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Does impaired grammatical comprehension provide evidence for an innate grammar module?

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ABSTRACT
Children with specific language impairment (SLI) have distinctive impairments in the comprehension of sentences that involve long-distance syntactic relationships. This has been interpreted as evidence for impairment in an innate grammatical module. An alternative theory attributes such difficulties to lower level problems with speech perception or deficits in phonological working memory. These theoretical accounts were contrasted using comprehension data from three subgroups: 20 children with SLI, 19 children with mild–moderate hearing loss, and normally developing children matched on age and/or language level. There were close similarities between the hearing-impaired and SLI groups on a measure of phoneme perception. Children with SLI did poorly on tests assessing knowledge of Binding principles and in assigning thematic roles in passive sentences whereas hearing-impaired children performed close to control levels, indicating that poor speech perception cannot account for this pattern of deficit. However, the pattern of errors on syntactic tasks and the relatively weak correlation between different indicators of syntactic deficit seemed incompatible with a modular hypothesis. We propose that limited processing capacity is the principal determinant of deficient syntactic comprehension in SLI.

The study of children with specific language impairment (SLI) in the context of otherwise normal development provides an opportunity to investigate the mechanisms and processes that children bring to the task of language learning and where these processes might break down in the case of SLI. Research over the years has provided essentially two contrasting causative theories of SLI. One view, which we refer to as a modular account, posits that grammatical knowledge is innate and that aspects of this knowledge are either missing in SLI (e.g., Gopnik & Crago, 1991) or mature very late (e.g., Rice & Wexler, 1996). The modular account put forward by Van der Lely and colleagues posits a "representational deficit for dependent relationships" (RDDR) in the syntactic system, which accounts for grammatical errors in both production and comprehension.

This theory is the focus of the research reported here. Although modular theories vary in details, they share the crucial notion that grammatical impairment in SLI is selective and independent of other nonsyntactic linguistic domains such as lexical knowledge or phonological processing.

Nevertheless, there is mounting evidence that most children with SLI experience a range of deficits outside the syntactic system. These include auditory perceptual deficits, memory deficits, and general processing capacity limitations (see Leonard, 1998, for a thorough review). A crucial question is whether these additional difficulties are simply associated symptoms of SLI or whether they are causally linked to the grammatical deficits. A nonmodular account of SLI was recently summarized by Joanisse and Seidenberg (1998): "there is good evidence that SLI is associated with impairments in the processing of speech; that these impairments affect the development of phonological representations; and that degraded phonological representations are the proximal cause of deviant acquisition of morphology and syntax, by virtue of their roles in learning and working memory" (p. 241). According to this view, grammatical deficits are seen as a secondary, downstream consequence of lower level perceptual deficits.

Modular versus nonmodular accounts: Evidence from children with hearing impairments

One way to tease apart the different causal theories is to investigate the syntactic abilities of children who have known deficits in areas thought to be important for language learning. Briscoe, Bishop, and Norbury (2001) noted that mild–moderate sensorineural hearing (SNH) impairment provides an informative comparison with SLI. As Moore (1998) pointed out, amplification does not normalize the hearing of people with cochlear hearing loss. Sounds may be perceived as unclear or distorted, especially when background noise is present. Of particular interest here is the fact that cochlear damage leads to poor temporal resolution at low sound levels and difficulty in following the temporal structure of everyday sounds: this suggests some similarities with the auditory perceptual difficulties described in SLI (e.g., Tallal, Miller, & Fitch, 1993). Briscoe et al. (2001) studied children with hearing losses (SNH) in the range of 20–70 dB and found that their performance on tests of phonological discrimination, short-term memory, and awareness was very similar to that of a group of children with SLI and well below control levels. However, the SNH group, unlike the SLI group, was largely unimpaired on tests of verbal short-term memory and literacy, suggesting that problems in speech perception cannot explain the pervasive verbal impairments seen in SLI. Norbury, Bishop, and Briscoe (2001) went on to compare these same groups of children on the production of finite verb morphology. The rationale was as follows: if intact speech perception is necessary for morphosyntactic development to proceed normally, then one would expect those children who experienced degraded auditory perception in the language learning years (the SNH group) to have deficits in verb morphology that mimic the deficits seen in SLI. This hypothesis was contrasted directly with the extended optional infinitive (EOI) account of SLI put forward by Rice and Wexler (1996).

The results appeared to favor the EOI account in finding severe and distinctive difficulties with verb morphology in only the SLI group. The SNH group of children were superior to those with SLI on expressive tasks of regular and irregular past tense morphology and measures of third person singular agreement, even though their speech discrimination abilities resembled those of the SLI group. This clearly indicated that low-level perceptual deficits alone cannot account for the impairments of morphosyntax seen in SLI. However, there were several pieces of data that did not fit well with a modular interpretation. First, 6 out of 19 children with SNH exhibited deficits similar to those seen in SLI. Although they constituted a minority of the SNH group, the number is considerably higher than one would expect to find in a normally hearing population, suggesting that perceptual deficits could act as a risk factor for SLI. Second, for all groups, the children's omission of verb inflections was dependent on nonsyntactic properties of the verb such as frequency and phonological complexity. Third, there was a relationship between tense marking and nonsyntactic language measures, such as vocabulary, nonword repetition, and recalling sentences, all tasks on which children with SLI do poorly. This suggested that processing limitations might play a crucial role in morphosyntactic deficits.

Although the study by Norbury et al. (2001) raised important issues about the nature of underlying deficits in SLI, it dealt exclusively with expressive syntax. One might expect that, if defective speech perception affects language learning, its effects would be seen more in receptive language than expressive. Although most of the literature on SLI has focused exclusively on expressive grammatical abilities, there is a small and growing literature on the comprehension of syntax. Again, causal explanations can be divided into modular and nonmodular accounts.

Grammatical comprehension: A modular account

Van der Lely, Rosen, and McClelland (1998) proposed that there is a homogeneous subtype of grammatical SLI (G-SLI), which is characterized by severe deficits in grammatical production and comprehension relative to nongrammatical language domains such as lexical knowledge or phonology. These authors suggest that these deficits are attributable to a RDDR in the underlying syntactic system, which leads to disproportionate difficulties using sentence elements that mark syntactic dependencies. An example of such a relationship includes the overt marking of verb tense (e.g., "I wash*ed* my hair yesterday"), which involves a syntactic dependency between the verb and the functional category of inflection (Van der Lely & Stollwerck, 1997). Children without this syntactic knowledge may produce bare verb stems in contexts where an inflected form is obligatory, an error type that is prolific in SLI (e.g., Rice & Wexler, 1996). In a series of studies, Van der Lely and colleagues provided evidence that children with SLI have difficulty in comprehension, as well as production, of long-distance dependencies. This is evidenced in poor comprehension of reversible active and passive sentences (Van der Lely & Harris, 1990); in a bias toward adjectival, rather than verbal, interpretation of truncated passives (Van der Lely, 1996); and in problems in applying Binding principles to assign pronominal reference in sentences (Van der Lely & Stollwerck, 1997). Van der Lely et al. (1998) argued that children with these deficits may perform normally on auditory and cognitive tasks, and they concluded that where nonlinguistic deficits are found in SLI may not be the cause of the grammatical impairments. They further argued that their results point to "the existence of a genetically determined specialisation of a sub-system in the brain required for grammar, and, it appears, for nothing else" (p. 1257).

Grammatical comprehension: Nonmodular accounts

The nonmodular accounts considered two factors that might affect children's comprehension of grammar: auditory perception and processing capacity. Bishop (1997) argued that perceptual deficits could impact the acquisition of a range of syntactic structures by increasing the ambiguity of both the inflected items and the items with which they contrast. For instance, if a child had difficulty perceiving items of low perceptual salience, such as *by* or the inflection *-s*, then statements such as "the boy is hit by the girl" and "the boy hits the girl" would both be represented as "boy hit girl," resulting in a breakdown of comprehension. Leonard and Eyer (1996) argued that morphemes such as *-ed* and *-s* and function words such as *the* and *a* are crucial for language development because they give cues to the grammatical category of unfamiliar words. For example, one does not need to known the meaning of "the zoop" to realize that *zoop* is a noun.

Other accounts focused on processing capacity, which are limitations in the amount of material that a child can comprehend when computing meaning from rapidly incoming input. Montgomery (1995, 2000) found that children with SLI showed deficits in both phonological memory capacity (as evidenced by poor repetition of polysyllabic nonwords) and working memory (as evidenced by poor recall of word lists when required to organize the recalled words into semantic category and then a size sequence). In a sentence comprehension task, children with SLI were impaired at comprehending the longer redundant sentences compared to controls and their own performance on the nonredundant sentences. These two sentence types varied only in length; they contained the same syntactic structures and semantic information. Furthermore, both memory measures were reliably correlated with the sentence comprehension task, suggesting that processing capacity was a key factor in sentence comprehension.

Distinguishing between theories: Sources of evidence

One kind of evidence that has been advanced to distinguish between theoretical accounts is the pattern of performance on tests of syntactic comprehension. An important point in Van der Lely's argument for modularity is that children with SLI are not simply immature in their syntactic comprehension: when compared with younger normally developing children matched on language level, they typically do worse. Nevertheless, Bishop (1997) noted that, in the production and comprehension of syntactic structures, children with SLI do not behave as if they have no grammatical knowledge. Their performance is typically worse than that of other children but nevertheless well above chance, which would suggest that the problem is one of deploying grammatical knowledge under real-time processing constraints, rather than the lack of such knowledge.

A second source of evidence comes from considering the relationship between different syntactic deficits. If a single modular deficit leads to problems in tense marking, thematic role assignment in reversible sentences, and the use of Binding principles, then we should be able to find children with G-SLI who show all these characteristics. Just such a case, AZ, was reported by Van der Lely and colleagues (Van der Lely, 1997; Van der Lely et al., 1998) who studied him between the ages of 6 and 13 years. Van der Lely et al. (1998) also briefly reported on six children with linguistic and cognitive profiles similar to those of AZ.

Bishop, Bright, James, Bishop, and Van der Lely (2000) investigated the notion of a distinct syndrome of G-SLI. They studied the understanding of active–passive sentences and Binding principles in a sample of 141 twin pairs, aged 7–13 years, including some selected for the presence of SLI. Like Van der Lely, Bishop et al. found that in both comprehension tasks the overall performance differentiated language-impaired children from those with normal language. However, the particular pattern of performance predicted by the RDDR was not entirely evident. Most children displayed only partial deficits on the RDDR measures, and those who had significant deficits across measures had concomitant impairments in other language functions. Bishop et al. concluded that the results leave open the possibility that children with SLI make errors on measures of grammatical comprehension for reasons other than a difficulty in deriving syntactic relationships among sentence constituents. The finding of partial manifestations of G-SLI in many children raised the question of whether the cases reported by Van der Lely are a qualitatively distinct subgroup of children or rather represent the extreme on a continuum of performance. It is possible, however, that the failure by Bishop et al. (2000) to find more cases of G-SLI reflects the fact that many children in their study had relatively mild forms of SLI.

In this article we consider a further source of evidence: children with hearing loss. We know that children with severe and profound hearing losses have difficulties in comprehending English syntax and may show unusual patterns of performance resembling those seen in receptive SLI (Bishop, 1983a). However, the interpretation of such findings is complicated, because these children typically learn language visually via signing, written language, and lipreading. Spoken English is, in effect, a second language for such children. A more realistic test of how far auditory deficits may influence the learning of syntax is provided by children with milder levels of permanent hearing loss, who are not part of the deaf community and are not exposed to signing. To date, only a handful of studies has been conducted on language development in such children and no study has focused specifically on syntactic comprehension. Following the Norbury et al. (2001) findings regarding expressive syntax in this population, in the current article we report data on syntactic comprehension in the same children, comparing their performance to that of a sample of children with SLI.

Aims of the current study

The study reported here replicates and extends the investigation conducted by Bishop et al. (2000) and explicitly compares children with documented mild–moderate hearing impairment to groups of normally hearing children and a group of normally hearing children with SLI. In doing so we sought to elucidate the following:

1. the extent to which children with mild–moderate hearing loss exhibit deficits similar to those seen in SLI and
2. how far the patterns of responding in syntactic comprehension are associated and can be explained by the RDDR versus alternative nonmodular accounts

METHODS

Participants

Children with SLI. Children with SLI were recruited from language units and special schools. All children were diagnosed by a speech and language therapist as having a primary language impairment. For inclusion into the study, all children had to achieve a standard score of 80 or better on a test of nonverbal reasoning (Raven's Coloured Matrices; Raven, Court, & Raven, 1986) and impairment (at least 1 *SD* below average) on at least two of four core language measures (see Appendix). To ensure a reasonably homogeneous group with SLI, all children were screened using the Children's Communication Checklist (Bishop, 1998) and excluded if they showed evidence of pragmatic impairment (score below 132). Children with expressive phonological impairments that interfered with intelligibility were excluded (less than 80% consonants correct on a picture-naming task). Using these criteria, 20 children aged between 6 and 13 years were selected from an initial pool of 44. These were split into a younger group, SLI-Y ($N = 14$, mean age = 8;9, age range 7;2–10;9) and an older group SLI-O ($N = 6$, mean age = 12;1, age range 11;9–13;0).[1]

Children with mild–moderate SNH loss. Children with mild–moderate SNH loss were recruited via peripatetic services for hearing-impaired children. We wanted to recruit all such children in a region who (a) attended mainstream classrooms full time, (b) were monolingual speakers of English, (c) did not use sign language, and (d) had no associated neurological impairment or syndrome. A total of 19 children aged from 5;9 to 10;7 years met the criteria for inclusion in the study. All of the children obtained standard scores on the Raven's Coloured Matrices within the normal range ($M = 110$, $SD = 14.07$). Because we were interested in seeing how a peripheral hearing loss affected language development, language status was treated as a dependent variable for this group and was not a selection criterion. Seven children had a history of speech and language therapy.

The childrens' hearing thresholds are given as pure tone averages (PTA) in decibels of hearing loss in the better ear at 250, 500, 1000, 2000, an 4000 Hz (British Society of Audiology, 1988). Three categories of hearing loss were

Table 1. *Mean* (SD) *age and score on tests used to match groups*

	SLI (N = 14)	SLI-O (N = 6)	SNH (N = 19)	CA (N = 20)	LA (N = 15)
Chronological age (months)	108.00	145.33	103.26	101.45	88.47
	(14.11)	(5.24)	(16.47)	(18.67)	(15.24)
BPVS (age equiv. months)	89.50	115.50	103.26	114.40	91.73
	(21.75)	(9.81)	(33.07)	(20.97)	(21.41)
Raven's matrices (standard score)	105.43	95.33	109.79	107.35	104.80
	(14.15)	(7.89)	(14.07)	(12.84)	(7.67)

identified in this sample. High frequency loss (3 subjects) was defined as hearing thresholds greater than 25 dB at two or more frequencies above 2000 Hz but with a PTA of less than 20 dB. Mild hearing impairment (13 subjects) was defined as a PTA of 20–40 dB. Moderate hearing impairment (3 subjects) was defined as a PTA of 41–70 dB. The average age at which children received hearing aids was 48 months (SD = 19.42). Eighteen of the children wore hearing aids, at least during school hours.

Control children. The two control groups were recruited from local primary schools and schools attended by the hearing-impaired children. All children achieved a standard score of 80 or above on Raven's matrices and scored within 1 SD of the mean on the core language measures. The control groups were matched to the two clinical groups in terms of the level of maternal education, as measured by the mean age when the mother left full-time education, $F(4, 63) = .100$, $p = .982$ (no significant differences among groups).

Control group A (CA) was matched on age and nonverbal ability to the SLI-Y and SNH groups. Control group B (CB) subjects were younger and acted as a language match group to the SLI-Y children (see Table 1). They were matched to the SLI-Y group on age equivalent scores of the British Picture Vocabulary Scales (BPVS), a measure of receptive vocabulary (Dunn, Dunn, Whetton, & Pintilie, 1982). The CA group was also matched to the SLI-O group on the BPVS age equivalent, thus providing language ability matches for the older children with SLI. Language ability control groups were included to explore the extent to which any potential deficits exhibited by the two clinical populations could be explained by a general linguistic delay.

Procedure

Each child was tested individually in a quiet room at the child's school or home by a single experimenter. The tests reported here were included as part of a longer assessment battery administered in two sessions of approximately 45 min each.

Core language measures. The core measures used in this study are described in detail in Norbury et al. (2001) and are outlined in the Appendix. Raw scores were converted to standard scores.

Tests of grammatical comprehension

Advanced Syntactic Test of Pronominal Reference (*ASTOP*). We used the same 24-item test as Bishop et al. (2000), which is a shortened version of the sentence–picture judgment task described by Van der Lely and Stollwerck (1997) to assess comprehension of pronominal reference. Half the items used reflexives and half used personal pronouns.

One of three possible pictures was presented to the child for each item. For instance, given the reflexive item "Mowgli says Baloo Bear is tickling himself," the child saw either a match (NR-M, a picture of Baloo tickling himself), a mismatch (NR-X, a picture of Baloo tickling Mowgli), or a syntactic mismatch (NR-S, a picture of Mowgli tickling himself). The same response possibilities occurred for the sentences containing pronouns (NP-M, NP-X, or NP-S).

Van der Lely and Stollwerck (1997) noted that children with SLI were able to use the semantic information inherent in reflexives to correctly identify a referent performing a self-directed action. This information would not help them solve the syntactic mismatch conditions or the pronoun mismatch condition, which rely solely on syntactic analysis. Therefore, the RDDR hypothesis predicts that not only will children with SLI obtain lower scores than controls overall, but they will also exhibit particular difficulty with the NR-S, NP-X, and NP-S conditions.

Test of Active and Passive Sentences (*TAPS*). A picture pointing paradigm was used in which the child had to choose one of four pictures that corresponded to a spoken sentence (as described by Bishop et al., 2000; Van der Lely, 1995). Three regular verbs (wash, mend, paint) and three irregular verbs (eat, hit, cut) were used in a total of 48 sentences. The four sentence types were as follows:

1. simple active: "The man eats the fish."
2. full passive: "The fish is eaten by the man."
3. short progressive passive: "The fish is being eaten."
4. short ambiguous (adjectival) passive: "The fish is eaten."

Each item consisted of four picture choices that corresponded to the following response types:

1. transitive (correct) response: the man is depicted eating the fish.
2. reversal response: the fish is depicted eating the man.
3. adjectival-stative response: the fish has been eaten (fish skeleton depicted).
4. semantic distracter: the man has been eaten (human skeleton depicted).

Note that the adjectival response is an alternative correct response for the short ambiguous passives. The RDDR hypothesis predicts that children with SLI will make more errors on all items compared to peers because of underspecified grammatical representations. Specific predictions regarding the pattern of response include increased reversal errors on full passives and a bias to adjectival responses for the ambiguous passives, because children treat the ambiguous passives as a syntactically simpler adjectival statement.

Table 2. *Mean standard scores* (SD) *on core language measures*

Test	SLI-Y (*n* = 14)	SLI-O (*n* = 6)	SNH (*n* = 19)	CA (*n* = 20)	CB (*n* = 15)
BPVS	85.93[a,b]	83.17[a,b]	98.63	110.15	103.2
	(12.10)	(7.19)	(16.22)	(7.87)	(8.89)
TROG	88.20[a,c]	93.67	108.26	112.90	100.20
	(12.98)	(10.54)	(18.72)	(16.16)	(12.00)
Recalling Sentences	3.86[a–c]	3.33[a–c]	8.79[a]	12.95	10.69
	(0.77)	(0.52)	(3.38)	(2.04)	(2.36)
CNRep	60.50[a,b]	55.00[a,b]	63.95[a,b]	98.74	83.47
	(9.02)	(0.00)	(15.01)	(16.51)	(15.17)

Note: Scores are based on a mean of 100 and a standard deviation of 15, except Recalling Sentences, which has a mean of 10 and a standard deviation of 3.
[a]Means are significantly lower than the CA group at $p < .01$ on the Scheffé test.
[b]Means are significantly lower than the CB group at $p < .05$ on the Scheffé test.
[c]Means are significantly lower than the SNH group at $p < .05$ on the Scheffé test.

RESULTS

Where appropriate, results were analyzed using one-way analysis of variance (ANOVA) with a .05 level of significance adopted. In cases where the overall F was significant, between-group differences were compared using a Scheffé test. For nonnormal data, the Kruskal–Wallis test was used and planned post hoc comparisons were conducted using Mann–Whitney tests.

Core measures

The standard scores achieved by each group are detailed in Table 2, together with a summary of statistically significant group contrasts. There was no significant difference among the groups on Raven's Matrices, $F(4, 69) = 1.68$, $p = .164$. As expected, significant group differences on the core language measures were found for the SLI groups compared to the control groups. The SNH group showed a more varied picture. We did not find a significant difference between controls and the SNH group on the BPVS, although there was substantial variation in scores for the hearing-impaired children. On the Test for Reception of Grammar (TROG, Bishop, 1983b), the SLI-Y group scored significantly worse than either the CA controls or the SNH group. There were no other group differences on this measure. The performance of the SNH group on Recalling Sentences was significantly below that of the CA controls but better than that of the SLI groups. Finally, the scores for the SNH and both SLI groups were significantly below both control groups on Gathercole and Baddeley's (1996) Children's Test of Nonword Repetition (CNRep). It should be noted that both CNRep and Recalling Sentences are tests that carry a high processing load and may therefore be sensitive to children who have processing impairments.

In summary, the SNH group tended to have more difficulty on expressive

Table 3. *Mean correct* (SD) *on ASTOP and TAPS*

Group	ASTOP (Total out of 24)	TAPS (Total out of 48)
SLI-Y	16.43 (3.06)	36.14 (7.07)
SLI-O	19.00 (2.37)	41.00 (6.07)
SNH	21.26 (2.42)	42.74 (4.25)
CA	20.65 (1.60)	44.95 (2.74)
CB	19.07 (4.15)	43.60 (3.92)

language measures than age matched controls. However, with the exception of CNRep, they outperformed the SLI-Y group on all other measures. Both SLI groups were impaired on all measures compared to controls.

Four of the children in the SNH group met our selection criteria for language impairment. This did not seem to be wholly explicable in terms of the amount of hearing loss because two had mild losses and two had moderate losses. Impairment was evident on both expressive and receptive measures, with three of them receiving standard scores on the BPVS of 80 or below and two with standard TROG scores of 80 or below.

Grammatical tests

We start by presenting data for each test that compare the performance of SLI, SNH, and control groups on overall accuracy and then move on to consider patterns of error. Finally, relationships between different indicators of G-SLI are considered.

ASTOP

Overall accuracy. The means and standard deviations for all groups are presented in Table 3. A one-way ANOVA was conducted to investigate the difference in group means on overall accuracy (match and mismatch conditions combined). As expected, a significant group difference was detected, $F(4, 69) = 7.022$, $p < .001$. Post hoc comparisons revealed that the SLI-Y group achieved significantly lower scores than the SNH group ($p < .001$) or the CA control group ($p < .001$). No other group differences were detected. A further analysis was conducted using a 5×2 repeated measures ANOVA with group as the between subjects variable and sentence type (match or mismatch) as the within subjects variable. This revealed both a significant main effect of sentence type and a significant Group × Sentence Type interaction condition: $F(1, 69) = 137.87$, $p < .001$; interaction: $F(4, 69) = 4.74$, $p = .002$. Post hoc comparisons revealed no group differences on the match conditions, and the poor performance by the SLI-Y group was entirely accounted for by the mismatch conditions. However, the significant main effect of sentence type suggests that all groups found the mismatch sentences more difficult.

Overall, the performance of the SNH group is comparable with the age matched peers (CA) while the performance of the SLI group is more in line with younger children of comparable linguistic level.

Error analysis. The RDDR hypothesis predicts that the SLI group will have disproportionate difficulties with the NP-X, NP-S, and NR-S sentence types because they require syntactic analysis without recourse to semantic cues. The significant Group × Sentence Type interaction suggested that young SLI children do have more difficulty with mismatch sentences than other groups. However, a more sensitive measure may be the difference score adopted by Bishop et al. (2000). In this measure the total number of errors on sentences not relying solely on syntactic knowledge for interpretation (NP-M, NR-M, NR-X) is subtracted from the total number of errors on the syntactic subset (NP-X, NP-S, NR-S). A large difference score reflects a disproportionate degree of difficulty with those sentence types requiring syntactic analysis.

The difference score reflects the total accuracy to some degree because children who do not make any errors will obtain a difference score of zero. Therefore, those who did not make any errors were excluded from this analysis. A Kruskal–Wallis analysis revealed a significant difference among groups, $\chi^2(4) = 9.758$, $p = .045$ (SNH: $N = 14$, $M = 2.43$, $SD = 1.87$; SLI-Y: $N = 14$, $M = 4.43$, $SD = 2.10$; SLI-O: $N = 6$, $M = 3.67$, $SD = 1.37$; CA: $N = 20$, $M = 2.35$, $SD = 1.63$; CB: $N = 14$, $M = 2.43$, $SD = 3.67$). The post hoc analysis revealed a significant difference between the SLI-Y group and their age matched controls ($U = 65.5$, $Z = 2.645$, $p = .008$). No other differences were significant.

TAPS

Overall accuracy. The means and standard deviations for total number of correct answers on TAPS are reported in Table 3. An exploration of the data revealed wide variation within the groups, particularly within the SLI groups. Owing to the nonnormality of the data, nonparametric tests were used to examine group differences. A Kruskal–Wallis test revealed significant group differences, $\chi^2(4) = 17.31$, $p = .002$. Planned post hoc comparisons were made using Mann–Whitney tests. As expected, there were significant group differences between the SLI-Y group and both control groups, $p < .01$. In addition, the comparison between SLI-Y and SNH was also significant ($U = 60$, $Z = -2.669$, $p = .008$). No other significant differences were revealed, again suggesting improved performance for the SLI group with age and the relatively intact abilities of the SNH group.

Error analysis. For simple active sentences, all groups were performing at ceiling levels with an accuracy of 90% or more. Figures 1–3 illustrate the proportion of different responses to the remaining three sentence types. It is apparent from the graphs that semantic errors are extremely rare in any group. It is also interesting to note that the most common error for all groups is an adjectival response.

The RDDR hypothesis makes specific predictions about responses to full pas-

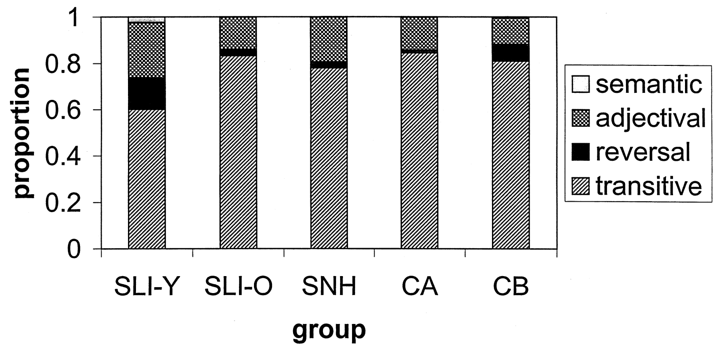

Figure 1. The proportions of different responses to full passive sentences.

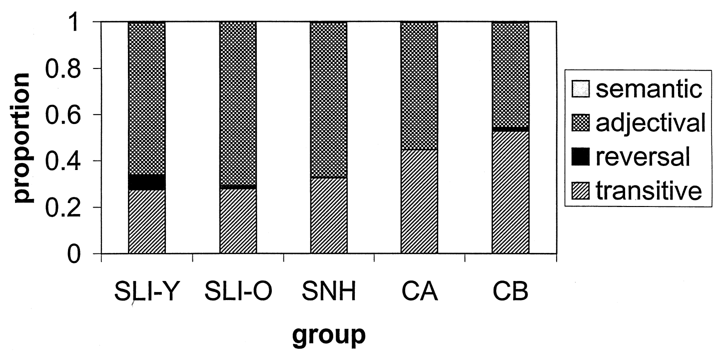

Figure 2. The proportions of different responses to short ambiguous passives.

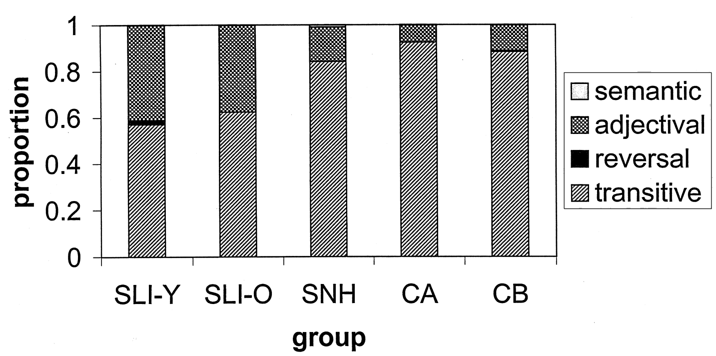

Figure 3. The proportions of different responses to short progressive passives.

sives and ambiguous passives. Considering full passives first, the mean transitive (correct) responses for each group are as follows (standard deviations given in the parentheses): SNH 9.37 (1.5); SLI-Y 7.21 (2.99); CA 10.15 (1.66); CB 9.73 (2.31); SLI-O 10.00 (1.79). A one-way ANOVA confirmed a significant group difference, $F(4, 69) = 4.665$, $p = .002$. Planned post hoc comparisons using Scheffé tests revealed significant group differences between SLI-Y and the two control groups (CA, $p = .005$; CB, $p = .041$).

The RDDR predicts that children with G-SLI will make a disproportionate number of reversal errors on full passives, but it does not predict semantic or adjectival errors. An examination of the proportion of errors that are reversals revealed that both SLI-Y and the younger CB controls made more such errors than the other groups: SNH .104 (.220); SLI-Y .406 (.342); CA. 01 (.280); CB .473 (.484); SLI-O .267 (.435). Significant group differences were confirmed using a Kruskal–Wallis analysis, $\chi^2(4) = 13.996$, $p = .007$. However, post hoc comparisons, with p adjusted to .006, failed to reveal any significant differences. This is probably a reflection of the substantial variation within the groups.

The graph in Figure 1 suggests that, when errors occur, they are likely to be adjectival errors. The Kruskal–Wallis tests indicated significant differences among the groups in mean proportion of errors on full passives that are adjectival interpretations: means: SNH .895 (.220); SLI-Y .534 (.356); CA .900 (.280); CB .509 (.501); SLI-O .733 (.435); $\chi^2(4) = 15.223$, $p = .004$. The CA, SNH, and older SLI groups were more accurate on full passives overall. However, when they did make errors, a significant proportion were adjectival responses, a response type not predicted by the RDDR hypothesis. On the other hand, as Figure 1 illustrates, the SLI-Y and CB groups were equally likely to make adjectival or reversal errors.

Next we consider responses to short ambiguous passives. The RDDR hypothesis predicts that children with SLI will show a preference for adjectival responses to ambiguous passives. Therefore, the proportion of correct responses to ambiguous passives that were adjectival was calculated. The means and standard deviations are as follows: SNH .673 (.160); SLI-Y .708 (.169); CA .553 (.206); CB .457 (.236); SLI-O .713 (.264). The proportions were analyzed using ANOVA, which revealed a significant group difference, $F(4, 69) = 4.296$, $p = .004$. A post hoc Scheffé analysis indicated that the only significant difference was between the CB controls and the SLI-Y group ($p = .031$).

The proportion of adjectival responses to ambiguous passives did not clearly separate language-impaired subjects from other groups. In addition, the hearing-impaired subjects performed very similarly to the SLI groups on the ambiguous passives. However, group means may mask important individual variation. For instance, a proportion of .500 could result if half the group always made an adjectival response and half the group always made a transitive response. One way to clarify this issue would be to examine how many children in each group demonstrated an adjectival response bias. For this purpose, 9 adjectival responses out of a possible 12 was considered indicative of a response bias, as the binomial probability of obtaining a score this extreme by chance is .073.

To simplify the analysis, the control groups and both SLI groups were combined. Eight children in the SNH group (42%) showed an adjectival response bias. Of the language-impaired children, 11 (55%) showed adjectival bias. In stark contrast, only 4 (11%) of the control children showed this bias. A chi-square analysis confirmed a significant categorical association between group membership and adjectival response for SLI versus controls: $\chi^2 = 12.18$, $p = .001$; SNH versus controls: $\chi^2 = 6.71$, $p = .013$. A comparison between the SLI and SNH groups was not significant. It therefore appears that the clinical groups were more likely than controls to provide an adjectival interpretation to a short ambiguous passive. However, it should be noted that around 50% of the children in the clinical groups did not show an adjectival bias.

One measure that clearly did distinguish the SLI subjects from other groups was an adjectival response to short progressive passives (e.g., "the fish is being eaten"). Unlike ambiguous passives, adjectival responses to progressive passives are scored as incorrect. The mean proportion of correct (transitive) responses for each group is as follows: SNH .842 (.220); SLI-Y .571 (.310); CA .925 (.118); CB .883 (.132); SLI-O .625 (.360). This difference was significant on the ANOVA, $F(4, 69) = 7.174$, $p < .001$. The SLI-Y group had significantly fewer correct responses than the SNH, $p = .021$; CA, $p = .001$; or CB, $p = .009$, groups. Figure 3 illustrates that virtually all errors made by any group were adjectival errors and that the SLI groups were equally likely to provide a transitive or adjectival response to the progressive passives. This result is not one explicitly predicted by the RDDR hypothesis and will be discussed later.

G-SLI indicators

Bishop et al. (2000) proposed that if SLI is a deficit of innate syntactic knowledge, then affected children should show equivalent impairment across a range of indicators. In this study it was possible to use indicators parallel to those studied by Bishop et al., plus two additional indicators from the expressive syntactic measures described by Norbury et al. (2001). The first indicator used by Bishop and coworkers was taken from TROG, a test of grammatical comprehension in which the child must choose one picture out of four to match a spoken sentence. It is scored in blocks of four items that correspond to different sentence constructions. Later blocks test the understanding of syntactic relationships that are relevant to the RDDR. Therefore, a subset of TROG items was examined. The raw number of correct items was summed for blocks H (reversible active sentences), L (reversible passives), N (subject postmodified by a verb phrase or prepositional phrase), and R (object modified by a relative clause) to produce a total of 16 possible correct. The means and standard deviations for the groups were as follows: SNH 14.37 (2.48); SLI-Y 12.36 (2.87); CA 14.65 (1.46); CB 12.67 (2.41); SLI-O 14.83 (.98). A Kruskal–Wallis analysis revealed a significant difference in the total number correct, $\chi^2(4) = 13.21$, $p = .01$. Multiple comparisons indicated that the SLI-Y and CB groups had significantly lower scores than the CA group ($p < .01$).

In order to identify subjects impaired on TROG and the two experimental comprehension tests (ASTOP and TAPS), the number of errors representing the bottom 5% of the CA group was taken as a cutoff. This corresponded to 4 or

Table 4. *Frequency of G-SLI error types per group*

	Percentage Showing Error Type							
Group	G1	G2	G3	G4	G5	G6	G7	G8
SLI-Y	43	57	64	36	86	50	50	86
SLI-O	0	33	33	0	67	67	33	100
SNH	11	11	21	5	26	42	16	26
CA	5	5	5	5	25	15	0	0
CB	33	33	7	33	40	7	0	7

Note: G1, grammatical errors on TROG blocks H, L, N, and R > 4; G2, total errors on ASTOP ≥ 7; G3, total errors on TAPS ≥ 10; G4, reversal errors on TAPS full passives ≥ 2; G5, ASTOP difference score (sum of errors on NP-X, NP-S, and NR-S, minus all other errors) ≥ 4; G6, bias to adjectival interpretation of short ambiguous passives ≥ 9; G7, total accuracy on third person singular elicitation of <66%; G8, score on total past tense marking of more than −1.5 *SD*.

more errors on the TROG subset (Grammatical Indicator 1- G1), 10 or more errors on TAPS (G2), and 7 or more errors on ASTOP (G3).

In addition to these quantitative indicators, a number of qualitative indicators identified by Bishop et al. (2000) were also included. These were the tendency to make reversal errors on full passives (3 or more errors out of 12; G4), a disproportionate number of syntactic errors on ASTOP (a difference score of 4 or more; G5), and a preference for adjectival responses to ambiguous passives (9 or more out of 12; G6).

In addition to deficits in syntactic comprehension, the RDDR hypothesis predicts deficits in the production of grammatical morphology. Therefore, two indicators from our previous study (Norbury et al., 2001) were included. These were a total score on marking of third person singular agreement (G7) and past tense (G8) on verbs in an obligatory context. These two measures reliably differentiated children with language impairment from nonaffected controls. For third person singular, a score of 66% (which represented the number of correct responses divided by the number of different verbs used) was used as a cutoff because no subject in either control group obtained a score lower than 66%. For past tense, a regression of total past score on age was used to compute a z score for each child. Those scoring more than 1.5 *SD* below the score expected for that age were identified as impaired on this task.

This analysis resulted in a total of eight possible indicators of G-SLI. Table 4 illustrates the frequency of occurrence of each indicator in relation to each group. Few of the indicators are present in more than 50% of group members, even in the language-impaired groups. The most reliable indicator of language impairment would appear to be G8, total past tense marking. The next highest scoring indicator for the SLI-Y group was G5, syntactic errors on ASTOP.

The next step is to consider the relationships among the indicators. Table 5 shows the correlations among the different indicators above the diagonal. These

Table 5. *Correlations (above diagonal) and phi coefficients (below diagonal) for associations between quantitative and categorical indicators of G-SLI*

	G1[a,b]	G2[c]	G3[c,d]	G4[a,b]	G5[c]	G6	G7[c,d]	G8[c,e]
G1		.458***	.344**	−.358**	−.431***	.063	.347**	.475***
G2	.289*		.436***	−.506***	−.937***	.058	.453***	.552***
G3	.146	.215		−.473***	−.431***	−.272*	.310*	.456***
G4	.213	.421***	.442***		.455***	−.099	(−.222)	(−.361)
G5	.414***	.522***	.301*	.213		−.110	−.374	−.497
G6	−.175	.028	.119	−.009	.121		−.150	−.163
G7	.349**	.349**	.457***	.148	.356**	.101		.728***
G8	.312**	.261*	.493***	.219	.415***	.323**	.538***	

[a]Those correlating with nonword reading at $p < .01$.
[b]Those correlating with nonword repetition at $p < .05$.
[c]Those correlating with nonword reading at $p < .001$.
[d]Those correlating with nonword repetition at $p < .01$.
[e]Those correlating with nonword repetition at $p < .001$.
*$p < .05$; **$p < .01$; ***$p < .001$.

are based on the whole range of raw test scores from which the indicators are derived without using any cutoffs. Phi coefficients, which measure categorical association, are given below the diagonal. These signify the extent to which impairment on one indicator is related to impairment on another. It can be seen that all correlations are significant, apart from the index for adjectival bias, G6, which is not correlated with any other measure. This indicator was therefore dropped from subsequent analyses, leaving a total of seven indicators of G-SLI.

Two children from the entire sample scored positive on all seven indicators, and one other child scored positive on six out of seven indicators. All of these children were from the SLI-Y group. On the surface, they look very similar to the G-SLI children described by Van der Lely et al. (1998). All three have standard scores above 100 on Raven's matrices and only one had significant vocabulary deficits (BPVS standard score of 63). However, close investigation of all assessment scores showed that each child had significant deficits on CNRep (all had standard scores below 67) and nonword reading (all had standard scores of 70 on the Graded Test of Nonword Reading; Snowling, Stothard, & McLean, 1996). The standard scores of these two measures were therefore added to the correlation matrix of indicators for G-SLI. The CNRep was significantly correlated (at $p < .01$) with the total accuracy on TAPS ($r = .341$), the production of third person singular ($r = .415$), and the production of total past tense ($r = .362$). Nonword reading was significantly correlated with all measures at $p < .01$ (TROG, $r = .352$; ASTOP, $r = .486$; TAPS, $r = .512$; reversal errors, $r = -.313$; ASTOP difference scores, $r = -.453$; third person singular, $r = .518$; total past tense, $r = .607$; CNRep, $r = .461$).

None of the G-SLI indicators occurred in more than 50% of the SNH group, and no single child scored positive on more than five indicators. As mentioned earlier, four children in the SNH group met our criteria for language impairment in this study. Of this subset, one scored positive on three out of seven indicators, one scored positive on four out of seven, and one scored positive on five out of seven. The remaining child scored positive on only one of the seven indicators. All of these children exhibited concomitant deficits in vocabulary and nonword repetition.

DISCUSSION

At the beginning of this article, we posed two questions to which we now return.

1. Do children with mild to moderate hearing loss show syntactic comprehension deficits resembling those seen in G-SLI?

We found that, despite consistently degraded auditory input at the time language skills were being acquired, children with mild–moderate hearing impairment do much better than those with SLI on these comprehension tasks. They consistently outperformed the SLI-Y group, and their pattern of responses was similar to the CA controls. As reported by Briscoe et al. (2001), these same children did as poorly as those with SLI on tests of phonological perception, memory, and awareness. They thus provide evidence against any hypothesis that maintains that low-level problems in phonological discrimination can account for the distinctive syntactic deficits seen in SLI. The only way to reconcile these data with a perceptual account would be to argue that the types of auditory impairment seen in SLI are different kinds than those seen in SNH and are uniquely detrimental for learning syntax. In SLI the emphasis was on temporal processing deficits (Tallal et al., 1993; Wright et al., 1997). However, what little is known of auditory temporal processing in people with SNH loss suggests that it is adversely affected (as is frequency discrimination; Moore, 1998). In future work with the SNH group we plan to use auditory temporal processing tasks similar to those used in studies of SLI to provide a direct comparison of their auditory temporal processing abilities.

2. To what extent do children with SLI exhibit deficits consistent with the RDDR?

Our study replicated previous research by Van der Lely and colleagues and Bishop et al. (2000), demonstrating that two tests of syntactic comprehension can differentiate children with language impairments from control groups with normal language. However, the patterns of responses on these tests led us to question whether the RDDR hypothesis gave the best account of the data.

First let us consider ASTOP. We found, like Van der Lely and Stollwerck (1997), that children with SLI performed better on the match than the mismatch sentences. Van der Lely proposed that this is because they generate an underspecified syntactic representation that is compatible with the depicted situation. However, mismatch sentences were more difficult for all the children in our study, and there was no indication that errors predicted by the RDDR were disproportionately more common in those with SLI. Foster-Cohen (1994) suggested that mismatch conditions are difficult because they present contradictory information in the test sentence in relation to the depicted context, thus violating rules of pragmatic relevance. She proposed that such sentences are more distracting and require more processing effort to resolve, and she used evidence from a range of studies illustrating that typically developing children have more difficulties with mismatch sentences than match. The syntactic mismatch sentences used here (NP-S and NR-S) may be particularly challenging because they require the processing of the entire sentence as opposed to only the subordinate clause. Thus, the difficulties experienced by children with SLI are open to alternative interpretations that do not implicate a modular deficit.

Turning now to TAPS, the RDDR predicts that children with SLI will show a bias toward the adjectival interpretation of short ambiguous passives because, again, they will generate underspecified syntactic representations of the target sentence in which only one thematic role is assigned. We found only a nonsignificant trend for children with SLI to favor the adjectival interpretation more than age matched control children, although our sample size was small for detecting such an effect. Furthermore, the results on short progressive passives suggest a different interpretation from the RDDR hypothesis. In children with SLI, adjectival responses were common to these items as well. A common feature of both types of short passive is that only one argument of the verb is overtly expressed in the test sentence. When they make an adjectival interpretation, the children are simply selecting the picture in which only one noun is depicted. Therefore, a picture of only one item is compatible with the salient message that the child has been given. This is supported by the fact that, when the control children and the SNH children made errors on this sentence type, they always chose the adjectival interpretation.

As predicted by the RDDR hypothesis, the SLI group made more reversal errors on full passives than the control groups, although there was a tendency for the younger control group to make reversal errors as well. The fact that the SNH group did not make reversal errors confirms that mild perceptual deficits per se are not sufficient to cause this kind of impairment in grammatical comprehension. However, this does not necessarily lead to the conclusion that SLI is the result of a deficit in an innate system for computing syntactic relationships. Children in the SLI-Y group were equally likely to choose an adjectival or reversal response when they made errors on full passives. What accounts for such responses?

Following on from the previous argument about the pragmatic relevance of the sentences in relation to the context, passive constructions are often used to draw the listener's attention to the object of the action. In a passive sentence this is the first argument of the verb heard by the listener and may therefore be the most salient. As children listen and try to process the passive sentence, they may begin to build up an adjectival interpretation as they did for the short passives. However, at the end of the sentence the second argument of the verb is overtly expressed. Therefore, if the children are still attending, they may realize that now two noun phrases need to be accounted for and this may result in some confusion. As a result, sometimes they are correct but other times they make a reversal error. Adjectival responses may occur because they are focusing on the object of the verb and not processing the entire sentence. This is speculation at the moment, and a more detailed investigation is warranted. However, it is consistent with the finding that when the control children made errors, they chose the adjectival interpretation.

Like Bishop et al. (2000), we found significant, but moderate associations among a range of indicators specified by the RDDR hypothesis. If there were an innate deficit in syntactic knowledge, we would expect the children to show a consistent degree of impairment across related indicators. Only three children (all from the SLI-Y group) scored positive on six or more of the seven indicators of G-SLI; and they all had significant deficits on nonword repetition and nonword reading, suggesting broader phonological impairments. Other children across all groups showed only partial impairments on the tasks specified by the RDDR hypothesis.

A synthesis of the findings

This study offers compelling evidence against any explanation of syntactic deficits in SLI as caused by low-level auditory perceptual problems. At first glance, the data seem supportive of the alternative hypothesis that we considered, the RDDR, with tests based on the RDDR proving sensitive to SLI. However, there are certain aspects of the data that are hard to accommodate within the RDDR. First, like Bishop et al. (2000), syntactic deficits seemed far more graded in severity than would be predicted by that theory, and they did not hang together to form a distinctive syndrome. Second, some of the error patterns seen in SLI were also observed in the control children. Furthermore, it was possible to explain many of the findings by assuming that the children's responses were influenced by nonsyntactic strategies (e.g., picking the picture depicting the same number of arguments as used in the test sentence) and processing limitations. The finding that indicators of G-SLI were related to measures tapping phonological short-term memory and phonological analysis is compatible with a nonmodular account of SLI that stresses processing limitations, such as that put forward by Montgomery (1995). In the literature on SLI, there has been a tendency to treat low-level perceptual problems together with processing capacity limitations as part of the same underlying problem (see Joanisse & Seidenberg, 1998; Leonard, 1998). In the original version of Leonard's surface hypothesis perceptual problems were highlighted; but as the theory has evolved, processing limitations have come more to the forefront. Data from this study suggest that limitations on working memory, rather than (or perhaps in addition to) difficulties in discriminating speech sounds, are critically related to syntactic deficits in SLI.

In conclusion, tests designed to measure the understanding of syntactic dependencies are sensitive to children with SLI. That children with hearing impairment do not usually show impairments on these tasks suggests that perceptual deficits alone cannot account for the grammatical comprehension deficits seen in SLI. However, the highly selective and consistent pattern of deficit predicted by the RDDR was not seen in our relatively homogeneous sample of children with SLI. The pattern of responses suggests that children may fail these tests for a variety of reasons. In particular, the relationship of phonological memory and processing skills to syntactic comprehension requires further investigation. Only then can we fully address the issues of innate language capacities in SLI.

APPENDIX

Core assessments

Assessment	Description
1. Raven's Coloured Progressive Matrices (Raven et al., 1986)	Test of nonverbal reasoning that requires child to choose one of six pieces to complete a pattern
2. British Picture Vocabulary Scales (Dunn et al., 1982)	Measure of receptive vocabulary in which child must choose one of four pictures to match a spoken word
3. Test for Reception of Grammar (TROG; Bishop, 1983b)	Assesses understanding of syntactic structures by having child point to one of four pictures that corresponds to a spoken test sentence
4. Clinical Evaluation of Language Fundamentals (CELF)–Revised–Recalling Sentences subtest (Semel, Wiig, & Secord, 1987)	Child asked to repeat sentences of increasing length and complexity in this measure of expressive language and sentence memory
5. Children's Test of Nonword Repetition (CNRep; Gathercole & Baddeley, 1996)	Index of phonological short-term memory that requires child to repeat nonwords of four to five syllables

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NOTE

1. An editorial decision resulted in the data for the SLI-O group being omitted from the Norbury, Bishop, and Briscoe (2001) article. Information on SLI-O performance on expressive verb morphology is available from the corresponding author.

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