABC	85	No
Ford & Milosky (2008)	16	16	57	58	97.06	6.99	95.69	6.84	KABC	90	Yes
Gillon (2000)	30	38	74	—	108.6	10.75	103	10.68	TONI–II	80	No
Girbau & Schwartz (2008)	11	11	109	106	103.6	12.92	95.09	6.82	TONI–III	—	No
Gray (2003a)	22	22	60	60.1	111	10.39	98.57	12.46	KABC	75	Yes
Gray (2003b)	30	30	55	54.4	108.4	12.06	95.46	8.98	KABC	85	Yes
Gray (2004)	20	20	59	57.9	107.6	12.65	105.2	41.02	KABC	75	Yes
Gray (2005)	24	24	61	60.8	109.3	15.28	104.9	11.45	KABC	75	Yes
Gray (2006)	9	9	54	52.6	109.3	14.18	105.3	12.13	KABC	75	Yes
	14	14	65	65.7	108.8	10.54	102.4	16.91	KABC	75	Yes
	15	15	76	75.7	107.2	13.3	94.73	8.48	KABC	75	Yes
Gray & Brinkley (2011)	42	42	55	56.7	109.5	10.29	101.9	13.2	KABC–II	75	Yes
Gray et al. (2012)	24	25	54	54.3	120.8	15.28	101	13.5	KBIT–II	75	Yes
Greenslade et al. (2009)	32	32	55	55.3	106.9	10.25	98.66	13	KABC–II	75	Yes
	22	10	60	57.8	102	12.6	96.5	12.03	KABC–II	75	No
Hanson & Montgomery (2002)	12	12	100	100	110	8.6	99	7.5	TONI–II	85	No
Hoffman (2000)	24	24	112	113	102.3	5.52	102.8	10.55	TONI–II	85	No
Horohov (1999)	18	18	72	74.4	99.4	12.6	92.7	4.7	CMMS	85	No
Horohov & Oetting (2004)	18	18	72	74.8	106.1	9.8	92.7	4.7	CMMS	85	No
Kouri et al. (2006)	21	14	96	102	98.71	12.12	92.57	7.23	TONI–III	85	No
Krantz & Leonard (2007)	15	15	62	62	113.2	10.96	104.7	8.32	CMMS	90	No
Leonard & Deevy (2011)	10	18	—	—	118.1	9.27	112.3	12.9	CMMS	85	No
Lum et al. (2012)	51	51	118	118	99.6	7.6	98	7.3	WASI	85	No
Marchman et al. (2004)	20	14	101	108	107.4	12.84	105.4	14.15	RCM	80	No
Marler (2000)	10	10	112	112	107	13	92	11	WASI	75	No
Marton et al. (2007)	15	15	106	107	110	16.59	104.5	17.12	TONI–III	90	No
McArthur & Bishop (2004)	16	16	176	175	97	11.81	93.75	14.06	RCM	75	No
McArthur & Hogben (2001)	15	14	99	95	109.9	10.94	105.4	14	WISC–III	85	No
McConnell (2010)	51	14	128	128	112	10.55	103	10	KBIT–II	85	Yes
McGregor et al. (2002)	16	16	73	74	106.6	12.72	92.88	10.3	CMMS	70	No
McGregor, Rost, Guo, & Sheng (2010)	17	16	82	82	106	11.94	96	12.19	KBIT	80	Yes
Merricks et al. (2004)	61	37	103	104	108	14	103	15	WISC–R	—	No
Miller (2004)	15	15	60	59	109.5	11.1	108.9	14.5	CMMS	80	No
Miller & Deevy (2006)	18	17	62	60	113	10	105	9	CMMS	90	No

(*table continues*)

Table 1 *(Continued).*

Study	*N* TD	*N* SLI	Age (months) TD	Age (months) SLI	Nonverbal IQ Scores TD *M*	TD *SD*	SLI *M*	SLI *SD*	IQ test	Cutoff	SES match
Montgomery (1995)	16	16	80	98.6	108.5	6.83	100.5	10.24	TONI–II	85	No
Montgomery (1999)	21	21	104	105	107	7.6	103.9	10.2	TONI–II	85	Yes
Montgomery (2000b)	12	12	102	102	103.2	5.3	100.1	4.8	TONI–II	85	No
Montgomery (2000a)	12	12	108	109	105.2	4.4	100.5	4.7	TONI–II	85	Yes
Montgomery (2002)	21	21	97	99.3	106.5	7.6	102.6	10.7	TONI–II	85	Yes
Montgomery (2004)	12	12	104	105	106	5.67	105	5.79	TONI–II	85	Yes
Montgomery (2008)	36	36	99	102	106.3	6	102.6	8.1	TONI–II	80	No
Montgomery & Evans (2009)	18	24	109	109	101.8	8.5	95.9	6.4	LIPS–R	85	No
Montgomery et al. (2009)	26	26	99	101	106.7	5.4	102.8	8.9	TONI–II	85	No
Montgomery & Leonard (1998)	21	21	105	104	107.8	8.9	104.3	9.9	TONI–II	85	No
Montgomery & Leonard (2006)	16	16	107	109	105.8	5.1	99.3	5.6	TONI–II	85	Yes
Montgomery & Windsor (2007)	48	48	105	105	106.8	7.1	101.9	6.9	TONI–II	85	No
Morgan (2010)	79	53	76	78.3	100.7	12.29	93.46	11.47	KABC–II	75	No
Newman (2003)	10	10	74	74.4	102.6	14	95	9.2	CMMS	70	Yes
Norbury (2005)	28	20	150	151	107.1	10.7	96.2	9.9	WASI	80	No
Norbury & Bishop (2002)	18	16	103	112	110.8	10.38	98.56	11.83	RCM	80	No
Norbury et al. (2001)	20	14	101	108	107.4	12.84	105.4	14.15	RCM	80	Yes
Norrix et al. (2007)	28	28	56	56	105.4	9.86	99.64	12	KABC–II	75	Yes
Oetting (1999)	20	20	76	77.2	103.2	7.33	96.45	6.16	CMMS	85	Yes
Oetting & Cleveland (2006)	12	6	71	75.2	102.9	11.81	94.5	5.75	CMMS	85	No
	24	10	72	73.3	103	9	92.6	3.95	CMMS	85	No
Oetting et al. (2008)	40	18	72	74.8	102.2	10.24	92.55	4.85	CMMS	85	No
Oetting & Horohov (1997)	11	11	75	75.8	103	8.45	98.36	4.38	CMMS	85	No
Owen (2011)	13	14	79	79	99.6	9.37	97.4	11.97	KBIT–II	—	No
Pankratz et al. (2007)	32	32	57	57.3	101.8	9.7	95.03	9.6	KABC	75	Yes
Paradis et al. (2010)	139	29	69	70	104	12	96	12	CMMS	75	No
Perona et al. (2005)	34	32	58	59.6	108.6	13.12	95.53	13.19	KABC	75	Yes
Plante et al. (2010)	29	29	57	55.5	108.3	10.48	97.38	13	KABC–II	75	Yes
Plante et al. (2011)	32	32	50	51	111	6.81	88.97	26.52	KABC–II	75	Yes
Polite & Leonard (2007)	10	12	64	63	120.7	14.1	104.5	7.9	CMMS	85	No
Polite et al. (2011)	12	12	61	61	118.3	9.2	106.5	12.28	CMMS	85	No
Redmond (2004)	13	10	79	79	107	6	104	11	CMMS	80	Yes
Redmond (2005)	13	10	79	79	107	6	104	11	CMMS	85	Yes
Redmond & Rice (2002)	17	12	96	96.3	115.8	14.94	97.5	11	CMMS	—	No
Rice (1995)	21	21	61	60.2	105.6	7.98	99.56	9.17	CMMS	85	No
Rice, Cleave, & Oetting (2000)	22	20	61	59.9	105.6	7.98	99.2	9.02	CMMS	85	No
Rice et al. (2006)	45	39	60	58.2	115.1	14.18	96.11	10.14	CMMS	85	No
Rice et al. (1998)	23	21	59	—	107	10	94	7	CMMS	85	No
Rice, Wexler, et al. (2000)	23	21	59	56	107	10	94	7	CMMS	—	No
Rice et al. (1999)	21	21	—	—	115	14	93	8	CMMS	85	No
Rosin (2007)	10	12	—	—	104.3	13.84	103.5	15.68	KBIT	—	No
Scheffler (2002)	13	12	92	92.3	99.3	10.1	92.2	10	TONI–III	85	Yes
Scott & Windsor (2000)	20	20	—	—	116	17	105	11	TONI–II	—	Yes
Seiger-Gardner & Brooks (2008)	18	18	112	103	105	14	99	11	TONI–II	80	No
Seiger-Gardner & Schwartz (2008)	20	20	112	108	107	11	94	11	TONI–II	85	Yes
Shafer et al. (2005)	11	8	107	111	100	9	95	9	TONI–II	70	No
Sheng & McGregor (2010)	10	14	87	86	108.9	16.41	95.36	13.67	KBIT	80	Yes
Skibbe, Moody, et al. (2010)	15	30	54	54.6	104.1	8.38	99.13	11.21	KBIT	80	Yes
Skibbe, Justice, et al. (2008)	52	56	54	54.5	105.1	8.73	97.16	14.93	KABC	70	Yes
Spaulding (2008)	31	31	56	55.9	107.2	11.07	100.7	11.67	KABC–II	75	Yes
Spaulding (2012)	16	16	51	50.8	106.1	7.51	102.9	8.64	KBIT–II	75	Yes
Spaulding et al. (2008)	23	23	58	58	114.9	9.92	96.26	9.85	KABC–II	75	Yes
Stark & Blackwell (1997)	19	31	95	94	109	7.4	101.5	10.95	WISC–R	80	No
Stark & Heinz (1996)	22	32	95	88.7	105	7.2	102	9.15	WISC–R	80	No
Thatcher (2010)	15	15	58	56.4	110.1	12.4	98.73	4.93	CMMS	85	No
	15	15	72	73.9	107.8	6.49	98.6	6.26	CMMS	85	No
	15	15	89	91.8	100.3	8.06	100.1	10.27	CMMS	85	No
Thordardottir (1998)	50	50	94	93.8	112.4	9.82	103.7	9.86	CMMS	—	No
Thordardottir (2008)	11	9	118	117	99.1	15	89.3	14.9	LIPS–R	70	Yes
Thordardottir & Weismer (2001)	50	50	93	93.6	113.4	11.16	103.5	9.81	CMMS	—	Yes
Tropper (2009)	22	12	134	139	108.2	13.37	93.17	6.71	TONI–III	85	No
Velez & Schwartz (2010)	13	13	—	—	110	11.67	98	11.25	TONI–III	85	No
Wadman et al. (2011)	28	28	168	166	105.4	11.85	91.04	8.39	WASI	85	Yes
Weismer et al. (1999)	20	20	95	93	110	7	104	9	CMMS	85	Yes

(*table continues*)

Table 1 *(Continued).*

Study	*N*		Age (months)		Nonverbal IQ Scores				IQ test	Cutoff	SES match
	TD	SLI	TD	SLI	TD *M*	TD *SD*	SLI *M*	SLI *SD*			
Weismer et al. (2000)	359	80	95	95.2	102.6	11.3	95.7	8.2	WISC–III	85	No
Williams et al. (1995)	16	10	—	—	101.4	14.9	80.7	8	KABC	—	No
Windsor & Hwang (1999)	23	23	—	—	117	15	106	11	TONI–II	—	Yes
Windsor et al. (2010)	65	19	96	101	103.5	10.7	93.4	11.7	TONI–III	85	No
Wolter & Apel (2010)	31	25	75	73	101.8	10.78	89.6	7.21	KBIT	80	No
Wright et al. (1997)	8	8	96	97	105.1	6.5	101	5.3	TONI–II	—	No
Wulfeck et al. (2004)	34	28	117	110	111.7	11.7	100.4	11.3	WISC–R	80	No
Wynn-Dancy (2001)	10	10	163	171	107.1	10.7	100.7	10.4	TONI–II	85	No
Yont et al. (2002)	12	12	49	49	107.5	9.74	95.42	5.43	CMMS	85	Yes
Zelaznik & Goffman (2010)	14	14	89	89	123	12	113	15	CMMS	85	No

Note. A dash in cells indicates data not reported. Multiple rows for one study indicates multiple studies within that article. TD = typically developing; SLI = specific language impairment; SES = socioeconomic status; KABC–II = Kaufman Assessment Battery for Children—Second Edition (Kaufman & Kaufman, 2004a); KBIT–II = Kaufman Brief Intelligence Test—Second Edition (Kaufman & Kaufman, 2004b); KABC = Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983); RCM = Raven's Colored Matrices; WASI = Wechsler Abbreviated Scale of Intelligence (Weschler, 1999); CMMS = Columbia Mental Maturity Scale (Burgemeister et al., 1972); LIPS–R = Leiter Intelligence Performance Scale—Revised (Roid & Miller, 1997); TONI–II = Test of Nonverbal Intelligence—Second Edition (Brown, Sherbenou, & Johnsen, 1990); KBIT = Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990); TONI–III = Test of Nonverbal Intelligence—Third Edition (Brown, Sherbenou, & Johnsen, 1997); WISC–III = Weschler Intelligence Scale for Children—Third Edition (Wechsler, 1991); WISC–R = Weschler Intelligence Scale for Children—Revised (Wechsler, 1974).

Results

Nonverbal Cognition Average Effect Size: TD Versus SLI

The initial analysis assessed the performance of 3,124 children with SLI relative to 3,872 TD children on norm-referenced tests of nonverbal cognition using an effect size metric. See Table 2 for the nonverbal IQ effect sizes for each individual study. Using the unconditional model, which ignored sources of variation, the average effect size was −0.743 (*SE* = .04, 95% CI [−0.814, −0.671]), which was statistically different from zero, $t(137) = -21.27$, $p < .0001$. This signified that, on average, children with SLI performed −0.74 standard deviations below their TD peers on nonverbal IQ tests. It is important to note that the between-study variance estimate was .068, indicating variation in effect sizes across studies. This can be noted in the forest plot in Figure 2.

Multilevel Modeling

One potential source of the variability was the different nonverbal IQ tests used across the research studies included in the analysis. Therefore, multilevel modeling was used to account for two sources of heterogeneity across studies within the same test type and between different tests and to obtain a more precise estimate of the overall effect size. Under the multilevel model, which accounted only for the variability within tests and the variability between tests, the effect size estimate decreased from the original −0.740 to −0.715 (*SE* = .05; 95% CI [−0.815, −0.616]), which remained statistically different from zero, $t(12) = -15.67$, $p < .0001$. The variability within the nonverbal IQ tests was 0.058, signifying that the majority of variability noted in the unconditional model was due to variability within the test type.

The multilevel model, which further adjusted for the three covariates (cutoff score, participants' age, SES), resulted in an effect size estimate of −0.693 (*SE* = .16; 95% CI [−1.049, −0.336]), which was statistically significant, $t(12) = -4.23$, $p = .0012$. The remaining between-study variability was 0.038, that, when compared with 0.058, indicated that the covariates were able to account for some of the differences between studies. Therefore, −0.693 appeared to be a more accurate representation of the effect size, with IQ test and the study-level covariates accounting for some of the variability in effect sizes observed across studies included in this meta-analysis.

Sensitivity Analysis

Although the average effect size was −0.693 standard deviations, the effect sizes varied from −1.89 standard deviations to 0.29 standard deviations. The variability in the effect sizes highlighted the potential that one study may be the reason that the average effect was statistically significant. Using a one-study-removal analysis, we conducted separate analyses to assess the residual impact on the overall effect size when each study was removed from the analysis. The removal of each individual study had limited impact on the magnitude of the average effect size or the confidence interval. The lowest average effect size obtained was −0.721 standard deviations, and the highest average effect size obtained was −0.684 standard deviations. No single study influenced the average effect size sufficiently to result in a nonsignificant finding. Therefore, the results of this analysis indicated that the average effect size was relatively stable.

Publication Bias

Researchers conducting a meta-analysis need to give serious consideration to publication bias. Publication bias refers to the likelihood that studies published on the topic

Table 2. Nonverbal IQ effect size for SLI group relative to TD group at study level.

Study	*N*	hg	95% CI	*z*	*p*
Ahmed et al. (2008)	38	−0.903	[−1.574, −0.232]	−2.638	.008
Alt (2011)	40	−0.612	[−1.247, 0.024]	−1.886	.059
Alt & Plante (2006)	46	−1.106	[−1.730, −0.481]	−3.471	.001
Alt et al. (2004)	52	−0.464	[−1.015, 0.088]	−1.648	.099
Anderson (2006)	30	0.285	[−0.435, 1.005]	0.776	.438
Archibald & Gathercole (2006a)	24	−1.106	[−1.976, −0.236]	−2.491	.013
Archibald & Gathercole (2006b)	30	−0.866	[−1.619, −0.113]	−2.253	.024
Archibald & Gathercole (2007)	29	−0.648	[−1.402, 0.105]	−1.686	.092
Bishop (2001)	292	−0.018	[−0.251, 0.215]	−0.154	.878
Bishop et al. (2000)	130	−1.257	[−1.639, −0.875]	−6.454	.000
Bishop et al. (2010)	32	−0.401	[−1.102, 0.300]	−1.122	.262
	32	−0.057	[−0.750, 0.636]	−0.160	.873
Bishop & Norbury (2005)	35	−1.059	[−1.773, −0.346]	−2.911	.004
Boynton Hauerwas, & Stone (2000)	73	−1.104	[−1.637, −0.571]	−4.061	.000
Briscoe et al. (2001)	34	−0.140	[−0.824, 0.544]	−0.401	.688
Clarke & Adams (2007)	50	−0.738	[−1.328, −0.147]	−2.448	.014
Coady et al. (2007)	42	−0.988	[−1.632, −0.344]	−3.005	.003
Collisson (2010)	26	−0.693	[−1.488, 0.103]	−1.707	.088
Conti-Ramsden et al. (2009)	241	−0.900	[−1.165, −0.635]	−6.650	.000
Corriveau et al. (2007)	42	−0.462	[−1.075, 0.152]	−1.474	.140
Creusere et al. (2004)	52	−0.677	[−1.237, −0.117]	−2.369	.018
Crosbie et al. (2004)	30	−0.579	[−1.312, 0.154]	−1.549	.121
De Fossé et al. (2004)	20	−1.121	[−2.084, −0.159]	−2.283	.022
Deevy et al. (2010)	76	−1.058	[−1.552, −0.564]	−4.197	.000
Donlan et al (2007)	103	−0.133	[−0.521, 0.254]	−0.673	.501
Durkin et al. (2011)	94	−0.739	[−1.158, −0.321]	−3.462	.001
Fazio (1998)	20	−0.311	[−1.194, 0.572]	−0.690	.490
Fazio (1999)	21	−1.008	[−1.929, −0.088]	−2.146	.032
Finneran et al. (2009)	26	−0.965	[−1.785, −0.145]	−2.307	.021
Fisher et al. (2007)	60	−1.174	[−1.725, −0.623]	−4.178	.000
Ford & Milosky (2003)	24	−1.413	[−2.325, −0.501]	−3.037	.002
Ford & Milosky (2008)	32	−0.193	[−0.888, 0.502]	−0.545	.586
Gillon (2000)	68	−0.520	[−1.007, −0.033]	−2.091	.037
Girbau & Schwartz (2008)	22	−0.796	[−1.671, 0.079]	−1.783	.075
Gray (2003a)	44	−1.060	[−1.695, −0.425]	−3.272	.001
Gray (2003b)	60	−1.198	[−1.751, −0.646]	−4.251	.000
Gray (2004)	40	−0.079	[−0.699, 0.541]	−0.250	.803
Gray (2005)	48	−0.322	[−0.892, 0.248]	−1.108	.268
Gray (2006)	18	−0.289	[−1.219, 0.641]	−0.608	.543
	28	−0.438	[−1.189, 0.313]	−1.142	.254
	30	−1.088	[−1.862, −0.314]	−2.754	.006
Gray & Brinkley (2011)	84	−0.638	[−1.077, −0.199]	−2.848	.004
Gray et al. (2012)	49	−1.354	[−1.980, −0.728]	−4.240	.000
Greenslade et al. (2009)	64	−0.699	[−1.204, −0.193]	−2.708	.007
	32	−0.431	[−1.187, 0.325]	−1.118	.264
Hanson & Montgomery (2002)	24	−1.316	[−2.214, −0.418]	−2.873	.004
Hoffman (2000)	48	0.058	[−0.508, 0.624]	0.202	.840
Horohov (1999)	36	−0.689	[−1.364, −0.014]	−2.001	.045
Horohov & Oetting (2004)	36	−1.705	[−2.480, −0.930]	−4.310	.000
Kouri et al. (2006)	35	−0.573	[−1.264, 0.118]	−1.625	.104
Krantz & Leonard (2007)	30	−0.849	[−1.601, −0.097]	−2.213	.027
Leonard & Deevy (2011)	28	−0.479	[−1.264, 0.306]	−1.197	.231
Lum et al. (2012)	102	−0.213	[−0.602, 0.176]	−1.073	.283
Marchman et al. (2004)	54	−0.317	[−0.854, 0.220]	−1.156	.248
Marler (2000)	20	−1.193	[−2.162, −0.224]	−2.414	.016
Marton et al. (2007)	30	−0.319	[−1.040, 0.402]	−0.868	.386
McArthur & Bishop (2004)	32	−0.244	[−0.940, 0.452]	−0.687	.492
McArthur & Hogben (2001)	29	−0.350	[−1.084, 0.385]	−0.933	.351
McConnell (2010)	65	−0.852	[−1.462, −0.241]	−2.735	.006
McGregor et al. (2002)	32	−1.156	[−1.912, −0.400]	−2.996	.003
McGregor et al. (2010)	33	−0.809	[−1.523, −0.095]	−2.221	.026
Merricks et al. (2004)	98	−0.345	[−0.756, 0.066]	−1.643	.100
Miller (2004)	30	−0.045	[−0.761, 0.671]	−0.124	.901
Miller & Deevy (2006)	35	−0.820	[−1.514, −0.127]	−2.318	.020
Montgomery (1995)	32	−0.892	[−1.623, −0.160]	−2.390	.017
Montgomery (1999)	42	−0.338	[−0.948, 0.271]	−1.087	.277

(*table continues*)

Table 2 *(Continued).*

Study	*N*	hg	95% CI	*z*	*p*
Montgomery (2000b)	24	−0.997	[−1.854, −0.139]	−2.278	.023
Montgomery (2000a)	24	−0.592	[−1.413, 0.229]	−1.413	.158
Montgomery (2002)	42	−0.412	[−1.024, 0.200]	−1.321	.187
Montgomery (2004)	24	−0.168	[−0.970, 0.633]	−0.412	.680
Montgomery (2008)	72	−0.514	[−0.983, −0.044]	−2.142	.032
Montgomery & Evans (2009)	42	−0.786	[−1.422, −0.150]	−2.421	.015
Montgomery et al. (2009)	52	−0.522	[−1.075, 0.032]	−1.848	.065
Montgomery & Leonard (1998)	42	−0.365	[−0.975, 0.246]	−1.171	.241
Montgomery & Leonard (2006)	32	−1.183	[−1.942, −0.424]	−3.055	.002
Montgomery & Windsor (2007)	96	−0.694	[−1.107, −0.282]	−3.299	.001
Morgan (2010)	132	−0.601	[−0.956, −0.245]	−3.309	.001
Newman (2003)	20	−0.614	[−1.516, 0.287]	−1.335	.182
Norbury (2005)	48	−1.037	[−1.650, −0.424]	−3.314	.001
Norbury & Bishop (2002)	34	−1.081	[−1.808, −0.354]	−2.915	.004
Norbury et al. (2001)	34	−0.140	[−0.824, 0.544]	−0.401	.688
Norrix et al. (2007)	56	−0.520	[−1.053, 0.013]	−1.911	.056
Oetting (1999)	40	−0.970	[−1.629, −0.311]	−2.885	.004
Oetting & Cleveland (2006)	18	−0.778	[−1.799, 0.243]	−1.493	.135
	34	−1.288	[−2.095, −0.482]	−3.131	.002
Oetting et al. (2008)	58	−1.065	[−1.657, −0.474]	−3.531	.000
Oetting & Horohov (1997)	22	−0.663	[−1.527, 0.200]	−1.506	.132
Owen (2011)	27	−0.198	[−0.955, 0.560]	−0.511	.609
Pankratz et al. (2007)	64	−0.694	[−1.200, −0.189]	−2.691	.007
Paradis et al. (2010)	168	−0.664	[−1.070, −0.257]	−3.200	.001
Perona et al. (2005)	66	−0.979	[−1.491, −0.466]	−3.743	.000
Plante et al. (2010)	58	−0.916	[−1.459, −0.373]	−3.306	.001
Plante et al. (2011)	64	−1.126	[−1.655, −0.596]	−4.165	.000
Polite & Leonard (2007)	22	−1.401	[−2.356, −0.445]	−2.873	.004
Polite et al. (2011)	24	−1.053	[−1.917, −0.189]	−2.388	.017
Redmond (2004)	23	−0.340	[−1.171, 0.492]	−0.801	.423
Redmond (2005)	23	−0.340	[−1.171, 0.492]	−0.801	.423
Redmond & Rice (2002)	29	−1.321	[−2.146, −0.497]	−3.141	.002
Rice (1995)	42	−0.684	[−1.308, −0.060]	−2.147	.032
Rice, Cleave, & Oetting (2000)	42	−0.734	[−1.361, −0.106]	−2.292	.022
Rice et al. (2006)	84	−1.509	[−1.997, −1.020]	−6.055	.000
Rice et al. (1998)	44	−1.467	[−2.140, −0.794]	−4.272	.000
Rice, Wexler, et al. (2000)	44	−1.467	[−2.140, −0.794]	−4.272	.000
Rice et al. (1999)	42	−1.893	[−2.633, −1.154]	−5.018	.000
Rosin (2007)	22	−0.048	[−0.888, 0.791]	−0.113	.910
Scheffler (2002)	25	−0.683	[−1.494, 0.128]	−1.650	.099
Scott & Windsor (2000)	40	−0.753	[−1.397, −0.109]	−2.293	.022
Seiger-Gardner & Brooks (2008)	36	−0.466	[−1.129, 0.197]	−1.377	.168
Seiger-Gardner & Schwartz (2008)	40	−1.158	[−1.833, −0.483]	−3.363	.001
Shafer et al. (2005)	19	−0.531	[−1.461, 0.400]	−1.118	.264
Sheng & McGregor (2010)	28	−0.872	[−1.653, −0.092]	−2.190	.029
Skibbe, Moody, et al. (2010)	45	−0.474	[−1.103, 0.154]	−1.480	.139
Skibbe, Justice, et al. (2008)	108	−0.640	[−1.028, −0.253]	−3.240	.001
Spaulding (2008)	62	−0.571	[−1.080, −0.063]	−2.202	.028
Spaulding (2012)	32	−0.387	[−1.087, 0.314]	−1.082	.279
Spaulding et al. (2008)	46	−1.850	[−2.551, −1.150]	−5.179	.000
Stark & Blackwell (1997)	50	−0.756	[−1.347, −0.164]	−2.503	.012
Stark & Heinz (1996)	54	−0.351	[−0.898, 0.196]	−1.258	.208
Thatcher (2010)	30	−1.176	[−1.959, −0.392]	−2.940	.003
	30	−1.404	[−2.215, −0.593]	−3.394	.001
	30	−0.015	[−0.730, 0.701]	−0.040	.968
Thordardottir (1998)	100	−0.875	[−1.286, −0.464]	−4.174	.000
Thordardottir (2008)	20	−0.628	[−1.535, 0.280]	−1.356	.175
Thordardottir & Weismer (2001)	100	−0.933	[−1.347, −0.520]	−4.422	.000
Tropper (2009)	34	−1.272	[−2.045, −0.498]	−3.223	.001
Velez & Schwartz (2010)	26	−1.014	[−1.839, −0.189]	−2.409	.016
Wadman et al. (2011)	56	−1.378	[−1.965, −0.791]	−4.602	.000
Weismer et al. (1999)	40	−0.729	[−1.372, −0.087]	−2.226	.026
Weismer et al. (2000)	439	−0.637	[−0.883, −0.391]	−5.079	.000
Williams et al. (1995)	26	−1.571	[−2.487, −0.655]	−3.362	.001
Windsor & Hwang (1999)	46	−0.822	[−1.426, −0.218]	−2.667	.008
Windsor et al. (2010)	84	−0.916	[−1.446, −0.385]	−3.384	.001

(*table continues*)

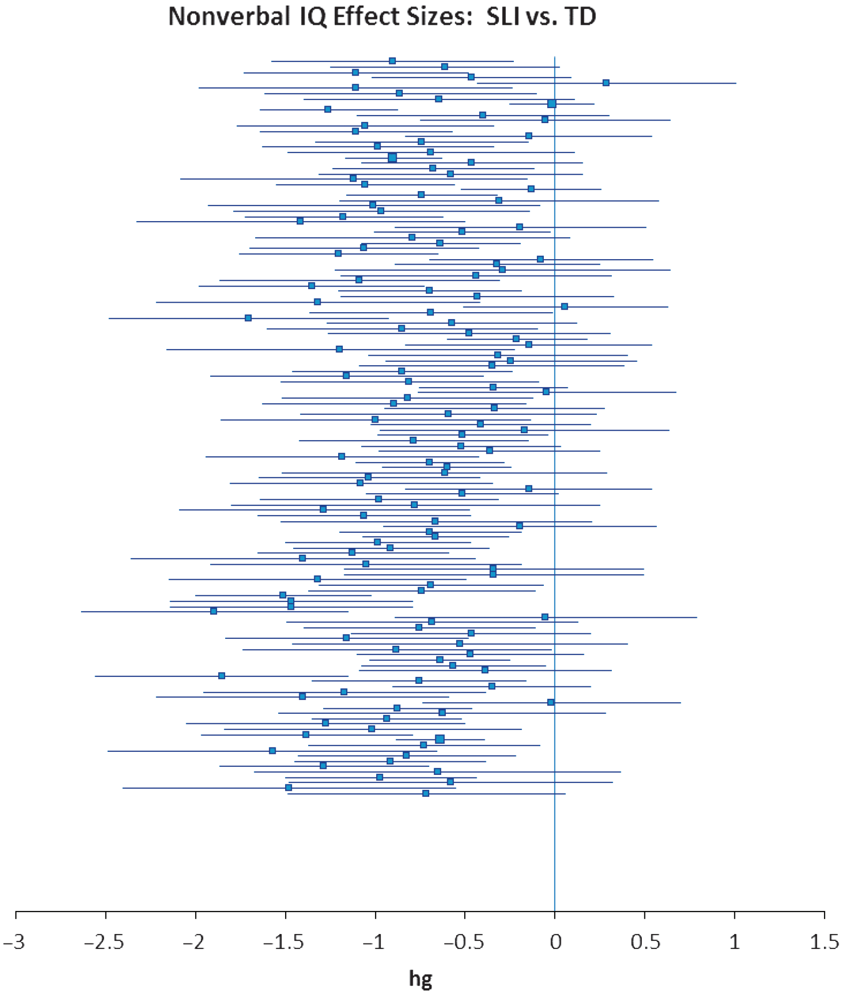
Table 2 *(Continued).*

Study	*N*	hg	95% CI	*z*	*p*
Wolter & Apel (2010)	56	−1.289	[−1.871, −0.707]	−4.340	.000
Wright et al. (1997)	16	−0.654	[−1.668, 0.360]	−1.263	.206
Wulfeck et al. (2004)	62	−0.968	[−1.499, −0.438]	−3.579	.000
Wynn-Dancy (2001)	20	−0.581	[−1.480, 0.318]	−1.266	.205
Yont et al. (2002)	24	−1.479	[−2.401, −0.557]	−3.145	.002
Zelaznik & Goffman (2010)	28	−0.715	[−1.483, 0.053]	−1.825	.068

Note. Multiple rows for one study indicates multiple studies within that article. hg = Hedges's *g* effect size.

of interest and identified for inclusion within the meta-analysis are apt to have larger effect sizes than unpublished work not identified for inclusion (Rothstein, Sutton, & Borenstein, 2005). Rosenthal (1979) suggested that, instead of speculating about the impact of unknown studies, it is more useful to determine what is calculable on the basis of existing data, the number of studies needed to nullify the results. Therefore, we conducted a fail-safe *N* analysis (Cooper, 1979) to determine how many unpublished studies that found no difference between the SLI and TD participants on nonverbal IQ tests would be needed to nullify our finding. The results, $z = -29.151$, $p < .001$, fail-safe $N = 33{,}914$, signified that 33,914 unpublished studies would be needed to make our finding insignificant.

Figure 2. Forest plot of nonverbal cognitive effect sizes for individual studies. Square points indicate summary statistics. Solid vertical line indicates 95% confidence interval. When lines cross zero, there is no significant difference between the TD and SLI groups in the scores on the nonverbal cognitive test. hg = Hedges's *g* effect size.



Discussion

The absence of general cognitive impairment is considered to be a prime exclusionary characteristic of SLI (Plante, 1998; Stark & Tallal, 1981). Both researchers and clinicians rely on nonverbal IQ test scores to estimate the intelligence and to verify the absence of cognitive impairment in children thought to have this disorder. This investigation was designed to determine whether children with SLI obtain lower scores on nonverbal IQ tests relative to their TD peers and, if they do, to determine how low the children with SLI score relative to TD children on these tests.

Without giving consideration to additional factors that could influence the results, the children with SLI, on average, scored nearly three quarters of a standard deviation lower than their TD peers across nonverbal IQ tests. However, there was substantial variability across research studies. Thirteen different nonverbal IQ tests were administered across 139 studies. Because prior work had found that children with SLI score differently on different nonverbal IQ tests (Cole et al., 1994; Miller & Gilbert, 2008), an additional analysis was conducted to account for potential between- and within-test variability. After accounting for the different nonverbal IQ tests, the effect size dropped slightly. The children with SLI scored −0.72 standard deviations below their TD peers. Accounting for additional variability owing to the low-boundary criterion used, the age of the participants, and whether studies matched for SES, the effect size dropped slightly again, to −0.69 standard deviations, but remained significant. Although this is consistent with a medium to large effect size according to Cohen's (1988) criteria, the effect size documented in this meta-analysis is quite large relative to that documented in a meta-analysis of meta-analyses of educational interventions in children, which found effect sizes ranging from .22 to .27 depending on the children's grade level (Hill, Bloome, Black, & Lipsey, 2008). On the basis of the typical standard score metric of IQ tests (a mean of 100 and a standard deviation of 15), our results indicate that, on average, children with SLI score slightly more than 10 points below their similar-aged peers.

Why do children with SLI, on average, score lower than their TD peers on nonverbal IQ tests? One possibility is that children with SLI exhibit deficits in nonverbal cognition that are distinctive from their linguistic deficits. Evidence for the independent co-occurrence of linguistic and nonverbal cognitive deficits in this population comes from studies that have found that nonverbal cognitive difficulties remain when children with SLI are compared with younger, language-matched children (e.g., Newton et al., 2010) and in studies that have controlled for pre-existing differences in nonverbal IQ through statistical procedures (e.g., Finneran et al., 2009; Spaulding, 2010; Tropper, 2009). Another explanation for why children with SLI score lower than their peers on nonverbal IQ tests is because common cognitive processes may underlie both verbal and nonverbal performance. For example, procedural memory, or the mechanism for the storage and later retrieval of sequential information (Lum & Bleses, 2012), is important for storing information about situations and events for conveying in narrative form (Dijk & Kintsch, 1983). Likewise, working memory, the processing and storage of information (Just & Carpenter, 1992), is needed to retain the referents for pronouns during both the production and comprehension of narratives. In addition to their impact on narrative skills, cognitive processes affect lexical acquisition, another area of difficulty for children with this disorder (e.g., Alt & Plante, 2006; Gray, 2003b, 2004; Rice et al., 1990). For example, attention appears to play a role in word learning. Attending to visual features, specifically the relevant cue of shape, has been shown to facilitate object count noun learning in young toddlers (Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002). Attention has also been shown to influence the word learning of 22-month-old infants in a fast-mapping task, as word learning performance decreased in the presence of distractions relative to when no distractions were present (Dixon & Salley, 2006).

The poorer nonverbal cognitive performance of children with SLI relative to their TD peers documented in this meta-analysis expands on prior studies that have supported the theoretical underpinnings characterizing SLI as a disorder that is not isolated to the linguistic system (e.g., Cole et al, 1994; Krassowski & Plante, 1997; Notari, Cole, & Mills, 1992). Specifically, our finding highlights the nonverbal cognitive difficulties encountered by children with SLI, adding evidence to the growing body of work supporting depressed nonverbal cognition as part of the clinical profile of children with this disorder.

However, although the results appear to support the cognitive-based theoretical perspective of SLI, an alternative explanation is that linguistic skills provide support for performance on nonverbal IQ tests. Difficulty understanding the directions, a linguistic skill, may impede performance on some nonverbal IQ tests. For example, when administering the Conceptual Thinking subtest of the KABC–II (Kaufman & Kaufman, 2004a), the instruction is to "Point to the one that doesn't belong." Young children with SLI may have difficulty understanding the directions by virtue of their language impairment. Consequently, they may perform more poorly than their TD peers, not necessarily because of poor conceptual knowledge but because of failure to comprehend the linguistic input. In comparison to difficulty with comprehending the directions, which may impede performance, the use of inner speech may improve a child's performance on nonverbal IQ tests. Inner speech, in contrast to vocal speech, is speech that one uses for various functions that is not spoken aloud. Prior work has documented that inner speech facilitates problem solving in difficult situations (Pintner, 1913). Children with SLI appear to experience a significant delay in their ability to use inner speech to mediate cognition (Lidstone, Meins, & Fernyhough, 2012). The purpose of nonverbal IQ tests is to tap into fluid reasoning, with tests specifically constructed to require children to problem solve when exposed to novel conditions. Therefore, as the difficulty level on nonverbal IQ test items increases, inner speech may play a contributory role in the child's success. Lack of effective inner speech may hinder the success on test items for children with SLI.

The interaction between language and cognition is likely to be indirect and complex and may or may not work the same in children who are typically developing and those who are not. Future work needs to be conducted to help to elucidate the independent contribution of linguistic and nonlinguistic skills to nonverbal IQ test scores, including how this may change with development. This is important to determine in order to obtain a better understanding of what nonverbal IQ tests are actually assessing for children with SLI.

In the meantime, clinicians, researchers, and policy decision makers should be wary of assuming that nonverbal IQ scores of children with SLI are unbiased and accurate representations of their intelligence. Although children with SLI scored 10 IQ points lower, on average, across studies on nonverbal IQ tests, prior work has documented that their nonverbal IQ scores do not predict their learning rate or their long-term outcomes (Cole et al., 1992; Tomblin, 2008). Our results provide further support for abandoning the policy of cognitive referencing, permitted in IDEA, 2004, Section 1414(b)(6). States or districts within states that currently recommend using cognitive referencing as a criterion for determining eligibility for language intervention services should be prepared for an increase in the number of students who are eligible for intervention when this unfounded policy is abandoned (Cirrin, 1996). The alternative, relying on an outdated policy with accumulating evidence contradicting its validity, would be unwise.

Although this meta-analysis provides valuable information in the finding of significant differences in the nonverbal IQ test performance of children with SLI and their TD peers, there continued to be variance across studies not accounted for in the multilevel model. In other words, a 10-point difference between children with SLI and TD children on nonverbal IQ test scores is a good estimate but not a perfect one. One likely factor for this variability is the heterogeneity known to exist in this population (Conti-Ramsden et al., 2009; Leonard, 1998). Advocates for the bioecological theory (Bronfenbrenner, 1979) argue that, in order to understanding children's development, it is important to assess their maturing biology, their familial environment, their community environment, their societal landscape, and the interaction among the four. Clearly, future work in understanding the contribution of these factors to the nonverbal cognition of children with SLI is needed, as the variables available and controlled for in this study did not fully capture this diversity or sufficiently explain the heterogeneity.

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