# Past tense morphology in specifically language impaired and normally developing children

Heather K.J. van der Lely
*Birkbeck College, University of London, London, UK*

Michael T. Ullman
*Department of Neuroscience, Georgetown University, Washington, DC, USA*

This study evaluates the input-processing deficit/single system and the grammar-specific deficit/dual system models to account for past tense formation in impaired and normal language development. We investigated regular and irregular past tense formation of 60 real and novel regular and irregular verbs in "Grammatical (G)-SLI" children (aged 9:3 to 12:10) and morphological- or vocabulary-matched younger control children. The G-SLI children and language ability (LA) controls showed quantitatively and qualitatively different patterns of performance. The LA controls, but not the

Requests for reprints should be addressed to H.K.J. van der Lely, Department of Psychology, Birkbeck College, University of London, Malet Street, London WC1E 7HX, UK. Email: h.vanderlely@psyc.bbk.ac.uk, or to M.T. Ullman, Department of Neuroscience, Georgetown University, 3900 Reservoir Road N.W., Washington, DC 20007, USA. Email: michael@giccs.georgetown.edu

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G-SLI children, showed a significant advantage of regular over irregular past tense marking for real and novel verbs. Past tense frequency affected the G-SLI children, but not the controls' production of regular verbs, even with stem access controlled for. The G-SLI children's production of regular forms was significantly lower than that of the control groups. Frequency and phonological properties had a similar and significant effect on the G-SLI and LA controls' irregular formation. The G-SLI children's irregular past tense production did not differ from that of the morphological controls, but was lower than that of the vocabulary controls. We argue that the dual mechanism/grammar-specific deficit provides a parsimonious explanation for normal and impaired performance, and suggest that grammatical computations underlying regular past tense formation in normal grammar are impaired (not missing) in G-SLI grammar.

## INTRODUCTION

Specific language impairment (SLI) is a heterogeneous disorder of language acquisition in children who do not have any other apparent cognitive, social, or neurological deficit that can obviously account for their impairment (Menyuk, 1964). The impairment affects around 7% of children (Leonard, 1998). Problems with inflectional morphology are frequently reported and are a prototypical characteristic of children with SLI (Bishop, 1994; Gopnik, 1990; Leonard, 1998; Oetting & Rice, 1993; Rice, Wexler, & Cleave, 1995). However, there is considerable controversy concerning the cause of the disorder and the nature of their inflectional morphology deficit. The controversy revolves around whether an input processing deficit (Bishop, 1997; Joanisse & Seidenberg, 1998b; Leonard, 1998; Tallal et al., 1996) or a grammar-specific deficit (Clahsen, 1989; Gopnik, 1990; Rice & Wexler, 1996; van der Lely, Rosen, & McClelland, 1998) causes SLI and whether or not representation of inflectional morphology is qualitatively different from that of normally developing children. One reason for this controversy is the variation in linguistic and cognitive characteristics found across different groups of children with SLI (Aram, Morris, & Hall, 1993; Bishop, Bishop, Bright, James, & van der Lely, 2000). The heterogeneity of SLI could reflect different causes of the disorder. To provide insight into this issue we investigated the production of real and novel regular and irregular verbs in a selected homogeneous SLI subgroup, 'Grammatical(G)-SLI children' (van der Lely, et al., 1998). Van der Lely and colleagues have claimed that G-SLI children have a primary deficit of the computational grammatical system (van der Lely, 1994, 1997a,b, 1998; van der Lely et al., 1998; van der Lely & Stollwerck, 1997). The apparent pure form of G-SLI found in this subgroup (van der Lely et al., 1998), but not in all subgroups of children with SLI (cf. Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995), makes them particularly well-suited to exploring the nature of their linguistic deficit and testing the opposing theories of SLI.

## Grammatical(G)-SLI

Van der Lely and colleagues have identified a subgroup of SLI subjects who they claim have a primary and disproportionate grammatical impairment—'Grammatical(G)-SLI children' (van der Lely, 1994, 1997,a,b, 1998; van der Lely et al., 1998; van der Lely & Stollwerck, 1997). G-SLI affects between 10–20% of children with a persisting SLI and IQ > 85, and is consistent with an autosomal (non-sex linked) dominant inheritance (van der Lely & Stollwerck, 1996). Investigations of auditory, articulatory, and cognitive abilities, thought by some researchers to explain SLI (Leonard, 1998; Tallal & Piercy, 1973; Tallal et al., 1996; Wright et al., 1996), did not reveal the co-occurring deficits that have been found in some children with SLI (van der Lely et al., 1998). Linguistically, G-SLI children show that they inconsistently manipulate core aspects of syntax, including tense and agreement marking (*My Dad go to work*), assigning thematic roles in passive sentences and embedded phrases and clauses (*The boy was pushed by the girl*; *The dog with the bone is* ...), assigning reference to pronouns or reflexives (*Mowgli says Baloo is tickling him/himself*), and producing Wh-questions (*Who Tom see someone in the kitchen?*) (van der Lely 1994, 1996a,b, 1998; van der Lely & Battell, 1998; van der Lely & Hennessey, 1999, van der Lely & Stollwerck, 1997). Thus, while G-SLI children share many grammatical inflectional characteristics with other SLI children (Bishop, 1997; Leonard, 1998), investigations also show that they make syntactic structural errors. However, aspects of language outside grammar, such as pragmatic inference and verbal logical reasoning are not impaired in G-SLI children (van der Lely et al., 1998; cf. Bishop, 1997). For example, G-SLI children show the appropriate pragmatic knowledge needed to determine conversational inferences, use pronouns in narratives, and to facilitate sentence comprehension (Surian, Baron-Cohen, & van der Lely, 1996; van der Lely, 1997b; van der Lely & Dewart, 1986; van der Lely & Stollwerck, 1997). The validity of G-SLI as a qualitatively distinct subgroup is an empirical issue to which this paper contributes.

## Regular and irregular inflectional morphology in children with SLI

The morphological representation and processing of regular and irregular morphology in children with SLI is of particular relevance to this study. Previous investigations of regular and irregular plural and past tense morphology in different groups of SLI children have revealed conflicting findings. On the one hand, the findings for young children with SLI indicate the relatively appropriate use of irregular morphology but abnormal use of regular morphology in comparison to language- or age-matched peers (Leonard, McGregor, & Allen, 1992; Oetting & Rice, 1993; Oetting & Horohov, 1997; Rice et al., 1995). This impairment is evinced in first, a greater number of omissions of past tense marking in obligatory contexts than language control children (Leonard, 1998). Second, there is less frequent use of over-regularisations of irregular words (*felled*; *mices*) and regularisations of novel words (*bips*) for SLI children than for children developing normally (Leonard, 1989; 1998; Marchman & Weismer, 1994; Marchman, Wulfeck, & Weismer, 1999). Third, frequency effects are reported in several studies for regularly inflected plural nouns and past-tense verbs for children with SLI but for normally developing children (Oetting & Horohov, 1997; Oetting & Rice, 1993; Ullman & Gopnik, 1999). An atypical frequency effect is also evident in German-speaking children with SLI. Normally developing German-speaking children over-generalise the regular-default, but relatively infrequent *-s* plural affix, whereas some children with SLI overgeneralise the most frequent *-en/n* plural affix (Bartke, 1998; Clahsen, Rothweiler, Woest, & Marcus, 1992). Finally, Marchman et al.'s (1997, 1999) analysis of children's regular and irregular error patterns of regular and irregular verbs, demonstrated that SLI children were more sensitive to frequency and phonological characteristics of stem and past tense forms than age-matched control children. However, Marchman's (1999) analysis did not focus on whether frequency and phonological patterns were having a different or similar effect on the proportion of correct regular and irregular forms, or on whether the SLI children's performance was qualitatively different from younger children of similar language abilities. Thus, to understand further the nature of inflectional morphology in SLI and normally developing children, this study investigates whether frequency is having a qualitatively different effect on the G-SLI and younger normally developing children's correct production of regular and irregular forms as well as on unmarked forms.

Alternatively, some researchers argue that some 5- to 8-year-old SLI children have normal representation of irregular and regular inflections (Clahsen et al., 1992; Marchman & Weismer, 1994; Marchman et al., 1999; Oetting & Horohov, 1997; Oetting & Rice, 1993). Oetting and Rice's (1993) study of noun compounds revealed that 5-year-old SLI children use irregular plurals inside compounds (*mice-eater*) but not regular plurals (**rats-eater*) – a pattern similar to that found in normally developing children (Gordon, 1985; Oetting & Rice, 1993; van der Lely & Christian, 2000). Moreover, Oetting and Horohov's (1997) data from 6-year-old SLI children indicated a normal distinction between past tense production of irregular and regular forms for irregular and denomalised verbs (*fly-flew/flied*). The SLI children produced 80% irregular past tense forms for the irregular verbs, while the age- and MLU-matched controls produced 85% and 41% irregular forms, respectively. For the denominal verbs, for which a regular past tense form is expected, the SLI children produced 46% regular inflections, whereas the age and MLU controls produced 77% and 67%. Thus, while the SLI children showed a distinction between the production of regular and irregular morphology, they appeared to use regular morphology less than their age or language peers did.

However, investigations of older SLI subjects indicate that the distinction between regular and irregular morphology found in normally developing children is not evident in their performance (Ullman & Gopnik, 1994, 1999; van der Lely & Christian, 2000). Ullman and Gopnik's (1994, 1999) study of a large family (the 'KE' family) found that impaired family members produced correct regular and irregular past tense forms at a similar rate, which in turn was worse than that of control subjects. Vargha-Khadem et al. (1995) reported a similar finding for the same impaired KE family members. Furthermore, van der Lely and Christian's (2000) study of 10–18-year-old subjects with G-SLI revealed a significant use of regular plurals inside compounds (**rats-eater*), unlike age- or language-matched control groups of children. However, both the G-SLI subjects and the control groups produced irregular plurals inside compounds (van der Lely & Christian, 2000). Note, although Oetting and Rice's (1993) investigation revealed that the majority (80%) of their 5-year-old SLI subjects showed the 'normal' regular-irregular distinction with irregular plurals but not regular plurals occurring inside compounds, three of the subjects (20%) used regular plurals inside compounds.

In sum: there appear to be qualitative differences in the nature of the SLI deficit in different populations of subjects. Although some children with SLI evidence a regular-irregular distinction found in normally developing children, suggesting normal morphological representations, a large number of studies report some impairment with regular morphology. One explanation for these different findings is that the full extent of the SLI deficit is not apparent until the child is older. Alternatively, the linguistic characteristics and the underlying nature of SLI may vary in different populations. This opens up the possibility that group means from heterogeneous groups of SLI children could hide potentially interesting differences. The contrasting findings emphasise the need for careful subject description in all investigations of SLI subjects and comparisons between findings of different studies if we are to shed light on these issues. This investigation of regular and irregular past tense production in the G-SLI subgroup provides an important step towards this goal and enables us to evaluate the alternative theories of SLI with respect to the nature of this subgroup's performance.

## The cause of G-SLI

The input-processing account hypotheses that impaired input processes and limited processing capacity causes SLI (Bishop, 1997; Elman et al., 1996; Joanisse & Seidenberg, 1998b; Leonard, 1998; Tallal et al., 1996). Tallal and colleagues claim that SLI can be traced to a deficit in the rate of auditory processing that is not language-specific (Bishop, 1997; Leonard, 1998; Tallal & Piercy, 1973; Tallal et al., 1996; Wright et al., 1996). Leonard et al. (1992) argues that this auditory perceptual deficit causes SLI children to have problems perceiving morphemes such as *-ed* or *-s*, which have 'low perceptual salience'. Therefore, additional resources are required to perceive such morphemes, which causes further difficulties learning morphological paradigms (Leonard, 1998; Leonard et al., 1992). Moreover, they claim that these children's general processing capacity limitations affect short-term (phonological) memory, the production of consonant clusters, the speed of processing and retrieving words such that consonants and final morphemes may be lost in the production process, and cause delay in lexical development which is seen as central to problems with inflectional morphology (Bishop, 1997; Conti-Ramsden & Jones, 1997; Elman et al., 1996; Gathercole & Baddeley, 1990; Joanisse & Seidenberg, 1998; Leonard, 1998; Marchman et al., 1999).

The different variants of the input-processing deficit hypothesis are consistent with the view that a single mechanism underlies regular (*rob-robbed*) and irregular (*give-gave*) past tense inflection (Bates & MacWhinney, 1987; Elman et al., 1996; Marchman, 1997; Plunkett & Marchman, 1991, 1993). The 'single system' account proposes that regular and irregular forms are represented and processed by a single associative memory system (Bates & MacWhinney, 1989; Elman et al., 1996; Joanisse & Seidenberg, 1998b; Plunkett & Marchman, 1991, 1993; Rumelhart & McClelland, 1986). Rule-like generalisations, such as the regular *-ed* inflectional rule, are thought to emerge over the course of learning associations between verb stems and past tense forms. Specifically, both regular and irregular mappings are learned by a constraint-satisfaction learning system that exploits the way in which surface-level features predict the relations between stem and past-tense forms (Marchman et al., 1999). Thus, the acquisition and productivity of inflectional morphology is based on lexical processing and development whereby lexical factors, such as item frequency and phonological attributes of 'neighbouring' verbs, are seen as central to the acquisition process (Bates & MacWhinney, 1989;

Daugherty & Seidenberg, 1992; Elman et al., 1996; Hare, Elman, & Daugherty, 1995; MacWhinney & Leinbach, 1991; MacDonald et al., 1994; McClelland et al., 1986; Marchman, 1993; Plunkett & Marchman, 1991; Rumelhart & McClelland, 1986). Therefore, based on the input-processing/single mechanism view comparisons between morphological productions of children with G-SLI with those of a younger group of children matched on their vocabulary development are of particular relevance.

The grammar-specific deficit account claims that impairments of mechanisms and/or representations specific to the grammatical system cause SLI (Clahsen, 1989; Gopnik, 1990; Gopnik & Crago, 1991; Rice & Wexler, 1996; Ullman & Gopnik, 1994, 1999; van der Lely, 1994; van der Lely et al., 1998). Therefore, aspects of language that rely on grammatical processes may be impaired while those that rely on other processes, such as associative learning and memory, may be spared. The grammar-specific deficit hypothesis assumes that cognitive mechanisms are specialised for particular functions, such as grammar, and so can be differentially impaired (Chomsky, 1986; Fodor, 1983; Pinker, 1994). Thus, this hypothesis is consistent with the dual-mechanism view of past-tense morphology which proposes that different mechanisms underlie regular and irregular inflectional morphology (Marcus et al., 1992; Pinker, 1999, 1991; Pinker & Prince, 1988, 1992). According to the 'dual-system' framework, irregular forms are stored in and retrieved from an associative lexical memory—similar to that proposed by the single system view to account for regular as well as irregular inflections (Pinker, 1991; Pinker & Prince, 1992). Thus, both the dual and single system accounts claim that irregular verbs are subject to lexical memory effects, such as frequency and phonological neighbourhood effects (Prasada & Pinker, 1993; Ullman, 1993, 1999). In contrast, dual system models propose that regular forms are computed by a grammatical rule, which underlies the *-ed* suffixation of the verb stem. Retrieval of an irregular past tense form blocks the rule (*gave* pre-empts *gived*). When an irregular form is not successfully retrieved, the rule may be applied, resulting in an over-regularisation (Marcus et al., 1992; Pinker, 1991). According to the dual system framework, lexical factors such as frequency or phonological properties of regular past tense should not affect their formation and thus, lexical development is not expected to strongly predict performance of regular past tense forms.

Therefore, in this study, the comparison between the production of regular and irregular past tense forms in G-SLI children and younger children matched on vocabulary ability enables us to test the contrasting predictions from the two accounts of G-SLI and the role of vocabulary in inflectional morphology development. The comparison between G-SLI children and children matched on vocabulary or morphological abilities enables us to evaluate whether the pattern of performance found for the

G-SLI children could be expected in normally developing children at a similar stage of vocabulary or morphological development.[1]

## Predictions

According to the single system account, for normally developing children lexical factors such as frequency and phonological similarity should account for much if not all of any differences between the use of regular and irregular forms (Marchman, 1997). Their production rate of novel irregularised past tense forms (*crive-crove*) should increase with age as memory traces of similar stem-past pairs strengthen (e.g., *drive-drove*, *dive-dove*). Therefore, frequency effects may be expected for both regular and irregular forms. However, frequency effects might not be found for regular verbs if the *-ed* mappings have been sufficiently learnt, such that memory traces of individual past tense forms are overwhelmed (Daugherty & Seidenberg, 1992; Seidenberg, 1992).

For the G-SLI children, the input-processing deficit hypothesis would predict a general impairment for their chronological age across regular and irregular past tense forms. However, as lexical development should predict inflectional morphological performance (Marchman et al., 1999), G-SLI children's performance should not differ from that of the vocabulary-matched control children. Moreover, the pattern of performance across regular and irregular real and novel verbs should be similar to the pattern found for normally developing children (Marchman & Weismer, 1994). However, should any differences be found between regular and irregular forms for the normally developing children, these may be exaggerated for the G-SLI children. Our logic for predicting this is based on Leonard's (1988) proposal that perceiving and producing the regular *-ed* morpheme requires extra processing capacity (Leonard et al., 1992). Therefore, we may expect all the children, and particularly G-SLI children, to be worse at producing regular than irregular past tense forms. With respect to frequency, to our knowledge no existing single-system model predicts that the type of damage leading to G-SLI should result in frequency effects for regulars, where they are not found for normal children. Therefore, the

[1] The Grammar-specific deficit account and the dual system models (and similarly the input-processing deficit and single system accounts) are independent, but share underlying theoretical assumptions about how the brain develops and functions. The accounts of SLI (e.g., van der Lely, 1998; Leonard, 1998) provide (a) a characterisation of SLI and (b) explicit predictions as to which aspects of language will or will not be impaired in children with SLI. The single/dual mechanism models are more general theories about how the mental lexicon is organised and while they should be able to accommodate both normal and impaired language development, they do not provide the level of explanatory detail of language breakdown as the specific hypotheses of SLI.

single system/input-processing deficit framework predicts that a similar frequency effect will be found for G-SLI children and normally developing children (Marchman & Weismer, 1994).

The dual system account predicts that normally developing children should be better at producing regular past tense forms, which are rule-produced, than irregulars, which are retrieved from memory. Differences between correct production of regular and irregular past tense verb forms may be particularly evident with low frequency verbs, which are less likely than high frequency verbs to be stored forms. This is because, according to the dual mechanism model, failure to retrieve a past tense form is likely to result in the default regular rule being applied (Marcus et al., 1992; Pinker, 1991). This would result in correct regular forms but incorrect over-regularised irregular forms. The dual-system model makes a clear prediction with respect to frequency effects. For normal children, frequency effects should be found for irregulars, but not for regulars. If past tense forms are computed by the application of a rule to their stems (e.g., *rob* + *-ed* = *robbed*), then once access to the stem (*rob*) is held constant, the frequency of the past tense form (*robbed*) should not predict the likelihood of the form's correct production. However, if past tense forms are retrieved from memory, their frequency should predict the likelihood of their correct retrieval, even with access to the stem held constant.

The grammar-specific deficit hypothesis predicts that G-SLI children should have particular difficulties computing the past tense *-ed* rule. Therefore, they may memorise both regular and irregular forms in the lexicon. This leads to the prediction that G-SLI children, unlike normally developing children, should show a similar performance on regular and irregular past tense production, and frequency effects for both past tense types. Furthermore, the G-SLI and normally developing children should evince a qualitatively different pattern of performance across regular and irregular past tense formation for real and novel verbs. G-SLI children should be particularly impaired in relation to the control children with regular but not irregular past tense formation. In addition, among the G-SLI children, the default regular rule may not be applied in the event of failure to retrieve an irregular form. However, some productivity of regular and irregular forms through associative mechanisms may be expected. Note, independently, the Grammar-specific deficit hypothesis predicts a general grammatical impairment affecting syntactic tense marking (Rice & Wexler, 1996; van der Lely 1998). Thus, this would result in a general increase in unmarked forms being produced in past tense contexts.

In sum: according to the input processing deficit/single system account lexical processing and development will predict both regular and irregular inflectional marking for the G-SLI children and controls. Conversely the grammar-specific deficit/dual system account predicts that lexical development and processing will account for irregular but not regular inflectional marking. Moreover, for the G-SLI children, in contrast to the control children, lexical factors are also predicted to affect regular past tense formation, as their grammatical rule-system is impaired. Thus, the clearest distinction between the input-processing deficit/single system and the grammar-specific deficit/dual system accounts may be found in the production of regular inflection and comparisons between the G-SLI and vocabulary-matched control children. Therefore, we will pay particular attention to these aspects of the data.

## METHODS

### Subjects

Four subject groups participated in the experiment: a subgroup of 12 G-SLI children and three groups of younger children with normally developing language. The three younger groups provided control groups for different aspects of language and allowed us to access developmental changes in children from ages 5:5 to 8:9.

### Grammatical(G)-SLI children

The 12 G-SLI children had a mean age of 11:3 (range 9:3–12:10). There were 10 boys and 2 girls. The selection criteria and procedure for the G-SLI subgroup have already been well documented (van der Lely 1996a,b; van der Lely & Stollwerck, 1996, 1997). Therefore, only a summary will be provided here. We excluded two types of children. First, we excluded any children without the grammatical deficits that form our selection criteria. Second, we excluded any children with co-occurring problems of speech production (dyspraxia), pragmatic aspects of language (Adams & Bishop, 1989) attention, or non-verbal abilities. It is emphasised that approximately only 20% of children with a persisting SLI and IQ >85 meet our G-SLI criteria (van der Lely & Stollwerck, 1996)

The G-SLI subjects' non-verbal cognitive abilities were assessed by performance subtests of standardised IQ tests (e.g., The British Ability Scales, Elliott et al., 1978). All the children's scores fell within normal limits for their chronological age (i.e., IQ >85, +/−1.0 *SD*). They had a mean IQ of 99.09 (11.46 *SD*). They were assessed on a battery of tests, which tapped a range of comprehension and expressive language abilities. The tests provided six standardised measurements of different aspects of language abilities in relation to the children's chronological ages. The six tests were used in the initial selection process, and four of them for matching the G-SLI children with control subjects. The G-SLI children's scores fell at least −1.5 *SD* below the expected sore for their chronological age on at least one standardised language test. In addition, each child made at least 20% subject-verb agreement or tense errors in obligatory contexts in spontaneous speech (Goellner, 1995; van der Lely, 1996b), and also 20% 'reversal errors' when assigning thematic roles in reversible full passive sentences (van der Lely, 1996a). Ten of the twelve children performed at chance when assigning reference to pronouns and reflexives when syntactic knowledge of binding principles was required (van der Lely & Stollwerck, 1997). All the children showed a required persistent and disproportionate impairment of grammatical abilities, compared to single word comprehension and expression, sentence length, and information content in their expressive language. A summary of the overall G-SLI group's subject details can be found in Table 1. Appendix A provides individual subjects' test scores on the six selection tests.

## Language ability control groups

Three groups of 12 normally developing younger children provided language ability matched (LA) control groups. Four of the standardised language tests, used for selecting and assessing the G-SLI children, were used for matching purposes. The youngest group (LA1 controls, mean age 5:9) were matched to the G-SLI children on two tests which tapped morpho-grammatical abilities:[2] The Grammatical closure subtest from the Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy, & Kirk, 1968)—a test of morphological production which includes regular and irregular morphology;

TABLE 1
Subject details: Chronological ages and raw scores from the four standardised tests, which were used for matching the G-SLI children with the control children

| | *G-SLI children (n=12) Mean (SD)* | *LA1 controls (n=12) Mean (SD)* | *LA2 controls (n=12) Mean (SD)* | *LA3 controls (n=12) Mean (SD)* | *Summary of analysis between groups* |
|---|---|---|---|---|---|
| Chronological age | 11:2 (1:1) | 5:9 (0:4) | 6:11 (0:4) | 7:11 (0.5) | |
| Range | 9:3–12:10 | 5:5–6:4 | 6:5–7:4 | 7:5–8:9 | |
| TROG | 13.08 (1.78) | 14.41 (8.56) | 16.00 (1.75) | 17.33 (1.23) | LA1=G-SLI<(LA2=LA3) |
| GC-ITPA | 20.00 (3.56) | 21.25 (3.16) | 26.25 (4.08) | 28.91 (2.19) | LA1=G-SLI<(LA2=LA3) |
| BPVS | 78.83 (8.93) | 56.25 (8.91) | 71.67 (9.71) | 80.00 (9.62) | LA1<G-SLI=(LA2<LA3) |
| NV-BAS | 17.91 (1.17) | 15.67 (1.61) | 17.17 (1.27) | 17.50 (0.90) | LA1<G-SLI=(LA2=LA3) |

TROG, Test for Reception of Grammar (Bishop, 1983); GC-ITPA, Grammatical Closure sub-test, Illinois Test of Psycholinguistic Abilities (Kirk et al., 1968); BPVS, British Picture Vocabulary Scales (Dunn et al., 1982); NV-BAS, Naming Vocabulary, British Ability Scales (Elliott et al., 1978).

[2] Note, these morpho-grammatical tests tap non-grammatical abilities, such as lexical-conceptual knowledge, as well as grammatical knowledge.

and the Test of Reception of Grammar (Bishop, 1983)—a test of sentence comprehension. The LA1 controls scored significantly lower than the G-SLI children on expressive and receptive tests of single word vocabulary knowledge. The two older control groups (the LA2 controls, mean age 6:11, and LA3 controls, mean age 7:11) were matched to the G-SLI children on their expression and comprehension of single words: Naming Vocabulary from the British Ability Scales (Elliott, Murray, & Pearson, 1978) and The British Picture Vocabulary Scales (Dunn, Dunn, Whetton, & Pintilie, 1982). However, the LA2 and LA3 controls scored significantly higher than the G-SLI children on the two tests of morpho-grammatical abilities. Table 1 provides a summary of the details. Further details can be found in van der Lely (1996a) and van der Lely and Stollwerck (1997).

## Materials

Each subject was presented with 60 verbs in the past tense production task. The verbs were drawn from the stimuli developed by Ullman (1993, 1999) and Ullman and Gopnik (1994, 1999). The verbs belonged to four classes. (1) 16 irregular verbs (*give-gave*), which take only an irregular past tense form. Thus 'doublet' verbs, such as *dive-dove/dived*, which take an irregular and a regular form, were excluded. (2) 16 regular verbs (*rob-robbed*), which take only a regular past tense form. Their stems were phonologically dissimilar to the stems of all irregular verbs. (3) 16 'novel irregular' verbs whose stems were phonologically similar to the stems of real irregular verbs, and which can take irregular or regular past tense forms (e.g., *crive-crove/crived*, *cf. drive-drove*). (4) 12 'novel regular' verbs (e.g., *brop-bropped*), whose stems were phonologically dissimilar to the stems of all irregulars, and phonologically similar to the stems of regular verbs. One irregular verb (*split*) and two novel irregular verbs (*ret*, *scrit*) were excluded from all analyses because their actual or likely past tense forms are identical to their stems.

Half of the real irregulars and half of the real regulars had high past tense frequencies (e.g., *gave*, *robbed*) and half had low past tense frequencies (e.g., *dug*, *stalked*). Frequency counts were drawn from the 17.9 million word British English COBUILD corpus of the University of Birmingham, by the Centre for Lexical Information (CELEX) at the University of Nijmegen. Individual verb frequencies were augmented by 1 and ln-transformed (see Appendix B1). A $2 \times 2$ verb type (regular/irregular) by frequency (low/high) ANOVA was carried out on the items' past tense COBUILD frequencies. The past tense frequencies for the irregular verbs overall were significantly higher than the regular verbs, $F(1, 27) = 9.50$, $p < .005$. A significant effect of frequency was found, $F(1, 27) = 43.78$, $p < .001$, but there was no significant interaction.

In order to ensure that the verbs selected for the task were familiar to the children, and that the children's familiarity reflected the frequencies provided by the COBUILD frequency counts, we carried out a stem familiarity task. All 12 G-SLI and 36 control children were asked to give a familiarity rating of the verb stems for all real and novel verbs. This task was carried out approximately 2 months after the past tense production task. Details of the stem familiarity procedure can be found in Appendix C. The children's mean stem familiarity ratings can be found in Table 2.

A correlation was carried out between the stem frequencies provided by the COBUILD counts and the G-SLI and control children's stem familiarity ratings. A high and significant correlation was found, $r(57) = .852$, $p < .0001$. This indicates that the COBUILD stem and past tense frequencies are an appropriate estimate of the familiarity and frequency of the verbs for our children.

The task was based on Berko's (1958) "Wug test". The verbs were presented in the context of two spoken sentences, such as "Every day I rob a bank. Just like every day, yesterday I ________ a bank". The introductory and elicitation sentences for each verb shared the same two-word complement or adjunct; both of these words were morphologically simple and of relatively high frequency. The sentences were drawn from those developed by Ullman (1993) and Ullman and Gopnik (1994, 1999), but were slightly modified for our British children. A full list of verbs and their accompanying arguments can be found in Appendix B.

## Procedure

Subjects were tested individually in a quiet room, and were seated beside the experimenter, who spoke the following instructions: "This is a game

TABLE 2
Mean stem familiarity ratings (0 to 4) for each subject group (standard deviations calculated over items)

| | | | G-SLI | | LA1 | | LA2 | | LA3 | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Verb class* | *Example* | | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| Regulars | | | 1.95 | 0.59 | 2.16 | 0.77 | 2.10 | 0.90 | 2.60 | 0.86 |
| High frequency | *rob* | $n=8$ | 2.01 | 0.45 | 2.42 | 0.77 | 2.42 | 0.61 | 2.88 | 0.69 |
| Low frequency | *flap* | $n=8$ | 1.90 | 0.73 | 1.90 | 0.73 | 1.77 | 1.05 | 2.33 | 0.98 |
| Irregulars | | | 2.51 | 0.65 | 2.69 | 0.58 | 2.65 | 0.60 | 3.24 | 0.28 |
| High frequency | *give* | $n=7$ | 2.77 | 0.61 | 2.98 | 0.41 | 2.94 | 0.49 | 3.39 | 0.24 |
| Low frequency | *dig* | $n=8$ | 2.25 | 0.61 | 2.40 | 0.61 | 2.36 | 0.58 | 3.24 | 0.25 |
| Novel regulars | *brop* | $n=12$ | 1.16 | 0.33 | 0.97 | 0.34 | 0.61 | 0.17 | 0.63 | 0.23 |
| Novel irregulars | *crive* | $n=14$ | 1.37 | 0.45 | 1.21 | 0.30 | 0.43 | 0.22 | 0.65 | 0.27 |

with some words. First I'll say something like 'Every day I **go** to work', and you have to repeat it. Then I'll give you a sentence describing the same event, but in the past: 'Just like every day, yesterday I ______'. You have to say the missing word and finish off the sentence. Just say the first thing you think of that sounds right. In some sentences you might not know some of the words. For example, 'Every day I **prame** quite well'. Just do the best you can." Further encouragement was given to the child if necessary (e.g., "What would you say for the missing word?"). The child was given three practice items: the item in the instructions, and two additional items – one real verb (Every day I **weep** over her) and one novel verb (Every day I **scrig** over there). When the experimenter was reasonably confident that the child understood the task, the test sentences were administered. All subjects received the same pseudo-randomised version of each task: The item order was randomised and then gone over by hand to ensure that similar-sounding forms were not ordered too close to each other. All sessions were audio-recorded with a Sony DAT recorder using an Electret condenser microphone (ECM-959), which was positioned on a stand approximately 20 cm to the side of the child's mouth. This provided a high quality recording, from which a detailed transcription was made. The past tense production task was given to 11 of the 12 G-SLI children; one subject (AT) was unavailable for testing.

*Coding of responses.* Subjects' responses to the missing past tense form (Just like every day, yesterday I __________) were assigned to one of four categories. (1) Unmarked form (e.g., *rob*, *give*, *crive*, *brop*). (2) Regularised *-ed*-suffixed past tense form (e.g., *robbed*, *gived*, *crived*, *bropped*). (3) Irregularised past tense form (e.g., *rob-rab*, *give-gave*, *crive-crove*, *brop-brap*). For novel irregular verbs, the categorisation of a response as an irregularisation was based on the similarity of its stem-past phonological transformation to the transformations of existing irregulars. For real and novel regular verbs (*rob*, *brap*), a response was categorised as an irregularisation if it entailed a vowel change (*rob-rab*, *brop-brap*). Thus there was more than one possible irregularised past for some verbs – e.g., *frink-frank/frunk/frought*). (4) 'Other responses', which included phonological errors as well as the use of an incorrect suffix (*-ing*, *-s*, *-er*), an irregular past participle (*break-broken*), or a semantically related word (*grind-corn*, *bend-broke*, *rush-ran*).

## RESULTS AND DISCUSSION

The majority of the G-SLI and control children's responses fell into three categories: unmarked, regularised, and irregularised (see coding above and

TABLE 3
Mean responses rates (as % of items) for high and low frequency regular and irregular verbs (standard deviations calculated over subjects)

| | | | *G-SLI* | | *LA1* | | *LA2* | | *LA3* | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Verb class* | *Response* | *Example* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| Regular verbs | | | | | | | | | | |
| High frequency | Unmarked | *rob* | 60.2 | 15.6 | 29.2 | 27.9 | 22.9 | 20.5 | 19.8 | 24.1 |
| (rob) | Irregularised | *rab* | 0 | | 0 | | 1.0 | 3.6 | 0 | |
| *n*=8 | Regularised | *robbed* | 33.0 | 18.8 | 66.7 | 27.9 | 71.9 | 20.8 | 80.2 | 24.1 |
| Low frequency | Unmarked | *flap* | 70.5 | 17.0 | 39.6 | 27.1 | 22.9 | 29.1 | 16.7 | 30.3 |
| (flap) | Irregularised | *flup* | 0 | | 0 | | 0 | | 0 | |
| *n*=8 | Regularised | *flapped* | 11.4 | 14.2 | 48.9 | 25.0 | 72.9 | 28.1 | 76.0 | 28.6 |
| Irregular verbs | | | | | | | | | | |
| High frequency | Unmarked | *give* | 67.5 | 28.6 | 35.7 | 30.8 | 7.1 | 16.7 | 19.0 | 29.4 |
| (give) | Irregularised | *gave* | 19.9 | 22.9 | 34.5 | 32.5 | 70.3 | 25.4 | 59.5 | 34.9 |
| *n*=7 | Regularised | *gived* | 10.4 | 12.9 | 28.6 | 25.8 | 19.0 | 19.6 | 17.9 | 21.2 |
| Low frequency | Unmarked | *dig* | 73.9 | 23.4 | 51.0 | 31.3 | 21.9 | 27.2 | 25.0 | 30.6 |
| (dig) | Irregularised | *dug* | 13.6 | 22.0 | 18.6 | 26.0 | 42.7 | 20.3 | 41.7 | 31.7 |
| *n*=8 | Regularised | *digged* | 5.7 | 12.9 | 21.9 | 17.0 | 25.0 | 19.2 | 24.0 | 23.5 |

Tables 3 and 4). There were a small number of 'other' responses, which we shall discuss first. This will be followed by the main analyses, which consider the unmarked, regularised, and irregularised responses to the real and novel verbs. ANOVAs were carried out by subject ($F_1$) and by item ($F_2$).

## Other responses

Phonological errors were extremely rare for real verbs (e.g., *bend-spend*) and accounted for less than 3% of responses for any group. There were no significant differences in the four subject groups' phonological errors for real verbs, $F_1(3, 43) = 0.38$, $p = .76$; $F_2(3, 93) = 0.63$, $p = .60$. However, for novel verbs, phonological errors for all types of responses (unmarked, regularised, irregularised forms) were more numerous (e.g., *plam-plang*, *trab-strab*, *brop-brok*, *vurn-vured*, *strink-skwinked*). Overall, responses containing phonological errors accounted for 17.25% of the G-SLI children's productions, and 11.45%, 5.10%, and 5.85% of the LA1, LA2 and LA3 controls' responses respectively. Analysis revealed that, for the novel verbs, the G-SLI children produced significantly more phonological errors than the LA1 controls, $F_1(1, 43) = 4.45$, $p = .041$;

TABLE 4
Mean responses rates (as % of items) for the novel verbs for the four subject groups (standard deviation calculated over subjects)

| | | | *G-SLI* | | *LA1* | | *LA2* | | *LA3* | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Verb class* | *Response* | *Example* | *Mean* % | *SD* | *Mean* % | *SD* | *Mean* % | *SD* | *Mean* % | *SD* |
| Novel regular | Unmarked | *brop* | 56.8 | 17.4 | 33.3 | 25.1 | 20.1 | 28.1 | 15.3 | 28.2 |
| | Irregular | *brap* | 1.5 | 3.4 | 6.3 | 5.2 | 2.8 | 5.4 | 2.1 | 3.8 |
| | Regular | *brapped* | 6.8 | 9.0 | 31.3 | 17.1 | 66.7 | 30.8 | 73.6 | 27.7 |
| Novel irregular | Unmarked | *crive* | 59.1 | 12.8 | 39.9 | 22.9 | 28.0 | 32.7 | 29.8 | 25.8 |
| | Irregular | *crove* | 3.9 | 5.9 | 9.5 | 18.6 | 8.9 | 14.6 | 9.5 | 12.3 |
| | Regular | *crived* | 7.1 | 7.1 | 22.6 | 14.9 | 55.4 | 34.5 | 50.6 | 26.3 |

$F_2(1, 27) = 4.63$, $p = .040$, and than the LA2 and LA3 controls, $F_1(1, 43) = 23.62$, $p < .001$; $F_2(1, 27) = 22.77$, $p < .001$.[3]

There were three semantic errors for the real verbs: *grind-corn* and *bend-broke*, produced by two G-SLI children, and *rush-run*, produced by an LA1 control child. Both the G-SLI children and control children produced real words for the novel verbs. There was often some phonological similarity between the novel word and the word produced by the child (e.g., *satch-sat*, *plam-plant*, *spuff-splashed*). Finally, there were a small number of forms with incorrect suffixes; -*s*-suffixed forms were produced by G-SLI subjects AZ (*thinks*, *splits*) and RJ (*flaps*), and the progressive -*ing* suffix was used once by G-SLI subject BS (*rushing*). The normal control children did not produce any inappropriately suffixed forms.

## Regular and irregular real verbs

The groups' mean number of unmarked, regularised and irregularised responses to the real verbs are shown in Table 3.

## Unmarked verb responses

The G-SLI subjects produced a large number (mean range 60 to 75%) of unmarked responses for the real verbs (*rob*, *give*) (see Table 3). The

[3] To ensure that possible phonological deficits leading to such errors among the G-SLI children were not significantly influencing the results, we carried out all the main analyses for the novel verbs (reported below) with such phonological errors included – for example, *frink-finked* was counted as an acceptable regular past tense response. The phonological errors were not found to affect the results. These analyses yielded the same pattern of results as when the phonological errors were excluded.

unmarked forms for the groups were analysed in a 4 (Group: G-SLI, LA1, LA2, LA3) $\times$ 2 (Verb type: regular, irregular) $\times$ 2 (Frequency: high, low) ANOVA. A significant main effect of group was found, $F_1(3, 43) = 11.29$, $p < .001$; $F_2(3, 81) = 87.52$, $p < .0001$. Further planned comparisons confirmed that the G-SLI children produced significantly more unmarked forms than the morphology-matched LA1 controls, $F_1(1, 43) = 9.15$, $p = .004$, $F_2(1, 30) = 48.26$, $p < .001$) and the older LA2 and LA3 vocabulary-matched controls,[4] $F_1(1, 43) = 33.37$, $p < .0001$; $F_2(1, 30) = 173.45$, $p < .0001$. In addition the LA1 controls produced significantly more unmarked forms than the LA2 and LA3 controls, $F_1(1, 43) = 5.66$, $p = .022$; $F_2(1, 30) = 35.20$, $p < .0001$.

The main effect of verb type was significant by subject, $F_1(1, 43) = 15.21$, $p < .001$, but not by item, $F_2(1, 29) = 0.43$, $p = .516$. This reflected a trend for a greater number of unmarked forms for the irregular verbs than the regular verbs over all subject groups (see Table 3). No other main effects were significant nor were any interactions significant.

In summary, the G-SLI children produced significantly more unmarked forms than each group of control children but the pattern of unmarked forms for the regular and irregular verbs was similar to that of the LA controls. Verb frequency did not significantly affect any of the groups' production of unmarked forms. Whilst the results suggest that more unmarked responses may be produced for irregular than regular verbs, this finding was not robust. Finally, the results suggest that in normally developing children there is some developmental change between 5 years and 6–8 years, with the older children producing fewer unmarked forms when using this elicitation paradigm.

## Correct responses (*rob-robbed, give-gave*)

A 4 (Group) $\times$ 2 (Verb type: regular, irregular) $\times$ 2 (Frequency: High, Low) ANOVA was used to analyse the correct responses of the G-SLI and control groups. The triple interaction was significant, $F_1(3, 43) = 5.42$, $p = .003$; $F_2(3, 81) = 3.79$, $p = .013$, indicating that frequency and verb type are differentially affecting the groups' correct responses. To investigate this further, we carried out two additional ANOVAs on the correct responses – first on the irregular verbs, and second on the regular verbs.

For the irregular verbs a 4 (Group) $\times$ 2 (Frequency) ANOVA revealed significant main effects for group, $F_1(3, 43) = 7.01$, $p < .001$; $F_2(3, 39) = 28.49$, $p < .001$, and frequency, $F_1(1, 43) = 26.08$, $p < .001$; $F_2(1, 13) =$

[4] We analysed the LA2 and LA3 control groups together in the planned comparisons when comparing their performance with the G-SLI children because both of these groups were matched on vocabulary scores to the G-SLI children.

6.64. $p = .023$. However, the interaction was not significant by subject or by item, $F_1(3, 43) = 1.80$, $p = .162$; $F_2(3, 39) = 1.55$, $p = .216$. This indicates that frequency played a similar role in the production of irregular verbs for all four groups of children.

Planned comparisons revealed that the G-SLI children's percentage of correct irregular verb responses was not significantly different from that of the LA1 controls for either the high frequency irregular verbs, $F_1(1, 43) = 1.50$, $p = .227$; $F_2(1, 6) = 3.84$, $p = .098$, or low frequency irregular verbs, $F_1(1, 43) = 0.26$, $p = .616$; $F_2(1, 7) = 1.26$, $p = .29$. However, their percentage of correct responses was significantly lower than the LA2 and LA3 controls for both the high frequency irregular verbs, $F_1(1, 43) = 17.99$, $p < .001$; $F_2(1, 6) = 48.45$, $p < .001$, and the low frequency irregular verbs, $F_1(1, 43) = 10.48$, $p = .002$, $F_2(1, 7) = 11.33$, $p = .012$. The LA1 controls' correct responses were also significantly lower than the LA2 and LA3 controls responses on the high frequency, $F_1(1, 43) = 8.53$, $p = .006$; $F_2(1, 6) = 38.83$, $p < .001$, and low frequency irregular verbs, $F_1(1, 43) = 7.49$, $p = .009$; $F_2(1, 7) = 14.31$, $p = .007$. Thus, the percentage of correct irregular responses for the G-SLI children was not significantly different from that of the morphology-matched controls but was significantly lower than the older vocabulary-matched control children. Verb frequency had a similar and significant effect on both the G-SLI children and the control children's performance, with high frequency verbs produced significantly better than low frequency irregular verbs.

For the regular verbs, the 4 (Group) $\times$ 2 (Frequency) ANOVA revealed a significant main effect of group, $F_1(3, 43) = 14.35$, $p < .001$; $F_2(3, 42) = 54.51$, $p < .001$. Planned comparisons revealed that, for both high frequency and low frequency verbs, the G-SLI children performed significantly worse than the younger, LA1 control subjects, $F_1(1, 43) = 12.10$, $p < .001$; $F_2(1, 7) = 19.79$, $p = .003$ high frequency; $F_1(1, 43) = 13.26$, $p < .001$; $F_2(1, 7) = 13.51$, $p = .008$ low frequency, and the older, LA2 and LA3, control groups, $F_1(1, 43) = 25.97$, $p < .001$; $F_2(1, 7) = 73.15$, $p < .0001$ high frequency; $F_1(1, 43) = 49.10$, $p < .001$, low frequency. The LA1 control children's correct regular responses were also significantly lower than the LA2 and LA3 controls on the low frequency verbs, $F_1(1, 43) = 8.51$, $p = .006$; $F_2(1, 7) = 10.36$, $p = .015$, but was significant by items but not by subject on the high frequency verbs, $F_1(1, 43) = 1.30$, $p = .260$; $F_2(1, 7) = 7.99$, $p = .026$.

For the regular verbs, the Group $\times$ Frequency interaction was significant by subject, $F_1(3, 43) = 4.39$, $p = .009$, and a trend in the same direction was found by item, $F_2(3, 42) = 2.50$, $p = .072$, suggesting that frequency differentially affected the groups' performance. This was confirmed by *t*-tests, which were used to investigate each group's correct responses for the high and low frequency regular verbs. The G-SLI children produced significantly more correct responses to the high frequency regular verbs (*robbed*) than the low frequency verbs (*flapped*), $t_1(10) = 4.2$, $p = .002$; $t_2(10) = 2.2$, $p = .042$. Whilst the LA1 controls showed some frequency effect for the regular verbs, this was significant by subject, $t_1(11) = 2.8$, $p = .018$, but not by item, $t_2(14) = 1.4$, $p = .17$. The older control groups showed no frequency effects for the regular verbs (see Table 3). Finally to investigate whether the children's familiarity with the verb stem, rather than the frequency of the past tense form, caused the different effects of frequency on regular verbs for the G-SLI children and the control groups, we carried out a correlation between the children's production rate of correct past tense forms and the past tense frequency, partialling out the children's own stem ratings. A high and significant correlation was obtained for the G-SLI children, $r(13) = 0.66$, $p = .008$. In contrast, the correlations for all three control groups accounted for only between 1.9% to 14.4% of the variance and were non-significant (LA1: $r(13) = 0.30$, $p = .284$; LA2: $r(13) = 0.38$, $p = .162$; LA3: $r(13) = 0.14$, $p = .625$). Thus, frequency had a stronger effect on the production of correct regular past tense forms for the G-SLI children and accounted for 43.6% of the variance – that is, at least three times as much as that of the control children.

In order to assess fully the groups' relative performance on the regular and irregular verbs, for each group we compared the percentage of correct past tense responses for the two verb types for both high frequency (*robbed* vs. *gave*) and low frequency (*flapped* vs. *dug*) verbs. The G-SLI children's correct regular and irregular responses were not significantly different for either high frequency verbs, $t_1(10) = 1.74$, $p = .112$; $t_2(13) = 1.18$, $p = .26$, or low frequency verbs, $t_1(10) = 0.31$, $p = .762$; $t_2(14) = -0.42$, $p = .678$. In contrast, the LA1 controls produced significantly more correct regular than irregular responses for both the high frequency verbs, $t_1(11) = 2.68$, $p = .021$; $t_2(13) = 3.24$, $p = .006$, and low frequency verbs, $t_1(11) = 4.14$, $p = .002$; $t_2(14) = 3.06$, $p = .008$. The LA2 controls' correct regular and irregular responses did not differ for the high frequency verbs, $t_1(11)$ 0.20, $p = .844$; $t_2(13) = 0.18$, $p = .857$, but regular responses were significantly better than irregular responses for low frequency verbs, $t_1(11) = 3.39$, $p = .006$; $t_2(14) = 2.58$, $p = .022$. Analysis also revealed that the LA3 controls performed consistently better on regular than irregular verbs for both the high frequency verbs, $t_1(11) = 2.41$, $p = .035$; $t_2(13) = 2.43$, $p = .030$, and low frequency verbs, $t_1(11)$ 4.65, $p < .001$, $t_2(13) = 14.02$, $p < .001$.

## Over-regularisations (*give-gived*)

Normal children sometimes produce 'over-regularisations' – forms like *gived*, which are inappropriate regularisations of irregular verbs. On the dual system, view, over-regularisations occur when children fail to retrieve the correct irregular past tense form (*gave*), and therefore resort to rule-based *-ed*-suffixation (Marcus et al., 1992; Pinker, 1991, 1999). On this view, if G-SLI children have a dysfunctional rule, they should over-regularise less than their controls. Note that the G-SLI children had more chances than the control children to over-regularise, because they made more errors on the irregular verbs. Nevertheless, analysis revealed the G-SLI children produced significantly fewer over-regularisations than the younger LA1 control children, $t_1(21) = 2.5, p = .021$; $t_2(29) = 4.6, p < .001$, and than the vocabulary matched LA2 and LA3 control children,[5] $t_1(29.35) = 2.63, p = .013$; $t_2(14) = 5.90, p < .001$.

## Summary

The results revealed that frequency of regular and irregular verbs had qualitatively different effects on the G-SLI children's and the vocabulary-matched control groups' performance. Furthermore, differences were evident between the pattern of performance of the G-SLI children and children matched on expressive morphology and sentence comprehension. For the irregular verbs, frequency had a similar and significant effect for both the G-SLI children and all the LA control groups' production, with high frequency past tense forms being produced more successfully than low frequency past tense forms. For the regular verbs, frequency differentially affected the G-SLI and control groups' performance, as indicated by the significant interaction. The G-SLI children showed a strong and consistent effect of frequency. In contrast, frequency did not significantly affect the LA2 and LA3, vocabulary-matched control childrens' responses (see Table 3). For the morphology-matched, LA1 controls the difference between high and low frequency regular verbs was significant in the analyses by subject but not by item, indicating a weak or inconsistent frequency effect. However, when the children's own stem familiarity ratings were taken into consideration, the correlation between the children's regular correct responses and past tense frequency was high and significant for the G-SLI children but was substantially lower and not significant for the LA1 controls as well as the vocabulary control groups. Thus, the LA1 controls' knowledge of the stem forms rather than the frequency of the past tense forms can largely account for the weak frequency effect found for them.

For the irregular verbs, the G-SLI children's rate of correct past tense responses did not differ from that of the LA1 controls for either high or low frequency verbs. However, the G-SLI children's rate of correct

[5] The degrees of freedom are adjusted for unequal groups.

responses was significantly lower than those of the LA2 and LA3 controls. In contrast, for the regular verbs and G-SLI children produced significantly fewer correct responses than all three LA control groups for both the high and low frequency verbs. This difference was most marked for the low frequency verbs.

The LA control children showed an advantage for regular over irregular correct responses. This regular verb advantage was generally significant for high frequency verbs and was consistently significant for low frequency verbs. Thus, any explanation for these data must take into account that although the overall frequency of the irregular verbs was higher than that of the regular verbs, normally developing children perform worse on irregular than regular verbs. In contrast, the G-SLI children did not show this regularity advantage, and no significant difference was found between their correct regular and irregular responses for high or low frequency verbs. It can be seen from Table 3, the G-SLI children's responses for the low frequency verbs do not even show a trend for regular past tenses to be produced more successfully than irregular past tense forms. Finally, the G-SLI children produced significantly fewer over-regularisations than the LA controls, despite the increased opportunity to produce overgeneralisation because of their low number of correct irregular responses.

## Novel verbs

The mean numbers of unmarked (*crive*, *brop*), regularised (*crived*, *bropped*), and irregularised (*crove*, *brap*) responses to the novel irregular and regular verbs can be found in Table 4.

## Unmarked forms

As with the real verbs, the G-SLI children produced a large number of unmarked forms for the novel verbs (see Table 4). A 4 (Group $\times$ 2 (Novel verb type: novel irregular, novel regular) ANOVA carried out on the unmarked responses revealed a significant main effect of group, $F_1(3,43) = 5.44$, $p = .003$; $F_2(3,72) = 38.08$, $p < .001$. A significant main effect for novel verb type was found by subject but not by item, $F_1(1,43) = 10.55$, $p = .002$; $F_2(1,24) = 3.22$, $p = .085$, indicating, as with the real verbs, a tendency for more unmarked forms to be produced for irregular than regular sounding verbs. The interaction was not significant, $F_1(3,43) = 1.10$, $p = .36$; $F_2(3,72) = 0.70$, $p = .55$. Follow-up planned comparisons revealed that the G-SLI children produced significantly more unmarked forms than the LA1 controls, $F_1(1,43) = 4.68$, $p = .036$; $F_2(1,25) = 23.41$, $p < .0001$, and the LA2 and LA3 controls, $F_1(1,43) = 16.21$, $p < .001$; $F_2(1,25) = 96.73$, $p < .0001$. The production rate of unmarked forms for the LA1 control was significantly lower than that of the LA2 and LA3 control groups by item but not by subject, $F_1(1,43) = 2.54$, $p = .118$; $F_2(1,25) = 16.93$, $p < .0001$.

## Novel irregular verbs

The regularised (*crived*) and irregularised (*crove*) responses to the novel irregular verbs were analysed in a 4 (Group) $\times$ 2 (Response type; regularised, irregularised) ANOVA. This revealed a significant interaction, $F_1(3,43) = 5.67$, $p < .002$; $F_2(3,39) = 27.01$, $p < .001$. To investigate this interaction further, we compared past tense production rates of regularised and irregularised responses (*crived* vs. *crove*) within each group. The LA control groups produced more regularised than irregularised past tense forms for the irregular novel verbs, even though these were phonologically similar to real irregular verbs (see Table 4). This difference was significant for the older LA control groups (LA2: $t_1(11) = 3.9$, $p < .002$; $t_2(13) = 8.7$, $p < .001$; LA3: $t_1(11) = 4.3$, $p < .001$; $t_2(13) = 5.9$, $p < .001$. For the LA1 controls the difference was not significant by subject but approached significance by item, $t_1(11) = 1.7$, $p = .117$; $t_2(13) = 2.1$, $p = .057$. In contrast, the G-SLI children's production rates were not significantly different for the two types of past tense forms, $t_1(10) = 1.50$, $p = .176$; $t_2(13) = 0.8$, $p = .431$.

In the production of regularisations (*crived*), the G-SLI children produced significantly fewer forms than each of the three control groups (LA1: $t_1(21) = 3.1$, $p = .005$; $t_2(13) = 3.9$, $p = .002$; LA2: $t_1(21) = 5.4$, $p < .001$; $t_2(13) = 9.7$, $p < .001$; LA3: $t_1(21) = 5.34$, $p < .001$; $t_2(13) = 7.8$, $p < .001$). In contrast, in the production of irregularisations (*crove*), the G-SLI children's performance was significantly different from that of the controls only for the *t*-tests with items as the error term, and not for the *t*-tests with subjects as the error term (LA1: $t_1(21) = 1.0$, $p = .349$; $t_2(13) = 4.0$, $p < .001$; LA2: $t_1(21) = 1.1$, $p = .300$; $t_2(13) = 3.6$, $p = .003$; LA3: $t_1(21) = 1.4$, $p = .183$; $t_2(13) = 2.4$, $p = .034$).

## Novel regular verbs

Analysis of the novel regular verb responses in a 4 (Group) $\times$ 2 (Response type: regularised [*bropped*], irregularised [*brap*]) ANOVA also revealed a significant interaction, $F_1(3,43) = 20.69$, $p < .001$; $F_2(3,33) = 46.37$, $p < .001$). Follow-up *t*-tests revealed that each of the three control groups produced significantly more regularised (*bropped*) than irregularised (*brap*) past tense forms (LA1: $t_1(11) = 4.7$, $p < .001$; $t_2(11) = 2.7$, $p = .019$; LA2: $t_1(11) = 7.3$, $p < .001$; $t_2(11) = 21.6$, $p < .001$; LA3: $t_1(11) = 8.8$, $p < .001$; $t_2(11) = 12.1$, $p < .001$). In contrast, for the G-SLI children the advantage of regularisations over irregularisations was inconsistent – no significant difference was found by subject but was by item, $t_1(11) = 1.6$,

$p = .132$; $t_2(11) = 2.2$, $p = .046$. Note, that the lack of significant by-subject difference may be partially attributed to the G-SLI children's overall low response rate (see Table 4).

In between-group analyses, the G-SLI children were significantly worse than each of the three control groups at producing regularised forms (*brop-bropped*) (LA1: $t_1(21) = 4.2$, $p < .001$; $t_2(11) = 4.3$, $p < .001$; LA2: $t_1(21) = 6.2$, $p < .001$; $t_2(11) = 28.0$, $p < .001$; LA3: $t_1(21) = 5.34$, $p < .001$; $t_2(13) = 7.6$, $p < .001$), but were not generally worse at producing irregularised forms (*brop-brap*), LA1: $t_1(21) = 2.6$, $p = .018$. For all other analyses $t < 0.9$, $p = .398$ and, therefore, these were not significant.

## Summary

For novel irregular verbs (*crive*), the control children generally produced significantly more regularisations (*crived*) than irregularisations (*crove*). In contrast, the G-SLI children produced regularisations and irregularisations at similar rates. For novel regular verbs all the groups produced fewer irregularisations than regularisations. Therefore, it appears that the G-SLI children and the control children are sensitive to the phonological characteristics of the verb when producing novel irregularisations. The G-SLI children's production rate of regularisations was significantly lower than that of the control children's production rate of regularisations. In contrast the G-SLI children's production rate of irregularisations did not consistently differ from that of the LA controls.

# GENERAL DISCUSSION

The results from this investigation into the production of regular and irregular past tense formation in children developing normally and in children with G-SLI reveal quantitative and qualitative differences in the groups' performance. The responses of the G-SLI children and the LA2 and LA3 controls were remarkably distinct in their pattern of regular and irregular production, the effect of frequency on regular past tense marking, and their level of production of past tense marking on verbs. While some similarities are found between the G-SLI children and the LA1 controls – not surprisingly as they were matched on morphological abilities – differences in the pattern of performance and the effects of frequency are also found between these groups.

We will now consider how well the input-processing deficit hypothesis and the grammar-specific deficit hypothesis can account for the findings from this study and, more generally, how well the single mechanism and dual mechanism frameworks can account for impaired and normal performance.

## The input-processing deficit/single mechanism account

Lexical effects were clearly influencing all the children's production of irregular forms, as predicted by single mechanism accounts, with significant frequency effects being found for irregular verbs and the phonological characteristics of the novel verbs determining irregular past tense use. Thus, the control groups, generally produced irregularisations for irregular rhyming novel verbs. In addition, performance on irregular verbs increased with age and vocabulary development. Conversely, for normally developing children, few lexical effects were evident for regular past tense marking. While no frequency effects were found for the older vocabulary-matched LA2 and LA3 control children for regular verbs, a weak frequency effect was found for the younger LA1 controls. One explanation for this weak frequency effect among the LA1 controls is that their stem-past mappings have not yet been sufficiently learnt to eliminate frequency effects. This suggestion is consistent with the predictions put forward by Daugherty and Seidenberg (1992). However, when access to the stem was controlled for by partialling out stem frequency, past tense frequency did not significantly predict performance. Furthermore, if the LA1 controls had not yet learnt general regular stem-past mappings, it is unclear why they showed the same advantage for regulars over irregulars for both high and low frequency verbs and novel verbs as the older children. One possibility for the general lack of regular frequency effects among the control children is that such effects were harder to find for regular than irregular verbs because the difference between high and low frequency was smaller for regular (1.7) than irregular (3.0) verbs. However, this seems unlikely, as the G-SLI children showed a clear and significant frequency effect for regular verbs, suggesting that the difference between high and low frequency verbs was sufficient to reveal an effect, if it was there to be found.

The advantage for regular over irregular past tense marking found for the LA controls is difficult to accommodate within a single mechanism view of inflectional morphology. The irregular verbs in this study were of an overall higher frequency than the regular forms, yet regular verbs were produced significantly better than irregular verbs and regular past tense marking was strongly favoured for even irregular rhyming novel verbs, as well as regular sounding novel verbs. One possibility is that the high type frequency for regular verbs could account for the regularity advantage found in this experiment. However, while frequency and regularity are conflated in the English inflectional system this is not so in other languages. In German, for example, a suffix added to a stem can form both irregular and regular inflectional forms for past participle and plural forms of words.

However, the less frequent plural *-s*, and the participle *-t*, which has a similar frequency as the irregular *-n* are preferentially produced as the default (regular) forms (Clahsen et al., 1992; Clahsen, 1999; Marcus et al., 1995). Thus, type frequency does not appear to be the crucial factor determining the selection and use of default forms, and therefore for reasons of parsimony we will not pursue this line of reasoning.

Finally, analysis of unmarked forms did not reveal that significantly more unmarked forms were produced for low frequency verbs than high frequency verbs, in contrast to Marchman et al.'s (1999) previous findings. However, a tendency to produce more unmarked forms for the real and novel irregular verbs than for the real and novel regular verbs was found. This suggests that the phonological characteristics of the verb stem-past mappings were affecting the children's productions to a limited extent, as unmarked forms may be acceptable as past tense forms for some irregular verbs (e.g., *hit*). However, it should be noted that we excluded no-change verbs such as *split*, *ret* and *scrit* from the analyses. Furthermore, although the irregular and regular novel verbs were carefully selected to control for irregular and regular neighbourhood size (Ullman, 1993) only a weak effect of the phonological characteristics was found. Thus, this is inconsistent with the strong claim that regular as well as irregular past tense patterns are primarily determined by a phonologically based constraint satisfaction system (Marchman, 1997).

We will now turn to the findings from the G-SLI children and evaluate the ability of the input-processing deficit within a single mechanism framework to account for impaired and normal performance. The G-SLI children's use of unmarked forms in past tense contexts, their particularly impaired production of regular past tense marking in comparison to the control children, and their limited ability to generalise the regular past tense marker to novel forms can be taken to support the single mechanism framework. First, the large number of unmarked forms found in this study for G-SLI children is consistent with the predictions of impaired input-processing in a single system model (Hoeffner & McClelland, 1993; Leonard, 1998; Marchman & Weismer, 1994; Marchman, 1997). Furthermore, the G-SLI children showed a tendency to produce more unmarked forms for the irregular real and novel verbs than for the regular real and novel verbs. This suggests that the G-SLI children, like their LA-matched peers, are sensitive to the phonological characteristics of the stem-past mappings when producing unmarked forms. However, the more detailed analysis reveals some inconsistencies with the input-processing deficit account. The input-processing deficit account predicts that more unmarked forms should be found for low frequency verbs (Marchman & Weismer, 1994). In the event, frequency did not have a significant effect on unmarked forms for either the G-SLI, or the LA control children. In addition, one might expect the G-SLI children to produce more uninflected forms for the regular known and novel verbs if they have problems perceiving or processing the *-ed* morpheme, but they did not. The production pattern of unmarked forms across known and novel regular and irregular verbs was similar for the G-SLI children and LA controls. Moreover, the very large number of unmarked forms found in this study of 9–13-year-old G-SLI children in contrast to the production of plural inflections (van der Lely & Christian, 2000) is difficult to account for by an input-processing deficit alone and suggests that other factors are significantly contributing to these errors.

The G-SLI children's significant deficit in regular past tense formation, and poor generalisation of the regular inflection to novel verbs is also consistent with the input-processing deficit account, whereby SLI children are thought to have particular problems perceiving and producing the regular past tense morphemes (Joanisse & Seidenberg, 1998*b*; Leonard, 1998). Conversely, the G-SLI and control children's qualitatively different patterns of performance reflected by the relative productivity of regular and irregular forms, and the effects of frequency on correct regular and irregular past tense forms of verbs, particularly in relation to the vocabulary control children, is inconsistent with the input-processing/single mechanism framework. Single mechanism accounts predict that the same factors affect regular and irregular forms for all children (Marchman & Weismer, 1994; Marchman et al., 1999). Therefore, it is unclear why an input-processing deficit should cause a frequency effect for regular past-tense verbs as well as irregular verbs for the G-SLI children, whereas this effect was only found for irregular verbs for the control children. Moreover, our findings do not support Marchman et al.'s (1999) prediction that children with SLI would perform in qualitatively and quantitatively similar ways to children matched on language abilities. The G-SLI children were matched on two tests tapping morphological expression and sentence understanding to a younger group of control children and on tests of vocabulary comprehension and expression to two older groups of control children. However, the G-SLI children's overall pattern of use of irregular and regular morphology does not appear to match that of children at any stage of normal language development. Therefore although, according to some accounts of the past tense morphology, vocabulary development predicts the use and pattern of past tense marking found in acquisition (Plunkett & Marchman, 1993), the results from this study indicate that vocabulary development is insufficient to predict the pattern of past tense formation found in normally developing and SLI children.

In conclusion, an input-processing deficit may account for some of the findings for the G-SLI children, such as their poor performance on regular verbs, their use of unmarked forms in past tense contexts, and their sensitivity to phonological characteristics when producing irregularisations. However, the contrasting patterns of performance in the use of regular and irregular forms and the contrasting effects of frequency for the G-SLI children and the control groups of children matched on different aspects of language are inconsistent with the input-processing deficit account and the theoretical framework underlying this account.

## The grammar-specific deficit/dual mechanism account

The dual-mechanism explanation for the lexical effects of frequency and phonological properties affecting the LA control groups' use of irregular past tense forms for real and novel verbs, and the development with age for correct irregular production is similar to the single-mechanism account. That is, irregular verbs are retrieved from a pattern associator memory, which can yield some productivity. Although this productivity is relatively limited, it can account for the production of irregular past tense novel forms (Prasada & Pinker, 1993; Xu & Pinker, 1995). Furthermore, the data indicate that this memory system for irregular verbs improves with age as predicted by both single and dual system accounts. However, in contrast to the single mechanism account, the dual mechanism account can provide a parsimonious explanation for the general regularity advantage and the lack of frequency effects for regular verbs found for the LA control children. The data indicate that for normally developing children regular past tense forms are rule products and so are not significantly affected by the properties of lexical memory (frequency and their sound patterns). Therefore, the regular rule applied as the default whenever memory access fails, can account for the greater number of regularisations than irregularisations produced for novel verbs – which was found even for those novel verbs that do not sound like existing regular verbs (i.e., for a subset of the irregular novel verbs). However, if all regular forms are rule produced it is unclear why a weak frequency effect was found for the youngest LA1 controls, although they still showed a clear regularity advantage. One possible explanation is that memorised forms are causing this weak effect by facilitating access to and keeping in memory the stem form during the process of adding the affix. This explanation is supported by the finding that, when stem frequency was partialled out of the analysis, the correlation between past-tense frequency and correct production of regular forms was no longer significant for the LA1 controls. Past-tense frequency accounted on average for 8.4% of the variance of the LA control groups' productions (range 1.9%–14.4%), whereas on average it accounted for five times as much for the G-SLI children (43.6%). The apparent support of a long-term memory system to facilitate recalling stem forms in the LA1 control group but not the older control groups is consistent with the view that phonological short-term memory develops with age and vocabulary ability (Gathercole, Service, Hitch, Adams & Martin, 1999). Thus, the older children's more advanced vocabulary abilities and we presume short-term memory abilities, may have made relying on long-term memory to recall low frequency stem forms redundant. In sum, the different pattern of regular and irregular past-tense marking for regular and irregular verbs and the differential effects of frequency found for the LA control children are consistent with the predictions of the dual mechanism account of past tense formation.

The lexical effects of frequency and phonological characteristics for irregular forms found for the G-SLI children, like the LA controls, is consistent with the predictions of the grammar-specific account of SLI in which the primary deficit is thought to be located in the grammatical system. However, it may have been expected that the G-SLI children would have performed as well as the vocabulary control children on irregular past tense formation if their associative-memory system is not impaired. There are several factors which could individually or collectively account for why this was not so. First, according to grammar-specific accounts of SLI, morphological deficits may be only one manifestation of their grammatical impairment. Therefore, problems with the syntactic representation of tense may cause infinitival or unmarked stem forms to be produced in a past tense context (Rice, Wexler, & Cleave, 1995; van der Lely, 1998). Thus, this can account for the general impairment in performance of the G-SLI children due to the large number of unmarked forms produced in past-tense contexts. Secondly, G-SLI children's verb development, particularly learning to structure lexical links between morphological variants of the same form—e.g., linking verb stem and past-tense forms—may be significantly impaired by their deficit in using syntactic cues (syntactic bootstrapping) to learn words (O'Hara & Johnston, 1997; van der Lely, 1994). This explanation is supported by the finding that the same G-SLI child, like many SLI children (Leonard, 1998), can produce and accept both the correct form (e.g., *fell*) and incorrect forms (*fall, falled*) in similar syntactic contexts (van der Lely, 1997a, b, 1998; van der Lely & Ullman, 1996). These errors suggest that G-SLI children store the past tense forms of irregular verbs but that the blocking mechanism, which normally prevents a regular inflection being affixed to a stem (Marcus et al., 1992) is not functioning appropriately. Further investigation of this possibility is warranted.

The differences in the production of regular forms found between the G-SLI children and the control children provide further support for the grammar-specific deficit account, whereby G-SLI children are impaired in the grammatical computations underlying the *-ed* suffixation rule, so that they tend to memorise regular as well as irregular past tense forms. Therefore, according to this view, lexical-associative properties should affect the G-SLI children's performance for regular and irregular formation. Consistent with this prediction was the significant effect of frequency on regular verbs, even when stem frequency was controlled for, found for the G-SLI children but not the control children. In addition, the absence of a regularity advantage for the G-SLI children, in contrast to the LA controls provides further support for the grammar-specific deficit account. However, although the difference between the G-SLI children's production of regular and irregular forms was not significant, there was a trend for more regular than irregular forms to be produced for high frequency (but not low frequency) known verbs and the regular and irregular novel verbs (see Tables 3 and 4). Furthermore, the question arises as to why the G-SLI children make any over-regularisations, if they are impaired in regular rule formation.

There are several factors that may contribute to an explanation of these findings. First, if G-SLI children are primarily memorising regular forms as indicated by the results, then the high token frequency of regular verbs could be contributing to the G-SLI children's performance, whereas it does not appear to be doing so to any great extent in normally developing children. The effect of frequency on regularly inflected verbs and nouns for children with SLI but not for normally developing children is a consistent finding in the literature (Leonard, 1998; Marchman et al., 1999; Oetting & Horohov, 1997; Oetting & Rice, 1993; Ullman & Gopnik, 1994, 1999). Moreover, if frequency is the cause of G-SLI children's pattern of use of regular forms and this is independent of the ‘‘normal’’ factors determining the default form, then we would expect that in languages where the default form is not the most frequent form, G-SLI children should incorrectly select the most frequent form, regardless of its morpho-syntactic properties. The atypical selection of the most frequent plural *-en* as the default form by German children with SLI but not by normally developing children (Bartke, 1998; Clahsen et al., 1992; Marcus et al., 1995), lends further support for the view that SLI children and normally developing children are using a different basis on which to form regular inflections. Thus, there is cross-linguistic evidence to suggest that, in contrast to normally developing children, frequency is largely determining the default inflectional form for children with SLI.

Second, productivity within the associative memory system (Xu & Pinker, 1995), although relatively limited, can account for the over-regularisations of irregular verbs. The poor ability of our children with G-SLI to overgeneralise to novel words is consistent with the resistance of associative models to overgeneralise to novel inputs, particularly when they do not sound like known forms (Prasada & Pinker, 1993).

A third possible explanation for the G-SLI children's performance is that the grammatical mechanism thought to underlie the regular rule formation is "impaired" rather than missing (cf. Ullman & Gopnik, 1994, 1999). In other words, the rule per se is not missing, but the implementation of the rule is impaired. This view concurs with van der Lely's "Representational Deficit in Dependent Relations" (RDDR) hypothesis which contends that G-SLI children's syntactic deficits are caused by a deficit in the computational grammatical system such that grammatical-structural rules, by definition obligatory in normal grammar, are optional in G-SLI grammar (see van der Lely, 1998). Thus, grammatical rules may function to a limited extent and facilitate to some minor degree the formation of regular past tense forms. Furthermore, it is evident that G-SLI children have considerable knowledge of the inflectional rule system generally, as they rarely produce inflected forms in appropriate contexts (Bishop, 1994; Leonard, 1998; Rice & Wexler, 1996). However, impaired rule functioning may cause G-SLI children to store regular forms like irregular forms and primarily rely on their associative memory system for producing known regular forms and even overgeneralising regular forms. This position may be contrasted with the missing rule hypothesis put forward by Gopnik and Crago (1991) to account for the regular and irregular production of real and novel verbs from the KE family of whom half suffer from SLI.

Finally, the effect of therapy, in which the regular rule is explicitly taught, may also contribute to the G-SLI children's tendency to produce more regularisations than irregularisations, especially in older children with SLI who have undergone years of intensive remedial training. A meta-linguistic rule, learned years after it is generally acquired in normally developing children may not reflect the same underlying mechanisms and representations as when it is learned "on-time". Further investigations which encompass derivational as well as inflectional morphology are required to distinguish whether G-SLI children's rule system is impaired or missing. In either case, it appears from these data that in functional terms their regular morphological system is qualitatively different from that of normally developing children.

In conclusion the predictions of the grammar-specific account are largely confirmed in this experiment. The grammar-specific deficit along with the underlying framework to this account provides a parsimonious and comprehensive explanation of the contrasting patterns of performance found for G-SLI children and younger normally developing children.

## Conclusion

The hypothesised grammar-specific deficit/dual mechanism model was found to explain the regular and irregular past tense production of normally developing and G-SLI children. In contrast to normally developing children, G-SLI children showed a consistent effect of past tense frequency for regular verbs, independent of stem frequency and produced regular and irregular forms at a similar rate. All of the groups showed effects of frequency and phonological characteristics in irregular past tense production. Moreover, the G-SLI children's performance on regular verbs was qualitatively different from that of the LA control groups, in particular the vocabulary control groups. The LA controls showed a consistent regularity advantage for real and novel verbs. The input-processing deficit account cannot account for this qualitative difference between the G-SLI children and the vocabulary control children in overall performance on regular and irregular past tense forms. The findings conflict with the predictions of the input-processing account, and the theoretical framework underlying this account which posits that the development of inflectional morphology is determined by vocabulary development and processing (Elman et al., 1996; Leonard, 1998; Marchman et al., 1999; Tallal et al., 1996). Conversely, the grammar-specific deficit/dual system account of past tense morphology provides a parsimonious explanation for both findings from G-SLI children and normally developing children. In addition, the findings from this study for G-SLI children, such as the frequency effects, the large number of unmarked forms, and similar performance on regular and irregular past tense verbs, generally concur with the findings from many studies of younger and older children with SLI (Bishop, 1994; Oetting & Horohov, 1997; Oetting & Rice, 1993; Leonard, 1998; Marchman & Weismer, 1994; Ullman & Gopnik, 1994, 1999; Vargha-Khadem et al., 1995). The fact that such similarities are found between these different studies, although some of the other children with SLI have co-occurring speech or more general auditory or cognitive deficits, questions whether such co-occurring deficits explain their language impairments, such as those found in inflectional morphology. Thus, contrary to some views of SLI (Elman et al., 1996, Joanisse & Seidenberg, 1998b) it appears that more general deficits do not have a significant effect on the nature of grammatical deficits as the same grammatical deficits are found in children without co-occurring impairments.

This study along with previous findings for G-SLI (van der Lely & Christian, 2000) indicates that their deficit affects mechanisms and/or representations underlying regularly inflected words as well as syntactic structures (van der Lely, 1994, 1996a, b, 1998; van der Lely & Stollwerck, 1997). The data provide further support for the view that G-SLI children are defective in forming and/or computing a grammatical rule for regular inflection that requires an abstract representation of the verb stem and past tense affix (cf. Gopnik & Crago, 1991; Ullman & Gopnik, 1994, 1999).

However, in this paper we advocate an impaired, rather than a missing, rule system. Moreover, while this impairment may account for the findings, there is likely to be more than one source for this deficit. One may involve the morphological ability to identify a verb stem and apply the *-ed* suffixation rule. (Gopnik & Crago, 1991; Ullman & Gopnik, 1994, 1999). In addition, grammatical knowledge may facilitate lexical links between morphological variants of the same word and facilitate vocabulary development through the use of syntactic cues (van der Lely, 1994; van der Lely & Christian, 2000). Such lexical morpho-grammatical links may be particularly important in facilitating the decrease in over-regularisations of irregular words in development. Another source for the impairment may be in the phonological representations of words. Phonological ‘‘knowledge’’ and the ability to form a detailed phonological representation of a word’s structure may provide the distinction between a stem and its affix. For example, the novel word [pri:kt] (like *streaked*) could only be an inflected form of the word [pri:k] because there are no comparable mono-morphemic forms which end in [–i:kt] (Harris, 1994). Thirdly, the ability to form appropriate syntactic relationships between constituents in the sentence is needed to determine when a tense marker must be obligatorily used. Thus, a grammatical deficit may impinge on all of these levels of grammar and may contribute to the G-SLI children’s pattern of performance in different ways.

Finally, the findings from this study of children developing normally and children with grammatical deficits provide a valuable source of data that need to be accounted for in further developments of models of the past tense inflectional system.

## REFERENCES


Adams, C., & Bishop, D. (1989). Conversational characteristics of children with semantic-pragmatic disorder. *British Journal of Disorders of Communication*, *24*, 211–240.

Aram, D., Morris, R., & Hall, N. (1993). Clinical and research congruence in identifying children with specific language impairment. *Journal of Speech and Hearing Research*, *36*, 580–591.

Bartke, S. (1998). *Experimentalle studien sur flexion und wortbildung: Pluralmorphologie und lexikalische komposition im unauffaellingen spracherwerb und im Dysgrammatismus.* Tübingenwen: Niemeyer Verlag.

Bates, E., & MacWhinney, B. (1987). Competition, variation, and language learning. In B. MacWhinney (Ed.), *Mechanisms of language acquisition*, pp. 157–193. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Bates, E., & MacWhinney, B. (1989). Functionalism and the competition model. In B. MacWhinney & E. Bates (Eds), *The cross linguistic study of sentence processing*, pp. 3–76. New York: Cambridge University Press.

Berko, J. (1958). The child’s learning of English morphology. *Word*, *14*, 150–177.

Bishop, D.V.M. (1983). *Test for Reception of Grammar*. [Available from author. University of Manchester.]

Bishop, D.V.M. (1994). Grammatical errors in specific language impairment: Competence or performance limitations? *Applied Psycholinguistics*, *15*, 507–550.

Bishop, D.V.M. (1997). *Uncommon understanding: Comprehension in specific language impairment.* Hove, UK: Psychology Press Ltd.

Bishop, D.V.M., Bishop, S., Bright, P., James, J. & van der Lely, H.K.J. (2000). Grammatical SLI: A distinct subtype of developmental language impairment? *Applied Psycholinguistics*, *21*, 159–181.

Chomsky, N. (1986). *Knowledge of language: Its nature, origin and use.* New York: Praeger.

Clahsen, H. (1989). The grammatical characterization of developmental dysphasia. *Linguistics*, *27*, 897–920.

Clahsen, H. (1999). Lexical entries and rules of language: A multidisciplinary study of German inflection. *Brain & Behavior Science*, *22*, 991–1060.

Clahsen, H., Rothweiler, M., Woest, A., & Marcus, G. (1992). Regular and irregular inflection in the acquisition of German noun plurals. *Cognition*, *45*, 225–255.

Conti-Ramsden, G., & Jones, M. (1997). Verb use in specific language impairment. *Journal of Speech, Language and Hearing Research*, *40*, 1298–1313.

Daugherty, K., & Seidenberg, M. (1992). Rules or connections? The past tense revisited. *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society*, pp. 259–264. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Dunn, L., Dunn, L., Whetton, C., & Pintilie, D. (1982). *The British Picture Vocabulary Scales*. Windsor: NFER-Nelson.

Elliott, C., Murray, D., & Pearson, L. (1978). *British Ability Scales.* Windsor: NFER-Nelson.

Elman, J., Bates, E., Johnson, M., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness: A connectionist perspective on development.* Cambridge, MA: MIT Press.

Fodor, J. (1983). *The modularity of mind.* Cambridge, MA: MIT Press.

Gathercole, S., & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, *29*, 336–360.

Gathercole, S., Service, E., Hitch, G., Adams, A-M., & Martin, A. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology*, *13*, 65–77.

Goellner, S. (1995). *Morphological deficits of children with specific language impairment: Evaluation of tense marking and agreement.* MA thesis, University of Essex.

Gopnik, M. (1990). Feature blindness: A case study. *Language Acquisition*, *1*, 139–164.

Gopnik, M. (1994). The family. *The McGill working papers in linguistics: Linguistic aspects of familial language impairment.* Vol. 10, pp. 1–5. Montreal: McGill University.

Gopnik, M., & Crago, M.B. (1991). Familial aggregation of a developmental language disorder. *Cognition*, *39*, 1–50.

Gordon, P. (1985). Level-ordering in lexical development. *Cognition*, *21*, 73–93.

Hare, M., Elman, J.L., & Daugherty, K.G. (1995). Default generalisation in connectionist networks. *Language and Cognitive Processes*, *10*, 601–630.

Harris, J. (1994). *English sound structure.* Oxford, UK: Blackwell.

Hoeffner, J.H., & McClelland, J.L. (1993). Can a perceptual processing deficit explain the impairment of inflectional morphology in development dysphasia? A computational investigation. In E. Clark (Ed.), *Proceedings of the 25th Annual child language research forum*, pp. 38–49. Stanford University, CA: Center for the Study of Language and Information.

Joanisse, M.F., & Seidenberg, M.S. (1998*a*). Dissociations between rule-governed forms and exceptions: A connectionist account. Poster presented at the *1998 Annual Meeting of the Cognitive Neuroscience Society*, San Francisco.

Joanisse, M., & Seidenberg, M. (1998*b*). Specific language impairment: a deficit in grammar or processing? *Trends in Cognitive Sciences*, *2*, 240–247.

Kirk, S., McCarthy, J., & Kirk, W. (1968). *Illinois Test of Psycholinguistic Abilities*. Urbana, IL: University Press.

Leonard, L.B. (1989). Language learnability and specific language impairment in children. *Applied Psycholinguistics*, *10*, 179–202.

Leonard, L.B. (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press.

Leonard, L.B., McGregor, K.K., & Allen, G.D. (1992). Grammatical morphology and speech perception in children with specific language impairment. *Journal of Speech and Hearing Research*, *35*, 1076–1085.

MacDonald, M.C., Pearlmutter, N.J., & Seidenberg, M.S. (1994). Lexical nature of syntactic ambiguity resolution. *Psychological Review*, *101*, 676–703.

MacWhinney, B., & Leinbach, J. (1991). Implementations are not conceptualizations: Revising the verb learning model. *Cognition*, *40*, 121–157.

Marchman, V.A. (1993). Constraints on plasticity in a connectionist model of the English past tense. *Journal of Cognitive Neuroscience*, *5*, 215–234.

Marchman, V. (1997). Children's productivity in the English past tense: The role of frequency, phonology and neighbourhood structure. *Cognitive Science*, *21*, 283–304.

Marchman, V., & Weismer, S. (1994). Patterns of productivity in children with G-SLI and NL: A study of the English past tense. Poster presented at the SRCLD 1994. [Available from the author, Dept. of Psychology, University of Wisconsin, Madison, USA.]

Marchman, V., Wulfeck, B., & Weismer, S. (1999). Morphological productivity in children with normal language and SLI: a study of English past tense. *Journal of Speech, Language and Hearing Research*, *42*, 206–219.

Marcus, G., Brinkman, U., Clahsen, H., Wiese, R., & Pinker, S. (1995). German inflection: The exception that proves the rule. *Cognitive Psychology*, *29*, 189–256.

Marcus, G.F., Pinker, S., Ullman, M., Hollander, M., Rosen, T.J., & Xu, F. (1992). Overregularization in language acquisition, *Monographs of the Society for Research in Child Development Series*. Vol. 57, pp. 1–182. Chicago: University of Chicago Press.

McClelland, J.L., Rumelhart, D.E., & PDP Research Group (Eds). (1986). *Parallel distributed processing: Explorations in the microstructure of cognition: Psychological and biological models*. (Vol. 2). Cambridge, MA: MIT Press.

Menyuk, P. (1964). Comparison of grammar of children with functionally deviant and normal speech. *Journal of Speech and Hearing Research*, *7*, 109–121.

Oetting, J., & Horohov, J. (1997). Past tense marking in chldren with and without specific language impairment. *Journal of Speech and Hearing Research*, *40*, 62–74.

Oetting, J., & Rice, M. (1993). Plural acquisition in children with specific language impairment. *Journal of Speech and Hearing Research*, *36*, 1236–1248.

O'Hara, M., & Johnston, J. (1997). Syntactic bootstrapping in children with specific language impairment. *European Journal of Disorders of Communication*, *2*, 189–205.

Pinker, S. (1991). Rules of language. *Science*, *253*, 530–535.

Pinker, S. (1994). *The language instinct*. New York: William Morrow.

Pinker, S. (1999). *Words and rules: The ingredients of language*. London: Weidenfeld & Nicolson.

Pinker, S., & Prince, A. (1988). On language and connectionism: Analysis of a parallel distributed processing model of language acquisition. *Cognition*, *28*, 73–193.

Pinker, S., & Prince, A. (1992, February 15–18). *Regular and irregular morphology and the psychological status of rules of grammar*. Paper presented at the 17th Annual Meeting of the Berkeley Linguistics Society.

Plunkett, K., & Marchman, V. (1991). U-Shaped learning and frequency effects in a multi-layered perceptron: Implications for child language acquisition. *Cognition*, *38*, 43–102.

Plunkett, K., & Marchman, V. (1993). From rote learning to system building: Acquiring verb morphology in children and connectionist nets. *Cognition*, *48*, 21–69.

Prasada, S., & Pinker, S. (1993). Similarity-based and rule-based generalizations in inflectional morphology. *Language and Cognitive Processes*, *8*, 1–56.

Renfrew, C. (1988). *Action Picture Test* (3rd edn). Oxford: Oxford Medical Illustration.

Renfrew, C. (1991). *The Bus Story: a test of continuous speech.* (2nd edn). Oxford: Published by author.

Rice, M. & Wexler, K. (1996). A phenotype of specific language impairment. In M. Rice (Ed.), *Toward a genetics of language*, pp. 215–238. Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Rice, M.L., Wexler, K., & Cleave, P.L. (1995). Specific language impairment as a period of extended optional infinitive. *Journal of Speech and Hearing Research*, *38*, 850–863.

Rumelhart, D.E., & McClelland, J.L. (1986). On learning the past tenses of English verbs. In J.L. McClelland, D.E. Rumelhart, & PDP Research Group (Eds), *Parallel distributed processing: Explorations in the microstructures of cognition* (Vol. 2). Cambridge, MA: Bradford/MIT press.

Seidenberg, M. (1992). Connectionism without tears. In S. Davis (Ed.), *Connectionism: Theory and practice*, pp 84–137. New York: Oxford University Press.

Surian, L., Baron-Cohen, S., & Van der Lely, H.K.J. (1996). Are children with autism deaf to Gricean Maxims? *Cognitive Neuropsychiatry*, *1*, 55–71.

Tallal, P., Miller, S., Bedi, G., Byma, G., Wang, Z., Nagarajan, S., Schreiner, W., Jenkins, W., & Merzenich, M. (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science*, *217*, 81–84.

Tallal, P., & Piercy, M. (1973). Deficits of non-verbal auditory perception in children with developmental aphasia. *Nature*, *241*, 468–469.

Ullman, M.T. (1993). *The computation of inflectional morphology.* Unpublished doctoral dissertation. Cambridge, MA: Massachusetts Institute of Technology.

Ullman, M.T. (1999). Acceptability ratings of regular and irregular past tense forms. Evidence for a dual-system model of language from word frequency and phonological neighbourhood effects. *Language and Cognitive Processes*, *14*, 46–67.

Ullman, M.T., & Gopnik, M. (1994). The production of inflectional morphology in hereditary specific language impairment. *The McGill working papers in linguistics: Linguistic aspects of familial language impairment.* Vol. 10, pp. 81–118. Montreal: McGill University.

Ullman, M.T., & Gopnik, M. (1999). The production of inflectional morphology in hereditary specific language impairment. *Applied Psycholinguistics*, *20*, 51–117.

van der Lely, H.K.J. (1994). Canonical linking rules: Forward versus reverse linking in normally developing and specifically language-impaired children. *Cognition*, *51*, 29–72.

van der Lely, H.J.K. (1996*a*). Specifically language impaired and normally developing children: Verbal passive vs. adjectival passive sentence interpretation. *Lingua*, *98*, 243–272.

van der Lely, H.K.J. (1996*b*). Language modularity and grammatically specific language impaired children, *Child Language*, pp. 188–201. UK: Multilingual Matters Ltd.

van der Lely, H.J.K. (1997*a*). Narrative discourse in grammatical specific language impaired children: A modular language deficit? *Journal of Child Language*, *24*, 221–256.

van der Lely, H.K.J. (1997*b*). Language and cognitive development in a grammatical G-SLI boy: Modularity and innateness. *Journal of Neurolinguistics*, *10*, 75–107.

van der Lely, H.K.J. (1998). G-SLI in children: Movement, economy and deficits in the computational syntactic system. *Language Acquisition*, *7*, 161–193.

van der Lely, H.K.J., & Battell, J. (1998). Wh-movement in specifically language impaired children. Paper presented at the 23rd Boston University Conference on Language Development. November 6–8, 1998. Boston, MA.

van der Lely, H.K.J., & Christian, V. (2000). Lexical word formation in children with grammatical SLI: a grammar-specific versus and input-processing deficit? *Cognition*, *75*, 33–63.

van der Lely, H.K.J., & Dewart, H. (1986). Sentence comprehension strategies in specific language impairment. *British Journal of Disorders of Communication*, *21*, 291–306.

van der Lely, H.K.J., & Hennessey, S. (1999). Linguistic determinism and theory of mind: Insight from children with SLI. The 24th Boston University Conference on Language Development. November 5–7, 1999. Boston, MA.

van der Lely, H.K.J., Rosen, S., & McClelland, A. (1998). Evidence for a grammar-specific deficit in children. *Current Biology*, *8*, 1253–1258.

van der Lely, H.K.J., & Stollwerck, L. (1996). A grammatical specific language impairment in children: An autosomal dominant inheritance? *Brain and Language*, *52*, 484–504.

van der Lely, H.K.J., & Stollwerck, L. (1997). Binding theory and specifically language impaired children. *Cognition*, *62*, 245–290.

van der Lely, H.K.J., & Ullman, M. (1996). The computation and representation of past-tense morphology in normally developing and specifically language impaired children. In A. Stringfellow, D. Cahan-Amitay, E. Hughes, & A. Zukowski (Eds.), *Proceedings of the 20th Annual Boston University Conference on Language Development* (pp. 816–827). Somerville, MA: Cascadilla Press.

Vargha-Khadem, F., Watkins, K., Alcock, K., Fletcher, P., & Passingham, R. (1995). Praxic and non-verbal cognitive deficits in a large family with a genetically transmitted speech and language disorder. *Proceedings of the National Academy of Sciences USA*, *92*, 930–933.

Wright, B., Lombardino, L., King, W., Puranik, C., Leonard, C., & Merzenich, M. (1996). Deficits in auditory temporal and spectral resolution in language impaired children. *Nature*, *387*, 176–178.

Xu, F., & Pinker, S. (1995). Weird past tense forms. *Journal of Child Language*, *22*, 531–556.

# APPENDIX A

G-SLI children's individual raw scores, *z*-scores or standard scores (based on subjects' age) and equivalent age score provided by the published tests used for the matching and selection procedure.

| | | *Language tests* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *BPVS* | | *TROG* | | *NV-BAS* | | *GC-ITPA* | |
| *G-SLI subjects* | *Age* | Raw score (*z*-score) | Equivalent age | Raw score (*z*-score) | Equivalent age | Raw score | Equivalent age | Raw score (*z*-score) | Equivalent age |
| JW | 9:3 | 60 (−1.7) | 6:5 | 10 (−2.2) | 5:3 | 17 * | 7:9 | 17 (−3.7) | 6:0 |
| WL | 9:5 | 72 (−0.9) | 7:9 | 12 (−1.7) | 5:9 | 17 * | 7:9 | 18 (−3.8) | 6:3 |
| JS | 9:10 | 89 (0.0) | 9:9 | 13 (−1.5) | 6:0 | 19 * | > 7:11 | 17 (−4.6) | 6:0 |
| AZ | 10:3 | 72 (−1.3) | 7:9 | 12 (−1.9) | 5:9 | 19 * | > 7:11 | 16 (−5.5) | 5:10 |
| RJ | 10:11 | 87 (−1.4) | 8:2 | 16 (−0.8) | 9:0 | 19 * | > 7:11 | 16 * | 5:10 |
| AZ | 11:0 | 72 (−1.7) | 7:9 | 12 (−2.1) | 5:9 | 18 * | > 7:11 | 24 * | 7:11 |
| CT | 11:11 | 86 (−1.1) | 9:0 | 13 (−2.2) | 6:0 | 18 * | > 7:11 | 21 * | 7:0 |
| SB | 12:0 | 90 (−0.7) | 9:5 | 15 (−1.6) | 8:0 | 17 * | 7:9 | 24 * | 7:11 |
| AT | 12:1 | 80 (−1.6) | 9:0 | 13 (−2.2) | 6:0 | 16 * | 6:3 | 17 * | 6:0 |
| BS | 12:2 | 78 (−1.8) | 8:5 | 12 (−2.5) | 5:9 | 20 * | > 7:11 | 22 * | 7:3 |
| AW | 12:2 | 84 (−1.5) | 9:3 | 16 (−1.2) | 9:0 | 17 * | > 7:11 | 22 * | 7:3 |
| MP | 12:10 | 87 (−1.4) | 7:9 | 13 (−2.2) | 6:0 | 18 * | > 7:11 | 26 * | 8:6 |

BPVS, British Picture Vocabulary Score (Dunn et al., 1982); TROG, Test of Reception of Grammar (Bishop, 1983); NV-BAS, Naming Vocabulary, British Ability Scales (Elliott et al., 1978); GC-ITPA, Grammatical Closure sub-test from Illinois Test of Psycholinguistic Abilities (Kirk et al., 1968). *, *z*-score not available.

## APPENDIX A cont'd.

| | *Language tests* | | | | | *Non-language* |
|---|---|---|---|---|---|---|
| | *Bus story* | | | *Action picture test* | | *BAS: IQ* |
| *G-SLI subject* | *Info. (age)* | *Sentence length (age)* | *Sub-clause (age)* | *Info (age)* | *Grammar (age)* | *Visual performance score* |
| JW | 28(6:1) | 14(8:2) | 2(4:8) | 34(6:9) | 23(5:3) | 105 |
| WL | 23(5:1) | 10(6:4) | 1(4:2) | 26.5(4:2) | 20(4:3) | 115 |
| JS | 29(6:4) | 11(6:10) | 1(4:2) | 33.5(6:6) | 26(6:3) | 90 |
| AZ | 42(5:3) | 13(7:10) | 2(4:8) | 28(4:8) | 20(4:3) | 119 |
| RJ | 27(5:10) | 8(4:7) | 1(4:2) | 34.5(7:0) | 22(5:0) | 110 |
| AZ | 22(4:11) | 11(6:10) | 1(4:2) | 34.5(7:0) | 25(6:0) | 105 |
| CT | 33(7:4) | 12(7:4) | 2(4:8) | 38(8:5) | 24(5:9) | 86 |
| SB | 20(4:7) | 12(7:4) | 3(5:10) | 35.5(7:6) | 23(5:3) | 92 |
| AT | 29(6:4) | 11(6:10) | 1(4:2) | 34.5(7:0) | 26(6:3) | 90 |
| BS | 30(6:7) | 11(6:10) | 2(4:8) | 35(7:3) | 26(6:3) | 99 |
| AW | 25(5:5) | 9(5:7) | 2(4:8) | 35(7:3) | 25(6:0) | 92 |
| MP | 32(7:1) | 9(5:7) | 1(4:2) | 35(7:3) | 28(6:9) | 86 |

Action Picture Test/Bus Story (Renfrew, 1988, 1991): Info, information score; sub-clause, number of subordinate clauses; age, equivalent age score; BAS, British Ability Scales.

# APPENDIX B1

Individual verb stems and past tense forms for regular and irregular verbs, together with their past tense frequencies (raw frequencies augmented by 1 and then ln-transformed), and the complement/adjuncts used in sentences for their presentation.

| | *Verb* | *Past tense form* | *Past tense freq COBUILD* | *Verb complement/ Adjunct* |
|---|---|---|---|---|
| Regular verbs | | | | |
| High frequency | slam | slammed | 3.6 | my door |
| | cross | crossed | 5.1 | Oxford Street |
| | rush | rushed | 4.4 | over there |
| | rob | robbed | 3.1 | a bank |
| | drop | dropped | 5.6 | my brush |
| | look | looked | 7.5 | at Susan |
| | stir | stirred | 4.0 | my soup |
| | soar | soared | 2.5 | over this |
| Mean | | | 4.5 | |
| *SD* | | | 1.6 | |
| Range | | | 2.5–7.5 | |
| Low frequency | scowl | scowled | 2.3 | at Joe |
| | tug | tugged | 2.9 | at it |
| | flush | flushed | 3.9 | the toilet |
| | mar | marred | 2.1 | its beauty |
| | chop | chopped | 3.7 | some garlic |
| | flap | flapped | 2.6 | my wings |
| | stalk | stalked | 2.7 | a rabbit |
| | scour | scoured | 2.1 | my pan |
| Mean | | | 2.8 | |
| *SD* | | | .7 | |
| Range | | | 2.1–3.9 | |
| Irregular verbs | | | | |
| High frequency | make | made | 8.2 | my lunch |
| | give | gave | 7.2 | away money |
| | think | thought | 7.2 | about you |
| | stand | stood | 6.7 | over here |
| | keep | kept | 6.6 | my food |
| | drive | drove | 5.0 | a car |
| | send | sent | 6.3 | a letter |
| Mean | | | 6.7 | |
| *SD* | | | 1.0 | |
| Range | | | 5.0–8.2 | |
| Low frequency | swim | swam | 5.0 | a mile |
| | dig | dug | 4.7 | a hole |
| | swing | swung | 4.4 | my bat |
| | wring | wrung | 0.0 | my towel |
| | grind | ground | 2.9 | the corn |
| | bend | bent | 4.0 | a spoon |
| | bite | bit | 4.2 | my tongue |
| | feed | fed | 4.5 | her cat |
| Mean | | | 3.7 | |
| *SD* | | | 1.9 | |
| Range | | | 0–5.0 | |

# APPENDIX B2

Individual novel verb stems and expected regularised and plausible irregularised past tense forms, together with the complements/adjuncts used in sentences for their presentation.

| | *Verb stem* | *Expected regularised past tense form* | *Plausible irregularised past tense form* | *Verb complement/ adjunct* |
|---|---|---|---|---|
| Novel regulars | | | | |
| | spuff | spuffed | spaff | for TV |
| | dotch | dotched | doach | your car |
| | stoff | stoffed | stoaf | my room |
| | cug | cugged | cogue | more furniture |
| | trab | trabbed | trub | a paper |
| | crog | crogged | crug | with John |
| | vask | vasked | vosk | a ring |
| | brop | bropped | brap | his jacket |
| | satch | satched | sotch | around water |
| | grush | grushed | grash | near Eric |
| | plam | plammed | plome | my leg |
| | scur | scurred | skeer | a bean |
| Novel irregulars | | | | |
| | strink | strinked | strunk | a horse |
| | frink | frinked | frunk | over dinner |
| | strise | strised | strose | for them |
| | crive | crived | crove | a lot |
| | shrell | shrelled | shrelt | with Chris |
| | vurn | vurned | vurnt | about London |
| | steeze | steezed | stoze | my watch |
| | shrim | shrimmed | shram | at home |
| | cleed | cleeded | cled | very well |
| | scrit | scritted | scrat | for Steve |
| | ret | retted | rit | around here |
| | sheel | sheeled | shelt | among them |
| | blide | blided | blid | with her |
| | prend | prended | prent | a mouse |
| | shreep | shreeped | shrept | my friend |
| | drite | drited | drit | a field |

# APPENDIX C

## Stem Familiarity Rating Task

**Procedure:** The subjects were tested individually in a quiet room, and were seated opposite the examiner. A card with five bars of increasing size was placed on the table in front of the child. A card with codes (0–4) corresponding to the bars was placed parallel to the bars in front of the examiner. The experimenter spoke the following instructions: "I am going to read you some words and ask you to tell me how many people you think might say each word. The word is going to be in a sentence. I will read each sentence out loud, and then ask you to show me on this picture how many people you think might say the word." The experimenter then pointed to the appropriate bar while saying "This one means almost nobody says the word; this one means very few people; this one means some people here is quite a lot of people; and this one means lots and lots of people." Three demonstrations were given: "So, for example, 'Every day I **go** to school.' The verb was stressed and repeated after the first one or two practice sentences was repeated in isolation to ensure that the child judged the verb and not the whole sentence. "**Go**, I think lots and lots of people might say that word. I've heard it a lot of times before. Have you?" The experimenter then pointed to bar 4, the tallest bar. "What about 'Every day I **weep** over her'? **Weep**, I think quite a lot of people might say that word." The experimenter then pointed to tower 3. "What about 'Every day I **prame** quite well'? Oh, I haven't heard that word much at all. I'd say only very few people might say that one." The experimenter then pointed to bar 1, the shortest bar. Two practice items were then administered: The experimenter said " 'Every day I **scrig** over there.' How many people might say that word? 'Every day I **play** in the park.' How many people might say that word?" When the experimenter was reasonably confident that the child understood the task indicated by him/her pointing to appropriate bars for two practice items, the test sentences were administered. The set of 60 verbs was pseudo-randomised using the same criteria as were used in the production task. All subjects received the same item presentation order.