

Chapter • 2

Cognition and Language

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There has been considerable interest among psychologists and scholars in a host of related fields in characterizing the nature of the relationship between language and cognition in both typical and atypical cases. Work in this area has focused on constructing theoretical accounts of the link between language and cognitive functioning in adults, as well as explaining developmental patterns observed in infancy and childhood. Historically, the conceptualization of this relationship has ranged from claims that language directs thought, exemplified by the Sapir-Whorfian notion of linguistic determinism, to accounts at the other end of the spectrum that have emphasized the influence of cognition on language, as in the strong form of the cognitive hypothesis based on a Piagetian framework.

Current modularity accounts (Pinker 1994), stemming from earlier claims of highly specialized systems subserving language (Chomsky 1964, 1988; Fodor 1983), assume that linguistic knowledge is encapsulated and largely independent of other cognitive domains. This view can be contrasted with various perspectives that assume an interactionist position, including connectionist and dynamic systems accounts that espouse an emergent view of language acquisition. As noted by MacWhinney (1999), emergent accounts of language development offer an alternative to the long-standing opposition between nativism and empiricism in that emergentism focuses on accounting, in mechanistic terms, for interactions between biological and environmental processes. Within this type of framework, we might expect that the nature of the interplay between language and cognition will shift in a dynamic manner as a function of a child's developmental trajectory.

Various researchers, particularly those seeking support for modularity claims, have been interested in examining ways in which language and cognitive functioning can become disassociated in atypical cases. Within the field of cognitive neuropsychology, adult neurological patients who demonstrate a dissociation between two areas of functioning are studied in order to gain insights into normal cognitive processes. Of particular interest are double dissociations involving patients who demonstrate mirror image patterns of deficits, which are seen as evidence for the notion that these aspects of functioning are logically independent.

This approach has been increasingly applied to developmental disorders as well as to acquired disorders in adults. Two types of developmental language disorders (characterized by uneven profiles) that have been examined within this framework include Williams syndrome and specific language impairment. Children with Williams syndrome (WS) have been characterized as having relatively complex language despite having generally deficient cognitive abilities, whereas children with specific language impairment (SLI) present a profile of poor language skills in the face of normal nonverbal abilities. On the surface, these patterns appear to represent a prototypic double dissociation. However, various studies have challenged these general characterizations of both WS (Karmiloff-Smith et al. 1997) and SLI (Johnston 1994; Leonard 1998) in terms of the clear distinction between spared and impaired aspects of functioning in language and cognitive domains. Further, the use of the neuropsychological model to investigate developmental disorders has been questioned on theoretical as well as empirical grounds (Bishop 1997, 1999; Juola and Plunkett 2000; Karmiloff-Smith 1997; Paterson et al. 1999). In an intriguing study reported in *Science*, Paterson and colleagues found that infants with WS performed relatively poorly on a language task but performed well on a task involving numerosity judgments. This is the reverse of the pattern seen in adults with WS, who have relatively good vocabulary abilities and poor number skills. These findings point to the danger in assuming that phenotypic outcomes involving uneven cognitive profiles observed in middle childhood or adulthood characterize infant starting states.

An alternate approach involves the use of experimental group design studies to explore particular aspects of functioning in children with varying language profiles. This is the approach that is frequently adopted by researchers whose main focus is to characterize the nature of developmental language disorders and who are secondarily concerned with utilizing atypical cases to inform theoretical models of normal cognitive processes. This is the tack that we have adopted in much of our research, which has examined cognitive and language abilities

in specific language impairment. The term SLI (alternately, "specific language delay") has been used to refer to a group of children who demonstrate language disorders in the absence of any clearly identifiable etiology. Key features characterizing this population are delayed onset and acquisition of language, normal nonverbal intelligence, normal hearing, and absence of emotional disturbance (no evidence of pervasive developmental disorder, PDD) or frank neurological deficits. Normal range cognitive functioning has typically been defined as nonverbal IQ of 85 or higher, though there is renewed debate about the appropriate cut-off for normal cognitive range and about whether a language-cognitive discrepancy is critical to classification of SLI. This is a point that will be considered in more detail below.

Theoretical accounts of SLI can be divided into two general camps. Competence-based, linguistic accounts of the disorder have been proposed that postulate specific deficits within aspects of the grammatical system, such as the Extended Optional Infinitive account (Rice and Wexler 1996; Rice, Wexler, and Redmond 1999). This view stems from a nativist, generative grammar framework in which language is viewed as a modular facility; therefore, the focus is solely on the nature of grammatical deficits in SLI and characterization of cognitive abilities is not an issue. On the other hand, SLI has been viewed as a manifestation of a broader cognitive impairment within various Processing Limitation accounts. The nature and basis of these accounts varies from hypotheses about specific constraints in temporal processing or in phonological working memory to claims that linguistic deficits are secondary to more general information processing limitations. The impetus for appealing to a more broadly defined limited capacity framework is to attempt to capture the range of deficits exhibited by children with SLI. Despite the label "SLI," it is well documented that these children demonstrate certain cognitive limitations in addition to their deficits in linguistic skills, even though they perform within the normal range on standardized measures of nonverbal intelligence (cf. Leonard 1998). For example, children with SLI have been shown to perform significantly worse than matched controls on nonverbal tasks involving hypothesis testing, inference construction, and visual imagery or mental rotation. Within a general processing limitation framework, one could account for difficulties that children with SLI demonstrate in linguistic processing as well as limitations on certain nonverbal tasks by proposing that these children are restricted in their ability to simultaneously hold in mind and manipulate multiple pieces of information, especially when rapid processing is required.

There are a number of models of language processing that incorporate the notion of a limited capacity system; those proposed by Baddeley and colleagues (Baddeley 1986; 1998; Gathercole and

Baddeley 1993) and Just, Carpenter, and colleagues (Daneman and Carpenter 1980; Just and Carpenter 1992) have been most influential in language disorders research. Although the details of these theories vary, the central premise is that there is a limited pool of cognitive operational resources available to perform computations and when demands exceed available resources, processing and storage of linguistic information is degraded. Within this perspective, an individual's success in comprehending and producing language is dependent upon the ability to actively maintain and integrate linguistic material in working memory and trade-offs are thought to occur within and across language domains as demands reach the limits of available resources.

Support for limited capacity models of language processing comes from several sources. Evidence of linguistic interactions and trade-offs has been reported within the language acquisition literature. For instance, increased naming errors have been observed to co-occur with rapid growth in productive vocabulary and increased rates of speaking in young children (Gershkoff-Stowe and Smith 1997). Experimental studies with adults have also demonstrated trade-off effects, such that speed and accuracy of linguistic processing declines as cognitive load is increased. Factors that have been observed to affect linguistic processing include degree of lexical ambiguity, degree of syntactic complexity or ambiguity, and constraints in processing time (Carpenter and Just 1989; MacDonald, Just, and Carpenter 1992; Miyake, Carpenter, and Just 1994). A number of investigations have reported direct associations between working memory capacity and language abilities for children and adults. Specifically, research has revealed an association between phonological working memory and vocabulary development in young children (Baddeley, Gathercole, and Papagno 1998; Gathercole and Baddeley 1990, 1993). School-age children's performance on working memory measures has been found to be significantly correlated with spoken language comprehension and with reading recognition and comprehension (Ellis Weismer, Evans, and Hesketh 1999; Gaulin and Campbell 1994; Seigneuric et al. 2000; Swanson 1996). Working memory capacity has been shown to predict a number of verbal abilities in adults including reading comprehension levels, understanding of ambiguous passages and syntactically complex sentences and the ability to make inferences (Carpenter, Miyake, and Just 1994; Daneman and Carpenter 1980, 1983; King and Just 1991).

Evidence from children with language disorders, based on language sample data, indicates that they exhibit various types of linguistic trade-offs suggesting capacity constraints. For example, these children are more likely to make speech production errors and to omit

words in longer, more grammatically complex sentences (Panagos and Prelock 1982). Children with SLI have also been found to make a disproportionate number of morphological errors compared to controls matched on mean length of utterance when producing utterances with high semantic complexity (Namazi and Johnston 1996). In prior experimental work, including some of our own research, limitations in processing capacity have been proposed to account for the poor performance of children with SLI in various areas, including deficient nonword repetition, poor novel word learning within sentences presented at fast speaking rates, and ineffective sentence comprehension processing (Edwards and Lahey 1998; Ellis Weismer and Hesketh 1996; Montgomery 1995, 2000). Building on this work, we sought to further examine the limited processing capacity account of SLI in these investigations.

The two studies summarized in this chapter were conducted as part of a longitudinal, epidemiologic investigation of SLI funded by the National Institutes of Health, directed by Dr. J. Bruce Tomblin, University of Iowa.¹ To establish this sample, a stratified cluster sampling procedure was used in which language abilities of 7,218 kindergarten children in rural, urban, and suburban areas of the upper Midwest were screened. Children who failed the screening (26%) and an equal number of controls were administered a diagnostic language battery using accepted diagnostic standards (Tomblin, Records, and Zhang 1996). Results indicated that the estimated prevalence rate for SLI in kindergarten is 7.4% (8% for boys and 6% for girls) (Tomblin et al. 1997). The 604 children who had been administered the full assessment protocol formed the sample who have been followed longitudinally by researchers from various universities as part of a project referred to as the Midwest Collaboration on Specific Language Impairment. For the studies described in this chapter, the data collection occurred when the children were in second and third grades.

In the first study (Ellis Weismer and Thordardottir 1999), we addressed two main questions. First, we asked whether performance on processing capacity measures accounts for significant variance in children's language abilities beyond that attributable to differences in nonverbal cognition. Secondly, we examined the role of nonverbal cognitive level in processing capacity limitations for children with language impairment. In this study we investigated performance of 134

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children with varying levels of nonverbal cognitive abilities on three processing capacity measures; their scores ranged from 2 standard deviations below the mean to 2 standard deviations above the mean (i.e., nonverbal IQ scores of 70–130). Children from three language/cognitive diagnostic categories were included in this study: (1) specific language impairment (SLI) group—normal range cognition (at least 85 IQ) but low language abilities; (2) nonspecific language impairment (NLI) group—low nonverbal cognition (70–84 IQ) and low language abilities; and (3) normal language (NL) controls—normal cognitive and language abilities.

As mentioned previously, the role of cognitive discrepancy criteria in defining SLI has recently come under scrutiny. Tager-Flusberg and Cooper (1999) have published a report based on an NIH-sponsored seminar on defining the phenotype of SLI. As they note in that report, dyslexia research has found the same basis for reading difficulty in children with a wide range of nonverbal IQs, leading to the elimination of nonverbal IQ level and discrepancy criteria in diagnosing reading impairment. Genetic research by Tomblin and Buckwalter (1998) has revealed similar heritability estimates for children with normal range nonverbal IQs and those with somewhat lower IQs. More recently, findings by Tomblin and Zhang (1999) for this same sample of children in the Iowa epidemiologic study have indicated that the basic language phenotype using standardized language measures is similar for children with language impairment whose nonverbal IQs fall above or below 85. These findings prompted us to examine the role of nonverbal cognitive level relative to processing capacity.

In these investigations we administered three processing capacity measures. We developed a Dual Processing Comprehension Task in which sentences (involving commands) are presented under competing and non-competing listening conditions. The children demonstrate their comprehension of the commands by manipulating the appropriate tokens. In the competing condition, primary and secondary sentences (distinguished by male/female speakers) are presented simultaneously. Children are instructed to respond first to the primary sentences (e.g., "Put the white square on the red circle") and then to the secondary sentences (e.g., "Touch the big boat and the little shoe"). These digitized sets of utterances are presented binaurally via headphones.

We also administered a version of a listening span measure, based on Daneman and Carpenter's (1980) listening span task, that was devised by Gaulin and Campbell (1994) to assess verbal working memory in typically developing children. This measure consists of sets of 1 to 6 short sentences. These simple sentences tap children's vocabulary and basic world knowledge. True/false responses are elicited follow-

ing each sentence to ensure comprehension processing (e.g., "Sugar is sweet"—True, "Carrots can dance"—False). Concurrently, children are asked to recall the last word in each sentence (e.g., "sweet" and "dance") after all sentences in the set have been presented.

The third task was a nonword repetition task, assumed to be a measure of phonological processing capacity. This task was a version devised by Dollaghan (1995) and used by Dollaghan and Campbell (1998). The nonword repetition task consists of a set of 16 nonsense words ranging in length from 1 syllable (e.g., "doif") to 4 syllables (e.g., "davonochig"), that children are asked to repeat immediately following the taped presentation of each item. The phonemes in the nonwords are early developing, acoustically salient sounds, stress patterns do not follow the typical English metrical stress pattern, and none of the syllables that make up the nonsense words correspond to actual English words.

It is important to note that although all of the processing capacity measures are restricted to linguistic processing and storage (verbal working memory), they do include controls for direct contributions of extant language knowledge. In the Dual Processing Comprehension Task, each child's competing condition performance was subtracted from the baseline level of sentence comprehension under non-competing listening conditions, resulting in a difference score. On the listening span measure, we analyzed word recall performance with and without the use of comprehension scores from the true/false items as a covariate (with the same results). The nonword repetition task consists of novel stimuli involving "low wordlikeness."

As shown in figure 1, hierarchical multiple regression analysis revealed that nonverbal cognitive scores combined with performance on processing measures predicted performance on a standardized measure of language comprehension and production ($r^2 = .41$, $p < .05$). The cognitive scores consisted of Performance IQs from the Wechsler Intelligence Scale for Children- III (Wechsler 1991) and language scores were based on the receptive and expressive subtests of the Clinical Evaluation of Language Fundamentals - 3 (Semel, Wiig, and Secord 1995). After the contribution of nonverbal cognition was accounted for (21% of the variance), each of the processing capacity measures added significant unique variance in language scores, though the listening span measure accounted for substantially more variance than the other two tasks. It is important to note the amount of variance left unaccounted for—clearly, processing capacity is not the entire story, a point we will return to later.

We then conducted group comparisons, excluding children who exhibited normal language skills at second grade but had a history of language delay. These comparisons revealed significant differences in

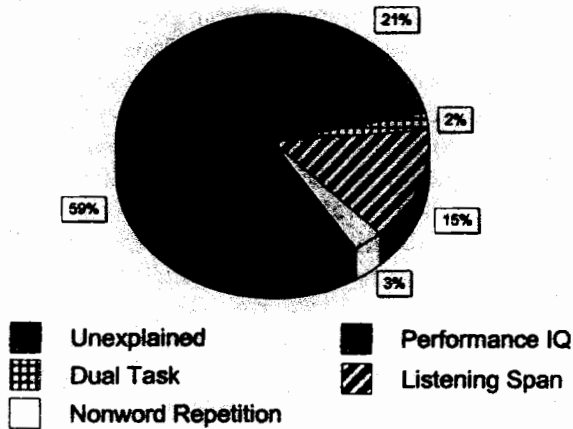


Figure 1. The amount of variance accounted for in children's performance on a standardized test of language comprehension and production, by performance IQ and the three processing capacity measures (Dual Processing Comprehension Task, Listening Span Task, Nonword Repetition Task).

processing capacity, as illustrated in figure 2. Children with SLI who met the cognitive discrepancy criterion (normal range nonverbal cognitive score of 85 or above, but low language abilities) performed significantly worse than controls on the Dual Processing Comprehension Task. The same pattern of results was found for analyses involving a broader definition of language impairment (LI) which included children with nonspecific language impairment who had low cognitive

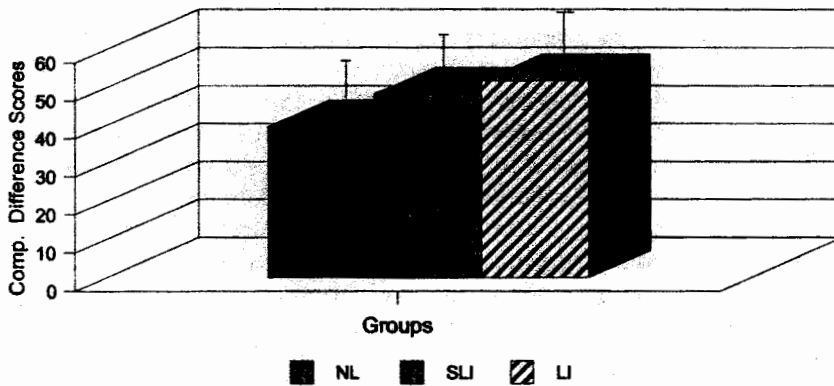


Figure 2. Mean comprehension difference scores on the Dual Processing Comprehension Task for the groups with normal language (NL), specific language impairment (SLI), and more broadly defined language impairment (LI).

abilities and low language skills and, therefore, did not meet the cognitive discrepancy criterion. As shown in figure 3, a similar pattern of results was found for the listening span task, in which both groups of children with language impairment were significantly worse than the NL controls but not significantly different from each other. Results for the nonword repetition task followed the same pattern, as illustrated in figure 4. Thus, the findings across these three processing capacity measures were highly consistent.

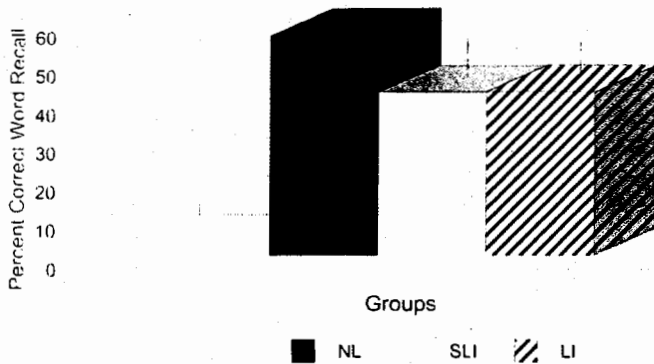


Figure 3. Mean percent word recall on the Listening Span Task for the groups with normal language (NL), specific language impairment (SLI), and more broadly defined language impairment (LI).

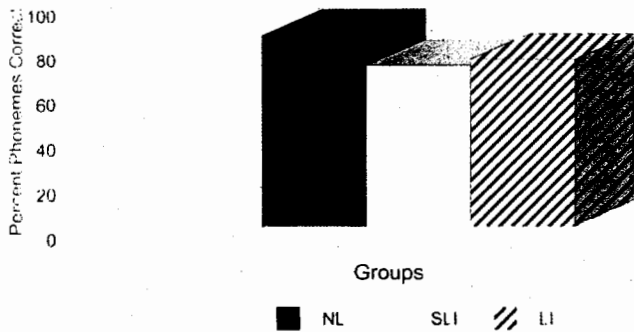


Figure 4. Mean percent phonemes correct on the Nonword Repetition Task for the groups with normal language (NL), specific language impairment (SLI), and more broadly defined language impairment (LI).

The following conclusions can be drawn from this study. First, findings support claims of an association between processing capacity in verbal working memory and language abilities in school-age children. Secondly, although nonverbal IQ (along with processing capacity scores) was predictive of language ability for the group as a whole, nonverbal cognitive level did not distinguish between the children with language impairment in terms of processing capacity. Finally, children with language impairment, strictly defined or more broadly defined in terms of cognitive level, evidenced restrictions in linguistic processing capacity compared to age-matched peers with normal language.

In the second study (Ellis Weismer et al. 2000), we took a more in depth look at nonword repetition performance as an index of phonological processing capacity. There has been considerable interest in various versions of this measure in language and working memory studies with adults as well as with children. It has also gained widespread attention in the language disorders literature. Bishop and colleagues have suggested that nonword repetition provides a phenotypic marker of SLI based on genetic research utilizing twin methodology (Bishop, North, and Donlan 1996). Dollaghan and Campbell (1998) have also reported that their nonword repetition task may have clinical utility as a screening measure. Prior work has been based on smaller, clinically referred samples of children with language impairment. Given some of the findings from the area of dyslexia, we know that characterizations can differ between population-based samples and samples consisting of children who are selected based on clinical referral. Therefore, we sought to confirm our earlier findings from subsets of this sample regarding deficits in nonword repetition and to explore its clinical utility in ruling in and ruling out language problems in children from varying backgrounds.

The specific research questions addressed by this study were as follows: (1) Are there significant differences in nonword repetition for children grouped according to second grade diagnostic category, and if so, what is the nature of the differences? (2) How accurately do nonword repetition task scores rule in and rule out cases based on diagnostic category or treatment status? and (3) Is nonword repetition performance similar for children from different ethnic/cultural backgrounds? In this study we examined the nonword repetition performance of 581 children with and without language impairment (although all 604 children in the epidemiologic sample had been administered this task, 22 children whose performance IQs fell below 70 were excluded from this study along with one child whose audiotaped responses were unavailable due to technical difficulties). In addition to the groups we examined in the previous study, we also included a Low Cognition (LC) group. The LC group consisted of 53

children whose IQs were between 1 and 2 standard deviations below the mean, but who had normal range language abilities.

Results revealed significant group effects for total percentage phonemes correct, such that children with specific language impairment (SLI) and nonspecific language impairment (NLI) performed significantly worse than both normal language (NL) controls and the low cognition (LC) group (see figure 5). There was no statistically significant difference between the SLI and NLI groups or between the NL and LC groups. We then looked at the impact of stimulus complexity on performance; these findings are depicted in figure 6. Repeated

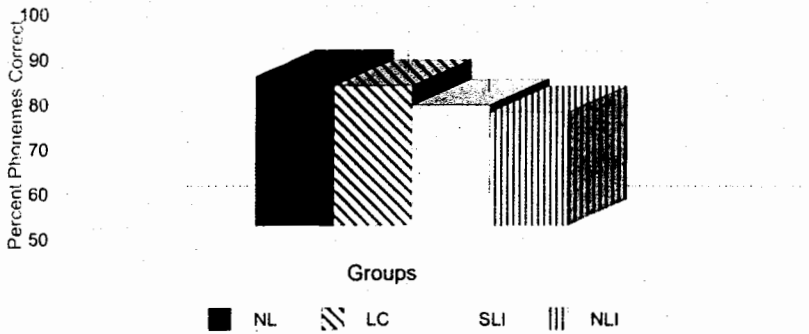


Figure 5. Diagnosis main effects: Mean percent phonemes correct on the Nonword Repetition Task for the diagnostic categories of normal language (NL), low cognition (LC), specific language impairment (SLI), and nonspecific language impairment (NLI).

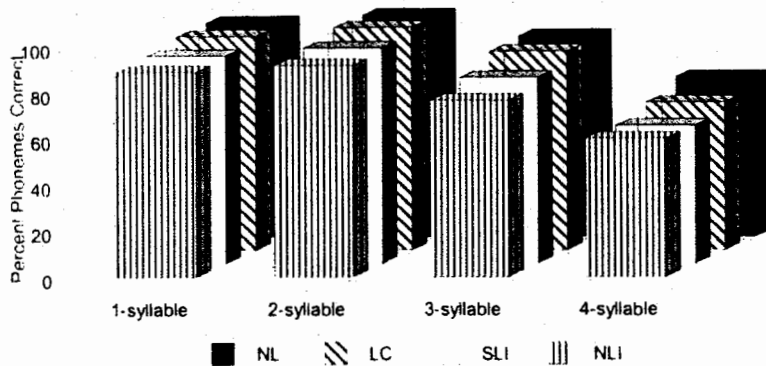


Figure 6. Diagnosis by syllable length effects: Mean percent phonemes correct on 1-, 2-, 3-, and 4-syllable targets on the Nonword Repetition Task for the diagnostic categories of normal language (NL), low cognition (LC), specific language impairment (SLI), and nonspecific language impairment (NLI).

measures analyses indicated a significant group (diagnosis) \times syllable length interaction. Although the children with language impairment (SLI and NLI) performed worse than those with normal language at each syllable length, the largest group differences occurred on the 3- and 4-syllable nonwords. This increased difficulty with more complex targets exhibited by the children with language impairment is consistent with a processing capacity limitation interpretation. Although the low cognitive (LC) group outperformed children with language impairment at each syllable length, this difference did not reach statistical significance for 4-syllable nonwords.

To address the issue of whether nonword repetition performance has clinical utility in distinguishing between children with language disorder and those without, we employed Likelihood (LH) ratio analysis procedures (cf. Sackett et al. 1991), using second grade diagnosis or treatment status as the gold standard. Results indicated that children with SLI were 4 $\frac{1}{2}$ times more likely to obtain low nonword repetition scores (below 60% accuracy) than NL controls, and those with NLI were 4 times more likely than controls to have scores in this range. In terms of ruling out the disorder, LH ratios of less than 1 indicated that high scores (above 91%) were more likely to come from controls. The LH ratio analyses for treatment status, using these same cut points, revealed that children in therapy were 10 times more likely to obtain low nonword repetition scores than those not in treatment and that none of the scores of 91% or better came from children in treatment. In a final analysis, we examined the distribution of scores broken down by race/ethnicity and found that, unlike many standardized language tests, there was no evidence of cultural bias in the pattern of responses on the nonword repetition task.

To summarize, these results from a large, population-based sample confirm that children with language impairment (whether defined narrowly or more broadly with respect to nonverbal cognition) exhibit deficits in nonword repetition, indicating restricted phonological processing capacity. The findings further support the contention that nonword repetition performance may provide a non-biased index to assist in ruling in or ruling out language disorder in children from varying cultural backgrounds.

In conclusion, findings from this project indicate that children with language impairment evidenced significantly poorer performance on each of the processing capacity measures than typically developing controls with normal language skills. This was the case for children with specific language impairment (defined in terms of cognitive discrepancy criteria) as well as those with both low cognitive and low language skills. Further, the findings suggest that processing capacity measures may have clinical utility in distinguishing between

children with and without language disorder. Overall, these results support the claim that capacity limitations in cognitive processing resources play a role in language disorders, though we do not view this research as attempting to identify THE cause of SLI. Like many researchers, we would ascribe to a model in which causal factors in language disorders are assumed to be heterogeneous, multifaceted, and interactive. That is, there are likely multiple, highly interactive factors at work that may operate differently for different children. Nevertheless, processing capacity limitations do appear to be a piece of the problem.

In future investigations we intend to explore the issue of the distinction between linguistic processing and verbal working memory in light of new theoretical frameworks that have been proposed (MacDonald and Christiansen 2002). We are also planning to examine whether children with SLI exhibit domain-specific or general processing capacity limitations, impacting processing of nonverbal as well as verbal stimuli. It should be noted that other investigators working on the Midwest Collaboration on SLI project with this same sample of children have found evidence that the children with language impairment exhibit reduced processing speed across modalities on a variety of tasks (Miller et al. 2001). In our future studies we will be comparing performance on a spatial working memory task to various linguistic processing and verbal working memory measures. Finally, we are currently using neuroimaging techniques (fMRI) with a small subset of the epidemiologic sample to assess whether children with language impairment exhibit atypical, reduced activation patterns on a linguistic processing and verbal working memory task.

The issues discussed in this chapter, related to IQ cutoff scores/cognitive discrepancy criteria and the consideration of processing capacity limitations, have potential clinical implications for assessment and treatment of children with language impairment. There appears to be mounting evidence that cognitive discrepancy criteria may not be particularly useful in establishing a meaningful phenotype of developmental language disorder. Further, several studies have demonstrated that children with flat cognitive-language profiles benefit as much from language intervention as those with discrepant profiles, i.e., both display similar responsiveness to treatment (Cole, Coggins, and Vanderstoep 1999; Cole, Dale, and Mills 1990; Fey, Long, and Cleave 1994). If we suspect that processing capacity limitations underlie language impairment, then measures tapping processing abilities should be included in our diagnostic batteries. Processing measures provide an index of implementation of language skills in real-time communicative contexts that can at least be a useful adjunct to information gained from traditional, knowledge-based tests. Several

studies have indicated that processing measures may be more useful than our standardized tests in distinguishing between language differences and disorders in children from culturally and linguistically diverse backgrounds (Campbell et al. 1997; Dollaghan and Campbell 1998). Treatment implications of limited processing capacity claims include paying attention to the manner in which linguistic models are presented, as well as the content, decreasing cognitive load by introducing new forms in highly familiar routines or scripts, and working to increase automaticity of newly acquired language skills before advancing to new goals (cf. Ellis Weismer 1996, 2000). Consideration of processing limitations may also be useful in early identification of children at risk for language impairment and in prediction of language outcomes. We are exploring this possibility in an ongoing longitudinal investigation² of the link between late onset of language development in toddlers and SLI (Ellis Weismer and Evans 2002). Advancing our understanding of the nature of the relationship between language and cognition in children with language disorder is not only of interest from a theoretical perspective, but may have important implications for diagnosis, prognosis, and treatment of children with language deficits.

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