Response Time in 14-Year-Olds With Language Impairment

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Purpose: To determine whether children with language impairment were slower than typically developing peers at age 14, and whether slowing, if present, was similar across task domains; whether differences in response time (RT) across domains were the same for children with specific language impairment (SLI) and nonspecific language impairment (NLI); and whether RT performance at age 9 predicted performance at age 14.
Method: Fourteen-year-old children with SLI (n = 20), NLI (n = 15), and typical development (NLD; n = 31) were administered several linguistic and nonlinguistic speeded tasks. The children had received the same tasks at age 9. RT performance was examined.
Results: Both the SLI and the NLI groups were significantly slower than the NLD group in motor, nonverbal cognitive, and language task domains, and there was no significant difference among domains. Individual analyses showed that most, but not all, children with SLI and NLI were slower than the NLD group mean. Slowing at age 9 and age 14 were moderately correlated.
Conclusions: The results suggest that slow RT is a persistent characteristic of many children with language impairment; however, the nature of the relationship between RT and language performance requires further investigation.

KEY WORDS: language functions and disorders, adolescents, experimental research

Children with specific language impairment (SLI) demonstrate language abilities significantly below what is expected for their age, but show no evidence of hearing impairment, frank neuropathology, autism spectrum disorders, or other factors usually associated with language impairment (Leonard, 1998). Their nonverbal cognitive functioning must, by definition, be within normal limits (see Tager-Flusberg & Cooper, 1999, for a discussion of this criterion), yet it is well documented that children with SLI have difficulties with many nonlinguistic cognitive tasks (Johnston, 1994; Leonard, 1998).

One area in which children with SLI demonstrate cognitive limitations is response time (RT). Children with SLI have been found to respond more slowly than age-matched peers on a variety of RT tasks. For example, Johnston and Ellis Weismer (1983) used a mental rotation task, in which children were asked to compare two complex shapes, one rotated to a different angle than the other, and determine if they were the same. Sininger, Klatzky, and Kirchner (1989) measured time required to determine if a digit had been part of a previously presented set. Windsor, Milbrath, Carney, and Rakowski (2001) provide a meta-analysis of archival RT data involving children with language impairment.

Although there are a number of studies of RT in children with language impairment, few longitudinal data have been available. Here we

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report data from a group of children who participated in the same battery of RT tasks at 9 and 14 years of age. Data from the age 9 data collection were reported in Miller, Kail, Leonard, and Tomblin (2001). In that paper, we found that children with language impairment (LI) had slower RTs across the entire battery of linguistic and nonlinguistic tasks compared with typically developing peers, in accordance with the results of meta-analyses by Kail (1994) and Windsor and Hwang (1999). We distinguished between children with SLI, whose nonverbal IQ scores were within normal limits, and children with nonspecific language impairment (NLI), who scored below normal limits on both language and nonverbal IQ. We found that children with NLI were slower than children with SLI. In the current study, we ask if children with SLI and NLI continue to be slower than age peers at age 14, if slowing is similar for different types of RT tasks, and if there are differences between the SLI and NLI groups.

Development and Response Time Across Domains

Over the course of normal development, RTs become faster, peaking in adolescence and young adulthood (Kail, 1991b). RT is considered by some researchers to index a global processing speed parameter that becomes faster as children grow older and slows again as adults age (Cerella & Hale, 1994). There is evidence, however, that developmental changes in speed over the life span are not uniform across all types of tasks. Cerella and Hale described several possible ways to divide RT tasks into theoretically and empirically distinct domains. One important division may be between simple perceptual-motor tasks and more complex tasks. Lima, Hale, and Myerson (1991) proposed a distinction between lexical and nonlexical tasks (which were in fact nonlinguistic). Examining a sample that included some of the children from the present study, Kail and Miller (2006) found differences between language and nonlanguage tasks that change over time. In our current work, we included both language and nonlanguage tasks. Our tasks can be categorized into three domains, which we refer to as *motor,* (nonverbal) *cognitive,* and *language,* and which have been investigated in the literature on RT (Cerella & Hale, 1994).

Slow RTs in children with LI are consistent with the hypothesis that a general neuromaturational delay underlies LI (Bishop & Edmundson, 1987; Locke, 1994). Locke suggested that in many cases of LI, a general neuromaturational delay slows early lexical development. Because of the lexical delay, children have not amassed the lexical knowledge needed to move into an analytic stage of language development (i.e. grammar) at the time when the neurological grammatical mechanism is available. If this critical period for grammatical development is missed, compensatory mechanisms must be called into use, leading to less than optimal language performance. According to this view, children with LI are unlikely ever to reach the level of proficiency of their peers. If Locke is correct, one would predict that children with LI would continue to be slower than age peers on RT tasks related to language, while nonlanguage tasks may improve if the general maturational delay is overcome.

In a longitudinal study, Bishop and Edmundson (1987) examined language and motor impairment in children with SLI from 3 ½ to 5 ½ years of age. The children with SLI took longer to perform a motor task than typically developing children, but over time the impaired children's performance approached that of controls. In contrast, only some of the children showed evidence of catching up with controls on language measures. On the basis of these findings, we might predict that motor RTs for children with LI will approach those of typically developing peers as the children move into adolescence.

However, in a cross-sectional study of children ranging in age from 8 to 13 years, Kohnert and Windsor (2004) found that children with LI (who had normal nonverbal IQs) were slower than typically developing peers on three perceptual-motor tasks—simple and choice visual detection tasks and a choice auditory detection task—but not on a fourth, simple auditory detection. Age was controlled for in the analyses. The same children were also tested for RT on language tasks (Kohnert, Windsor, & Miller, 2004; Windsor & Kohnert, 2004). They were slower than peers on word recognition and picture naming, but not on an auditory lexical-decision task.

RT is not only a reflection of processing speed, however. It is also affected by knowledge. For example, in picture naming tasks, adults who are proficient language users are slower to name low-frequency words compared with high-frequency words (Johnson, Paivio, & Clark, 1996). The difference in RT can be interpreted as an indication that more frequent words have a stronger representation (Nation, Marshall, & Snowling, 2001); that is, the individual "knows" high-frequency words better. An example from language disorders is found in Kail and Leonard (1986); on the basis of the results of several tasks designed to tap lexical knowledge in various ways, they concluded that the slower RTs of children with SLI were due to their less extensive lexical knowledge, compared with age-matched peers.

If language knowledge—semantic or syntactic—contributes to RT performance, then we might expect a developmental pattern rather different from the predictions of a neuromaturational delay model. Children with LI do gain knowledge of language over time. As they move into adolescence, a general speed deficit may delay RTs on all tasks, but for language tasks, increasing knowledge may lead to better RT performance. Whereas RTs might still be delayed relative to typically developing peers, language tasks would be less delayed than cognitive tasks (e.g., mental rotation) that rely minimally on knowledge and maximally on processing.

In summary, there are both theoretical and empirical reasons to expect that RT slowing in children with LI at age 14 will not be identical across motor, cognitive, and language domains. However, it is difficult to make predictions about how RTs in the three domains will differ, because the mechanisms contributing to RTs and to language impairment are not fully understood. Among the information about language impairment that is lacking is whether SLI and NLI are underlyingly different (Bishop, 1994). We expect, based on prior findings (Miller et al., 2001), that the children with NLI will be slower than the children with SLI, but we do not know if the pattern across domains will be similar for the two groups.

As developmental questions are at issue, it is appropriate to ask whether RT performance at age 9 predicts performance at age 14. A finding that children with LI are slower than age peers at both times does not necessarily imply that individuals within the groups are relatively slow or fast at both times. Correlational analyses relating RTs at the two time points will allow us to estimate the degree to which an individual's standing relative to the sample at age 9 is consistent with the individual's relative standing at age 14. The relationships between RTs at the two times may vary according to domain.

Research Questions

The current study addressed four research questions. The first was whether the children with language impairment, both SLI and NLI, who were slower than typically developing peers at age 9 continued to be slower at age 14. The second question was whether slowing, if present, was similar across domains. Third, we asked if the differences in RT across domains were the same for children with SLI and NLI. Our fourth question was influenced by the finding that although, as a group, children with SLI and NLI usually demonstrate slower RTs than typically developing peers, slowing may not be characteristic of all children with language impairment (Miller et al., 2001; Windsor & Hwang, 1999), and it is not known if individuals who are slow will remain so over time. With data from the same children at two time points, we asked whether RT performance at age 9 predicted performance at age 14; that is, did children who were relatively fast (or slow) at age 9 retain their standing in the sample at age 14?

Method

Participants

The participants were a subset of those involved in a large-scale investigation of the prevalence of SLI conducted at the University of Iowa (Tomblin et al., 1997). A large sample of kindergarten children was drawn from urban, suburban, and rural schools in midwestern communities. All the children received a brief language screening test composed of 40 items from the Test of Language Development—Second Edition: Primary (TOLD–P:2; Newcomer & Hammill, 1988). All children who failed the screening, and approximately 33% of those who passed, were recruited to participate in a diagnostic test battery. Children were excluded from participation in the diagnostic phase if they (a) did not have English as their primary language or came from a home where English was not the predominant language; (b) had a history of mental retardation, autism, or neurological problems; or (c) were blind or used hearing aids. Details of the sampling and procedure can be found in Tomblin et al.

The diagnostic battery included measures of hearing, language, speech, and nonverbal intelligence. Children with persistent bilateral hearing deficits were excluded from further testing. For performance IQ, a combined standard score greater than 87 on two subtests of the Wechsler Preschool and Primary Scale of Intelligence—Revised (Wechsler, 1989) was considered to be an age-appropriate level. Language ability was measured by a battery including selected subtests of the TOLD–P:2 (Newcomer & Hammill, 1988) and a narrative story task involving both production and comprehension (Culatta, Page, & Ellis, 1983). Scores were standardized based on local norms and combined to form five composite scores. A child was considered below age level on the language battery when two or more composite scores were 1.25 *SD*s below the mean for the child's age group. Further information about the diagnostic testing is given in Tomblin, Records, and Zhang (1996).

The parents of all children who participated in the diagnostic procedure were invited to join a registry. All children in the registry who were language impaired at kindergarten were invited to participate in a longitudinal study; 231 (82% of those invited) agreed to join. In addition, 442 children whose language status was normal at kindergarten were randomly sampled and invited to participate; 373 agreed. See Tomblin, Zhang, Buckwalter, and Catts (2000) for details regarding the subject recruitment and selection process.

These children were administered a similar diagnostic battery 2 years after the original diagnostic phase, when most of the children were in second grade. Language tests included the Peabody Picture Vocabulary

Test—Revised (PPVT–R; Dunn & Dunn, 1981), the Comprehensive Receptive and Expressive Vocabulary Test (CREVT; Wallace & Hammill, 1994), and selected subtests of the Clinical Evaluation of Language Fundamentals—Third Edition (CELF–3; Semel, Wiig, & Secord, 1994), as well as an experimental measure of narrative production. Nonverbal intelligence was measured using the Performance Scale of the Wechsler Intelligence Scale for Children—III (WISC–III; Wechsler, 1991). Composite scores were computed in the same manner as for the kindergarten battery, and diagnostic classifications were made.

For Miller et al. (2001), we selected three groups of children from the sample described previously whose performance placed them in the same diagnostic category at both testing points (in kindergarten and 2 years later). The NLI group (n = 19) was made up of children who scored below age expectations on both performance IQ and language; however, all of these children had performance IQs between 72 and 83 (i.e., they would not be considered mentally retarded). The SLI group consisted of 29 children whose performance IQ was age appropriate but who scored below age expectations on language, while the normally developing (NLD) group consisted of 29 children whose performance IQ and language scores were within the age-appropriate range. The NLD and SLI groups were matched for performance IQ. Each group's mean was 99, with a 95% confidence interval of 96–102. The groups did not differ significantly, $t(56) = 0.03, p > .95$. The performance IQ of children with NLI was significantly lower than the children with SLI, $t(46) = 10.5, p < .0001$.

Of these 77 children, 70 participated in the RT tasks again when they were about 14 years old. As part of the larger study, all of the children received a diagnostic battery including the PPVT–R, the Expressive scale of the CREVT, the Concepts and Directions and Recalling Sentences subtests of the CELF–3, and the Qualitative Reading Inventory—3 (QRI; Leslie & Caldwell, 2001) to assess discourse comprehension and production. For the purposes of placing children into diagnostic categories, the WISC–III Block Design and Picture Completion subtests were used as a measure of performance IQ. The children who participated in the RT tasks also received two untimed subtests of the Universal Nonverbal Intelligence Test (UNIT; Bracken & McCallum, 1998).

Table 1 summarizes test scores from the diagnostic battery administered at age 14 for each group, including nationally normed standard scores for the PPVT–R, CREVT–R, and CELF–3. Scores for the QRI are composite z scores, combining the listening comprehension and expressive discourse portions of the QRI. The language and QRI z scores were obtained by normalizing based on the distribution of the entire sample of 527 children tested in the Iowa project at age 14. Of the 70 children who participated in the RT tasks, 4 scored within normal limits on language but below normal limits on performance IQ. At the time these children participated in the first round of RT data collection, 1 had been classified as NLD, 1 as SLI, and 2 as NLI. These children were excluded from analysis for the present study; therefore, N = 66. Some children in the NLD, SLI, and NLI groups at age 14 had been classified earlier in a different diagnostic category: 8 of the NLD group had been SLI, 4 of the SLI group had been NLD and 2 NLI, and 1 of the NLI group had been NLD and 4 SLI. Analyses were based on diagnosis at age 14.

Analyses of variance (ANOVAs) were performed, and significant main effects of group (ps < .01) were found for all language and IQ variables. Post hoc comparisons were conducted using the unequal N honestly significant difference (HSD) test, a modification of the Tukey test (Statsoft, 2004). The NLD group had significantly better scores (ps < .01) than both the SLI and the NLI groups for the UNIT, language z score, and all standardized language tests. For performance IQ, the NLD and SLI groups did not differ, but both had higher mean scores than the NLI group (ps < .05).

Table 1. Number of participants, mean (standard deviation) nonverbal IQ scores, mean language composite z scores, mean language test standard scores, and demographic data by group.

Variable	NLD	SLI	NLI
n	31	20	15
Performance IQ SS	100 (8)	103 (11)	74 (7)
UNIT SS	99 (10)	91 (11)	88 (10)
Language z	−0.17 (0.71)	−1.54 (0.34)	−1.88 (0.66)
QRI oral composite z	−0.22 (0.81)	−0.97 (0.59)	−1.13 (0.44)
PPVT–R SS	99 (14)	83 (10)	76 (10)
CREVT–R SS	94 (12)	80 (7)	81 (6)
CELF–3 SS			
Concepts and Directions	9 (3)	6 (3)	5 (1)
Recalling Sentences	9 (2)	5 (2)	4 (2)
Age (years; months)	13; 11 (5)	13; 11 (6)	13; 11 (5)
Sex			
Male/female	16/15	12/8	5/10
Ethnicity			
White	29	17	11
Black	1	3	4
Asian	0	0	0
Hispanic	1	0	0
Mother's education			
(mean years)	14 (3)	13 (1)	12 (1)

Note. NLD = normal development; SLI = specific language impairment; NLI = nonspecific language impairment; SS = scaled score ; UNIT = Universal Nonverbal Intelligence Test ; QRI = Qualitative Reading Inventory—3; PPVT–R = Peabody Picture Vocabulary Test—Revised; CREVT = Comprehensive Receptive and Expressive Vocabulary Test; CELF—3 Clinical Evaluation of Language Fundamentals—Third Edition.

Table 1 also shows data regarding sex, age, ethnicity, and socioeconomic status (SES) for each group. The measure used for SES is years of mother's education, which has been found to be a good predictor of language outcome (Chapman, Schwartz, & Kay-Raining Bird, 1991). There was a significant effect of group for this variable ($p < .02$); education data were missing for 1 child in the NLD group. Post hoc unequal N HSD tests showed that mother's education was significantly higher for the NLD group compared with the NLI group ($p < .05$).

Design and Materials

All tasks were presented on a laptop computer, and children responded by striking a key on the keyboard or by speaking a word on the picture naming task (see below). Auditory stimuli were presented monaurally by computer over headphones. Each task included multiple conditions. With three exceptions (described below), trials for different conditions were in quasi-random order; one trial for each condition occurred, randomly ordered, then another set of randomly ordered trials, and so on. Trials in the simple RT task were truly randomly ordered; trials for the tapping and picture matching tasks were blocked. Two main types of tasks were used: nonlinguistic tasks and linguistic tasks. The tasks were chosen to tap a wide range of linguistic and nonlinguistic abilities. Table 2 provides a summary of the tasks, with a brief description and statement of how RT was measured for each. Examples of the stimulus items are shown in Table 2 and can also be found in Miller et al. (2001).

Nonlinguistic tasks. There were two types of nonlinguistic tasks: motor and nonverbal cognitive. The motor tasks involved motor performance only, with minimal language and cognitive components. In the *tapping* task, the child was asked to tap a key as many times as possible in 5 s. The beginning and end of each interval were signaled both visually (by the words "Start" and "Stop") and aurally (by a tone). There were three tapping conditions, with three trials in each. The trials were blocked by condition. In the first condition, the child tapped one key with the index finger of the preferred hand. In the second, the child tapped two keys (located on the same row but with one key between them) in alternation, using the index finger of the preferred hand. In the third condition, the child tapped the same two keys in alternation, but used the first two fingers of the preferred hand. Each key was marked by a colored dot, a different color for each key.

The other motor task was a *simple RT* task. The child was instructed to strike a key marked by a colored dot as quickly as possible in response to a visual signal. On each trial, the child first saw the word "Ready," followed by the response signal (three asterisks) after a delay of 1, 2, or 5 s. There were eight trials at each delay. The conditions were randomly ordered, so the child could not anticipate the length of the delay.

The nonverbal cognitive tasks involved more cognitive operations than the motor tasks, but did not include linguistic components nor lend themselves to verbal mediation. Both of the nonverbal cognitive tasks, *visual search* and *mental rotation,* are commonly used in the cognitive development literature to assess speed of processing (see Kail, 1991a, for a review). In the visual search task, simple nonsense figures (from Kail, Pellegrino, & Carter, 1980; see Figure 1 for examples) were used. The child was shown a target figure and then required to scan a five-member array for the target, which remained visible. The child was instructed to scan the array from left to right, pressing one key (marked with a green dot) when the target was present or a different key (marked with a red dot) when it was absent. There were six conditions in this task, as the target could be in any of the five positions from left to right or it could be absent. There were six trials per condition.

In the mental rotation task, the same figures were used as in the visual search. A target figure was shown on the left, simultaneously with the same figure on the right. The child had to press one key (marked with a green dot) when the second figure was exactly the same as the target or a different key (marked with a red dot) when it was a mirror image. The second figure was rotated 0°, 60°, or 120° clockwise from its canonical position. There were six trials in each of the six conditions.

Linguistic tasks. Three types of linguistic tasks were used: lexical tasks were intended to require the child to access word meanings, grammatical tasks required a response based on the syntactic structure of a sentence, and phonological tasks involved judgments about speech sounds. There were two of each task subtype. In all tasks requiring a keypress response, the child pressed one key (marked with a green dot) for a yes or positive response and a different key (marked with a red dot) for a no or negative response.

One lexical task, *picture matching,* required the child to judge whether two pictures, presented simultaneously, matched on a given criterion. This task involves accessing lexical items and components of their meanings, such as category membership. It was based on a task used by Kail and Leonard (1986, Experiment 3), but used different pictures. Trials were blocked by condition, with 12 trials in each condition. In the first block of trials, the child judged whether the two pictures were identical physically. In the second block, the child judged whether the pictures had the same name (e.g., two nonidentical cats). In the third block, the child judged whether they belonged to the same category (e.g., animals).

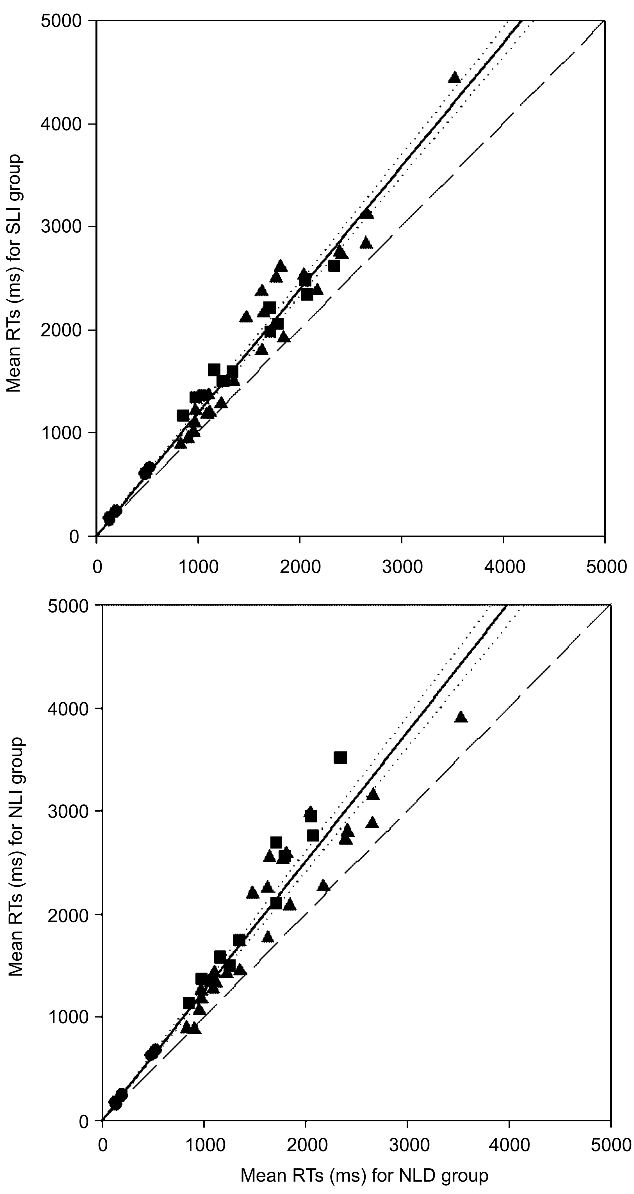
In *picture naming,* derived from Leonard, Nippold, Kail, and Hale (1983), the child named aloud pictures that appeared on the screen. Like picture matching,

Table 2. Description of response time (RT) tasks.

Task type	Description	Example stimuli	RT measurement
Nonlinguistic			
Motor			
Tapping	Tap one or two keys as quickly as possible for 5 s.	Beginning of trial signaled by "Start" and tone; end of trial signaled by "Stop" and tone.	ms per tap.
Simple RT	Strike a key in response to "***."	Trial signaled by "Ready," followed by "***" in 1, 2 or 5 s.	ms from onset of "***" to keypress.
Nonverbal cognitive			
Visual search	Strike one key if target is present, another if absent.	Array of nonsense figures.	ms from onset of array to keypress.
Mental rotation	Strike one key if second figure matches target, another if mirror image.	Pair of nonsense figures.	ms from onset of stimulus pair to keypress.
Linguistic			
Lexical			
Picture matching	Strike one key if two pictures match on criterion, another if not.	Black-on-white drawings of animals, furniture, vehicles.	ms from stimulus completion to keypress.
Picture naming	Speak name of picture shown.	Black-on-white drawings of objects (e.g. truck, baby).	ms from completion of picture to onset of verbal response.
Grammatical			
Truth value	Strike one key if picture matches sentence heard, another if not.	Black-on-white drawings paired with sentences, for example, The girl is chasing the cat. The girl is being chased by the cat. The horse and the dog are chasing the cat.	ms from onset of auditory stimulus (sentence) to keypress.
Grammaticality	Strike one key if sentence is correct, another if incorrect	*All of our dogs is white/Two of these cars are brand new. *In the morning we orange juice drink/At lunch my mom eats a sandwich. *Bobby put the cup the table/You have to hit nails with a hammer.	Incorrect sentence: ms from onset of anomalous material to keypress. Correct sentence: ms from onset of final word to keypress.
Phonological			
Judge rhymes	Strike one key if stimuli rhyme, another if not.	Black-on-white drawing of a shirt followed by written word *dirt*.	ms from completion of second stimulus to keypress.
Judge initial consonants	Strike one key if stimuli start with same sound, another if not.	Black-on-white drawing of a clock followed by spoken word *clown*.	ms from completion of second stimulus to keypress.

picture naming involves lexical access, but also includes a production component. Time from stimulus onset to onset of verbal response was the RT. Response onset was detected when the input from a headworn microphone passed a threshold amplitude. The names of the pictures varied in frequency of occurrence in English; the three conditions were high, medium, and low frequency, with eight trials in each condition. High-frequency words had simple frequencies of between 132 and 288 in the third-grade corpus of Carroll, Davies, and Richman (1971). Medium-frequency words were between 36 and 81, and low-frequency words ranged from 1 to 24.

Figure 1. Fit of mean RTs to Equation 1 for children with SLI (upper panel) and children with NLI (lower panel) versus children with NLD. Each data point represents the mean scores from one of the 42 conditions. Circles represent motor tasks, squares cognitive tasks, and triangles language tasks. Dashed lines indicate a slope of one. Dotted lines show the 95% confidence interval. RT = response time; SLI = specific language development; NLI = nonspecific language impairment; NLD = normal development.



One grammatical task was *truth-value judgment*. The child was shown a picture. After 2 s, a sentence was presented auditorily while the picture remained visible. The child judged whether the meaning of the sentence matched the picture. There were three types of sentences: simple active, simple passive, and active with a compound subject noun phrase. Six matches and six mismatches were presented for each sentence type. In the other grammar task, *grammaticality judgment,* the child judged whether an auditorily presented sentence was "good" or "bad." Half of the sentences were grammatically correct; the incorrect sentences erred in one of three ways: subject–verb agreement was incorrect, word order was incorrect, or a preposition was omitted from an oblique argument. Six correct and six incorrect sentences were presented for each sentence type.

Two phonological tasks were given, which shared a common structure. A picture appeared at the top of the computer screen, followed, after 4 s, by a word presented auditorily, a printed word at the bottom of the screen, or a picture at the bottom of the screen. Each of these conditions included 12 trials, for a total of 36 trials in each task. In the *judging rhymes* task, the child judged whether the second stimulus rhymed with the first. In the *judging initial consonants* task, the child judged whether the second stimulus began with the same sound as the first.

Procedure

Data were collected, as part of a larger battery of tests and experimental tasks, by examiners who visited the child's home or school in a specially equipped van. The tasks were divided into two sessions, which took a total of 50–60 min to complete. Both sessions contained one of each type of task: motor, nonlinguistic cognitive, lexical, grammatical, and phonological. All children did the tasks in the same order. Children were instructed to always respond as quickly as possible without sacrificing accuracy. A set of practice trials preceded each task. The examiner repeated the practice trials as many times as necessary to ensure that the child understood the task. For all tasks in which the response was a keypress, children were instructed to rest their preferred hand on the computer just below the keys to be used, which were marked by colored dots. In addition to the practice items, the mental rotation task included a brief introduction to the nonsense figures used in the task. These were presented on cards, so that the examiner could show the child what each figure looked like in its normal and mirror-image versions and also rotate the figures to demonstrate how they would appear in the task.

Results

Prior to performing analyses, we eliminated two types of RTs: (a) those from trials in which the response was incorrect and (b) those less than 10 ms. The latter were considered too short to be legitimate responses to the stimuli. We refer to RTs in these two categories as unusable trials.

Mean RTs in each condition were then calculated for each individual by averaging across trials within condition, and outliers were removed, as is usual for RT studies (e.g., Bowers, Vigliocco, Stadthagen-Gonzalez, & Vinson, 1999; Kail, 1991b). Outlier trials were identified within each condition for each individual. Low outliers were defined as any RT less than 350 ms, except for the motor tasks, in which shorter RTs were common, and the picture naming task, in which 300 ms was the cutoff. Then, any RT greater than twice the mean was identified as an outlier. This procedure was repeated until there were no outliers. Of usable, correct trials, the percentages excluded as outliers across all participants and conditions were NLD 1.8%, SLI 2.8%, and NLI 1.8%. The total percentages of trials eliminated (unusable and outliers) were NLD 7%, SLI 13%, and NLI 13%. The mean numbers of valid responses, those used to compute the RTs, are shown in Appendix A, organized by group, task, and condition. Also shown are mean RT values. Valid response data are not shown for the tapping task, as there was only one instance of missing data. In all analyses using RTs, if a child had fewer than three valid RTs in one or more conditions of a particular task, no mean was computed for that condition (i.e., the child was missing data for that condition). In Appendix A, the number of children contributing data for each condition is shown.

Accuracy

Accuracy of response was calculated as a proportion for each condition after excluding unusable trials but before removing trials with outlier RTs. Accuracy was not computed for the motor tasks, as there were no correct or incorrect responses for those tasks. Group means for each condition are shown in Appendix B. All groups performed well above the level of chance (i.e., 50%) throughout. ANOVAs were performed on the accuracy data; an arcsin transformation was applied to the proportions of accurate responses. In five of the eight tasks, there were significant ($p < .05$) main effects for group. The effects were of medium magnitude for mental rotation ($f = .31$), judging grammaticality ($f = .26$), judging rhymes ($f = .34$), and judging initial consonants ($f = .33$); for judging truth value, the effect size was small ($f = .12$). Pairwise comparisons were made using the unequal N HSD post hoc test, with an alpha level of .05. The NLD group was significantly more accurate than the NLI group on mental rotation, judging grammaticality, judging rhymes, and judging initial consonants. The NLD group was significantly more accurate than the SLI group on judging grammaticality. The SLI group was significantly more accurate than the NLI group on mental rotation. Although there was a significant main effect for group on judging truth value, none of the post hoc pairwise comparisons reached significance.

Preliminary Analyses

Replicating analyses performed by Miller et al. (2001), we fit the data from the 42 task conditions to Equation 1, computing separate functions for the SLI and NLI groups.

$$\mathrm{RT}_{\mathrm{SLI/NLI}} = m \times \mathrm{RT}_{\mathrm{NLD}} \tag{1}$$

For the SLI group, $R^2 = .96$; for the NLI group, $R^2 = .92$. The slowing coefficient, or slope, for the SLI group was 1.20. The 95% confidence interval, 1.16–1.23, did not include 1, indicating that the children with SLI were significantly slower than their typically developing peers. The slope for the NLI group was 1.26, with a 95% confidence interval of 1.20–1.31. Thus, the children with NLI were also significantly slower than the NLD children. The confidence intervals for the SLI and NLI groups overlapped. Scatterplots with regression lines are shown in Figure 1. Reference lines with a slope of 1 are provided, and confidence intervals are shown.

The method described previously is a Brinley function (Brinley, 1965), commonly used for comparing the RTs of two groups across multiple elicitation conditions and tasks. It has been demonstrated, however, that this method is not appropriate for such comparisons; among other problems, it does not account for the fact that experimental conditions are nested within tasks (e.g., Kail & Salthouse, 1994; Sliwinksi & Hall, 1998; Windsor et al., 2001). Furthermore, all of the data in the current study came from a single sample of children. That is, in addition to variance attributable to tasks, we must account for variance attributable to individual participants.

To deal with this issue, we adopted the following approach. We modified Equation 1 and refit it for each individual in each of the three groups. These modifications to Equation 1 are reflected in Equation 2 by the subscripts i, j, and k (i = 1 to n_j, the number of subjects in group j; j = NLD, SLI, and NLI; and k = motor, cognitive, and language).

$$\mathrm{RT}_{ijk} = b_{ijk} + m_{ijk} \times \mathrm{RT}_{\mathrm{NLD},\,k} \tag{2}$$

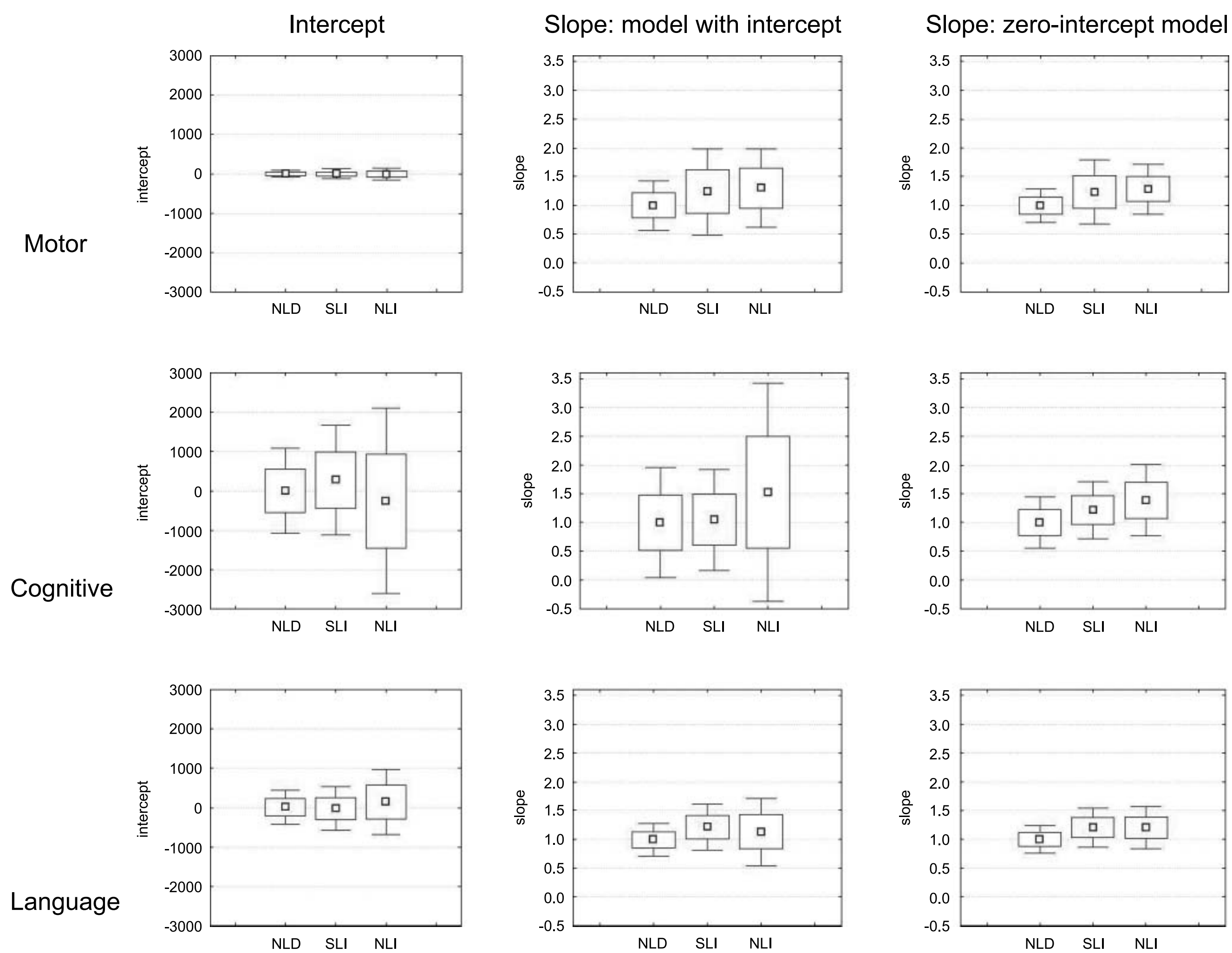
We fit Equation 2 with and without the intercept (b_{ijk}). Also, when fitting Equation 2 for each individual i in the NLD group, $\mathrm{RT}_{\mathrm{NLD},k}$ was recomputed using all subjects except subject i. This jackknife procedure was used for individuals in the NLD group so that the mean slope and intercept for the NLD group are not trivially 1 and 0, respectively. Thus, for each individual, the mean RT for an experimental condition was computed by averaging across the trials in that condition, and these individual mean RTs were regressed against the means for the NLD group as a whole. These person-level regression equations were estimated, separately for the motor (6 conditions), cognitive (12 conditions), and language domains (24 conditions), obtaining estimates for each individual of the slope for each domain relative to the NLD group; in other words, Brinley functions for the motor, cognitive, and language domains were generated for each individual using Equation 2. The person-specific nature of the Brinley function depicted by Equation 2 is apparent from the subscript i attached to the coefficient m. Using Equation 2 to generate individual Brinley functions takes into account dependence of observations at the individual level because the analysis returns a single slope for the individual for each condition. In the next step, the slope estimates for individuals were entered in an ANOVA to assess the main effects of group and domain on the mean slope of the Brinley functions, as well as the interaction of these factors. At this second stage, slopes for the same subject from the three domains are treated as repeated measures.

As mentioned, Equation 2 was fit with and without the intercept term. The specification of Equation 2 implies that the person-level intercept is the expected RT in a domain for that person when mean RT for the NLD group is 0. As such, the intercept of Equation 2 is a parameter estimated outside the bounds of the data and does not reflect how fast or slow the individual is, on average, relative to the NLD group. We compared the results for estimating Equation 2 with and without the intercept terms by examining the standard errors of the slopes obtained from the two sets of estimations. For each group and each domain, the square root of the mean of the squared standard error was computed. In this way, we could compare, for example, the mean slope standard error for the SLI group in the motor domain with and without an intercept term included in the model. In each case, the mean standard error was smaller when the intercept term was not included, ranging from 32% to 53% of the mean standard error of the model with intercept. Average slopes by group and domain did not vary substantially under the two approaches to fitting Equation 2, but variability in slopes was considerably greater when the intercept term was included in the model. For comparison purposes, Figure 2 shows side-by-side boxplots of the distributions of the slope estimates under the two approaches. The slope estimates used in the second stage were those obtained from the zero-intercept model.

One objection to fitting Equation 2 at the person level, and then using these slope estimates as dependent variables in a second-stage analysis of group and domain effects on the slopes, is that this two-stage approach does not take into account differential precision in the individual slope estimates in the second-stage analysis. Typically, one would want to give greater weight in the second-stage analysis to those slopes that have been estimated with greater precision. However, differential precision is not a concern in the present case. Specifically, the precision in the slope estimate for a given person in a given domain is a function of two factors. The first factor is error variance, or the degree to which individual mean RTs for an individual do not fall exactly on the regression line for that individual. As error variance increases, precision in the slope estimate decreases. The second factor is variability in the predictor values; as variability in the predictor values increases, precision in the slope estimate also increases. To the extent that these factors differ from one individual to the next, so too will the precision in the slope estimates vary from one individual to another. However, the first of these two factors (error variance) is typically assumed to be the same across individuals, and, in fact, would be estimated by pooling information across individuals. Differences across individuals in the estimate of error variance are typically considered to be error, and are averaged out by pooling across individuals to obtain a single estimate of error variance or, at worst, a separate estimate of error variance for each group of subjects. Error variance is never considered to be person specific (i.e., different for each individual subject).

The second factor affecting precision in the slope estimates, variance in the predictor values, corresponds to variability in the NLD mean RTs across the different conditions within a given domain. Because the NLD mean RTs are the same for all individuals in the NLI and SLI groups, except to the extent that individual subjects were not observed in some conditions, this factor, too, is the same for all individuals in both the NLI and SLI groups. Thus, differences in slope precision across individuals in the study are minor, reflecting the fact that a handful of individuals were not observed in all conditions. In fact, examination of the variance in the predictor values across individuals within each group showed that for the SLI group in the language domain, 4 of 20 cases had values that differed from the remainder of the group. For these 4 cases, the variance in the predictor values ranged from 96% to 97% of the variance for cases that had maximum variability in the predictors. One case in the SLI group had 86% of maximum variance in the cognitive domain. In the NLI group, 2 of 15 cases in the language domain did not have maximum variance in the predictors (90%–99% of maximum); 5 of 15 cases in the cognitive domain did not have the maximum variance, and in these cases the variance in the predictors ranged from 66% to 90% of the maximum. Given these minor differences across cases, and the small number of affected cases, differential weighting of the slopes in the second-level analysis would minimally affect the results; consequently, we opted to use equal weighting for all cases. These minimal differences across individuals also suggest that a multilevel approach

Figure 2. Boxplots showing distributions of intercepts (first column) and slopes (second column) for regression models including an intercept parameter, and slopes for zero-intercept models (third column). Boxplots show mean, mean ± 1 *SD*, and mean ± 1.96 × *SD*.



to the analysis would yield quite similar estimates of the second-stage estimates. We opted for the two-stage approach over the multilevel approach because of the ease of handling the three domains at the second stage, which would have required a multivariate multilevel model.

RT Slowing by Group and Domain

The slope estimates for individuals, generated as described previously, were entered into a mixed-model ANOVA to assess the main effects of group and domain, as well as the interaction of these factors. The main effect of group was significant, $F(2, 63) = 18.76$, $p < .0001$; partial $\eta^2 = .37$. The mean slopes (and standard deviations) for the NLD, SLI, and NLI groups, respectively, were 1.00 (0.17), 1.22 (0.24), and 1.29 (0.25). Post hoc analysis using the Unequal *N* HSD test showed that the average slope of the NLD group was significantly less than that of the SLI group ($p < .001$) and the NLI group ($p < .001$). The main effect of domain did not reach significance, $F(2, 126) = 2.92$, $p < .06$; partial $\eta^2 = .03$. The mean slopes (and standard deviations) for the motor, cognitive, and language domains, respectively, were 1.17 (0.21), 1.20 (0.26), and 1.13 (0.15). Although the domain effect did not reach significance at the .05 level, given the research questions about domain differences, planned comparisons were performed. The means and standard deviations by group and domain are shown in Table 3. For the NLD and SLI groups, there were no significant differences between the domains ($\alpha = .05$). For the NLI group, the cognitive domain differed significantly from the language domain ($p < .01$). The cognitive–motor difference was marginal ($p = .08$), and the language–motor difference was not significant ($p > .13$).

The Group × Domain interaction did not reach significance, $F(4, 126) = 2.07$, $p < .09$; partial $\eta^2 = .02$, based on the univariate approach to repeated measures, which

Table 3. Mean (and standard deviation) slopes by group and domain.

	Group		
Domain	**NLD**	**SLI**	**NLI**
Motor	1.00 (0.14)	1.24 (0.28)	1.28 (0.22)
Cognitive	1.00 (0.23)	1.22 (0.25)	1.39 (0.32)
Language	1.00 (0.12)	1.20 (0.17)	1.20 (0.18)

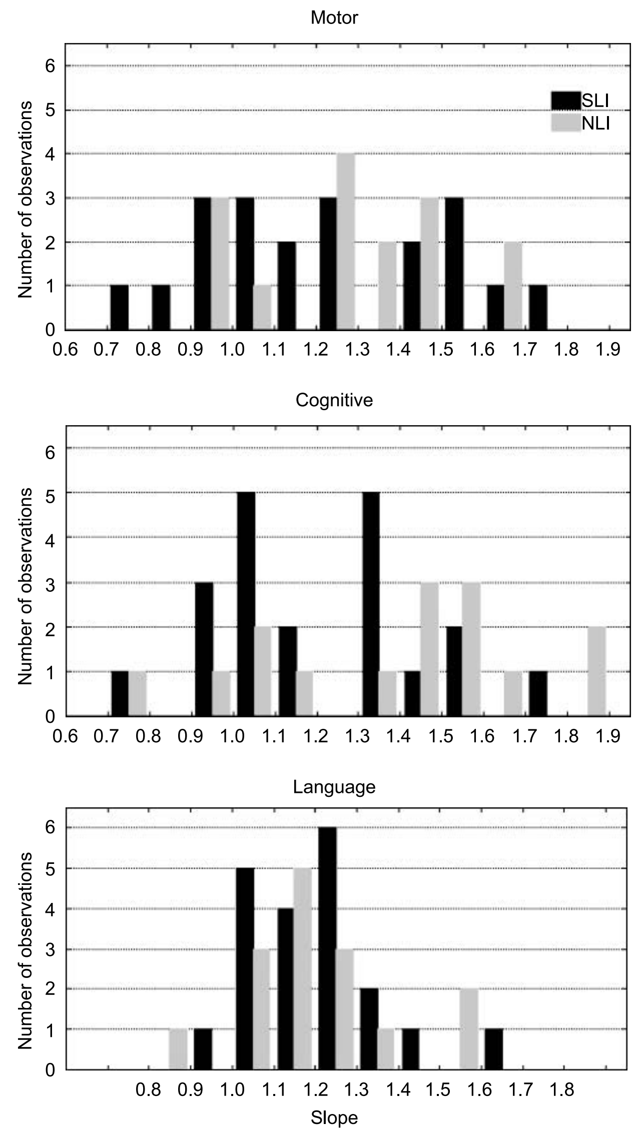
was deemed appropriate given that the sphericity assumption was not violated according to the Mauchley test. Planned comparisons were performed to test for group differences in each domain (see Table 3 for means and standard deviations). For each of the three domains, the NLD group differed significantly from the SLI and NLI groups (all ps $< .01$), but the SLI and NLI groups did not differ from one another.

Given that slowing is similar across domains, it is possible that the slowing in the language and cognitive domains can be accounted for by perceptual-motor factors. To test this possibility, we performed an analysis of covariance (ANCOVA), with the slopes for the language and cognitive domains as the repeated measures dependent variable and the slope for the motor domain as the covariate. A significant main effect of group was found, $F(2, 62) = 4.81$, $p < .02$; partial $\eta^2 = .13$, suggesting that perceptual-motor factors are not entirely responsible for the observed group differences in the language and cognitive domains. Post hoc analysis using the unequal N HSD test showed that the average slope of the NLD group was significantly less than that of the SLI group ($p < .001$) and the NLI group ($p < .001$), but the SLI and NLI groups did not differ. The main effect of domain was significant in the ANCOVA, with $F(1, 62) = 5.48$, $p < .03$; partial $\eta^2 = .08$. Planned comparisons of the domains within groups indicated that the main effect was due to the greater slope in the cognitive domain for the NLI group ($p < .02$). As in the ANOVA, the Group × Domain interaction did not reach significance, $F(2, 62) = 2.46$, $p < .10$; partial $\eta^2 = .07$.

The children with SLI and NLI were, on average, slower than the NLD children. However, there were a few children in each group that were not significantly slower than the NLD average. Figure 3 shows the distribution of slopes for the children in the SLI and NLI groups for each domain. On the basis of the individually determined 95% confidence intervals, 7 children with SLI had slopes ≤1 for motor tasks, 7 for cognitive tasks, and 6 for language tasks. For the NLI group, the corresponding numbers were 5, 5, and 4.

Prediction of RT from age 9 to age 14. To assess the degree to which RT at an earlier age predicted RT 5 years later, we computed correlations between RT at age 9 and at age 14. First, the RTs within each condition were standardized on the mean for that condition including

Figure 3. Distribution of slopes by group for the motor domain (upper panel), the cognitive domain (middle panel), and the language domain (lower panel).



all participants. These z scores were averaged across conditions to yield four summary scores: an overall z score (mean of all 42 conditions), a linguistic z score (mean of 24 linguistic task conditions), a motor z score (mean of 6 task conditions of the tapping and simple RT tasks), and a cognitive z score (mean of 12 conditions of the visual search and mental rotation tasks). The correlations for each of these scores from age 9 to 14 are summarized by group in Table 4. All correlations for the SLI group were moderate and significant. For the NLI group, only the correlation for the cognitive tasks was not significant, and it was markedly lower than the other correlations. For the NLD group, only the correlation for the motor tasks was not significant. The NLI group had a higher

Table 4. Correlations between ages 9 and 14 RT means, by group and task domain.

Task	Group		
	NLD	SLI	NLI
All tasks	.54**	.52*	.71**
Language tasks	.45*	.53*	.86**
Motor tasks	.28	.66**	.66**
Cognitive tasks	.45*	.48*	.20

*$p < .05$. **$p < .01$.

correlation than the other groups for the language tasks. Significant differences were found for the NLI–NLD comparison ($z = 2.34$, $p < .01$) and the NLI–SLI comparison ($z = 1.87$, $p < .05$). The NLD group appeared to have a lower correlation than the other groups for the motor tasks, but the differences were not significant at the .05 level.

Correlations between ages 9 and 14 were also computed using slopes as the dependent measure. Slopes for age 14 were computed as described earlier; slopes for age 9 were computed by comparing each group to the NLD group based on second-grade diagnosis. As shown in Table 5, the pattern of correlations was similar to that found for z scores. Significant associations were found for all groups when all tasks were taken together, for all three domains for the SLI group, and for the NLI group on the language tasks, which was the largest correlation. Several of the correlations for slopes were smaller in magnitude than the corresponding correlations for RTs; this difference was probably due to reduced reliability of slope estimation relative to estimation of means.

We also computed the correlations among domains separately for ages 9 and 14. These correlations are shown in Table 6. At both ages, only the children with SLI had significant correlations for all pairings of the three domains. The correlation between the cognitive and language domains was also significant at both ages for the NLD and NLI groups.

Table 5. Correlations between ages 9 and 14 slopes, by group and task domain.

Task	Group		
	NLD	SLI	NLI
All tasks	.50**	.62**	.83**
Language tasks	.31	.66**	.90**
Motor tasks	−.01	.57**	.46
Cognitive tasks	.34	.60**	.06

*$p < .05$. **$p < .01$.

Table 6. Correlations of RT means among domains, by group.

Group/age	Relationship		
	Motor × Cognitive	Motor × Language	Cognitive × Language
Age 9			
NLD	.33	.09	.50**
SLI	.73**	.50*	.65**
NLI	.25	.30	.63*
Age 14			
NLD	.28	.21	.43*
SLI	.81**	.60**	.61**
NLI	.42	.14	.60*

*$p < .05$. **$p < .01$.

Discussion

The first question addressed by this study was whether children with language impairment, who were slower than typically developing peers at age 9, continued to be slower at age 14. Children with SLI and children with NLI were, on average, slower than NLD peers across the motor, cognitive, and language domains. This result suggests that in early adolescence, relatively slow RTs continue to be characteristic of children with SLI and NLI as a group. The slowness cannot be attributed entirely to perceptual-motor factors. The second research question was whether the slowing was similar across the motor, cognitive, and language domains. No significant difference was found between the domains; that is, the average of individuals' speed relative to the NLD group did not differ noticeably for motor, cognitive, and language tasks. However, comparisons of domains within groups suggested that for the NLI group, RTs in the cognitive domain were slower than for language tasks. Another way to compare across domains is to examine the intercorrelations among them. The results of these correlations (see Table 6) suggest that an individual's RT relative to his or her group was not necessarily the same for all domains. Children with SLI appeared to be consistent across domains; for all groups, the cognitive and language domains were more closely related to each other than to the motor domain.

The third research question was whether children with SLI and NLI differed in the degree of slowing across domains. The Group × Domain interaction was not significant, and pairwise comparisons showed that the mean slopes of the SLI and NLI groups did not differ for any of the domains, although both groups differed significantly from the NLD group. As noted previously, however, the NLI group showed slower RTs for cognitive than for language tasks.

Our fourth research question was whether RT performance at age 9 predicted performance at age 14; that is, did children who were relatively fast (or slow) at age 9 retain their standing in the sample at age 14? Taking all tasks together, we found moderate, significant correlations between RTs at age 9 and age 14 for all three groups (NLD, SLI, and NLI). We also computed correlations separately for the task domains (motor, nonverbal cognitive, and linguistic). Correlations were significant and moderate to high on language tasks for all three groups, moderate and significant on motor tasks for the SLI and NLI groups, and moderate and significant on cognitive tasks for NLD and SLI groups. When using slopes rather than RTs in the correlations, we found significant correlations for the SLI group in all three domains and for the NLI group in the language domain. Correlations of moderate magnitude that did not reach significance were found for the NLD group on language and cognitive tasks and for the NLI group on motor tasks.

With data from only two points in time, we cannot reliably estimate a developmental function. Although RT at age 9 has some predictive value for RT 5 years later, clearly other factors are also at work, as evidenced by the moderate correlations and by the fact that a few children with LI are not slower than NLD peers. One limitation of this study is the classification of individuals into diagnostic categories. Future studies could examine individual differences in language ability or performance IQ and relate these variables to RT and to change in RT (see Lahey, Edwards, & Munson, 2001).

In the introduction, we presented evidence suggesting that there might be domain differences in the RT slowing of adolescents with SLI and NLI. Our analyses did not detect such differences for children with SLI, but the cognitive domain was found to be relatively slow in children with NLI, suggesting that the relationship of performance IQ to processing speed requires investigation. Also, research is needed in which tasks are carefully chosen for the processes and knowledge that they require, and difficulty is equated across task domains. In the current study, the motor tasks yielded much shorter RTs than any of the cognitive and language tasks, making cross-domain comparison somewhat difficult to interpret.

Like their typically developing peers, children with SLI and NLI become faster at performing speeded tasks as they grow older, yet in early adolescence, many of them are still slower than their peers on a wide range of tasks, including some that do not require linguistic knowledge. Our data support the conclusion of Kohnert and Windsor (2004), that "response speed on basic nonlinguistic processing tasks may hold significant clinical promise" (p. 901) for assessment of language impairment. To fulfill that promise, future investigations must determine why and under what circumstances children with LI are slow processors of information.

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Appendix A (p. 1 of 2). Mean response time (standard deviation) and mean number of valid responses (in italics) by group and condition.

Task/Group	Condition											
Tapping												
	n	1 finger/1 key	*n*	1 finger/2 keys	*n*	2 fingers/2 keys						
NLD	30	134 (23)	31	196 (32)	31	124 (39)						
SLI	20	149 (22)	20	235 (38)	20	172 (62)						
NLI	15	155 (29)	15	237 (57)	15	174 (66)						
Simple RT												
	n	1 s	*n*	2 s	*n*	5 s						
NLD	31	528 (94) *7.4*	31	478 (77) *7.4*	31	497 (83) *7.5*						
SLI	20	662 (159) *7.4*	20	603 (159) *7.6*	20	594 (159) *7.6*						
NLI	15	675 (124) *7.9*	15	626 (141) *7.7*	15	636 (129) *7.8*						
Visual search												
		First		Second		Third		Fourth		Fifth		Absent
NLD	31	852 (221) *5.8*	31	976 (292) *5.5*	31	1,058 (325) *5.8*	31	1,159 (279) *5.7*	31	1,344 (281) *5.5*	31	1,706 (448) *5.7*
SLI	20	1,161 (507) *5.4*	20	1,346 (483) *5.6*	20	1,365 (460) *5.8*	20	1,611 (507) *5.6*	20	1,595 (384) *5.7*	20	2,211 (611) *5.6*
NLI	15	1,134 (275) *5.7*	15	1,372 (373) *5.9*	15	1,357 (416) *5.7*	15	1,586 (361) *5.8*	15	1,743 (458) *5.6*	15	2,108 (574) *5.8*
Mental rotation												
	Forward						Reverse					
	n	0	*n*	60	*n*	120	*n*	0	*n*	60	*n*	120
NLD	31	1,249 (326) *5.8*	31	1,791 (522) *5.5*	31	2,054 (575) *5.4*	31	1,708 (448) *5.7*	31	2,072 (568) *5.5*	31	2,342 (791) *5.4*
SLI	20	1,512 (401) *6.0*	20	2,122 (521) *5.7*	19	2,482 (607) *5.6*	20	2,005 (504) *5.5*	20	2,414 (656) *5.1*	20	2,706 (640) *5.2*
NLI	15	1,493 (365) *5.7*	13	2,804 (882) *4.8*	13	3,074 (791) *4.8*	12	2,655 (746) *5.6*	15	2,800 (1083) *4.8*	14	3,397 (1,494) *4.8*
Picture matching												
	n	Physical	*n*	Name	*n*	Category						
NLD	31	972 (271) *11.4*	31	974 (226) *11.8*	31	1,102 (251) *11.4*						
SLI	20	1,092 (237) *11.4*	20	1,215 (286) *11.4*	20	1,366 (417) *11.0*						
NLI	15	1,178 (338) *11.4*	15	1,257 (394) *11.7*	15	1,435 (436) *11.4*						
Picture naming												
	n	High	*n*	Medium	*n*	Low						
NLD	28	830 (128) *7.3*	28	905 (169) *7.3*	28	954 (172) *7.1*						
SLI	19	891 (199) *7.3*	19	947 (198) *7.0*	19	1,001 (228) *6.6*						
NLI	15	884 (234) *7.1*	15	890 (191) *6.7*	14	1,059 (245) *6.5*						

Appendix A (p. 2 of 2). Mean response time (standard deviation) and mean number of valid responses (in italics) by group and condition.

Task /Group	Condition											
Judging truth value												
	Match						Mismatch					
	n	Active	*n*	Passive	*n*	Compound	*n*	Active	*n*	Passive	*n*	Compound
NLD	31	2,171 (308) *5.9*	31	2,412 (290) *5.8*	31	2,653 (297) *5.9*	31	2,394 (260) *6.0*	31	2,664 (326) *5.8*	31	3,523 (605) *5.1*
SLI	20	2,375 (324) *5.9*	20	2,729 (395) *5.7*	20	2,831 (373) *5.8*	20	2,758 (432) *5.8*	20	3,117 (511) *5.6*	20	4,434 (931) *4.7*
NLI	15	2,260 (254) *5.8*	15	2,799 (484) *5.6*	15	2,872 (324) *5.6*	15	2,723 (504) *5.9*	15	3,151 (760) *5.7*	15	3,903 (771) *4.9*
Judging grammaticality												
	Correct						Incorrect					
	n	Order	*n*	Agreement	*n*	Omission	*n*	Order	*n*	Agreement	*n*	Omission
NLD	31	1,227 (403) *5.9*	31	1,121 (385) *5.7*	31	1,091 (339) *5.5*	31	1,628 (190) *5.9*	31	1,842 (572) *5.7*	31	1,352 (289) *5.9*
SLI	20	1,366 (468) *5.5*	20	1,222 (375) *5.4*	20	1,204 (326) *5.2*	20	1,836 (335) *5.7*	17	1,919 (410) *4.8*	20	1,518 (361) *5.5*
NLI	15	1,396 (519) *5.4*	15	1,302 (504) *5.0*	15	1,256 (454) *5.5*	14	1,768 (286) *5.9*	14	2,084 (354) *5.1*	14	1,455 (310) *5.6*
Judging rhymes												
	n	Picture	*n*	Print	*n*	Auditory						
NLD	31	1,812 (384) *10.8*	31	1,626 (351) *11.4*	31	1,477 (310) *11.3*						
SLI	20	2,606 (870) *10.1*	20	2,366 (745) *10.4*	20	2,118 (633) *10.6*						
NLI	15	2,587 (976) *9.0*	15	2,246 (895) *10.0*	15	2,195 (974) *10.0*						
Judging consonants												
	n	Picture	*n*	Print	*n*	Auditory						
NLD	31	2,043 (683) *10.4*	31	1,772 (515) *10.9*	31	1,647 (555) *10.5*						
SLI	20	2,527 (499) *9.0*	20	2,502 (1,122) *10.4*	20	2,164 (644) *10.0*						
NLI	15	2,972 (1,024) *9.1*	15	2,529 (657) *10.1*	15	2,551 (1,096) *9.4*						

Note. Maximum possible valid responses per condition: 12 for picture matching, judging rhymes and judging consonants; 8 for simple response time (RT) and picture naming; 6 for visual search, mental rotation, judging truth value, and judging grammaticality. For tapping, all participants produced three valid trials in each condition, except 1 NLD participant whose data were missing in the first condition. NLD = normal developing; SLI = specific language impairment; NLI = nonspecific language impairment.

Appendix B. Mean proportion of correct responses (standard deviation) by group and condition.

Task/Group	Condition					
Visual search						
	First	Second	Third	Fourth	Fifth	Absent
NLD	0.98 (0.05)	0.98 (0.05)	0.98 (0.05)	0.97 (0.07)	0.93 (0.11)	0.96 (0.07)
SLI	0.99 (0.07)	0.97 (0.07)	0.99 (0.04)	0.99 (0.04)	0.98 (0.08)	0.97 (0.06)
NLI	1.00 (0.00)	0.99 (0.04)	0.97 (0.07)	0.98 (0.06)	0.96 (0.13)	0.99 (0.04)
Mental rotation						
	Forward			Reverse		
	0	60	120	0	60	120
NLD	0.97 (0.08)	0.94 (0.09)	0.91 (0.11)	0.96 (0.08)	0.94 (0.09)	0.91 (0.13)
SLI	1.00 (0.00)	0.98 (0.06)	0.93 (0.16)	0.93 (0.10)	0.90 (0.10)	0.91 (0.09)
NLI	0.98 (0.06)	0.73 (0.29)	0.72 (0.30)	0.80 (0.29)	0.83 (0.18)	0.77 (0.22)
Picture matching						
	Physical	Name	Category			
NLD	0.98 (0.03)	0.99 (0.03)	0.96 (0.06)			
SLI	0.98 (0.08)	0.98 (0.05)	0.95 (0.07)			
NLI	0.99 (0.02)	0.99 (0.03)	0.98 (0.05)			
Picture naming						
	High	Medium	Low			
NLD	0.99 (0.04)	0.98 (0.06)	0.95 (0.07)			
SLI	0.98 (0.06)	0.93 (0.11)	0.92 (0.11)			
NLI	0.97 (0.08)	0.97 (0.08)	0.85 (0.14)			
Judging truth value						
	Match			Mismatch		
	Active	Passive	Compound	Active	Passive	Compound
NLD	0.98 (0.05)	0.97 (0.06)	0.99 (0.03)	1.00 (0.00)	0.97 (0.06)	0.84 (0.14)
SLI	0.99 (0.04)	0.95 (0.08)	0.98 (0.05)	0.97 (0.07)	0.94 (0.10)	0.78 (0.17)
NLI	0.98 (0.06)	0.93 (0.10)	0.94 (0.08)	1.00 (0.00)	0.94 (0.10)	0.82 (0.15)
Judging grammaticality						
	Correct			Incorrect		
	Order	Agreement	Omission	Order	Agreement	Omission
NLD	0.98 (0.05)	0.97 (0.07)	0.96 (0.08)	0.99 (0.03)	0.96 (0.09)	0.99 (0.04)
SLI	0.96 (0.11)	0.93 (0.10)	0.92 (0.11)	0.98 (0.06)	0.74 (0.24)	0.95 (0.11)
NLI	0.93 (0.08)	0.88 (0.15)	0.96 (0.10)	0.94 (0.17)	0.79 (0.27)	0.87 (0.25)
Judging rhymes						
	Picture	Print	Auditory			
NLD	0.94 (0.05)	0.97 (0.06)	0.98 (0.04)			
SLI	0.91 (0.11)	0.93 (0.13)	0.93 (0.11)			
NLI	0.78 (0.18)	0.86 (0.17)	0.87 (0.19)			
Judging consonants						
	Picture	Print	Auditory			
NLD	0.91 (0.10)	0.94 (0.08)	0.92 (0.07)			
SLI	0.81 (0.15)	0.89 (0.16)	0.87 (0.10)			
NLI	0.77 (0.15)	0.87 (0.14)	0.81 (0.13)			

Note. Accuracy measures are not appropriate for the tapping and simple RT tasks. All means and standard deviations are based on data from 31 children with NLD, 20 children with SLI, and 15 children with NLI.