

Inflectional morphology in a family with inherited specific language impairment

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ABSTRACT

The production of regular and irregular past tense forms was investigated among the members of an English-speaking family with a hereditary disorder of language. Unlike the control subjects, the family members affected by the disorder failed to generate overregularizations (e.g., *digged*) or novel regular forms (*plammed*, *crived*), whereas they did produce novel irregularizations (*crive-crove*). They showed word frequency effects for regular past tense forms (*looked*) and had trouble producing regulars and irregulars (*looked*, *dug*). This pattern cannot be easily explained by deficits of articulation or of perceptual processing, by previous simulations of impairments to a single-mechanism system, or by the extended optional infinitive hypothesis. We argue that the pattern is consistent with a three-level explanation. First, we posit a grammatical deficit of rules or morphological paradigms. This may be caused by a dysfunction of a frontal/basal-ganglia “procedural memory” system previously implicated in the implicit learning and use of motor and cognitive skills. Second, in contexts requiring inflection in the normal adult grammar, the affected subjects appear to retrieve word forms as a function of their accessibility and conceptual appropriateness (“conceptual selection”). Their acquisition and use of these word forms may rely on a “declarative memory” system previously implicated in the explicit learning and use of facts and events. Third, a compensatory strategy may be at work. Some family members may have explicitly learned a strategy of adding suffix-like endings to forms retrieved by conceptual selection. The morphological errors of young normal children appear to be similar to those of the affected family members, who may have been left stranded with conceptual selection by a specific developmental arrest. The same underlying deficit may also explain the impaired subjects’ difficulties with derivational morphology.

Specific language impairment (SLI) may be defined as a developmental disorder of language that cannot be explained by a hearing loss, a general cognitive impairment, an emotional disorder, or environmental deprivation (Bishop, 1992). Although SLI is a heterogeneous disorder (Leonard, 1998), there have

been reports of subgroups of people with SLI whose language impairments are relatively homogeneous (e.g., Adams & Bishop, 1989). Of particular interest are reports of SLI subgroups whose language impairments may be hereditary and, it has been argued, specific to grammar (Clahsen, 1989; Gopnik, 1990b; Gopnik & Crago, 1991; van der Lely, 1996b).

The investigation of such SLI subgroups may elucidate four important questions about the psychological, neural, and developmental underpinnings of language. (1) Are the mental lexicon, in which words are stored, and the mental grammar, which specifies how words combine into larger words, phrases, and sentences, subserved by distinct mechanisms (Pinker, 1991) or a common mechanism (Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett, 1996)? (2) If these two language capacities are subserved by distinct mechanisms, is the grammar-computing mechanism dedicated to grammar or some aspect of grammar or does it underlie nonlanguage functions as well (see Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz, & Pinker 1997)? (3) Can the neural systems subserving the lexicon and the grammar be localized and, if so, to where? (4) If the language of grammatically impaired people with SLI resembles that of young normal children, can investigations of SLI language elucidate the structure of child language and the process of normal language acquisition? In addition, the study of SLI subgroups' language impairments may lead to a better understanding of the nature of SLI itself, perhaps leading to diagnostic and therapeutic advances for the condition.

In this article, we address these four questions by investigating the production of English past tense and other inflectional forms in an SLI subgroup of native English-speaking people whose hereditary language impairment, it has been hypothesized, may be specific to grammar (Gopnik, 1990a, 1990b, 1994d; Gopnik & Crago, 1991). We focus on inflectional morphology for three reasons.

First, inflectional morphological impairments have been shown to occur in several SLI subgroups of native English speakers (e.g., Leonard, Bortolini, Caselli, McGregor, & Sabbadini, 1992; Rice, Wexler, & Cleave, 1995; van der Lely & Ullman, 1996), including the subgroup discussed in this article. It has also been reported in SLI native speakers of German (Clahsen, 1989), Italian (Leonard, Bortolini et al., 1992), Hebrew (Dromi, Leonard, & Shtiman, 1993), Japanese (Fukuda & Fukuda, 1994; Fukuda & Gopnik, 1994), Greek (Dalalakis, 1994), and Inuktitut (Crago & Allen, 1994). Thus, our findings might potentially be generalized to many subgroups of SLI across a number of languages.

Second, inflectional morphology has been extensively studied from psycholinguistic (Kim, Pinker, Prince, & Prasada, 1991; Marcus, Brinkmann, Clahsen, Wiese, & Pinker, 1995; Prasada & Pinker, 1993; Ullman, 1993, 1999), developmental (Marcus et al., 1992), neurological (Ullman, in press; Ullman, Corkin et al., 1997; Ullman, Izvorski, Love, Yee, Swinney, & Hickok, in press), neuroimaging (Jaeger et al., 1996; Ullman, Bergida, & O'Craven, 1997), and electrophysiological (Newman, Neville, & Ullman, 1998; Penke et al., 1997; Weyerts, Penke, Dohrn, Clahsen, & Münte, 1996) perspectives (see Pinker, 1991). This extensive and interdisciplinary research on a relatively simple language system provides a foundation on which to build our understanding of the linguistic impairment of SLI.

Third, and most important, inflectional morphological transformations such as English past tense are particularly well-suited for testing whether the mental lexicon and the mental grammar may be subserved by distinct mechanisms (Pinker, 1994) or by a single mechanism (Elman et al., 1996). Regularly inflected past tense forms (e.g., *look-looked*, *play-played*) are structured according to a set of rules (append an *-ed* suffix to the stem), whereas irregularly inflected forms do not all follow the same stem-past pattern (e.g., *sing-sang*, *fling-flung*, *bring-brought*). According to a dual mechanism view, irregular past tense forms are retrieved from an associative memory, whereas regular past tense forms are computed in real time by a distinct rule-processing system (Pinker, 1991, 1994). When an irregular form is not successfully retrieved, the rule-processing system may take over, resulting in “overregularization” errors (*flinged*, *digged*). In contrast, according to a single mechanism view, regular as well as irregular forms are learned in, and computed over, an associative memory. On this perspective, there is no distinct system for rule processing; rather, rules are nothing but descriptions of the regularities in the language (Elman et al., 1996; Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986).

Dual mechanisms versus a single mechanism: Previous evidence

Several lines of evidence have been presented as support for the dual mechanism theory. First, psycholinguistic studies of adults have suggested that irregular past tense forms are retrieved from associative memory, whereas regular past tense forms are computed in real time by a rule-processing system. If irregular forms are retrieved from associative memory, then those that are encountered frequently or that share memory traces with many other similar-sounding neighboring forms (e.g., *sing-sang*, *ring-rang*, *spring-sprang*) should have stronger memory traces and therefore should be better remembered than those of lower frequency or with few neighbors. Prasada, Pinker, and Snyder (1990) reported that subjects took significantly more time to produce low-frequency than high-frequency past tense forms for irregular verbs, holding stem frequency constant. In contrast, time to production was not significantly longer for low-frequency than high-frequency regular past tense forms, holding stem frequency constant. Ullman (1993, 1999) found that acceptability ratings of irregular past tense forms (*blew*) correlated with their word frequencies and with a measure of neighborhood size, which was based on the type and token frequencies of similar-sounding verbs (*grew*, *threw*). This pattern held even when a measure of stem access was held constant. In contrast, acceptability ratings of regulars (*walked*) correlated neither with their word frequencies nor with the neighborhood size measure (*stalked*, *balked*), holding a measure of access constant. Although single system models may attribute the lack of word frequency effects to the high type frequency of similar-sounding regulars, which may overwhelm the memory traces of individual words (Daugherty & Seidenberg, 1992; Seidenberg & Daugherty, 1992), it is not clear whether single system models could explain the contrasting neighborhood effects (Ullman, 1999). These results are thus taken to suggest that irregulars are retrieved from an associative memory storing distributed representations of their phonological forms, whereas regulars (*looked*) are computed in real time by a distinct system.

Second, developmental studies have revealed similar contrasts in children. Two groups of children (approximate mean ages of 7 and 8) showed word frequency effects in the elicited production of irregular but not regular past tense forms (van der Lely & Ullman, submitted). Overregularization rates (*blowed*) in the spontaneous speech of younger children correlated negatively with past tense frequency (*blew*) and with the number of similar-sounding irregular verbs (*threw, grew*) but did not correlate with the number of similar-sounding regular verbs (*flowed, rowed*) (Marcus et al., 1992).

The production of regular and irregular past tense forms has also been examined in people with Williams syndrome, a hereditary developmental disorder associated with severe mental retardation. People with this disorder may have spared syntactic abilities but abnormal lexical retrieval (Bellugi, Wang, & Jernigan, 1994). Young adults with Williams syndrome were shown to be more impaired at producing irregular than regular past tense (*blew* vs. *walked*) and plural (*mice* vs. *rats*) forms. The majority of their errors on irregulars were overregularizations (*blowed, mouses*) (Bromberg et al., 1994). These results dissociate irregular and regular inflected forms, and they link irregulars to lexical memory and regulars to syntactic abilities.

Third, neurological studies of adults with acquired brain damage have revealed double dissociations between the use of regular and irregular forms. Patients who have temporal lobe lesions and relatively spared frontal/basal-ganglia structures and who demonstrate impairments remembering words or facts (those with posterior aphasia or Alzheimer's disease) have more trouble producing irregular than regular English past tense forms (Ullman, in press; Ullman et al., 1993, 1994, in press; Ullman, Corkin et al., 1997) and Italian present tense and past participle forms (Cappa & Ullman, 1998). In contrast, patients who have frontal/basal-ganglia damage and relatively spared temporal lobe structures and who may have impairments of syntactic processing and/or learning and use of motor and cognitive skills (those with anterior aphasia or Parkinson's disease) show the opposite pattern (Ullman, in press; Ullman et al., 1993, 1994, in press; Ullman, Corkin et al., 1997). These double dissociations have been taken to suggest that lexical memory is part of a "declarative memory" system rooted in the temporal lobes and previously implicated in the memory for facts and events, whereas grammatical rules are processed at least in part by a "procedural memory" system rooted in frontal/basal-ganglia structures and previously implicated in the implicit learning and use of motor and cognitive skills (Ullman, in press; Ullman, Corkin et al., 1997).

The existence of distinct neural underpinnings for regular and irregular past tense processing is further strengthened by double dissociations in priming. Marslen-Wilson and Tyler (1997) reported that one aphasic subject showed priming between past tense and stem forms for regulars (e.g., *jumped* primed *jump*) but not irregulars (e.g., *gave* did not prime *give*), whereas two aphasic subjects showed the opposite pattern.

Ullman and his colleagues found that basal ganglia degeneration leading to the suppression of movement (hypokinesia in patients with Parkinson's or Huntington's disease) also leads to rule suppression (resulting in the omission of the past tense *-ed* suffix), whereas basal ganglia degeneration leading to excess

movement (hyperkinesia in patients with Huntington's disease) also leads to excess rule use (the production of forms like *dugged* and *walkeded*) (Ullman, in press; Ullman, Corkin et al., 1997). This contrast suggests that basal ganglia circuitry contributes to grammatical rule processing, and that the well-studied basal ganglia circuits underlying motor programming may play a comparable role in rule programming.

Fourth, neuroimaging investigations have revealed intriguing dissociations between the production of regular and irregular past tense forms. In a positron emission tomography (PET) study, Jaeger et al. (1996) asked healthy men to read out loud lists of irregular, regular, and novel verb stems and to produce their past tense forms. When past tense production was compared to verb stem reading, left temporal and temporo-parietal regions yielded greater statistical significance for irregular than regular or novel verbs, whereas a left prefrontal region was associated with greater statistical significance for regular and novel verbs. Unfortunately, this contrast is problematic for several respects. First, it was not found when past tense production conditions were compared to a rest condition. Second, activation differences found from a comparison of two conditions could be caused by an increase in one condition or a decrease in the other; in the absence of an examination of activation decreases, these cannot be distinguished. Third, the blocking of large numbers of items, a design required by the PET technology, might allow subjects to use a strategy to produce the regulars, all of which undergo *-ed* suffixation, but not the irregulars, each of which requires a particular stem-past transformation.

In a functional magnetic resonance imaging (fMRI) study, five healthy right-handed men were asked to produce the past tense forms of regular and irregular verbs (Ullman, Bergida et al., 1997). The subjects showed similar patterns of activation. The production of irregulars but not regulars yielded a substantial activation decrease, compared to fixation, in temporal/temporo-parietal regions. In prefrontal cortex, regulars but not irregulars showed an activation decrease, compared to fixation. Although the specific causes of these activation decreases remain to be investigated, the double dissociations suggest that irregulars and regulars have distinct neural underpinnings linked to temporal and frontal regions. Like the PET study, in this fMRI study, regular and irregular stimuli were grouped separately, although in blocks of only 10 verbs. Thus, the findings must be treated with caution.

Fifth, in two electrophysiological studies of healthy German subjects (Penke et al., 1997; Weyerts et al., 1996), distinct patterns of event-related potentials (ERPs) were found for regular and irregular inflection of verbs and nouns. An ERP study of healthy adults found that violations of regular but not irregular English past tense forms yielded a left frontal negativity, whereas violations of irregulars but not regulars elicited a more posterior negativity (Newman, Neville, & Ullman, 1998).

Although these lines of evidence have been taken as strong support for a dual system view, the controversy between the two theories has continued. In particular, single system proponents have argued that many findings taken to support the dual system perspective are also compatible with single system models (Cottrell & Plunkett, 1991; Daugherty & Seidenberg, 1992; Hare, Elman, & Daugh-

erty, 1995; Hoeffner, 1992; Hoeffner & McClelland, 1993; MacWhinney & Leinbach, 1991; Marchman, 1993; Plunkett & Marchman, 1991, 1993; Seidenberg & Hoeffner, in press). It is therefore important to gather additional evidence to help resolve the controversy.

SLI and the dual versus single mechanism controversy

Under a dual system view, grammar or a component of grammar may be impaired in some SLI subgroups, while lexical memory is left relatively intact. Indeed, a number of different hypotheses have posited an SLI deficit specific to grammar, although these hypotheses differ with respect to the linguistic character of the impairment: Gopnik and colleagues' feature blindness and feature checking hypotheses (Gopnik, 1990a, 1990b; Gopnik & Crago, 1991); Clahsen's (1989) missing agreement account; Rice, Wexler, and Cleave's (1995) extended optional infinitive hypothesis; and van der Lely's representational deficit for syntactic dependent relationships hypothesis (van der Lely 1996a, 1996b; van der Lely & Stollwerck, 1997).

We propose that the learning and use of grammatical rules implicitly learned by normal individuals are dysfunctional in the particular SLI subgroup under study and perhaps in other SLI subgroups as well. Lexical memory, in contrast, is posited to be relatively spared. The subjects affected with the impairment are predicted to have trouble with rule-governed *-ed* suffixation. They may therefore show a lack of overregularizations (*dig-digged*) and regularizations of novel verbs (*plammed, crived*) and may have trouble generating past tense forms of very low-frequency regular verbs. In the absence of intact suffixation rules, they may be forced to memorize regular as well as irregular past tense forms. Unlike normal children (van der Lely & Ullman, submitted) and adults (Prasada et al., 1990; Ullman, 1993, 1999), they would be expected to show frequency effects for regular as well as irregular past tense forms. If regular and irregular forms are stored, similar production rates may be found for the two past tense types. Moreover, if syntactic processing is normally dependent on grammatical rules that are dysfunctional in this population, then the production of all types of past tense forms (irregular as well as regular) for real and novel verbs may be impaired in past tense processing tasks involving syntax. In summary, if grammatical rules are dysfunctional, suffixed forms which are unlikely to have been memorized (novel past tenses and overregularizations) may be difficult to produce; frequency effects should be found for regular and irregular past tense forms; and the production of all past tense forms may be impaired in certain past tense processing tasks because of syntactic deficits.

Under a single system view, grammar cannot be selectively impaired in SLI, although different patterns of impairment may be associated with the computation of regular and irregular forms. Marchman (1993) investigated the effects of "lesions" (i.e., the random elimination of hidden units) in a connectionist model of the acquisition and computation of English past tense. Greater damage prior to or during training led to greater impairments in the learning and computation of regular past tense forms, whereas the learning and computation of irregular past tense forms were relatively impervious to damage. Greater damage prior to

training led to greater deficits in the production of suffixed past tense forms of novel verbs whose stems are dissimilar to the stems of real irregulars (“novel regulars” such as *plam–plammed*) – although even when the maximum percentage of hidden units (44%) was lesioned, the network correctly suffixed about 40% of these novel verb stems. In contrast, damage did not affect the production of novel “no-change” past tense forms of verbs whose stems are similar to the stems of real no-change irregulars (“novel irregulars” such as *scrit–scrit*; cf. *hit–hit*). The result of lesions on novel verbs whose stems resemble irregular vowel-change verbs (e.g., *crive–crove*; cf. *drive–drove*) was not discussed, presumably because the intact network produced vowel-change irregularizations (e.g., *crove*) at a very low rate. Hoeffner and McClelland (1993) attempted to simulate a perceptual processing deficit, which has been hypothesized to underlie SLI and to result in difficulties learning items with low phonological salience, such as the *-ed* suffix (Leonard, Bortolini et al., 1992; Tallal, Stark, & Mellits, 1985). They presented a three-layer network with “normal” regular and irregular items and with items whose phonological input to the model was weakened. The “impaired” network was only slightly less accurate than the normal network at producing irregular past tense forms, but it was significantly worse at producing regular past tense forms. In summary, if these connectionist simulations are taken as models of SLI (see Marchman & Weismer, 1994), they predict that people with SLI should have more difficulty producing regular than irregular past tense forms. Marchman’s (1993) simulations also predicted impaired performance at the production of novel regularizations (*plammed*). Neither study made predictions about frequency effects.

The KE family

The SLI subgroup investigated in this article is composed of the impaired members of a multigenerational native English-speaking family in England (the “KE family”; see Matthews, 1994, for a detailed set of studies on this family; see also Gopnik, 1994c). The familial distribution of the disorder indicates that it is hereditary and is transmitted by an autosomal dominant genetic mutation (Gopnik 1990a, 1990b; Gopnik & Crago, 1991; Hurst, Baraister, Auger, Graham, & Norell, 1990; Pembrey, 1992). Figure 1 shows the family pedigree, indicating the relationships between affected and unaffected family members. Hurst et al. (1990) reported that the unaffected family members “have no speech or language difficulties” (p. 354), which argues against a purely social or dialectal explanation of their affected relatives’ impairment.

The affected family members have a language impairment which has been described as grammatical in nature (Gopnik 1990a, 1990b; Gopnik & Crago, 1991). The impairment is strongly associated with past tense difficulties, leading Gopnik (1994d, p. 131) to conclude that the affected family members “do not reliably control tense marking on verbs.” They also have trouble with plural inflection (Gillon & Gopnik, 1994; Goad & Rebellati, 1994) and derivational morphology (Gopnik & Crago, 1991) and may suffer from other linguistic deficits as well (Fee, 1995; Gopnik & Crago, 1991; Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995).

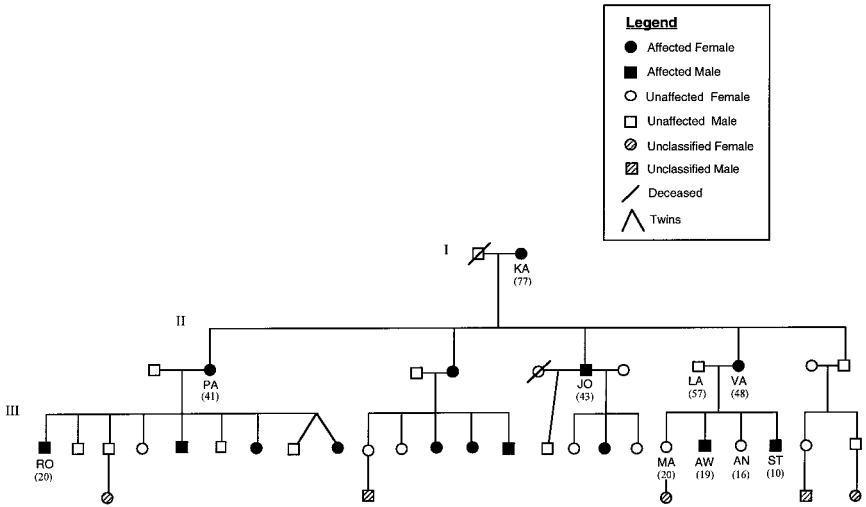


Figure 1. Family tree showing the provisional classification of affected and unaffected members. Roman numerals indicate each of the three generations. Family members tested on the past tense production task are identified by the two-letter codes used in the article. Their ages at the date of testing are displayed in parentheses.

Crucially, the linguistic impairment appears to be limited in scope, as lexical memory seems to be relatively intact. Vargha-Khadem et al. (1995) reported that the affected family members were not statistically significantly worse ($p > .05$) than their unaffected relatives at object naming (“Tell me the name of the object in this picture”) and picture vocabulary (“Show me the picture for this word”).

This apparent dichotomy between impaired grammar and relatively spared lexicon may parallel nonlanguage dichotomies. In particular, the affected KE family members appear to have motor deficits, whereas their hearing and intelligence are relatively spared. The motor deficits were first reported by Hurst et al. (1990), who examined four of the affected family members and reported that “[a]rticulation was also defective, and they were considered to have a moderate to severe degree of dyspraxia. They could position the tongue and lips for simple movements, but failed when a sequence of movements was required” (p. 354). Vargha-Khadem et al. (1995) found that impaired family members were significantly worse than control subjects in two tests of orofacial praxis. In addition, they reported that “the affected members were significantly more impaired on the simultaneous and successive movements than on the single movements” and concluded that “the praxic deficits of the affected members are not confined to articulation but also involve nonlinguistic oral and facial movements” (p. 932).

This apparent coexistence of motor deficits and grammatical deficits, with a relative sparing of lexical memory, is consistent with a dysfunction of frontal/basal-ganglia circuitry. Previous evidence implicates this circuitry in procedural memory – that is, the implicit learning of motor, perceptuomotor, and cognitive

skills and “habits” (Mishkin, Malamut, & Bachevalier, 1984; Squire, Knowlton, & Musen, 1993). In addition, it appears to underlie motor programming (Young & Penney, 1993) and the use of long-established motor skills, such as driving or using a key (Heilman & Rothi, 1993; Heilman, Watson, & Rothi, 1997). It may be particularly important for learning and performing skills involving sequences (Graybiel, 1995; Willingham, in press). Evidence from animal studies suggests that the circuitry may also be critical in the expression of innate behavioral routines (see Graybiel, 1995). Ullman and his colleagues (Ullman, in press; Ullman, Corkin et al., 1997) argued that this system may underlie the learning and use of grammatical rules, while being less important in the learning and use of words, which, they hypothesized, may be subserved by a well-studied declarative memory system – a system rooted in the temporal lobes that has been implicated in the memory for facts and events (Mishkin et al., 1984; Squire et al., 1993). Indeed, the affected family member’s relative sparing of lexical memory is consistent with a relative sparing of declarative memory. The view that the affected subjects’ grammatical and motor deficits can be accounted for by a dysfunction of procedural memory is strengthened by a recent MRI study, which revealed bilateral abnormalities in the basal ganglia of affected family members. Their caudate nuclei contained less gray matter and were significantly smaller than those of their unaffected relatives (Watkins et al., 1997).

In contrast to their motor deficits, Hurst et al. (1990) reported that the “[h]earing and intelligence of all affected members were within the normal range” (p. 354). Similarly, Pembrey (1992) found that the affected members had no “hearing loss [and] low intelligence” (p. 54). He reported that their mean performance IQ on the Wechsler Intelligence scales for adults (WAIS-R) and children (WISC-R) (Wechsler 1974, 1981) was 95 (range, 80–112). This is well within the normal range – that is, above a score of 85, above which 84% of the population falls. Similarly, Vargha-Khadem et al. (1995) reported a WAIS-R/WISC-R mean performance IQ of 86 (range, 71–111) for affected family members, also within the normal range.¹

In summary, previous evidence suggests that the affected family members have an impairment of inflectional (and possibly derivational) morphology and of motor functions. In contrast, lexical memory and hearing appear to be relatively spared, and there is no convincing evidence for a general cognitive deficit. These findings are consistent with our hypothesis that the affected subjects have an impairment of the frontal/basal-ganglia procedural memory system, with a relative sparing of declarative memory (see also Paradis & Gopnik, 1994).

In this article, we describe the results of an in-depth study of the elicited production of past tense forms. Affected and unaffected family members and unrelated age-matched control subjects were asked to inflect regular verbs (*look–looked*), irregular verbs (*dig–dug*), and novel verbs (*plam–plammed*, *crive–crove/crived*). Individual subject analyses compare the performance of each family member with that of their unrelated age-matched controls. Group analyses compare the performance of affected family members with that of unaffected family members. Raw data from other studies of the KE family is also

Table 1. *Affected and unaffected family members tested on the past tense production task*

Subject	Gender	Age (years)	Prior identification
ST	M	10	affected
AW	M	19	affected
RO	M	20	affected
PA	F	41	affected
JO	M	43	affected
VA	F	48	affected
KA	F	77	affected
AN	F	16	unaffected
MA	F	20	unaffected
LA	M	57	unaffected

Note: Ages shown are at date of testing.

reanalyzed, and previously reported data on the family is discussed in the context of each result.

METHOD

Subjects

Ten family members were tested: seven were affected, and three were unaffected by the disorder (see Table 1). The distinction between affected and unaffected family members was made by Hurst et al. (1990) and confirmed by Pembrey (1992). The “two children of questionable status” reported by Pembrey (1992, p. 54) were not included in our study. In addition, we used two criteria to distinguish affected from unaffected individuals. Family members who had been diagnosed as language-impaired by the school system and were shown to have an impairment on language or motor tests in one or more previous investigations were classified as affected. Those who had not been diagnosed as language-impaired by the school system and, to our knowledge, had not shown language or motor impairments in previous investigations were classified as unaffected. These criteria successfully categorized all but one family member reported in the present study. The grandmother of the family (KA) was not formally diagnosed by the school system, presumably because such services did not exist when she was of school age. However, she did meet the criterion for impaired performance. We therefore classified her as affected.

Materials

Each subject was shown 56 verbs, which were drawn from four classes: (a) 16 irregular verbs (*dig–dug*), which take only an irregular past tense form (thus doublet verbs, such as *dive–dove/dived*, which take both an irregular and a regu-

lar past tense form, were excluded); (b) 16 regular verbs (*look-looked*), which take only a regular past tense form and whose stems are phonologically dissimilar to the stems of all irregular verbs; (c) 16 novel irregular verbs, whose stems are phonologically similar to the stems of real irregular verbs and may take irregularized or regularized past tense forms (e.g., *crive-crove/crived*; cf. *drive-drove*); (d) 12 novel regular verbs (e.g., *plam-plammed*), whose stems are phonologically dissimilar to the stems of all irregular 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, and therefore the production of past tense and stem forms cannot be distinguished. An additional irregular verb (*grind*) was excluded from analysis because its past tense form (*ground*) exists as a distinct verb. See Tables 2 and 3 for a list of the verbs, together with the real verbs' COBUILD word frequency counts, which are used in all frequency analyses in this article. These relative frequency counts were drawn from the 17.9 million world British COBUILD corpus and were made available to us by the Centre for Lexical Information (CELEX) at the University of Nijmegen in the Netherlands. The counts disambiguate different parts of speech, thus distinguishing the use of *dropped* as a past participle from *dropped* as a past tense. The counts were natural log transformed, after being augmented by 1 to avoid $\ln(0)$. The irregular verbs had higher past tense frequencies than the regular verbs: independent measures $t(28) = 3.1$, $p = .005$.

The verbs were selected according to six criteria. First, we chose the real regulars and irregulars to cover a wide stem and past tense frequency range. Second, we avoided auxiliary or modal verbs (*do*, *be*, *have*). Third, we eliminated real regulars and irregulars we judged to be possible denominal verbs (derived from a noun), de-adjectival verbs (derived from an adjective), or verbs of onomatopoeic origin. Fourth, we attempted to avoid real verbs whose stems or expected past tense forms are phonologically or orthographically identical or highly similar to other real words. Thus, *rise* was excluded because its past tense form, *rose*, is also a noun. Fifth, we tried to avoid real and novel verb stems which contain graphemes that do not map to a unique sound in English. Thus, we eliminated verbs like *blow*, whose orthography is similar to that of both *flow* or *allow*. Sixth, all novel forms had to have acceptable English spellings. Thus, forms such as *krog* and *krive* were forsaken in favor of *crog* and *crive*.

All 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." All sentences were written to conform to several criteria, with the goals of ensuring consistency among the items and facilitating the task for language-impaired subjects. First, every past tense eliciting sentence was written in the completive aspect. Second, every stem sentence began with "Every day I," while every past tense sentence began with "Just like every day, yesterday I." Third, all verbs were followed by a two-word complement or adjunct; both words were selected to be underived and of relatively high frequency. Fourth, the two-word complements or adjuncts for novel verbs were chosen to minimize the possibility that the subject would inflect the novel verb by analogy to an existing similar-sounding verb. For example, we avoided arguments for the novel verb *brop* that might

Table 2. *Verb stems and past tense forms for the 16 regular and 14 irregular verbs on which the analyses were based*

Verb stem	Stem (unmarked) frequency COBUILD	Regular/ regularized past	Past tense frequency COBUILD	Irregular past	Past tense frequency COBUILD	Verb complement/ adjunct
Regular Verbs						
slam	2.2	slammed	3.6			the door
cross	4.5	crossed	5.1			the street
rush	4.1	rushed	4.4			to work
rob	3.3	robbed	3.1			a bank
drop	5.0	dropped	5.6			my brush
look	7.2	looked	7.5			at Susan
stir	3.3	stirred	4.0			the soup
soar	2.1	soared	2.5			over this
scowl	1.6	scowled	2.3			at Joe
tug	2.6	tugged	2.9			at it
flush	2.3	flushed	3.9			the toilet
mar	2.5	marred	2.1			their perfection
chop	2.5	chopped	3.7			some garlic
flap	2.6	flapped	2.6			my wings
stalk	2.6	stalked	2.7			a moose
scour	1.1	scoured	2.1			the pot
<i>M</i>	3.1		3.6			
<i>SD</i>	1.5		1.5			
Range	1.1–7.2		2.1–7.5			
Irregular Verbs						
make	7.6	maked	0.0	made	8.2	my lunch
give	7.0	gived	0.0	gave	7.2	to charity
think	8.0	thinked	0.0	thought	7.2	about you
stand	5.8	standed	0.0	stood	6.7	right here
keep	6.7	keeped	0.0	kept	6.6	my food
drive	5.3	drived	0.0	drove	5.0	a Ford
send	5.9	sended	0.0	sent	6.3	a letter
swim	4.0	swimmed	0.0	swam	3.5	a mile
dig	3.7	digged	0.0	dug	3.4	a hole
swing	4.2	swinged	0.0	swung	4.4	my bat
wring	1.6	wringed	0.0	wrung	2.3	my towel
bend	3.9	bended	1.1	bent	3.9	the spoon
bite	3.7	bited	0.0	bit	6.3	my tongue
feed	4.4	feeded	0.0	fed	5.0	the cat
<i>M</i>	5.2				5.4	
<i>SD</i>	1.8				1.8	
Range	1.6–8.0				2.3–8.2	

Note: Also shown are their COBUILD word frequencies (raw frequencies augmented by 1 and then natural log-transformed) and the complements/adjuncts used in sentences for their presentation to subjects.

Table 3. *Verb stems for the 12 novel regular and 14 novel irregular verbs on which the analyses were based*

Verb stem	Expected regularized past tense form	Example of plausible irregularized past tense form	Verb complement/adjunct
Novel Regulars			
spuff	spuffed		for TV
dotch	dotched		my car
stoff	stoffed		my room
cug	cugged		more furniture
trab	trabbed		the paper
crog	crogged		to John
vask	vasked		the ring
brop	broped		his jacket
satch	satched		to water
grush	grushed		near Eric
plam	plammed		my leg
scur	scurred		a bean
Novel Irregulars			
strink	strinked	strunk	a horse
frink	frinked	frunk	during dinner
strise	strised	strose	for them
crive	crived	crove	in France
shrell	shrelled	shrelt	with Chris
vurn	vurned	vurnt	to Boston
steeze	steezed	stoze	my watch
shrim	shrimmed	shram	at home
cleed	cleeded	clled	quite well
sheel	sheeled	shelt	among them
blide	blided	blid	with her
prend	prended	prent	the mouse
shreep	shreeped	shrept	my child
drite	drited	drote	the beach

Note: Also shown are the expected regularized and plausible irregularized past tense forms and the complements/adjuncts used in sentences for presentation to the subjects.

remind the subject of *drop*; thus, sentences like “Every day I *brop* a penny” were avoided. Fifth, we attempted to avoid word-initial alveolar stops [t] and [d] in the first word of each complement or adjunct in order to increase the chance of our identification of any word-final alveolar stops produced by the subjects. Of the 60 items, only 6 had a word-initial [t] or [d] in this postverb position. See Tables 2 and 3 for a full list of verbs, together with their complements or adjuncts.

Procedure

Subjects were tested individually. We first told each subject that she/he would see some sentences with missing words and asked her/him to tell us the word she/he thought fit best in the blank. The subject and the experimenter each had a printed version of the test. All unrelated control subjects and unaffected family members, as well as four of the affected family members, read the sentences out loud to themselves. The experimenter read the sentences out loud to the other three affected family members (KA, RO, VA), who had the printed sentences in front of them as well, because these subjects had trouble reading. The performance of each of these three family members, individually and as a group, was not different from that of the other affected family members. Therefore, it is unlikely that reading the stimuli yielded a different pattern of results than hearing the stimuli. All affected family members were given four practice items: *prame* (novel regular), *weep* (real irregular), *go* (real irregular), and *scrig* (novel irregular). All subjects received the same pseudo-randomized order of items. The item order was randomized by computer program (the routine “perm” from the UNIX-based package Unixstat; Perlman, 1986) and then gone over by hand to ensure that similar-sounding forms were not ordered too close to each other. During the testing of each subject, a native speaker of American English wrote down all responses. The entire session was audiotaped. A native speaker of Canadian English who was not present during testing transcribed the responses from tape. A native speaker of American English who was not present during testing coded each response based on the initial and tape-based transcriptions.

To disentangle articulatory and morphological deficits, we coded forms appended with an alveolar stop as being *-ed* suffixed. Thus, /*robt*/, with an unvoiced alveolar stop instead of the correct voiced form, was tabulated as a morphologically correct past tense form of *rob* even though it was phonologically inaccurate. Each response was assigned to one of several response types.

1. *Past-marked*: the expected past tense surface form of real verbs (*look–looked*, *dig–dug*) and the regularly inflected form of novel regular verbs (*plam–plammed*). Overregularizations (*dig–digged*) were not coded as past-marked. For novel irregular verbs, we coded as past-marked both regularized forms (*crive–crived*) and irregularizations (*crive–crove*; cf. *drive–drove*, *dive–dove*), all of which underwent a vowel change. We use the term “past-marked form” rather than “past tense form” to emphasize the distinction between the surface form, which we are coding, and the mechanisms underlying the production of those forms in normal adults, which we argue are abnormal in the affected family members.
2. *Overregularized*: *-ed* suffixed irregular stems (*dig–digged*).
3. *Alternatively marked*: an overtly marked form other than a past-marked or overregularized form of the prompted verb, including *-s* suffixed (e.g., *make–makes*), *-ing* suffixed (*soar–soaring*), or *-en* suffixed forms (*give–given*). The affected subjects produced a single instance of an irregular passive or perfect form which was not *-en* suffixed (*swum*). We did not code *swum* as alternatively marked because the form was also produced in the task by an unaffected

family member, suggesting that it may have been a dialectally acceptable past tense form.

4. *Unmarked*: the unmarked verb form (e.g., *look–look, dig–dig, plam–plam, crive–crive*).
5. *Conceptually plausible*: a response which we judged to be conceptually plausible in the sentence but not an inflectional variant of the prompted verb (e.g., *slam the door–banged; look at Susan–saw; send a letter – write*).
6. *Phonologically proximate*: a real word not conceptually plausible in the sentence context but phonologically similar to the prompted verb (e.g., *soar–score, flap–flip*).
7. *Unclear response*: an unclear response that could not be classified by the coders.
8. *No response*: no response to the prompt or subject responded with “no.”

RESULTS AND DISCUSSION

In this section, we describe individual subject analyses, in which each family member’s responses are compared to those of unrelated age-matched control subjects, and group analyses, in which the affected family member’s responses are compared to those of their unaffected relatives. We show that the two sets of analyses yield converging results with respect to the affected individuals’ impairments.

Individual subject analyses

Two methods were used to compare each family member’s response rates to those of a group of unrelated age-matched controls. First, it was determined whether each subject’s response rate of past-marked forms fell more than 1.5 interquartile ranges (1.5 times the distance between the 25th and 75th percentiles) below the 25th percentile score of the sample of his or her age-matched control subjects. This point, the “lower fence,” is commonly used as a cutoff, beyond which points are designated as outliers (Tukey, 1977). An analogous approach was used to determine whether each subject’s response rate of unmarked forms was an outlier above the “upper fence” – 1.5 interquartile ranges above the 75th percentile. The identification of outliers using this approach does not assume a normal distribution and therefore is quite robust.

Second, when the subject had the lowest (or highest) score for the group comprised of himself/herself and age-matched controls, the equation 1 divided by the sample size (including the subject and controls) was used to determine the probability of the person having fallen at that rank position by chance alone, assuming she/he came from the same parent distribution as the others. If this probability is sufficiently low, it questions the likelihood that the subject comes from the parent distribution. In general, for any rank position, an analogous probability was computed as the rank position of the subject’s response rate divided by the sample size (including the subject). This gave the probability of the subject being that extreme by chance alone. For example, with a total sample

Table 4. Percentages of the major response types given for each of the four verb classes in the past tense production task by each affected (aff.) and unaffected (unaff.) family member, their unrelated age-matched control groups, and three groups of family members (unaffected, SLI4, and SLI5)

	Child controls	ST aff.	Young controls	AN unaff.	MA unaff.	AW aff.	RO aff.	Middle controls	LA unaff.	PA aff.	JO aff.	VA aff.	Elderly controls	KA aff.	Fam. unaff.	SLI4 aff.	SLI5 aff.	
# of Subjects	6	1	40	1	1	1	1	8	1	1	1	1	10	1	3	4	5	
Sex		M		F	F	M	M		M	F	M	F		F				
Age (years)	9	10	21	16	20	19	20	48	57	41	43	48	74	77		39	35	
Regulars	e.g., <i>look</i>																	
Past-marked	<i>looked</i>	85 (65)	50	99 (97)	100	94	69	13	99 (100)	100	100	100	31	98 (88)	31	98	31	39
Unmarked	<i>look</i>	13 (23)	31	0 (0)	0	6	13	25	0 (0)	0	0	0	56	2 (13)	31	2	36	31
Alt. marked	<i>looks/looking</i>	1	6	0	0	0	0	0	n.a.	0	0	0	6	n.a.	0	0	3	2
Conc. plaus.	<i>see/saw</i>	1	0	0	0	0	0	13	n.a.	0	0	0	0	n.a.	19	0	8	6
Phon. prox.	<i>hook</i>	1	0	0	0	0	0	6	n.a.	0	0	0	0	n.a.	6	0	3	2
Unclear resp.		0	13	0	0	0	19	6	n.a.	0	0	0	6	n.a.	0	0	6	9
No response		0	0	0	0	0	0	38	n.a.	0	0	0	0	n.a.	13	0	13	10
Irregulars	e.g., <i>bite</i>																	
Past-marked	<i>bit</i>	56 (17)	7	96 (94)	93	86	36	64	95 (85)	100	79	93	0	97 (88)	21	93	23	26
Unmarked	<i>bite</i>	7 (55)	57	0 (0)	0	0	36	0	1 (0)	0	0	0	79	0 (0)	57	0	48	46
Over-regular	<i>bited</i>	26	0	0	0	0	21	0	n.a.	0	0	0	0	n.a.	0	0	0	4
Alt. marked	<i>bites/biting</i>	0	21	0	0	0	0	7	n.a.	0	0	0	0	n.a.	7	0	9	7
Over-irregular	<i>bote</i>	9	0	2	7	14	0	7	n.a.	0	14	7	7	n.a.	7	7	5	4
Conc. plaus.	<i>chew/chewed</i>	0	14	0	0	0	0	0	n.a.	0	0	0	7	n.a.	7	0	7	6
Unclear resp.		1	0	0	0	0	7	0	n.a.	0	7	0	7	n.a.	0	0	2	3
No response		0	0	0	0	0	0	21	n.a.	0	0	0	0	n.a.	0	0	5	4

size (including subject and controls) of 10, if the subject were second lowest, the probability would be .2 that the person was that extreme by chance alone.

The subjects were separated into four age groups (see Table 4). Family member ST (age 10 at the time of testing) was compared to six child control subjects with a mean age of 9 years ($SD = 1.7$ years); AN (age 16), AW (age 19), RO (age 20), and MA (age 20) were compared to forty young controls with a mean age of 21 ($SD = 3.2$); PA (age 41), JO (age 43), VA (age 48), and LA (age 57) were compared to eight middle controls with a mean age of 48 ($SD = 10.8$); KA (age 77) was compared to ten elderly controls with a mean age of 74 ($SD = 3.2$). All unrelated control subjects were native speakers of American or Canadian English. The control subjects' response rates were calculated from a superset of the verbs presented to the family members, including 18 real irregular, 20 real regular, and 20 novel regular verbs. This list of irregulars included two no-change verbs (*hit-hit*, *slit-slit*), whose past tense forms were counted as correct. Control subjects' responses for novel irregular verbs were not available, and so no comparison of the performance of individual family members and that of age-matched controls on novel irregulars is presented. However, group comparisons between affected and unaffected family members' performance on novel irregular verbs are reported here.

ST (10 years old) was previously identified as language-impaired and had been receiving treatment in a special school for language-impaired children from the age of 5. His novel regular items (*plam*) yielded no past-marked forms. This novel regular score of 0% correct was lower than his age-matched controls' lower fence of 65%, with a probability of $1/7 = .14$ that the score was due to chance alone. (See Table 4 for the production rates for all subjects.) His novel irregular items (*crive*) yielded no regularizations (*crived*) but 21% irregularizations (*crove*). He never overregularized (*dig-digged*). These data suggest that ST was unable to perform *-ed* suffixation.

A logistic regression (Wald $\chi^2 = 3.50$, two-tailed $p = .062$, standardized coefficient = 2.28)² revealed a borderline statistically significant positive association (as indicated by the standardized coefficient) between ST's production rate of regular past-marked forms (*look-looked*) and their word frequencies, holding stem frequency constant (i.e., partialing out stem frequency – the frequencies of unmarked forms). The result suggests that regular past-marked forms were retrieved from memory rather than being formed by the application of an *-ed* suffixation rule to the stem (*look + -ed* → *looked*). If past-marked forms are rule products, stem frequency should have a positive association with their production rate, whereas past tense frequency should account for no variance once stem frequency is held constant. If past-marked forms are retrieved from memory, their frequency should account for much of their production rate variance even when stem frequency is held constant. Thus, the presence of an association between past tense frequency and the production rate of regular past-marked forms, holding stem frequency constant, indicates that these regular forms were retrieved from memory. In contrast, the lack of any positive association at all between the production rate of regular past-marked forms and stem frequency, holding past tense frequency constant, strengthens the view that ST's past-

marked forms were not rule products; in fact, the association was not even positive (standardized coefficient = -1.62 , with Wald $\chi^2 = 1.90$, $p = .168$).

ST also had difficulty producing real regular and irregular past-marked forms (for regulars, 50% correct < controls' lower fence of 65%, with a probability of .14; for irregulars, 7% correct < 17% controls' lower fence, $p = .14$). Thus, in contrast to the single mechanism predictions made by Marchman (1993) and Hoeffner and McClelland (1993), ST was worse at producing irregular than regular past-marked forms. He uttered unmarked forms at an abnormally high rate for the two past tense types (for regulars, 31% > 23% controls' upper fence, $p = .14$; for irregulars, 57% > 55% controls' upper fence, $p = .14$). Interestingly, and in contrast, for novel regulars (*plam*), his production rate of unmarked forms was quite low (8%), well below his age-matched controls' upper fence of 55% (indeed, even below their mean of 18%) and less than his own production rate of unmarked forms for regulars and irregulars. Instead, for novel verbs he produced a number of real verb forms which were conceptually plausible in their sentence contexts (e.g., *plam* my leg-*broken*).

KA (77 years old), who was previously identified as language-impaired, had responses similar to those of ST. An absence of *-ed* suffixation was indicated by her lack of novel regular past-marked forms (0% < 63% lower fence, $p = .09$) and of overregularizations, despite her difficulties at inflecting irregulars (21% correct). For novel irregulars (*crive*), she produced no regularizations (*crived*), whereas 14% of her responses were irregularizations (*crove*). Though logistic regression revealed no statistically significant association between her production rate of regular past-marked forms and past tense frequency, holding stem frequency constant (Wald $\chi^2 = .76$, $p = .384$, standardized coefficient = $-.77$), neither was there a positive association with stem frequency, holding past tense frequency constant (Wald $\chi^2 = 0$, $p = .979$, standardized coefficient = $-.02$). This pair of nonsignificant results supports neither the retrieval nor rule production of her real regular past-marked forms. Like ST, and in contrast to the single system predictions of Marchman (1993) and Hoeffner and McClelland (1993), she was worse at producing past-marked forms of irregulars than of regulars. She produced both types of past-marked forms less successfully than did her control subjects (for regulars, 31% < 88% lower fence, $p = .09$; for irregulars, 21% < 88% lower fence, $p = .09$), instead producing an abnormally high number of unmarked forms (for regulars, 31% > 13% upper fence, $p = .09$; for irregulars, 57% > 0% upper fence, $p = .09$). She was also similar to ST in the comparatively low number of unmarked forms she produced for novel regulars – just above the upper fence of her controls (17% > 13%, $p = .09$) and substantially less than her production rate of unmarked forms for real regulars and irregulars. Like ST, for the novel verbs she produced real verb forms which were conceptually plausible in their sentence contexts.

VA (48 years old) was previously identified as language-impaired and had a response pattern similar to that of ST and KA. She produced only one novel regular past-marked form (8% < 75% lower fence, $p = .11$) and no overregularizations, despite her ample opportunity to overregularize because of her inability to produce any irregular past-marked forms. Her novel irregular items (*crive*)

yielded no regularizations (*crived*) and 7% irregularizations (*crove*). Her memorization of regular past-marked forms (*looked*) was indicated by the statistically significant positive association between her production rate of regular past-marked forms and past tense frequency, holding stem frequency constant (Wald $\chi^2 = 3.67$, $p = .055$, standardized coefficient = 3.30). Moreover, there was no positive association between her production rate of regular past-marked forms and stem frequency, holding past tense frequency constant (in fact, the association was borderline significantly negative: Wald $\chi^2 = 3.13$, $p = .077$, standardized coefficient = -2.75). Like ST and KA, she was impaired at producing regular (31% < 100% lower fence, $p = .11$) and irregular (0% < 85% lower fence, $p = .11$) past-marked forms (being much worse at producing irregulars), instead uttering unmarked forms at an abnormally high rate (for regulars, 56% > 0% upper fence, $p = .11$; for irregulars, 79% > 0% upper fence, $p = .11$). Unlike ST and KA, her production of unmarked forms for novel regulars was well above the upper fence of her control subjects (25% > 0%, $p = .11$), but like ST and KA, this rate was well below her production rate of unmarked forms for real regulars and irregulars.

RO (20 years old) was previously identified as language-impaired, and his performance was similar to the three affected subjects just discussed. He produced no past-marked forms for novel regulars (0% < 84% lower fence, $p = .02$) and no overregularizations, despite a relatively low success rate at inflecting irregulars (64%). Like VA, his novel irregulars (*crive*) yielded no regularizations (*crived*) and 7% irregularizations (*crove*). A logistic regression revealed no statistically significant association between regular past tense production and either past tense frequency, holding stem frequency constant (Wald $\chi^2 = 0$, $p = .945$, standardized coefficient = -.09), or stem frequency, holding past tense frequency constant (Wald $\chi^2 = .06$, $p = .8$, standardized coefficient = .32). These results are attributable to a lack of variance, given that RO produced only two regular past-marked forms. Like the other inflectionally impaired subjects described here, he had difficulty producing past-marked forms for regulars (13% < 100% lower fence, $p = .02$) and irregulars (64% < 94% lower fence, $p = .02$), instead uttering unmarked forms at an abnormally high rate for regulars (25% > 0% upper fence, $p = .02$) but not for irregulars (0% = 0% upper fence). He was the only affected family member whose higher performance on irregular rather than regular verbs is consistent with Marchman's (1993) and Hoeffner and McClelland's (1993) single system connectionist simulations. He produced no unmarked forms at all for the novel regulars; he gave no response for most novel verbs.

AW (19 years old), who was previously identified as language-impaired, produced only one past-marked form for novel regulars (8% < 84% lower fence, $p = .02$). Novel irregulars (*crive*) yielded one regularization (7%) and one irregularization (7%). He overregularized three times (21% of irregular items, which constituted 33% of his errors on irregular verbs). In fact, he was the only affected family member to overregularize at all.

This unexpected contrast between his production of overregularizations and his failure at producing novel regular past-marked forms may be attributable to

an explicitly learned strategy of adding an *-ed* ending to forms retrieved from memory. Two days after taking our test, when we asked him how he did so well, he explained with pride that in the special school he attended he had been taught that if you wanted to talk about something that happened today you added *-i-n-g*, but if it was in the past you had to add *-e-d*: “at school [I] learn it at school. In the past tense put *-e-d* on it. If it’s today it’s *-i-n-g*. Like swimming: ‘I went swimming today’ and ‘Yesterday I swammed’.” Indeed, he was the only subject to say that he used a strategy. None of the family members voluntarily stated that they had used a strategy. We also asked subject JO why he had performed so well, but he did not give a clear answer. The hypothesis that he pseudo-suffixed forms retrieved from memory is strengthened by the finding that for the irregular items he produced not only three overregularizations (*digged*, *wringed*, *keeped*), but also one doubly marked irregular form (*give-gaved*), as well as *swammed* in the example from his spontaneous speech. These data suggest that in past tense contexts AW added an *-ed* ending to whichever form he retrieved from the lexicon, and that, like the other inflectionally impaired family members, he retrieved past-marked as well as unmarked forms. Note that the irregular doubly inflected forms (*gaved*, *swammed*) may be better explained by such a strategy than by a standard morphological suffixation rule because normal overregularizing children only rarely produce such forms (Marcus et al., 1992). Consistent with AW having learned to add *-ed* endings, he produced more past-marked regular forms (*looked*)³ and fewer unmarked regular forms (*look*) than the four inflectionally impaired subjects, whereas for irregulars his past-marked and unmarked forms were near the mean of these four subjects (see the SLI4 column in Table 4). A phonetic analysis, presented later, suggested that AW’s overregularizations were formed in a manner consistent with an explicitly learned pseudo-suffixation strategy rather than with an implicitly learned morphological suffixation rule (see also Goad & Rebellati, 1994).

A logistic regression revealed no statistically significant association between past tense frequency and the production rate of past-marked forms for regulars (*look-looked*), holding stem frequency constant (Wald $\chi^2 = 0$, $p = .949$, standardized coefficient = $-.05$). Interestingly, a weak positive association was found between the production rate of past-marked regulars and stem frequency, holding past tense frequency constant (Wald $\chi^2 = 1.42$, $p = .233$, standardized coefficient = 1.18). This last result is consistent with AW having added *-ed* endings to unmarked forms, as stem frequency should predict the retrieval rate of unmarked forms. In contrast, for ST and VA, the other subjects with high standardized coefficients (absolute values greater than 1), there were negative associations between stem frequency and regular past-marked success – which is consistent with “frequency competition” between past-marked and unmarked forms.

In other respects, AW was similar to the other four overtly inflectionally impaired subjects. He was impaired at producing regular (69% < 100% lower fence, $p = .02$) and irregular (36% < 94% lower fence, $p = .02$) past-marked forms, was worse at irregulars than regulars, and uttered an abnormally high rate of unmarked forms instead (for regulars, 13% > 0% upper fence, $p = .02$; for irregulars, 36% > 0% upper fence, $p = .02$). He produced only one unmarked

form for novel regulars (8% > 0% upper fence, $p = .05$), a rate lower than his production rate of unmarked forms for real regulars and irregulars. Note that his failure to produce past-marked and unmarked forms for novel regulars, in comparison to his production of past-marked and unmarked forms for real verbs, is consistent with a strategy of adding an *-ed* ending to forms retrieved from memory.

PA (41 years old) was previously identified as language-impaired. A detailed phonetic analysis of her responses, presented later, revealed a deficit very similar to that of the other impaired family members. However, when her responses were coded in the same manner as all the other responses reported here (i.e., without paying close attention to phonetics), they seemed to suggest that she was relatively unimpaired. Her production rate for novel regular past-marked forms was above her controls' lower fence (83% > 75%), her regulars (100%) yielded no errors (thus precluding a logistic regression to test the predictiveness of past tense frequency on the production rate of regulars), and her irregular past-marked responses were just below her controls' lower fence (79% < 85%, $p = .11$). In addition, this coding did not reveal a single unmarked form for regulars, irregulars, or novel regulars. Unlike the other affected subjects, she produced many more regularizations (*crived*) than irregularizations (*crove*) for novel irregulars (36% vs. 7%). Intriguingly, this production rate of 7% for irregularization (*crove*) was about the same as that of the other affected subjects but much lower than that of the unaffected family members, suggesting that her superior performance at regularization and real verbs did not extend to an ability to generalize irregular past tense patterns. She produced no overregularizations, despite several errors on irregular verbs.

JO (43 years old) was similar to PA. Although he had previously been identified as language-impaired, his production rate for novel regulars was just at the controls' lower fence (75% = 75%, $p = .11$), he made no errors at regulars (100% correct), and his irregular past-marked production rate was actually above that of his age-matched controls' lower fence (93% > 85%). Like PA, he failed to produce a single unmarked form for regulars, irregulars, or novel regulars. He showed the same pattern on novel irregulars (*crive*) as PA, with 36% of the items yielding regularizations (*crived*) and only 7% yielding irregularizations (*crove*). A detailed phonetic analysis, presented later, revealed that his performance at producing regularizations of novel regular and novel irregular verbs (*plammed*, *crived*) was actually much poorer than indicated by the non-phonetic analyses. Like PA, he produced no overregularizations.

MA (20 years old) was never identified as affected by the familial disorder. As expected, her production rate for novel regulars was above that of her age-matched controls' lower fence (92% > 84%), although her production rate for real regulars (94% < 100% lower fence, $p = .02$) and irregulars (86% < 94% lower fence, $p = .05$) was slightly below. She produced no unmarked forms.

AN (16 years old) was never identified as affected by the familial disorder. Her past tense production performance was above that of her age-matched controls' lower fence for novel regulars (92% > 84%), she made no errors at regu-

lars (100% correct), and her production rate was just below the lower fence for irregulars (93% < 94%, $p = .29$), although this did not approach statistical significance. She produced no unmarked forms.

LA (57 years old) is related to the family by marriage only. As expected, his past tense production performance was above that of his age-matched controls' lower fence for novel regulars (92% > 75%), and he made no errors at either regulars (100%) or irregulars (100%). He produced no unmarked forms.

Group analyses

The individual subject analyses of nonphonetically coded responses suggest that five affected family members (ST, RO, VA, KA, AW) did not apply implicitly learned morphological *-ed* suffixation rules in the past tense production task; rather, at least two of them retrieved real regular past-marked forms from memory. Moreover, these five overtly inflectionally impaired subjects had difficulty producing real irregular as well as regular past-marked forms. In this section we report group analyses which strengthen these conclusions.

All analyses were performed over two groups composed of the five subjects who showed overt impairments in the past tense production task: (a) all five (hereafter referred to as SLI5: ST, RO, VA, KA, and AW), and (b) a subset of four of them (SLI4) from which AW was excluded to avoid possible confounds caused by his explicitly learned pseudo-suffixation strategy. The group of unaffected family members was composed of MA, AN, and LA. The two affected subjects (JO and PA) whose deficit in past tense production is revealed primarily by the phonetic analyses were excluded from these group analyses because their nonphonetically coded responses belie their impairment.

Failure to produce novel regular past-marked forms (plam–plammed). Novel regular past-marked forms were produced less successfully by the affected than the unaffected family members, as measured by independent measures t tests (SLI4: $t(5) = 38.03$, $p < .001$; SLI5: $t(6) = 33.99$, $p < .001$). (All t tests are reported as two-tailed unless otherwise indicated.) In fact, the inflectionally impaired subjects' past tense production rate for novel regulars (only 2 items correct out of the five subjects' 16 verbs each; i.e., out of 80 items) was not significantly different from zero, as measured by one-tailed t tests of whether the sample mean differed significantly from a population mean of zero (SLI4: $t(3) = 1.0$, $p = .782$; SLI5: $t(4) = 1.63$, $p = .356$). Note that, since only positive values could be obtained, this t test is biased in the direction of rejecting the hypothesis that the population mean is zero, thus lending added credence to the nonsignificant finding. In contrast, the three unaffected family members each produced 92% correct novel regular past-marked forms.

Failure to produce regularized past-marked forms of novel irregulars (crive–crived). The affected subjects also produced few regularizations of novel irregulars than the three unaffected control subjects, as measured by independent measures t tests (SLI4: $t(5) = 4.93$, $p = .004$; SLI5: $t(6) = 5.37$, $p = .002$). Moreover, their

rate of regularization (1/70: 1 item correct out of the five impaired subjects' 14 verbs each) was not significantly different from zero (SLI4: no regularizations at all; SLI5: $t(4) = 1.0, p = .748$), as measured by one-tailed t tests of whether the sample mean differed significantly from a population mean of zero. In contrast, the normal family members' production rate of regularizations for novel irregulars was statistically significantly greater than zero, $t(2) = 4.12, p = .054$.

The impaired subjects' difficulty at producing *-ed* suffixed forms for novel verbs cannot be fully explained by a difficulty in processing novel verb stems because, unlike their unaffected relatives, they produced irregularizations of novel irregulars (*crive-crove*) at a higher rate than novel regular past-marked forms (*plam-plammed*). This was revealed by a statistically significant interaction from a mixed between-subject (inflectionally impaired and unaffected groups) and within-subject (novel irregularizations and novel regulars) ANOVA (SLI4: $F(1, 5) = 48.82, p = .001$; SLI5: $F(1, 6) = 52.36, p < .001$). Follow-up paired t tests indicated that, while the impaired subjects produced several times as many irregularizations (SLI4: 12%; SLI5: 11%) as past-marked novel regulars (SLI4: 2%; SLI5: 3%) (SLI4: $t(3) = 2.17, p = .118$; SLI5: $t(4) = 1.87, p = .136$), the normal subjects reversed this pattern, with a paired t test revealing statistically significantly more novel regulars (*plammed*, 92%) than irregularizations of novel irregulars (*crove*, 38%), $t(2) = 6.18, p = .025$. Four of the five impaired subjects produced irregularizations of novel irregulars at the same or a higher rate as novel regulars. Note that their relative difficulty with novel regulars occurred despite the fact that there were more chances to produce novel regulars (*plam-plammed*) than irregularizations of novel irregulars (*crive-crove*), given that novel irregulars can also be regularized (*crive-crived*).

Similarly, the impaired subjects produced significantly more irregularizations (*crive-crove*) (SLI4: 11%; SLI5: 11%) than regularizations (*crive-crived*) (SLI4: 0%; SLI5: 1%) of novel irregulars, as revealed by paired t tests (SLI4: $t(3) = 3.66, p = .035$; SLI5: $t(4) = 2.75, p = .052$). In contrast, the normal subjects produced more regularizations (50%) than irregularizations (38%), although this difference was not significant, $t(4) = .58, p = .620$. The finding that the same verb stems yielded more irregularizations than regularizations for the affected subjects but not the unaffected subjects further argues against the possibility that regularizations of novel verbs were rare only because their stems were hard to process. Moreover, the impaired subjects' prolific production of conceptually appropriate real verb forms for the novel items is an additional indication that their failure to produce novel *-ed* suffixed forms is not attributable to an inability to understand the conceptual goal of the task.

In contrast to the affected subjects' inability to produce novel regulars (*plammed*) and regularizations of novel irregulars (*crived*), their production rate of novel irregularizations (*crive-crove*) was significantly different from zero, as measured by one-tailed t tests of whether the sample mean differed significantly from a population mean of zero (SLI4: $t(3) = 3.66, p = .035$; SLI5: $t(4) = 4.00, p = .016$). Thus, although the affected family members produced irregularizations at a lower rate than their unaffected relatives (SLI4: $t(5) = 3.10, p = .027$; SLI5: $t(6) = 3.63, p = .011$), they were indeed able to produce novel irregulariz-

ations, whereas the production rate of novel regularizations (*plammed*, *crived*) did not differ significantly from zero. As we will argue, an explicitly learned compensatory strategy might explain the affected subjects' production of even these few novel regularizations.

In an earlier study, Goad and Rebellati (1994) reported results from a detailed phonetic analysis of a plural elicitation task of real and novel nouns (This is a *card*. These are ____.; This is a *zooop*. These are ____.) given to the impaired family member VA. The analysis revealed that only 7% of the novel nouns yielded correct plurals (*zooop-zooops*), in contrast to 47% of the real nouns (*card-cards*).

Failure to overregularize. The lack of overregularizations among the affected subjects (none, apart from AW's apparently pseudo-suffixed forms) suggests a dysfunctional *-ed* suffixation rule. This view is strengthened by the low production rate of irregular past-marked forms (SLI4: 23%; SLI5: 26%), which provided the subjects with ample opportunity to overregularize. The lack of overregularizations demonstrates that the inability to suffix is not limited to novel verbs. Moreover, the impaired subjects' production of a large number of unmarked forms for irregulars (*dig-dig*) (SLI4: 48%; SLI5: 46%) indicates that, although unmarked forms were accessible, they remained unsuffixed. In contrast, other populations tend to overregularize upon failure to retrieve an irregular, indicating intact rule processing: normal children (Marcus et al., 1992; van der Lely & Ullman, 1996, submitted), patients with Alzheimer's disease (Ullman, in press; Ullman et al., 1993; Ullman, Corkin et al., 1997), and patients with posterior aphasia (Ullman et al., in press; Ullman, Corkin et al., 1997).

We reanalyzed the forms produced by eight affected family members (KA, VA, RO, AW, PA, JO, TO, and CA; at the date of testing, TO was a 10-year-old boy, and CA was a 43-year-old woman) in a past tense elicitation task of two irregulars (*is-was*, *go-went*), with *is* used as a main verb (task described in Gopnik & Crago, 1991). We found that, even though three subjects produced incorrect responses for *is* (38%) and four subjects produced incorrect responses for *go* (50%), there were no overregularizations (e.g., *be-be'd*, *is-is'd*, *am-am'd*, *go-goed*).

We reanalyzed the spontaneous speech initially reported by Gopnik (1994d). Out of a total of 238 irregular verbs produced in semantically past contexts by seven affected adult family members (KA, VA, RO, AW, PA, JO, and CA), of which 28% were not correct past-marked forms, there was only one overregularization – *flied*, produced by VA. Spontaneous speech from two affected children (ST, who was 8 years old at the time of testing, and TO, who was 11) yielded similar results. Of 67 irregular verbs in semantically past contexts, of which 39 (58%) were not correctly past-marked, ST produced a single overregularization (a doubly inflected form, *broked*). Similarly, of 54 irregular verbs, of which 26 (48%) were not correctly past-marked, TO produced only one overregularization (*eated*). In comparison, the three normal children reported by Marcus et al. (1992) had spontaneous speech overregularization rates of 13%, 16%, and 10%.

Frequency effects for regular past-marked forms (look-looked). We have seen that in the individual subject analyses, for two of the five overtly inflectionally impaired subjects (ST and VA), logistic regressions yielded a borderline significant positive association between production rates of regular past-marked forms (*looked*) and past tense frequency, holding stem frequency constant, whereas for the remaining three subjects (AW, RO, and KA) there was no such positive association. We explained the lack of a positive association for AW as being consistent with his use of an explicitly learned pseudo-suffixation strategy, while for RO it is attributable to a lack of variance, given that he produced only two past-marked forms for regular verbs.

It is not surprising that some subjects did not show a positive association. In the present study, the irregular verbs did not show consistent past tense frequency effects, even though studies of normal adults have revealed frequency effects for irregular past tense forms, suggesting retrieval from memory (Prasada et al., 1990; Stemberger & MacWhinney, 1988; Ullman, 1993, 1999). In analogous logistic regressions, two of the five overtly inflectionally impaired subjects showed no positive association between the production rate of irregular past-marked forms (*dug*) and past tense frequency, holding stem frequency constant. Thus, if irregular past-marked forms, which are very likely to be retrieved from memory, showed only inconsistent past tense frequency effects, the same inconsistent pattern might be expected for regular past-marked forms, even if they are also retrieved from memory.

The lack of consistent frequency effects for the impaired subjects' production of regular and irregular past-marked forms could be explained by the small verb sample size in our experiment (14 irregulars and 16 regulars for each subject).

Given that the individual subject analyses indicated that the five overtly inflectionally impaired subjects were relatively homogeneous with respect to all six response variables examined, it seemed justifiable to perform frequency analyses on the responses of the full group of impaired subjects. Indeed, a logistic regression revealed a borderline significant positive association between the production rate of regular past-marked forms and past tense frequency, holding stem frequency constant, for the SLI4 group (Wald $\chi^2 = 3.6$, $p = .058$, standardized coefficient = .84).⁴ Even the SLI5 group, which includes the pseudo-suffixing AW, showed a positive association, though only approaching significance (Wald $\chi^2 = 2.26$, $p = .133$, standardized coefficient = .54). In contrast, the judgment or production of regular past tense forms by normal children or adults has been found not to yield frequency effects once stem access is held constant (Prasada et al., 1990; Ullman, 1993, 1999; van der Lely & Ullman, submitted). This contrast suggests that the impaired subjects' past-marked regulars (*looked*) were retrieved from memory rather than being rule products like those of normal children and adults. Crucially, this in turn suggests that unimpaired individuals, but not the impaired family members, compute regular past tense forms by applying an *-ed* suffixation rule to verb stems. Interestingly, four studies of children with SLI also reported frequency effects for regular items – three on past tense production tasks (Marchman & Weismer, 1994; Oetting & Horohov, 1997; van der Lely & Ullman, submitted) and one with plural production (Oet-

ting & Rice, 1993) – suggesting that the findings may extend to other SLI sub-groups.

In addition, if the regular past-marked forms were rule products, their rate of production should be positively associated with their stem frequencies, even with their past tense frequencies held constant. However, no such positive association was revealed by logistic regressions for either the SLI4 (Wald $\chi^2 = 2.58$, $p = .108$, standardized coefficient = $-.69$) or the SLI5 (Wald $\chi^2 = .95$, $p = .329$, standardized coefficient = $-.35$) group.

Impaired production of real regular and irregular past-marked forms. In the unlikely event that the affected individuals' impairment were limited exclusively to the use of morphological suffixation rules and involved no other rules of grammar, the subjects' production of real regular and irregular past-marked forms would be expected to be intact because both are predicted to be retrieved from memory. However, we found that the individual impaired subjects' production rates of regular and irregular past-marked forms were significantly lower than those of each subject's age-matched controls. This impairment also emerged in the group analyses. The impaired subjects were less successful than their unaffected relatives at producing correctly past-marked forms, as measured by independent measures t tests for regulars (SLI4: $t(5) = 7.34$, $p = .001$; SLI5: $t(6) = 4.62$, $p = .004$) and for irregulars (SLI4: $t(5) = 4.04$, $p = .010$; SLI5: $t(6) = 4.35$, $p = .005$). Moreover, the impaired subjects were somewhat less impaired at producing irregular (SLI4: 23%; SLI5: 26%) than regular (SLI4: 31%; SLI5: 39%) past-marked forms, which contrasts with the single mechanism predictions made by Marchman (1993) and Hoeffner and McClelland (1993).

Five other studies provide additional evidence for an impairment in the affected family members' production of real inflected forms. First, Gopnik and Crago (1991) and Gopnik (1994d) reported results from elicitation tasks of forms in past tense (four verbs), progressive (two verbs), third person singular present tense (two verbs), and future (two verbs) obligatory contexts given to eight affected (KA, VA, RO, AW, PA, JO, TO, and CA) and six unaffected family members (MA, PT, JA, SH, AN, and BO). They found that, while 92% of the items elicited correct responses from the unaffected family members, only 38% of the items elicited correct responses from the affected members. Second, affected family member VA produced only 47% correct plurals for real nouns (*card-cards*) in Goad and Rebellati's (1994) plural elicitation task. Third, out of a total of 294 verbs (238 irregulars and 56 regulars) produced in semantically past contexts by seven affected family members (KA, VA, RO, AW, PA, JO, and CA) (see Gopnik, 1994d), only 69% were correct past-marked forms (72% of the irregulars, 57% of the regulars). In contrast, 100% of the 18 regulars and 96% of the 77 irregulars produced in semantically past contexts in spontaneous speech by five normal family members (AN, PT, JA, SH, and MA) were correctly past-marked. Fourth, we reanalyzed the verb forms written by two affected family members (CH was 12 years old at the time, and TO was 10 years old) in school notebooks in obligatory past tense contexts (see Gopnik & Crago, 1991). Only 60% of the regular and 89% of the irregular verb form tokens were

past-marked. Fifth, Vargha-Khadem et al. (1995) reported that affected family members made significantly more errors than their unaffected relatives at the elicited production of real regular and irregular past tense forms.

Summary

Several lines of evidence presented here suggest that affected family members do not have intact suffixation rules. First, they are unable to produce *-ed* suffixed novel verbs (*plam–plammed*, *crive–crived*) or plural-marked nouns (*zoop–zoops*), whereas they are relatively spared at producing novel irregularizations (*crive–crove*). Second, they do not overregularize (*dig–digged*) when they fail to produce irregular past-marked forms. Third, their success at producing regular past-marked forms (*looked*) correlates with past tense frequency, holding stem frequency constant, but not with stem frequency, holding past tense frequency constant. The contrast between this result and a lack of such past tense frequency effects in normal controls indicates that, whereas the affected subjects retrieve regular past-marked forms (*looked*) from memory, unaffected subjects construct past tense forms by the application of an *-ed* suffixation rule. Finally, the impairment appears to extend beyond the use of morphological suffixation rules, as affected family members have difficulty producing the stored regular and irregular past-marked forms. This may indicate that the grammatical impairment extends beyond morphology to syntax.

PREVIOUS EXPLANATIONS

In this section, we examine several hypotheses that have been proposed to account for the behavioral impairments associated with SLI. We argue that none of these hypotheses can adequately explain the data presented here.

Articulatory or phonological deficit

As discussed earlier, two studies have reported motor deficits, including articulatory impairments, among the affected family members (Hurst et al., 1990; Vargha-Khadem et al., 1995). Such deficits could lead to difficulties in performing the motor sequencing presumably involved in the production of the final consonant clusters found in many inflected forms (*looked*, *stalked*, *kept*, *crept*). Because many *-ed* final consonant clusters may be difficult to articulate, perhaps leading to the production of unmarked forms (*look*, *stalk*), an articulatory deficit might resemble a dysfunction of an *-ed* suffixation rule. Indeed, in the past tense production task, all five overtly inflectionally impaired subjects produced an abnormally large number of unmarked forms for the regular verbs. In fact, for regular verbs, the SLI4 mean production rate was higher for unmarked (36%) than for correctly past-marked (31%) forms (see Table 4). However, several lines of evidence suggest that an articulatory deficit cannot fully account for the

impairments in inflectional morphology discussed earlier (see Gopnik, 1994a, for additional discussion on the articulatory deficit).

First, it is not clear how an articulatory deficit could explain the five overtly inflectionally impaired subjects' striking failure at producing irregular past-marked forms, compared to age-matched and unaffected family control subjects, given that only 3 of the 14 correct past tense forms of the irregular items (*bent*, *sent*, *kept*) had final consonant clusters containing more than one consonant. Past-marked forms of irregulars were not produced more successfully than those of regulars; in fact, they were produced nonsignificantly less successfully (SLI4: $t(3) = .39$, $p = .719$; SLI5: $t(4) = .78$, $p = .479$), despite the fact that the codas of all 16 regular past tense forms contained clusters of two consonants.

Second, while an articulatory deficit might result in the truncation of regular past-marked forms (*looked*) to their corresponding unmarked forms (*look*), it is not obvious how such a deficit could result in the truncation of irregulars (*kept*) to their unmarked forms (*keep*), given that most irregular past tense forms (including the 14 in our task) do not phonologically contain their stems. Yet the impaired family members produced unmarked forms of irregulars (*keep*) more often than did their age-matched control subjects and their unaffected family control subjects (SLI4: $t(5) = 2.58$, $p = .042$; SLI5: $t(6) = 2.51$, $p = .061$).

Third, the predicted analogous errors for irregulars, in which complex consonant clusters would be reduced by one or more phonemes, were not found. Neither our initial coding nor the phonetic analysis revealed any responses like *keep-kep* or *stand-stan/sand/tand/tan*.

Fourth, an articulatory deficit resulting in the reduction of real regular past-marked forms (*looked*) to unmarked forms (*look*) should cause a similar reduction for novel regulars (*planned* to *plam*). Yet the impaired subjects produced very few unmarked forms for novel regulars, despite their failure to produce the correct past-marked forms. Their rate of producing these unmarked forms (only 7 unmarked forms out of 80 items – i.e., out of the 5 overtly inflectionally impaired subjects' 16 novel regulars each) was not statistically significantly different from zero (SLI4: $t(3) = 2.30$, $p = .210$; SLI5: $t(4) = 2.67$, $p = .108$), as measured by one-tailed t tests of whether the sample mean differed significantly from a population mean of zero. Because only positive values could be obtained, this test is biased in the direction of rejecting the hypothesis that the population mean is zero, further strengthening the hypothesis that the subjects fail to produce unmarked forms of novel regulars. They produced statistically significantly more unmarked forms for real than novel regulars (SLI4: $t(3) = 6.60$, $p = .007$; SLI5: $t(4) = 4.30$, $p = .013$) and for real irregulars than for novel regulars (SLI4: $t(3) = 2.92$, $p = .062$; SLI5: $t(4) = 3.55$, $p = .024$).

Fifth, it is not clear how an articulatory deficit might lead to frequency effects for regular past-marked forms, which are not found for normal children and adults.

Sixth, the lack of correct forms in semantically past contexts in the notebook writing of two language-impaired family members and the tendency to write many unmarked forms instead cannot easily be explained by an articulatory deficit.

Seventh, Gopnik (1994d) found that unmarked forms of real regulars and irregulars were given significantly higher acceptability ratings by affected than unaffected family members. It is not clear how an articulatory deficit alone could yield this result.

Several of these arguments also indicate that the impaired subjects' observed past tense production pattern could not be fully explained by a phonological impairment. Fee (1995) reported that affected members of the KE family commonly uttered forms with word-final consonant cluster reductions (e.g., *clothes* → /koz/) or consonant deletions (e.g., *coat* → /ko/). Such phonological processes might lead to the production of unmarked regular forms (e.g., *look*, *play*) in past tense contexts. However, these processes would not lead to the production of unmarked irregulars (*keep*), nor would they explain the observed absence of unmarked novel verb forms (*crive*, *plam*). It is also not clear how a phonological impairment could explain the frequency effects found for regular past-marked forms. Thus, a phonological impairment does not fully account for the observed pattern of errors in the past tense production task.

Perceptual processing deficit

Evidence suggests that many people with SLI have a deficit in processing linguistic and nonlinguistic stimuli of brief duration (Tallal & Piercy, 1973; Tallal, Stark, Kallman, & Mellitas, 1980; Tallal et al., 1985). Such a deficit could lead to difficulty in learning and computing inflectional morphology (Leonard, 1989, 1998; Leonard, McGregor, & Allen, 1992). Because inflectional morphemes such as *-ed* are not prominent, including the fact that they are usually unstressed and of short duration, particularly in comparison to the verb stems to which they are attached, they may have a lower likelihood of being perceived than the stem. This might hinder not only the learning of the rule, but also the construction of inflectional paradigms (mappings from a word root to its inflected forms) (Carstairs, 1987; Pinker, 1984) for any stored inflected forms that may be difficult to perceive in their entirety (e.g., *looked*, *kept*). In contrast, fully stressed inflected forms, including many irregular past tense forms (*bit*, *dug*), should be more easily perceived, and thus their mappings should be formed more successfully than those of regulars (Leonard, 1998).

This explanation can account for the impaired family members' failure to learn not only the morphological suffixation rules, but also the mappings between regular verbs (*look*) and their stored past tense form (*looked*). However, the finding that irregular past-marked forms were not produced more successfully than regular past-marked forms does not appear to be consistent with a perceptual processing deficit, particularly in light of the fact that only 3 of the 14 correct irregular past tense forms in our task had the added perceptual difficulty of having a final consonant cluster with more than one consonant (*bent*, *sent*, *kept*). Moreover, it is not clear how the perceptual processing account can explain the affected family members' high rate of production of unmarked forms for real irregulars whose past tenses have single final consonants (*dig*–*dug*); the high acceptability ratings given to these unmarked forms in obligatory past

tense contexts (Gopnik, 1994d); or the affected family members' lack of phonologically reduced forms such as *keep-kep* in the past tense production task. (See Gopnik, 1994b, for additional discussion on the perceptual processing deficit.)

Impairment in a single mechanism system modeled by a connectionist network

As discussed earlier, two studies investigated the effects of impairments on single system connectionist models' learning and computation of regular and irregular past tense forms. Marchman (1993) lesioned a connectionist network by randomly eliminating hidden units, whereas Hoeffner and McClelland (1993) tested the perceptual processing deficit hypothesis (Tallal et al., 1985; Leonard, McGregor et al., 1992) by presenting "weakened" items to a connectionist network. Both sets of simulations yielded worse performance in learning and computing regular than irregular past tense forms. In contrast, the affected family members showed the opposite pattern, being more impaired at producing irregular than regular past tense forms, despite the fact that the past tense COBUILD word frequencies were higher for the irregular than regular items. Moreover, both studies reported that the impaired networks were strikingly less accurate than the normal networks at computing regular past tense forms, whereas the computation of irregulars was relatively impervious to the impairment. However, the impaired family members made many errors in producing past tense forms of both verb types. Marchman (1993) reported that networks lesioned "prenatally" yielded between 40% and 70% suffixed forms for novel verbs. We found that the impaired family members' production of novel regulars (*plam-plammed*) was not significantly different from zero. Finally, it is not clear how single system models could account for the frequency effects we observed among the affected family members for regular past-marked forms, given that frequency effects have been found for irregular but not regular past tense forms among normal children (van der Lely & Ullman, submitted) and adults (Prasada et al., 1990; Ullman, 1993, 1999).

Extended optional infinitive hypothesis

Rice, Wexler, and Cleave (1995) proposed the extended optional infinitive hypothesis, which claims that there is a stage in the development of young normal children in which they do not obligatorily mark tense in main clauses but nevertheless know the grammatical properties of finiteness, including that finite verbs must show agreement and tense. "[T]he predictions of the Optional Infinitive stage will hold for children with SLI, with the further stipulation that this stage will be extended or prolonged for a greater period of time for these children. We do not know, in fact, if individuals with SLI will ever fully leave this stage. Thus, we predict an Extended Optional Infinitive stage" (pp. 852–853).

SLI children and adults whose inflectional morphology is explained by this account should produce both nonfinite and correct finite forms but no incorrect finite forms. Because nonfinite forms in English appear as bare stems, the account predicts that in past tense contexts only past tense forms and bare stems

should be produced. Thus the account correctly predicts the observed impaired family members' production of unmarked as well as past-marked forms for real regulars and irregulars.

However, it is not clear how the hypothesis accounts for four lines of data. First, given that in the optional infinitive stage only bare stem and correct finite forms should be produced, it is not obvious why the affected subjects should have produced alternatively inflected forms (e.g., *look-looks/looking*) in our past tense production task, in Gopnik and Crago's (1991) elicited production task, and in nonelicited speech (Gopnik, 1994d) and writing (Gopnik & Crago, 1991) in semantically past contexts.

Second, if the grammar selects for unmarked and past-marked forms, is it not surprising that there was a failure to produce both types of forms for novel verbs? The absence of unmarked forms is especially surprising, given that these forms were presented in each stem sentence and thus should have been available to the subject. In fact, the novel regular verbs (*plam*) resulted in more conceptually plausible real verb forms (*scur a bean-eat*) than suffixed or unmarked novel regulars. For the SLI4 group, 27% of the novel regular items yielded conceptually plausible unrelated forms, whereas only 2% yielded past-marked and 13% unmarked forms (see Table 4). This result is better explained by the retrieval of forms from memory as a function of their conceptual appropriateness than by a grammar allowing only past tense and nonfinite forms.

Third, we will present evidence suggesting that selection of forms produced in obligatory past tense contexts is a function of the forms' relative frequency. The more frequent a past-marked form (*looked*) relative to its corresponding unmarked (*look*) or alternatively marked (*looks/looking*) forms, the greater its likelihood of being selected and produced. It is unclear how the extended optional infinitive account might explain these results.

Fourth, it is not clear how the hypothesis explains Goad and Rebellati's (1994) finding that impaired family members also had difficulty producing plural forms.

Other explanations: Task specificity and temporality

The impairment is not task specific. The affected family members showed impairments not only in the elicited production of past tense and plural forms, but also in the production of regular and irregular past tense forms in nonelicited speech and writing contexts and in the judgment of forms in past tense contexts (Gopnik, 1994d).

The impaired subjects' performance in past tense contexts might be explained as a conceptual difficulty in understanding the notion of temporality. However, this would not explain their deficits in pluralization (Goad & Rebellati, 1994). In addition, independent evidence suggests that they do understand temporality. We have observed that in spontaneous speech, while they often produced the unmarked form of the verb instead of the past-marked form in temporally past contexts, they did not make similar errors in their use of temporal adverbs.

A THREE-LEVEL EXPLANATION

Each of the explanations just discussed seems to be motivated by an attempt to account for the data at a single level, such that a hypothesized deficit leads directly to the observed errors. Thus, the dearth of *-ed* suffixed forms in the speech of people with SLI has been explained by a difficulty at pronouncing or learning the *-ed* suffix or at learning to mark tense. However, it is logically possible that an impairment of a given system, *A*, leads to the reliance on a relatively intact system, *B*, whose mechanisms might in turn explain the impaired subjects' performance. Indeed, this may not be unlikely in developmental disorders, in which system *A* would not be relied on if it did not develop normally. We propose that such an explanation best accounts for the behavior of the affected family members in contexts requiring inflection in the normal adult grammar.

Specifically, we suggest the following three-level explanation of the affected family members' performance. First, they have a deficit which affects the grammar underlying inflectional morphology as well as other grammatical functions. This would explain their inability to produce new *-ed* suffixed forms. A dysfunction of the frontal/basal-ganglia procedural memory system may explain this grammatical deficit as well as their motor deficits. Second, in the absence of an intact grammar, they rely on a relatively intact conceptual system in contexts normally requiring inflection. They select forms from the lexicon on the basis of the forms' conceptual appropriateness and accessibility ("conceptual selection"). This functionality may depend on the declarative memory system. We are also open to the possibility that the impaired subjects may also learn to depend upon statistical patterns of surface word order, but this idea is not explored in the present article. Third, some of the affected subjects have explicitly learned a compensatory strategy of adding an *-ed* ending to these conceptually selected forms. Declarative memory may also underlie the explicit learning of this strategy.

A GRAMMATICAL DEFICIT

To explain the impaired subjects' suffixation deficit and their difficulties at producing the stored regular and irregular past-marked forms, we propose that the grammar underlying inflection is dysfunctional in comparison to the normal adult grammar. We argue that the data are consistent with two types of grammatical deficits, which are proposed as valid alternatives. In neither case do we claim that the deficit is domain-specific. In particular, we suggest that the observed language difficulties may be a linguistic manifestation of abnormalities to frontal/basal-ganglia circuitry.

Rule deficit hypothesis

According to the rule deficit hypothesis, the affected family members are afflicted with a dysfunction of the learning, representation, and/or processing of grammatical rules, including morphological suffixation rules. This can explain

not only their inability to suffix new forms (*plammed*, *crived*, *digged*), but also their tendency to memorize regular as well as irregular forms (*looked*, *dug*). Such a dysfunction may also lead to syntactic processing difficulties that could account for the affected subjects' impairments at computing appropriately marked real irregular and regular forms in sentence contexts. Indeed, we expect that a grammatical rule deficit would also impair syntactic rules. Therefore syntactic processing, including the processing of tense, should be affected.

This hypothesized rule deficit may be rooted in abnormalities of frontal/basal-ganglia circuitry. We would therefore expect impairments of other functions which are normally dependent on this circuitry. This could explain the affected family members' motor programming difficulties (Hurst et al., 1990; Vargha-Khadem et al., 1995) and their particular difficulties with sequential movements (Hurst et al., 1990; see also Figure 3 in Vargha-Khadem et al., 1995). In contrast, the relative sparing of lexical memory may be explained by a relative sparing of the declarative memory system (see Ullman, in press; Ullman, Corkin et al., 1997).

Although the rule deficit hypothesis appears to explain most of our data, it is not clear why the affected subjects were worse than their unaffected relatives at producing novel irregularizations (*crive*–*crove*) and why they failed to produce novel regularizations (*plam*–*plammed*, *crive*–*crived*) and overregularizations (*dig*–*digged*). Both single system and dual system models posit the existence of an associative memory which contains stem-past mappings and underlies generalizations of stem-past patterns to novel past tense forms. Single system models assume that such an associative memory underlies the representation and computation of all real and novel regular and irregular past tense forms (Plunkett & Marchman, 1993; Rumelhart et al., 1986). Dual system models propose that an associative memory subserves the computation of existing and novel irregulars (Pinker, 1991; Prasada & Pinker, 1993; Ullman, 1993, 1999) as well as certain regulars (Ullman, 1993, in press). If the affected family members' language impairment were limited to rule use, it is not clear why they would not generalize from the stored irregular and regular forms to new irregularizations (*crive*–*crove*) and regularizations (*plam*–*plammed*, *crive*–*crived*, *dig*–*digged*). We consider three mutually compatible explanations for the dearth of such generalizations.

First, the affected subjects might have had difficulty carrying out the task with novel verbs stems. However, this does not fully account for the observed lack of productivity. As we will argue, the affected family members understood the task conceptually: they produced conceptually plausible forms in the novel verb sentence contexts (e.g., *crive* in France–*went to*). More importantly, they failed to produce overregularizations, whose stems are not novel.

Second, the associative memory component may not be very productive in either normal or affected individuals. Indeed, studies examining irregularizations of real and novel verbs by normal adults and children have found much less productivity of irregular stem-past patterns than of the regular pattern (Bybee & Moder, 1983; Marcus et al., 1992; Prasada & Pinker, 1993; van der Lely & Ullman, 1996, submitted; Xu & Pinker, 1995). Although this contrast could be explained by the smaller number of irregular than regular verbs following a

given stem-past pattern, it is also consistent with a dual system model in which regulars are generated by the productive application of a rule, whereas irregulars are stored in a memory system that leads to minimal productivity of stem-past patterns. Such a lack of productivity could largely explain the affected subjects' scarcity of new past tense forms, especially in conjunction with any additional difficulties.

Third, the underlying impairment might affect linguistic functions other than rules. In particular, evidence suggests that frontal/basal-ganglia circuitry may underlie the "look-up" (i.e., search or retrieval) of lexical forms, while being less important in tasks such as word recognition, which minimize the need for these functions (Buckner & Tulving, 1995; Dubois, Boller, Pillon, & Agid, 1991; Goodglass, 1993; Kosslyn, 1994; Shimamura, 1995). If this circuitry were abnormal in the affected family members, then tasks that minimize the need to look-up past-marked forms should reduce or eliminate any differences in performance between affected and unaffected family members. Indeed, Gopnik (1994d) reported that affected and unaffected family members did not differ significantly on their acceptability ratings of real past tense forms. Look-up difficulties could not only help explain our finding that the affected subjects had trouble producing existing regular and irregular past tense forms, but also account for their problems in producing novel forms, if the computation of those forms were dependent on the look-up of existing ones (i.e., if the production of *crive*–*crove* required accessing similar stem-past pairs such as *drive*–*drove* or *dive*–*dove*). Indeed, we will argue that the look-up, however impaired, of similar sounding real stem-past pairs could account for the subjects' superior performance at producing novel irregularizations (*crove*) compared to novel regularizations (*crived*, *plammed*).

Paradigm formation deficit hypothesis

An alternative hypothesis posits a deficit in paradigm formation. Normal children must learn the grammatical mapping between verb and past tense form for irregulars as well as the mapping from verb to the suffixation transformation for regulars. Indeed, according to the paradigm formation model (Carstairs, 1987; Pinker, 1984; see also Spencer, 1991), inflecting words (typically nouns, verbs, and adjectives) are associated with a matrix or "paradigm" of their grammatically modified forms (e.g., for verbs, first person singular present, first person plural present, first person singular past, and so on). These are specified either as individual lexical items, for irregulars, or as affixes, for the application of a rule. The paradigm formation deficit hypothesis posits that these grammatical mappings between words and their paradigm entries are not properly learned, represented, or computed by the affected family members.

According to this view, the use of all inflected forms should be impaired. Morphological suffixation would be dysfunctional because the mapping between verb and *-ed* is dysfunctional. This can explain the affected family members' lack of novel regularizations (*plammed*, *crived*) or overregularizations (*digged*). Moreover, there should be deficits in the learning, representation, or computation of the stem-past mappings of stored real regular and irregular verbs, which

could account for the affected subjects' difficulties in producing real regular and irregular past-marked forms. Note, however, that a stem-past mapping deficit should not preclude the learning of past-marked and other inflectionally marked forms as lexical items without their inflectional relations.

One intriguing possibility is that the affected subjects suffer from a general impairment in their implicit learning of mappings between inputs and outputs in the learning of functions. On this view, one manifestation of this disorder is an inability to learn mappings between words and their inflections in paradigm formation. Such a general implicit mapping deficit might be explained by a dysfunction of frontal/basal-ganglia circuitry. For example, Knowlton, Mangels, and Squire (1996) reported that patients with Parkinson's disease, who suffer from degeneration in frontal/basal-ganglia structures, failed to learn the mappings between two sets of visually presented items which were probabilistically associated in their presentation to the subjects. The patients' failure to learn these mappings contrasted with their intact memory for specific details of the training episodes, suggesting spared declarative memory. This dichotomy may parallel the language dichotomy shown by the affected family members. Their morphological deficits may be attributed to impairments at learning mappings in the formation of morphological paradigms, whereas we argue that they are able to remember the individual lexical items from which those mappings would normally be abstracted.

CONCEPTUAL SELECTION

We hypothesize that, given the affected subjects' dysfunctional grammar, they resort to a coherent system of producing forms in inflectional contexts by relying on their conceptual system. The conceptual selection hypothesis – which assumes the existence of a conceptual system autonomous from, but linked to, grammar (e.g., Jackendoff, 1990) – posits that in inflectional contexts affected family members select word forms as a function of the appropriateness and accessibility of their associated conceptual representations. The appropriateness of such a representation is hypothesized to be a function of its similarity to a concept that is formed on-line during sentence production and comprehension and is associated with the position where the inflected form is normally inserted. The conceptual representation's accessibility in a given sentence context is hypothesized to increase with the frequency with which its associated word form occurs in sentence contexts whose on-line concepts are similar to the current one; accessibility may also be a function of priming, such that recently heard word forms are more accessible.

We do not take a strong position as to whether the mechanisms of conceptual selection also exist in normal adults. However, we suggest that young normal children rely on conceptual selection in inflectional contexts. If this is indeed correct, it would not be surprising if a system that is useful to children remains active in adults, although limited to noninflectional contexts. We speculate that, while normal adults do not rely on conceptual selection in inflectional contexts, depending instead on a distinct grammatical system, it is plausible that they invoke conceptual selection for other functions, such as object naming. Accord-

ing to this view, in naming the object *butte* we may select the form *mountain* because the latter is more accessible, being a more frequent word referring to a similar concept.

We assume a prototype model of concepts (e.g., Rosch, 1978) in which the probability of selection of a given exemplar of a concept increases with its similarity to the prototype of the concept. Thus, the more similar a concept associated with a word form is to the on-line concept, the more likely it is that the word form will be selected. Note that evidence suggests that complex concepts formed on-line have the same graded qualities as stored concepts (Kahneman & Miller, 1986).

Although the conceptual selection hypothesis is not wedded to any particular model of similarity, in this article we assume Tversky's (1977) feature-based contrast model. In this model, the similarity between two objects increases with the number of features they have in common and decreases with the number of features unique to one or the other object. Two objects can therefore be similar (positive similarity) or dissimilar (negative similarity). Thus, similarity is hypothesized to increase with the number of features shared between an exemplar and a prototype and to decrease with the number of features unique to one or the other. We hypothesize that, for the affected family members, all verb forms are associated with conceptual representations whose features reflect the contexts in which those forms are encountered. These features are hypothesized to describe not only the event or action associated with the verb (e.g., "looking," "digging"), but also other conceptual features associated with the conceptual context in which the form was used, including temporality (e.g., pastness), person/number, and aspect (e.g., completive). Consistent with the contrast model, we assume that features have different degrees of salience in different contexts, and that, consistent with probabilistic feature models of concepts, "the features that represent a concept are salient ones that have a substantial probability of occurring in instances of the concept" (Smith & Medin, 1981, p. 62).

Produced forms were conceptually plausible

We argue that all forms produced in the past tense production task for real regular and irregular verbs were either selected because of their conceptual plausibility or were performance errors. At least 78% of the SLI4 group's regulars (78% for SLI5) and 87% of their irregulars (89% for SLI5) were conceptually plausible. As a percentage of actual responses (excluding the items eliciting no response), this corresponds to 91% of regulars (88% for SLI5) and 92% of irregulars (93% for SLI5).

Past-marked forms (look–looked, dig–dug). Regular past-marked forms (31% of SLI4 items; 39% of SLI5) and irregular past-marked forms (23% for SLI4; 26% for SLI5) were clearly highly conceptually appropriate in the promoted contexts. In addition, 5% of the SLI4 group's irregular items (4% for SLI5) yielded overregularizations, which were found for three items: *swim–swum*, *swing–swang*, *wring–wrang*. Each of these forms is a plausible dialectal past tense variation because all were also produced by at least one unaffected family

member. Thus, as many as 28% of irregular items (SLI4; 30% for SLI5) were past-marked forms. (We remain agnostic as to whether all past-marked forms were selected by conceptual selection or whether some percentage were computed by a partially intact grammatical system.)

Two factors should contribute to the conceptual appropriateness of real past-marked forms in the context of the task sentences. First, they are associated with the same conceptual event or state (e.g., “looking”) as that of the prompted verbs in the sentence (e.g., *look*), and thus their associated concepts should have *m* features matching those of the on-line concept hypothesized to be formed. Second, we expect there to be a match of *n* features of temporality. Past-marked forms should be strongly associated with conceptual of past temporality, given that they are normally heard in semantically past contexts, and thus should match the past temporality of the task sentences. Because past-marked forms occur in both completive and noncompletive contexts, features of aspect may or may not be represented.

Unmarked forms (look–look, dig–dig). Unlike the unaffected family members, the inflectionally impaired subjects produced unmarked forms in abundance, both for regulars (36% of SLI4 items; 31% of SLI5) and irregulars (48% of SLI4; 46% of SLI5). Like past-marked forms, unmarked forms describe the same event or state (e.g., “looking”) as the prompted verb and hence should have *m* features matching those of the on-line concept. Unlike past-marked forms, unmarked forms may remain undifferentiated with respect to temporality and aspect, because they are found in a variety of temporal and aspectual contexts (e.g., for temporality, in past [I didn’t *look* at it] and future [I will *look* at it] contexts). Thus, unmarked forms may have *n* mismatched features of temporality and *p* mismatched features of aspect.

Alternatively marked forms (look–looks/looking, dig–digs/digging, give–gives/giving/given). A total of 3% of the SLI4 group’s regular items (2% for SLI5) and 9% of their irregular items (7% for SLI5) yielded alternatively marked forms of the prompted verb. As with past-marked and unmarked forms, these forms describe the same event or state as the prompted verbs, yielding *m* matched features. However, alternatively marked forms are clearly inappropriate with respect to aspect or temporality, and thus, according to the contrast model, their similarity to the on-line concept should decrease accordingly.

Verb forms with *-ing* suffixes (*looking*, *digging*) occur in semantically past (I was *digging*), present (I am *digging*), and future (I will be *digging*) contexts and so may remain uncoded with respect to temporality. However, *-ing* suffixed verb forms are always noncompletive in aspect, thus yielding a probable mismatch with the completive aspect found in all task sentences. The expected decrease in similarity between *-ing* suffixed forms and the on-line concept should be twice the *p* features representing aspect because both the forms and the on-line concept have features representing aspect, and those features are mismatched. Thus *-ing* suffixed forms should be worse than unmarked forms in

terms of their goodness of match. There were two progressive forms produced for irregulars (*standing, driving*) and one for regulars (*soaring*).

Perfect (I had *watched/driven* it) and passive (I was *kicked/bitten*) forms occur in past as well as nonpast contexts (I will have *watched*, I will be *watched*) and thus may remain undifferentiated with respect to temporality. In other respects they are even more conceptually incompatible with the sentences in our task (Every day I *dig* a hole. Just like every day, yesterday I ____ a hole.). The perfect (I have *eaten*) indicates the continuing relevance of a past situation, whereas the simple past (I *ate*) expected in the task sentences makes no such suggestion. Moreover, in English the perfect may not be used together with a particular specification of the time of the past situation (*Yesterday I *have/had* eaten) (Comrie, 1976). The passive is also clearly conceptually incompatible in the task sentences; its use would imply a switch of thematic roles, which would be highly semantically implausible, given the complements and adjuncts in our sentences (Every day I *dig* a hole. *Yesterday I was *dug* by a hole). There were two perfect or passive forms produced (*given, bitten*) for irregulars. Note that for regulars perfect and passive forms cannot be distinguished from past tense forms.

Verb forms with *-s* suffixes (*looks, digs*) are always heard in third person singular present tense contexts. Therefore they should be associated with conceptual features of presentness, yielding a mismatch in temporality with the task's semantically past sentences and a mismatch of person with the task's first person singular sentences. Because the forms as well as the on-line concepts are hypothesized to have conceptual features representing temporality and person/number and because those features are mismatched, there should be a mismatch of two times the *n* features of temporality and two times the *q* features of person/number. The *-s* suffixed forms therefore should be less conceptually appropriate than unmarked or *-ing* marked forms. There were two third person singular forms produced by unaffected subjects, one for an irregular verb (*make-makes*) and one for a regular (*mar-mars*).

Conceptually plausible (look-see/saw). A total of 8% of the SLI4 group's regular items (6% for SLI5) and 7% of their irregular items (6% for SLI5) were verb forms that were not inflectional variants of the prompted verb but were conceptually plausible in the expected context (e.g., *look* at Susan – *saw*). See Table 5 for the full list of such responses. The event or state described by such forms is plausible in the sentence context, although not as appropriate as that of the expected verb (e.g., “seeing” vs. “looking”). These conceptually plausible but unrelated forms should therefore be less conceptually appropriate than past-marked forms of the expected verb. Interestingly, all conceptually plausible forms produced were either past-marked or unmarked and thus better matched with respect to temporality and/or aspect with the on-line concept than alternatively marked forms (*sees, seeing*) would be.

Unclear responses. Several responses for regular (6% for SLI4; 9% for SLI5) and irregular (2% for SLI4; 3% for SLI5) verbs were unclear to the coders and therefore could not be classified.

Table 5. *The full list of conceptually plausible verb forms unrelated to the prompted verb that were produced for prompted real regulars and irregulars by affected family members*

Prompted verb and context	Conceptually plausible response	Subject
slam the door	banged	KA
look at Susan	saw	KA
keep my food	had	KA
chop some garlic	had, cut	KA
flush the toilet	flow	RO
look at Susan	saw	RO
make my lunch	bought	ST
send a letter	write	ST
bend the spoon	eat with a spoon	VA

Note: Unaffected family members produced no such forms.

Phonological proximates. Two regular items (3% for SLI4; 2% for SLI5) but no irregular items led to phonologically proximate responses (*soar–score*, *flap–flip*). These responses were plausible performance errors because they were only uttered by the impaired subjects (KA and RO) to whom the sentences were read out loud. It is possible that these subjects may have misanalyzed the verbs based on the oral presentation in the stem sentences.

No responses. A total of 13% of the SLI4 group’s real regulars (10% for SLI5) and 5% of their real irregulars (4% for SLI5) elicited no response at all from the five overtly inflectionally impaired subjects.

In summary, past-marked forms are hypothesized to be the most conceptually appropriate, followed by unmarked forms, *-ing* marked forms, and then perfect, passive, and *-s* marked forms. Conceptually plausible but inflectionally unrelated forms are less appropriate than past-marked forms of the expected verb. It is important to note that, according to the conceptual selection hypothesis, factors other than conceptual appropriateness may influence the selection of a form, such as the availability of unmarked forms in the current task (*Every day I rob a bank*) and the relative frequency of differently marked forms.

Evidence from three earlier studies is consistent with conceptual selection in that all forms produced for real verbs by affected family members in these studies were either conceptually plausible in their sentence contexts or were plausible performance errors.

First, we reanalyzed the forms produced by affected family members in the elicited production task originally reported in Gopnik and Crago (1991) and Gopnik (1994d). We found the same set of response types as in the elicited past

tense production task reported in this article. The four past tense elicitation sentences (*kiss–kissed*, *walk–walked*, *go–went*, *be–was*) yielded only past-marked (*walked*), unmarked (*walk*), alternatively marked (*walks*), conceptually plausible unrelated forms (Every day he *walks* four miles. Yesterday he *has a rest/went on the bus*), or no response. Likewise, the two third person singular elicitation sentences (*ride–rides*, *fix–fixes*) yielded only correct *-s* marked forms (*rides*), unmarked forms (*ride*), alternatively marked forms (*rode*), conceptually plausible unrelated verb forms (*ride–run*), or no response. The two progressive elicitation sentences (*cry–is crying*, *make–are making*) yielded only *-ing* marked (*crying*), unmarked (*make*), conceptually plausible unrelated verb forms (*cry–smile/sad/is happy*), or no response. Second, for the plural elicitation task reported in Goad and Rebellati (1994), the affected individuals uttered correct plural-marked (*bicycles*) and unmarked (*sleeve, man*) forms. Third, affected family members' spontaneous speech (Gopnik, 1994d) yielded past-marked, unmarked, and alternatively marked forms for regular and irregular verbs in semantically past contexts. Note that in spontaneous speech all verb forms that are conceptually plausible are assumed to be intended, and thus one cannot consider those responses to be conceptually plausible but “inflectionally unrelated.”

Forms with greater conceptual appropriateness were produced more often

If the conceptual representations of certain response types (e.g., past-marked, such as *looked*) were more similar than those of others (e.g., alternatively marked, such as *looks*) to the on-line concept formed in the prompted context, then the more similar ones should be selected more often, all else being equal. This follows from the demonstration that, when subjects are asked to generate exemplars of a concept, they tend to retrieve more typical exemplars before less typical ones (Rosch, 1978).

We have argued that past-marked forms are very well matched to the concept formed on-line, unmarked forms are less well matched, and alternatively marked *-ing*, *-s*, and *-en* suffixed forms are worst matched of all. Conceptually plausible but inflectionally unrelated forms are also less well matched than past-marked forms.

For regular verbs, past-marked and unmarked forms were more commonly produced than alternatively marked or conceptually plausible unrelated verb forms, as revealed by the main effect of one-way repeated measures ANOVAs with four levels (response rates of past-marked, unmarked, alternatively marked, and conceptually plausible unrelated verb forms) (SLI4: $F(3, 9) = 7.42, p = .008$; SLI5: $F(3, 12) = 6.68, p = .007$). Follow-up *t* tests indicated that regular past-marked forms were produced more frequently than alternatively marked forms (SLI4: $t(3) = 4.38, p = .022$; SLI5: $t(4) = 3.81, p = .019$) or conceptually plausible unrelated verb forms (SLI4: $t(3) = 2.12, p = .124$; SLI5: $t(4) = 2.6, p = .06$). Similarly, regular unmarked forms were produced more frequently than alternatively marked forms (SLI4: $t(3) = 5.53, p = .012$; SLI5: $t(4) = 4.76, p = .009$) or conceptually plausible unrelated verb forms (SLI4: $t(3) = 2.66, p = .076$; SLI5: $t(4) = 2.88, p = .045$). For irregular verbs, the main effects of analogous repeated

measures ANOVAs approached significance (SLI4: $F(3, 9) = 2.14, p = .166$; SLI5: $F(3, 12) = 3.33, p = .057$). Follow-up t tests showed that, while the higher response rates of irregular past-marked over alternatively marked forms (SLI4: $t(3) = .93, p = .422$; SLI5: $t(4) = 1.47, p = .216$) or conceptually plausible unrelated verb forms (SLI4: $t(3) = .96, p = .410$; SLI5: $t(4) = 1.47, p = .215$) were not statistically significant, for irregular unmarked forms the analogous differences were borderline or statistically significant. Unmarked forms were produced more often than either alternatively marked forms (SLI4: $t(3) = 2.21, p = .115$; SLI5: $t(4) = 2.79, p = .049$) or conceptually plausible unrelated verb forms (SLI4: $t(3) = 2.74, p = .072$; SLI5: $t(4) = 3.43, p = .027$).

In addition, the fact that all conceptually plausible but inflectionally unrelated verb forms produced for regulars and irregulars were either past-marked (*look-saw*) or unmarked (*send a letter-write*) suggests that past-marked and unmarked forms were more appropriate than alternatively marked forms, while reaffirming the partial conceptual mismatch of these unrelated verbs. That is, the pattern suggests that the mismatch resulting from the unrelated verb is only acceptable if the conditions for the match are favorable in other respects. This finding underscores the superiority of the match of past-marked and unmarked forms compared to alternatively marked forms as well as the inferiority of the match of conceptually plausible unrelated forms compared to forms related to the prompted verb itself.

If unmarked forms are less conceptually appropriate than past-marked forms in past tense contexts, the impaired subjects should have produced fewer unmarked than past-marked forms in the task. However, this result was not obtained. Rather, there was no statistically significant difference between the production rate of past-marked and unmarked forms, as measured by paired t tests, for either regulars (SL14: $t(3) = -.48, p = .663$; SL15: $t(4) = .54, p = .619$) or irregulars (SL14: $t(3) = -.81, p = .476$; SL15: $t(4) = -.82, p = .458$). In fact, in three of these analyses the production rate of unmarked forms is nonsignificantly higher than that of past-marked forms (see Table 4 for means).

This unexpected abundance of unmarked forms may be attributed to some combination of three factors. First, if temporality is indeed coded for, the unmarked forms may be no less conceptually appropriate than past-marked forms, because unmarked forms are heard in semantically past contexts. Second, the profusion of unmarked forms may be a task-specific phenomenon, resulting from a greater availability of unmarked than past-marked forms, as a result of the presentation of the stem in each sentence pair (Every day I *dig* a hole. Just like every day, yesterday I ____ a hole). This follows from findings suggesting that, in such elicited contexts, the production of unmarked forms or suffixed unmarked forms (i.e., overregularizations) is higher than in experimental situations lacking an initial presentation of the stem (see Marcus et al., 1992). If this hypothesis is correct, we should expect the unmarked form bias to diminish when the stem is not presented. Indeed, there were half as many unmarked (33%) as past-marked (66%) forms among the conceptually plausible unrelated verb forms produced for real regulars and irregulars (see Table 5). Similarly, the tabulation of forms produced in semantically past contexts in spontaneous speech revealed a clear advantage of past-marked over unmarked forms. Third,

the particular abundance of unmarked forms for irregular verbs (see Table 4) may be a result of “frequency competition,” because the irregular but not the regular items in our task did not have higher past tense than stem frequencies.

We reanalyzed the responses produced by the eight affected family members’ elicitation of past tense, progressive, and third person singular forms in the experiment originally reported in Gopnik and Crago (1991). For the four past tense elicitation sentences, 50% of responses (16 responses) were past-marked, 25% (8 responses) were unmarked, 3% (1 response, *walks*) were alternatively marked, 19% (6 responses) were conceptually plausible unrelated verb forms, and 3% (1 item) yielded no response. Thus, the past-marked forms were twice as common as the unmarked forms, which were in turn much more common than the alternatively marked forms. For the two progressive elicitation sentences, 25% of responses (4 responses) were *-ing* marked, 13% (2 responses) were unmarked, 56% (9 responses) were conceptually plausible unrelated verb forms, and one item elicited no response. Thus, there were twice as many *-ing* marked forms as unmarked forms and no alternatively marked forms at all. For the two third person singular present tense elicitation sentences, 19% of responses (3 responses) were *-s* marked, 31% (5 responses) were unmarked, 25% (4 responses) were alternatively marked, 19% (3 responses) were conceptually plausible unrelated verb forms, and one sentence elicited no response. Thus, over the three types of elicited production sentences (past tense, progressive, and third person singular present tense), 35% of the items yielded the expected surface forms (e.g., past-marked for past contexts), 23% yielded unmarked forms, 8% yielded alternatively marked forms, 28% yielded conceptually plausible unrelated verb forms, and the remaining 5% elicited no response. These results are consistent with the conceptual selection hypothesis. The expected surface forms were produced more often than conceptually plausible unrelated forms and unmarked forms, which were in turn produced more often than alternatively inflected forms.

The plural elicitation task given to affected subject VA by Goad and Rebellati (1994) resulted in 47% plural-marked forms (e.g., *bicycles*, *mice*) and fewer than 5% unmarked forms (e.g., *sleeve*, *man*) for the real nouns.

We reanalyzed the verb forms occurring in semantically past contexts that had been written in school notebooks by two affected family members (see Gopnik & Crago, 1991). For TO, we found that, of the 46 regular items, 67% (31 items) were past-marked, 26% (12 items) were unmarked, and the remaining 7% (3 items) were *-ing* marked. Similarly, of the 46 irregular items, 59% (27 items) were past-marked, 20% (9 items) were unmarked, 13% (6 items) were *-ing* marked, and the remaining 9% (4 items) were interpreted as omissions. For CH, we found that, of the 17 regulars, 29% (5 items) were past-marked, and the remaining 71% (12 items) were unmarked. Of the 104 irregulars, 93% (97 items) were past-marked, and the remaining 7% (7 items) were unmarked. Over the two subjects, of the 63 regulars, 57% were past-marked, while 38% were unmarked. Of the 150 irregulars, 82% were past-marked, 11% were unmarked, 4% were *-ing* marked, and the remaining 3% were considered omissions.

We also reanalyzed the spontaneous speech in semantically past contexts first reported by Gopnik (1994d). Of the 56 regulars, 57% (32 items) were past-

marked, 38% (21 items) were unmarked, and 5% (3 items) were alternatively marked. Of the 238 irregulars, 72% (172 items) were past-marked, 18% (43 items) were unmarked, and 18% (42 items) were alternatively marked.

In addition to comparing forms of differing degrees of appropriateness in the same context (e.g., temporally past contexts), we can also examine the effect of changing the context while holding the forms constant. If a conceptual analogue to person/number contributes to the conceptual match between the selected form and a concept formed on-line in the sentence, we should expect a greater percentage of *-s* marked forms (e.g., *digs*) in semantically past third person singular (e.g., Yesterday he *digs*) than in first person singular (Yesterday I *digs*) contexts. In an analysis of spontaneous speech of affected family members (KA, VA, RO, AW, PA, JO, and CA), we found that, of the 33 third person singular past tense contexts, 12% (4 items) were *-s* marked, a rate that is strikingly higher than the 1% produced in the first person singular context in our task. These results are consistent with the hypothesis that selection is based on conceptual features.

*Selection was a function of relative form frequency:
"Frequency competition"*

Evidence from Barsalou (1985) suggests that the more often an item is heard as a member of a given concept, the better an exemplar it will be of that concept. Thus, the more often a verb form (e.g., *dug*) is heard referring to a given event or state in semantically past contexts ("digging"), the better an exemplar it should be of the concept formed in such contexts and the more likely the form will be selected by affected family members in the past tense contexts of our task (Every day I dig a hole. Yesterday I ____ a hole).

If more than one verb form is heard in semantically similar past contexts, more than one verb form may be a relatively good exemplar of a given concept. For example, because the form *dig* is heard in past contexts highly similar to those in which *dug* occurs (e.g., I wanted to dig a hole; I saw Doug dig a ditch; I did not dig a trench), the two forms may compete for selection. The more frequent form may be selected more often than the other because it was heard more often in the relevant context, even if its featural match is not as good.

Frequency counts extracted from COBUILD are approximations of the relative frequencies of the use of verb forms in contexts similar to those in the past tense production task sentences. Therefore, verb forms' relative frequency counts may predict the likelihood of their selection by the affected subjects. The higher a form's frequency count relative to the frequencies of other conceptually appropriate forms, the more likely it will be selected, under the condition that its similarity to the concept formed on-line in the past tense sentence is greater than zero (i.e., if it is similar rather than dissimilar). We would expect selection competition between past-marked and unmarked forms on the basis of their relative frequencies because both types of forms are hypothesized to be relatively good matches to the on-line concept.

To test this frequency competition hypothesis on past-marked and unmarked forms, we ran logistic regressions on the past-marked and unmarked responses of each of the five overtly inflectionally impaired subjects, as well as on the

Table 6. *Results from logistic regressions modeling the probability of producing the past-marked as opposed to the unmarked form, with past tense frequency as the predictor and stem frequency held constant*

Subject	Parameter estimate	Wald χ^2	<i>p</i>
Regulars			
ST	1.92	2.38	0.123
KA	-0.11	0.03	0.860
VA	3.32	3.38	0.066
RO	1.37	0.30	0.586
AW	-0.30	0.09	0.766
SLI4	1.09	4.00	0.046
SLI5	0.65	2.34	0.126
Irregulars			
ST	n.a. ^a		
KA	1.28	1.21	0.271
VA	n.a. ^b		
RO	n.a. ^c		
AW	0.49	0.44	0.507
SLI4 ^d	1.46	2.64	0.104
SLI5 ^d	1.01	3.39	0.065

^aConvergence not attained in regression.

^bNo past tense responses.

^cNo stem responses.

^dWithout VA or RO.

SLI4 and SLI5 groups, separately for regulars and irregulars, modeling the probability of the production of past-marked forms as opposed to the production of unmarked forms, with past tense frequency and stem frequency as predictors. As shown in Table 6, we found a pattern of positive relations between past tense frequency and the tendency to produce a past-marked form as opposed to an unmarked form, holding stem frequency (i.e., the frequency of unmarked forms) constant. Ignoring the pseudo-suffixing AW's regulars, all but one individual subject regression over regulars or irregulars yielded positive associations, one of which (VA for regulars) was borderline significant. The remaining regression (KA for regulars) cannot be taken to indicate a negative association, as it had a Wald χ^2 statistic close to zero and a *p* value of .860. All four group analyses yielded positive associations. The association for the SL15 irregulars was borderline significant, while the association for the SLI4 regulars was statistically significant.

Likewise, we found a pattern of positive relations between stem frequency and the tendency to produce an unmarked form as opposed to a past-marked form, holding past tense frequency constant, as shown in Table 7. Other than for AW's pseudo-suffixing regulars, all subjects had a positive association, one

Table 7. *Results from logistic regressions modeling the probability of producing the unmarked as opposed to the past-marked form, with stem frequency as the predictor and past tense frequency held constant*

Subject	Parameter estimate	Wald χ^2	<i>p</i>
Regulars			
ST	1.44	1.35	0.245
KA	0.28	0.19	0.666
VA	2.88	2.88	0.090
RO	1.31	0.29	0.590
AW	-0.68	0.40	0.527
SLI4	0.92	2.95	0.086
SLI5	0.46	1.19	0.275
Irregulars			
ST	n.a. ^a		
KA	1.61	1.39	0.238
VA	n.a. ^b		
RO	n.a. ^c		
AW	0.65	0.70	0.402
SLI4 ^d	1.22	1.89	0.170
SLI5 ^d	0.90	2.66	0.103

^aConvergence not attained in regression.

^bNo past tense responses.

^cNo stem responses.

^dWithout VA or RO.

of which was borderline significant. Similarly, all four group analyses yielded positive associations, one of which was borderline significant.

These results suggest that the impaired subjects' selection of past-marked and unmarked forms is lexically based and frequency sensitive, and that the two types of forms compete for selection as a function of their relative frequencies. Moreover, the regression models indicated (not displayed here) that at high past tense frequencies and low stem frequencies past-marked forms tended to be produced, while at high stem frequencies and low past tense frequencies unmarked forms tended to be produced. This further supports frequency competition, suggesting that any differences in conceptual appropriateness between past-marked and unmarked forms were overridden by large relative frequency advantages.

Frequency competition may also account for our finding that the impaired subjects had lower production rates for real irregulars than for real regulars (see Table 4), even though the irregular forms had higher past tense frequencies than the regular forms. This pattern held even for the SLI4 group, whose production rate of regular past-marked forms could not be inflated by AW's pseudo-suffixation strategy. The finding may be explained by the fact that for the 16 regular

items past tense frequency was significantly higher than stem frequency, $t(15) = 3.90$, $p = .001$, whereas for the 14 irregular items this difference was not significant, $t(13) = 1.35$, $p = .199$ (see Table 2 for frequency means). Frequency competition predicts that the past-marked form will tend to be selected over the unmarked form for the regular items, whereas this bias does not exist for the irregular items. In the Appendix we show that, over much larger samples of English verbs, regulars have lower past tense than stem frequencies, whereas irregulars have past tense frequencies at least as high as their stem frequencies. Thus, frequency competition may explain previous reports that people with SLI are worse at producing regular than irregular past tense forms. In addition, this imbalance between regulars and irregulars with respect to relative stem and past tense frequencies might explain our finding that the affected family members produced significantly more irregularizations (e.g., *crive*–*crove*) than regularizations (*crive*–*crived*, *plam*–*plammed*) of novel verbs. On average, affected family members should be more successful at retrieving similar-sounding past-marked forms of irregulars (*drove*, *dove*) than of regulars (*jived*, *dammed*); for regulars, they should tend to retrieve unmarked forms (*jive*, *dam*) instead. This may lead them to analogize more successfully from the irregular than the regular stem-past pattern to novel forms.

We argued that in our task *-ing* marked forms were less conceptually appropriate than unmarked forms largely because of the verbal *-ing* forms' noncompletive aspect, which mismatched the completive aspect found in all sentences in our task. We therefore expected *-ing* forms to be at least as conceptually appropriate as unmarked forms in noncompletive sentence contexts. Indeed, the affected subjects produced *-ing* forms at a higher rate in contexts whose aspect was not specifically known to be completive. However, even in these contexts, the affected family members' rate of production of *-ing* forms was substantially lower than their rate of production of unmarked forms. This predominance of unmarked over *-ing* marked forms can be explained by frequency competition. We found that for 5,299 regular and irregular verbs the frequency of unmarked forms was significantly higher than that of their corresponding *-ing* forms: 7.7 versus 3.4, $t(5,298) = 3.79$, $p < .001$ (raw frequency counts from Francis & Kucera, 1982), and 219.7 versus 128.7, $t(5,298) = 3.54$, $p < .001$ (raw Associated Press frequency counts) (see Appendix for more details on these frequency counts). Thus, unmarked forms should be selected significantly more often than their corresponding *-ing* forms, as we observed.

We have argued that, if two forms are associated with conceptual representations which are equally similar to the on-line concept, the accessibility competition between the two should result in the higher frequency representation being selected. Conversely, if the forms of one response type (e.g., alternatively marked forms) produced by the affected subjects are consistently of higher frequency than those of other types, this would indicate that the higher frequency forms are less conceptually appropriate and are only selected when their frequency advantage outweighs their conceptual disadvantage. Thus, if alternatively marked (*look*–*looks/looking*) and conceptually plausible unrelated verb forms (*look*–*saw/see*) are less conceptually appropriate than the past-marked and

unmarked forms in the task sentence contexts, the alternatively marked and conceptually plausible unrelated verb forms that are produced should tend to be more frequent than the past-marked (*looked*) and unmarked (*look*) forms of their prompted verbs.

We found that the alternatively inflected forms had higher frequencies than the past-marked or unmarked forms of their prompted verbs, as indicated by the main effect of a one-way repeated measures ANOVA with three levels (stem frequency, past tense frequency, alternatively marked form frequency), $F(2, 12) = 4.34$, $p = .038$, and follow-up paired t tests. Alternatively marked form frequency was statistically significantly greater than stem frequency, $t(6) = 3.85$, $p = .008$, and nonsignificantly greater than past tense frequency, $t(6) = 1.32$, $p = .236$. A similar pattern was found for the conceptually plausible unrelated verb forms, although the analyses were not statistically significant. The main effect of a one-way repeated measure ANOVA with three levels (past tense frequency, stem frequency, frequency of conceptually plausible unrelated verb forms) was not statistically significant, $F(2, 14) = 2.05$, $p = .166$, although the mean of the conceptually plausible forms' frequencies (6.43) was higher than the mean of either the stem frequencies (5.04) or past tense frequencies (5.70) of the prompted verbs. These results are consistent with the view that, while these conceptually plausible unrelated verb forms may have been somewhat less conceptually appropriate than the past-marked and unmarked forms of their prompted verbs, they tended to be more appropriate than alternatively marked forms. This is consistent with the results from our reanalysis of the elicited production tasks reported by Gopnik and Crago (1991), which showed that correctly marked, unmarked, and conceptually plausible unrelated forms were produced far more commonly than alternatively marked forms.

There has been little previous investigation of frequency effects of the forms produced in obligatory inflected contexts by the affected family members. However, Gopnik and Crago (1991) reported one result which supports the hypothesis that unmarked and past-marked forms are both acceptable in past tense contexts, and that their relative frequencies affect their respective selection. The authors noticed that, in the obligatory past tense contexts of TO's and CH's notebook writing,

of the 11 regular verbs, only four, each of which occurs only once, are correct in their first occurrence: "showed," "asked," "called," and "picked." If we look at the frequencies of these verbs in the [unmarked form] and [past-marked form] (Kucera & Francis, 1967) we find ask, 128, asked, 398; call, 188, called, 401; pick, 55, picked, 78; show, 287, showed, 141. For all of these words except "show" the past tense form is more frequent than the present tense [unmarked] form. For the other seven that occur [as unmarked forms] in their first occurrence all except one (stop 120, stopped 129) occur less frequently in their past-tense form. These forms occur incorrectly at first and are corrected [in the notebooks] by the teacher. (p. 39)

This suggests that in past tense contexts TO and CH tended to select unmarked forms when they were more frequent than past-marked forms and past-marked forms when they were more frequent than unmarked forms.

Only lexicalized forms were successfully produced

If forms are selected on the basis of their conceptual representations and lexical accessibility, only forms already heard – and therefore which are lexicalized and for which a conceptual representation could be created – should be produced. Thus, while past-marked (*looked*), unmarked (*look*), and alternatively marked forms (*looks/looking*) should be produced for real verbs, their analogous forms for novel verbs (*plammed*, *plam*, *plams/plamming*) should not be uttered. Indeed, past-marked forms were produced more often for real than for novel verbs, whose rate of production was not significantly different from zero. Similarly, real unmarked forms were produced more often than novel unmarked forms, whose rate of production was likewise not significantly different from zero. Real alternatively inflected forms (seven forms or 6% of the SLI4 items over real regulars and irregulars) were also produced more often than novel alternatively inflected forms, of which there was only one produced (1% of the SLI4 responses over novel regulars and novel irregulars).

Crucially, this failure to produce novel past-marked, unmarked, or alternatively marked forms does not seem to be attributable to an inability to understand the conceptual goal of the task. Many conceptually appropriate responses were produced for these novel verbs: for novel regulars, 27% of SLI4 items (21% for SLI5); for novel irregulars, 14% of SLI4 items (11% for SLI5). See Table 4 for individual subject means and Table 8 for a list of responses. This suggests that even the production of forms for novel verbs was a function of conceptual appropriateness. As expected, the majority of these conceptually plausible responses were past-marked (nine forms or 43%) and unmarked (nine forms or 43%), with only one *-ing* form (5%) and two perfect forms (10%).

Goad and Rebellati (1994) found that subject VA produced 47% plural-marked forms (*bicycles*) for real nouns but only 7% for novel nouns (*zoop-zoops*).

Evidence from a study of acceptability ratings

Gopnik (1994d) reported that the unmarked forms of regular and irregular verbs were given significantly higher acceptability ratings in past tense contexts (Yesterday when my eyeglasses got dirty, I *wipe* them) by affected than unaffected family members. Moreover, this difference was unlikely to be due to a high-rating bias on the part of the affected subjects, because their ratings of the correct past tense forms of the same regular and irregular verbs were lower (although not significantly so) than the analogous ratings of the control subjects. Nor was the difference likely to be explained by the affected subjects' reluctance to use the bottom of the rating scale, as they resembled their unaffected relatives in giving low ratings to vowel-change forms of regular verbs (Yesterday, when my glasses got dirty, I *wope* them). Thus, the affected family members did not reject the unmarked forms as being ungrammatical in past tense contexts. Interestingly, the unmarked forms were given lower ratings than the past tense forms. For regulars, the mean rating (on a scale of 1 to a high rating of 7) of

Table 8. *Conceptually plausible responses produced by the affected family members for prompted novel regular and novel irregular verbs*

Prompted verb and context	Conceptually plausible response	Subject
strink a horse	stroke	KA
spuff for TV	saw	KA
frink during dinner	thought	RO
crive in France	went to	ST
vurn to Boston	return to	ST
cleed quite well	doing	ST
scrit to Steve	wrote	ST
drite the beach	sat do some bathing	ST
stoff my room	tidy make a mess	ST
trab the paper	read [stem]	ST
vask the ring	married	ST
plam my leg	broken	ST
shrell with Chris	was pleased	VA
drite the beach	walk	VA
spuff for TV	watched	VA
dotch my car	drove	VA
stoff my room	clean	VA
cug more furniture	polished	VA
crog to John	think of	VA
satch to water	drink the	VA
scur a bean	eat	VA

Note: Unaffected family members made no such responses.

unmarked forms was 4.28 and of past tense forms, 6.50; for irregulars, the respective means were 3.58 and 6.40. These results are consistent with conceptual selection, in which past-marked and unmarked forms should both be appropriate in past tense contexts, with past-marked more conceptually appropriate than unmarked.

Summary

We proposed that, in the absence of an intact normal adult grammatical system, the affected family members resort to conceptual selection, which entails the retrieval of forms from the lexicon as a function of those forms' conceptual appropriateness and lexical accessibility, relative to other conceptually plausible forms. Five lines of evidence were presented to support conceptual selection. First, we argued that all forms produced were performance errors or plausible conceptual matches: past-marked (*look-looked*), unmarked (*look-look*), alternatively marked (*look-looks/looking*), or conceptually plausible forms of a different verb (*look-saw*). Moreover, we showed that certain types of forms might be

more conceptually appropriate than others in the task's past tense contexts: past-marked more than conceptually plausible unrelated verb forms or unmarked forms, which in turn are more appropriate than alternatively marked forms. Second, those types of forms more conceptually appropriate were produced more often than those less appropriate. Third, the higher a form's frequency relative to other plausible forms, the more likely its production. According to frequency competition, two or more conceptually appropriate forms compete on the basis of their relative frequencies. Moreover, less appropriate forms tend to be produced particularly when they are more frequent than their more appropriate alternatives. Fourth, there was a failure to produce forms of novel verbs (*plammed*, *plam*, *plams*, *plamming*), which have no associated conceptual representations. In contrast, forms with associated conceptual representations were produced for this same set of novel verbs (*scur a bean* – *eat*). Fifth, in past tense contexts, unmarked forms were given high acceptability ratings, although not as high as those of past-marked forms.

AN EXPLICITLY LEARNED COMPENSATORY STRATEGY

Thus far we have argued that the family members with difficulties in productive inflectional morphology are afflicted with a deficit of the grammar underlying inflection; in lieu of relying on this dysfunctional system for the production of inflected forms, they select forms on the basis of their conceptual appropriateness and accessibility (conceptual selection). Here we show that some affected family members may have explicitly learned a strategy to compensate for their deficit, appending suffix-like endings to forms retrieved by conceptual selection. We show that this strategy is learned only by some affected subjects and not necessarily in all inflectional contexts. For example, affected subject VA used such a strategy in plural but not past tense contexts. The strategy is revealed by detailed phonetic analyses of the subjects' responses. Moreover, the two family members who had previously been identified as affected but who appeared to perform well on our past tense production task according to our initial coding (PA and JO) are also revealed by these detailed phonetic analyses to have inflectional deficits similar to those of the other affected subjects.

The phonologist Heather Goad, in her work on the real and novel plurals produced by the affected members of this family, recognized the relevance of the phonetic variation in the form of plural *-s* endings. Goad and Rebellati (1994) reported that the phonological "errors," which had been assumed to be noise in the morphological system caused by a general articulatory impairment, were actually principled errors. A range of phonological distortions were observed, including an absence of voicing assimilation between the stem and the ending; the inappropriate insertion of epenthetic vowels after stems that do not end in a sibilant; the absence of epenthetic vowels after stems ending in sibilants, resulting in geminated sibilants, which are not allowed in English; stress on the ending itself; and the insertion of pauses between the stem and its ending. Goad and Rebellati argued that this range of phonological errors cannot be accounted for by any consistent articulatory explanation. The phonological shape of the plural-like pseudo-suffixed forms suggests that the endings in question

are not incorporated into the stem as a true inflectional ending would be but are appended to the stem by a different process.

This original observation about noun plurals led us to reexamine the forms with *-ed* endings produced by affected family members in the past tense elicitation task. We performed detailed phonetic analyses on the responses of four affected (AW, PA, JO, VA) and one unaffected (AN) family member.⁵

A similar pattern of errors to the one observed in plural formation (Goad & Rebellati, 1994) was also observed among the past-like forms produced by the three affected family members, including the two subjects (PA and JO) who had appeared to perform well on the past tense production task. It is unclear how the range, kind, and distribution of these errors could be accounted for solely by an articulatory deficit. The unaffected family member (AN) did not make any errors, and therefore such errors cannot be attributed to the affected family members' dialect.

AW. We argued in the individual subject analyses that AW used an explicitly learned and consciously applied pseudo-suffixation strategy when producing forms in past tense contexts. Among other lines of evidence in support of this view, we reported his statement that at school he had explicitly learned to add *-d* in past contexts. The phonetic analysis further bolstered the hypothesis that he added *-ed* endings according to a pseudo-suffixation strategy. First, all of AW's overregularizations' *-ed* endings were phonologically ill-formed, with a pause between the unmarked form and the *-ed*, such as *wring-wring...d*, or with stress on the ending itself. This suggests that these endings were not appended by the same process that underlies suffixation in unaffected individuals. Note that it does not appear that this pattern of pauses and stressed endings could be accounted for by any of the five phonological processes that Fee (1995) observed among the affected family members because all of these processes involved reduction (of consonant clusters), deletion (of word-final consonants), or substitution (of consonants). Second, the phonetic analysis revealed that AW's response to one real regular verb was doubly marked (*stalk-stalkeded*), which is consistent with the final *-ed* having been appended to a past-marked form retrieved from memory (*stalked*), just as it appears to have been appended to irregular past-marked forms in AW's production of doubly marked irregulars (*give-gaved*, *swim-swammed*). Third, only two real regular past-marked forms and, possibly, one novel regular past-marked form had phonologically well-formed *-ed* suffixes. Finally, the phonetic analysis did not reveal a single irregular past-marked form (including among alveolar-stop-final forms such as *made* or *fed*) with a pause preceding the word-final consonant, such as was found among the real and novel regular past-marked forms. This suggests that AW's distorted *-ed* final phonology was not attributable solely to articulatory or phonological difficulties.

It might seem surprising that AW would produce any *-ed* final novel past-marked forms with correct phonological shape, given his hypothesized dysfunctional suffixation rules. However, the existence of such apparently normal forms does not necessarily indicate that their production was carried out with an intact (or even partially intact) rule; our phonetic analysis may not have detected all

forms produced by the hypothesized pseudo-suffixation strategy. This is demonstrated by the finding, also obtained by the phonetic analysis, that AW produced a number of forms whose word-final *-ed* had the form of the wrong allomorph but were produced without any discernible distortion or break between the ending and the verb form to which it was attached. Thus, if AW had by chance alone selected a phonological sequence corresponding to the correct allomorph (not too improbable, given the small finite number of possible allomorphs), we would not be able to determine with certainty that it was not formed by a pseudo-suffixation strategy.

PA. Whereas the initial coding of PA's responses indicated that 100% of the sixteen regular items yielded correct past tense forms, the phonetic analysis revealed only 44% (seven responses) to be correct, with incorrect *-ed* endings on the remainder. Similarly, the initial coding had indicated that 83% of the novel regulars were correctly formed past tenses, but the phonetic analysis revealed only one correctly suffixed item. Moreover, the analysis also revealed two doubly marked forms (*plam-planneded*, *grind-grounded*), supporting the conceptual selection hypothesis that past-marked forms are retrieved from memory and may be pseudo-suffixed. PA's difficulty at producing past-marked forms of novel irregulars was also revealed. She produced no irregularizations (*crive-crove*) and only one regularization (*shrim-shrimmed*). Note that, as with AW, the existence of apparently well formed *-ed* suffixes does not necessarily indicate that they were produced by a morphological suffixation rule. Like AW, PA produced *-ed* suffixed forms with incorrect allomorphs (e.g., *scour-scourt*, *spuff-spuffid*) for which the phonetic analysis could detect no break between the final *-ed* and the form to which it was attached. Interestingly, the phonetic analysis revealed that PA's past-marked production rates for real regulars, novel regulars, and novel irregulars was similar to those rates for the SLI4 subjects, whose mean success rate was 31% for real regulars (44% for PA), 2% for novel regulars (8% for PA), and 0% regularizations (7% for PA) and 12% irregularizations (0% for PA) of novel irregulars. As with AW, PA's phonetic analysis did not reveal a single past tense irregular form (including among alveolar stop-final forms such as *made* or *fed*) containing a pause like those found among the real and novel regular past-marked forms, suggesting that her suffixation difficulties were not attributable solely to articulatory or phonological problems. Finally, PA also showed evidence of using an explicit add *-s* rule in the formation of real and novel plurals (from Goad & Rebellati, 1994).

JO. The phonetic analysis confirmed that JO was strikingly more accurate than the other affected family members at producing correct past-marked forms for real verbs. The initial coding of 93% correctly past-marked real irregulars was confirmed. The phonetic analysis revealed one unmarked form for real regulars (*rush-rush*) not identified by the initial coding, thus yielding 93% correct for regular verbs as well. In contrast, the phonetic analysis of the novel verbs disclosed JO's impairment. He produced only 25% (3 of 12) correct novel regular past-marked forms, compared with a nonphonetically coded score of 92% for each of the three unaffected family members (this nonphonetic coding of 92%

was confirmed for the unaffected individual AN by phonetic analysis). Moreover, several of his incorrect responses for novel verbs had *-ed* endings that contained a pause before the *-ed* ending, consistent with a pseudo-suffixation strategy. Of the novel irregulars (*crive*), only 14% (2 of 14 items) yielded regularizations (*crive–crived*) and 7% (1 item) yielded irregularizations (*crive–crove*), production rates similar to those of the overtly inflectionally impaired SLI4 subjects (see Table 4). These data suggest that, whereas JO had developed an efficient means of retrieving correct past-marked forms from memory, a dysfunction in the use of morphological suffixation rules prevented him from producing novel *-ed* suffixed forms.

VA. Not all of the affected family members uttered errors consistent with an explicitly learned pseudo-suffixation strategy. A phonetic analysis of VA's responses indicated that none of her forms contained pauses or were otherwise phonologically abnormal. Interestingly, the phonetic analysis did reveal that the single novel regular past-marked form identified by the initial coding (*grush–grushed*) in fact involved a transformation to a real word (*grush–crushed*), underscoring VA's inability to carry out past tense suffixation. In contrast to her lack of phonological distortions in past tense production, her phonological errors in Goad and Rebellati's (1994) plural production task suggested her use of a pseudo-suffixation strategy in plural contexts, thus demonstrating that such strategies can be learned independently for different inflectional contexts.

AN. A phonetic analysis carried out on the responses of this unaffected family member revealed the well-formedness of all her suffixed forms. This demonstrates the validity of the phonetic analysis and suggests that the affected subjects' distorted suffixed forms were not attributable to their dialect.

Thus, some affected family members appear to have learned a compensatory strategy which they used to append *-ed* endings to words apparently retrieved from memory by conceptual selection, yielding phonologically abnormal concatenations. This strategy was explicitly learned by at least one subject, AW. It does not appear that the pattern of errors could be fully explained by the phonological processes observed by Fee (1995) among the affected family members. The results revealed by the phonetic analysis thus strengthen conceptual selection and indicate that both PA and JO suffered from a dysfunction of inflectional morphology not indicated by our initial analyses.

It is not clear whether the pseudo-suffixation strategy fully explains JO's performance on the past tense production task. After all, he was better than the other affected individuals at producing correct past-marked forms for real irregulars, suggesting an ability to distinguish between unmarked and past-marked stored forms. We consider two alternative explanations for this discrepancy. First, JO may be less affected than his relatives and therefore able to acquire some aspects of language in a manner not available to his more affected relatives. This could explain his success at irregular verbs. But it does not appear to be consistent with his difficulty with novel verbs. If his impairment were less severe, it seems reasonable that he should be better than his less affected rela-

tives at inflecting novel verbs. The phonetic analyses revealed that this does not appear to be the case. According to a second account, JO's impairment is similar in quality and degree to that of the other affected family members, but he has explicitly learned compensatory strategies for overcoming his deficit or has learned to use conceptual selection more efficiently.

Similar results were obtained by Goad and Rebellati (1994), who found that both PA and VA produced real and novel plurals with distorted *-s* suffixes. The finding that VA uttered badly formed *-s* suffixed forms in contexts requiring pluralization but well-formed *-ed* final forms in contexts requiring past tense production demonstrates that such strategies can be learned independently.

ORIGIN AND SCOPE OF THE DEFICIT

We propose that the mechanisms underlying the affected subjects' production of forms in contexts requiring inflection in the adult grammar is similar to those of young normal children, and that both groups lack the adult grammar for inflection, relying on conceptual selection instead. On this view, some dysfunction prevents affected family members from passing from a state of conceptual selection to a state of possessing the adult inflectional grammar. We are not claiming that affected family members are similar to young children in all linguistic or cognitive respects, but rather that certain mechanisms underlying the computation of inflected forms (and perhaps certain other linguistic and nonlinguistic functions) that have not yet developed in young normal children have remained undeveloped in the affected family members.

Young children's performance in contexts requiring inflection

The productive inflectional morphology of young normal children may be similar to that of the affected family members. The same young children who show no evidence of using a suffixation rule for a particular inflection (e.g., they do not overregularize past tense forms) are also unsuccessful at producing real correctly marked inflectional forms. In analyses of data from the three children investigated by Cazden (1968) and Brown (1973), Marcus et al. (1992) found that correct marking rates for regular and irregular past-tense forms were low before overregularization, and, crucially, they increased dramatically with the appearance of overregularizations. Thus, we find a co-occurrence between marking and the rule. The young child shows no evidence of rule use while she/he fails to mark tense consistently; there is then a transition to a state wherein rule use is revealed through overregularizations and the rate of successful marking of regular and irregular forms increases. This co-occurrence of rule use and obligatory marking in normal children suggests that these two phenomena are linked, and that the affected family members are similar to young children in their inflectional abilities.

This similarity between the performance of young normal children and the affected family members may reflect an underlying similarity of their linguistic systems. Specifically, young children who neither apply suffixation rules nor use consistent tense marking in obligatory contexts may not yet have learned

either grammatical rules or morphological paradigms. And whereas normal children proceed to acquire the grammatical underpinnings necessary to compute inflection, the affected individuals do not. Some evidence suggests that young normal children might also select forms in inflectional contexts according to conceptual selection. Like the affected members of the family, young normal children produce not only the expected surface inflected forms (e.g., past-marked in past contexts), but also unmarked forms (Brown, 1973; Cazden, 1968; Marcus et al., 1992) and alternatively inflected forms (Leonard, Bortolini et al., 1992; Menyuk, 1964; Mervis & Johnson, 1991).

A specific developmental arrest

We hypothesize that in the affected KE family members mutated genetic material has led to abnormalities of structures underlying the acquisition, representation, and/or processing of grammatical rules or morphological paradigms, as well as certain other language and nonlanguage functions. This is consistent with our proposal that the affected individuals may be afflicted with a dysfunction of frontal/basal-ganglia structures. It is important to note that this hypothesis does not necessarily imply that grammatical deficits in SLI are explained by mutations of genetic material underlying the development of neural systems. It is also quite plausible that abnormal or excessive genetic material may have led to early damage of normally developing brain structures, analogous to the mutations leading to brain damage later in life in hereditary disorders such as Huntington's disease (see Pembrey, 1992).

Scope of the deficit

Thus far we have restricted our investigation to deficits of inflectional morphology. However, other impairments have been reported among affected family members. Gopnik and Crago (1991) found that affected family members were significantly worse than unaffected family members on a task of productive derivational morphology (I don't like his pride. He is too ____). Moreover, Gopnik and Crago reported that

the performance of [the affected subjects] on the derivational morphology test was very similar to their performance on the task of elicited inflectional morphology, both in terms of their scores relative to those of the normals and also in terms of the strategy they used to answer the questions. In both of these tests the language-impaired subjects seemed not to be able to understand that the point of the test was to manipulate an underlying grammatical rule, though the normals understood with no hesitation. Even when they were prompted with examples and with specific instructions they seemed unable to perceive that there was an underlying pattern that was governed by a general rule. In this context their strategy of responding semantically was intelligent. (p. 44)

Thus, affected subjects' difficulties with inflectional and derivational morphology may share a common explanation. Specifically, the hypothesized dys-

function of grammatical rules or of morphological paradigms (see Carstairs, 1987) and a reliance on conceptual selection may explain the affected subjects' impairments at derivational morphology.

SUMMARY AND CONCLUSION

We have attempted to characterize and explain at least some aspects of the language deficit of a subgroup of people afflicted with SLI. The subgroup is composed of members of a British family affected with a hereditary disorder. Previous investigations have suggested impairments of grammar and motor functions but the possible sparing of lexical memory and general cognition. To confirm and characterize the grammatical deficit, we carried out an in depth investigation of productive inflectional morphology, focusing on past tense production. Affected and unaffected family members and unrelated age-matched controls were tested. The results, in conjunction with findings from previous studies of past tense and plural inflection in this family, suggest the following.

First, none of the family members previously identified as affected by the disorder showed any evidence of using morphological suffixation rules (e.g., *look* + *-ed* → *looked*). They did not overregularize (*digged*), they failed to produce regularizations of novel verbs (*plammed*, *crived*) but were relatively spared at producing novel irregularizations (*crive*–*crove*), and, unlike normal subjects, they showed frequency effects for regular past-marked forms (*looked*), indicating that these forms were retrieved from memory rather than being produced by the application of a suffixation rule. Second, all but one affected family member was impaired at the production of regular and irregular past-marked forms (*looked*, *dug*) and made errors such as *look*, *looks*, *looking*, *see*, and *saw*. Third, this pattern cannot be fully explained by several previously proposed explanations of SLI, including deficits of articulation or perceptual processing, previous simulations of impairments to a single mechanism system, or the extended optional infinitive hypothesis. Fourth, the pattern is consistent with the following three-level explanation: (i) the affected family members have a dysfunction of implicitly learned grammatical rules or morphological paradigms, possibly caused by procedural memory deficits originating in frontal/basal-ganglia circuitry abnormalities that also affect certain nonlinguistic functions, including motor skills; (ii) in contexts requiring inflection in the normal adult grammar, the affected subjects rely on conceptual selection, retrieving word forms as a function of their conceptual appropriateness and accessibility (conceptual selection may depend on the declarative memory system); (iii) certain subjects adopt an apparently explicitly learned pseudo-suffixation strategy, adding suffix-like endings to forms retrieved by conceptual selection (learning this strategy may also depend upon declarative memory). Fifth, the morphological errors of young normal children may be similar to those of the affected family members, who may have been left stranded with conceptual selection by a specific developmental arrest. Finally, the three-level explanation posited for the affected individual's performance in tasks of inflectional morphology may also account for their performance in tasks of derivational morphology.

We have suggested that the investigation of SLI subgroups such as the affected members of the KE family might shed light on four important questions about the psychological, neural, and developmental underpinnings of language. First, are the mental lexicon and the mental grammar subserved by distinct mechanisms (Pinker, 1991) or a common mechanism (Elman et al., 1996)? We have argued that the results presented here – in particular, the suffixation rule dysfunction and the frequency effects found for regular past-marked forms produced by the affected but not the control subjects – support a dual mechanism view. It remains to be seen whether reports of phonological (Fee, 1995) or syntactic (Gopnik & Crago, 1991) deficits can also be explained by the grammatical impairments which we have hypothesized. Second, if lexicon and grammar are subserved by distinct mechanisms, are those mechanisms underlying grammar dedicated to this function or do they also underlie nonlanguage functions? We have suggested that the KE family members' impairment appears to be consistent with the hypothesis that grammatical rule learning and use depends on a frontal/basal-ganglia procedural memory system, whereas lexical memory depends on a temporal lobe declarative memory (Ullman, in press; Ullman, Corkin et al., 1997). Their disorder may involve a dysfunction of procedural memory in (at least) the grammar and motor domains, while leaving declarative (and lexical) memory relatively spared. Third, can the neural structures subserving the lexicon and the grammar be identified? Given that the affected family members show basal ganglia abnormalities (Watkins et al., 1997) and motor programming deficits (Vargha-Khadem et al., 1995) and given that independent evidence suggests links between the frontal/basal-ganglia circuitry and grammatical rule use (Ullman, in press; Ullman, Corkin et al., 1997), it is plausible that a dysfunction of this circuitry underlies their grammatical deficit. Fourth, if the language of grammatically impaired people with SLI resembles that of young normal children, can investigations of their language elucidate the structure of child language and the process of normal language acquisition? We have suggested that young children may be similar to the affected family members in lacking morphological suffixation rules or morphological paradigms and in relying instead on conceptual selection to produce forms in contexts requiring inflection in the normal adult grammar. Finally, we have suggested that the study of SLI language impairments may lead to a better understanding of the nature of SLI itself, perhaps leading to diagnostic and therapeutic advances for the condition. If, indeed, subgroups of people with SLI who are similar to the affected members of the KE family suffer from a frontal/basal-ganglia dysfunction of procedural memory, then data from numerous investigations of the neural, computational, and developmental underpinnings of this memory system in humans and animals may be pertinent to SLI and could potentially lead to new therapeutic and clinical approaches for its treatment.

APPENDIX

In support of the conceptual selection hypothesis, we presented evidence suggesting that past-marked (*looked*, *dug*) and unmarked (*look*, *dig*) forms compete for selection as a function of their relative frequency. According to the frequency competition hypothesis,

the greater the frequency advantage of a past tense form over its stem or of a stem over its past tense form, the more likely its selection. We showed that, for the 16 regular items in our past tense production test, past tense frequency was significantly higher than stem frequency, whereas for the 14 irregular items this difference was not significant. We argued that this could explain the finding that the impaired subjects had lower production rates for irregular than for regular past-marked forms. According to frequency competition, for regulars past tense forms should be selected more often than stem forms, whereas for irregulars this difference should not be found.

We now show that, over much larger samples of verbs, regular verbs have lower past tense than stem frequencies, whereas irregular verbs have past tense frequencies as least as high as their stem frequencies. Thus, frequency competition might account for previously reported findings that SLI subjects are more successful at producing irregular than regular past tense forms (see Gopnik, 1994d; Gopnik & Crago, 1991; Leonard, 1989; Oetting & Horohov, 1997).

Method

We tested this hypothesis by examining the stem and past tense frequencies of 5,047 regular and 88 irregular verbs in the English language. We performed analyses on data from three relative frequency counts: one was derived by Francis and Kucera (1982) from 1 million words of text drawn from several sources selected to cover a range of topics; a second one was extracted from a 44 million word corpus of unedited Associated Press news wires from February through December of 1988 by a stochastic part-of-speech analyzer (Church, 1988); and a third was drawn from the 17.9 million word COBUILD corpus of the University of Birmingham in England by the Centre for Lexical Information (CELEX) at the University of Nijmegen in the Netherlands. All three frequency counts disambiguated different parts of speech (e.g., *played* used as a past tense has a separate count from *played* used as past participle). All analyses were carried out on the natural logarithm (\ln) of each raw frequency count, which was first augmented by 1 to avoid $\ln(0)$.

The verbs were drawn from a computerized database (constructed by Ullman) which contains orthographic, phonological, and frequency information on 5,350 English verbs. The 5,047 regulars included all verbs in the database which take only a regular past tense form, thereby excluding doublet verbs such as *dive-dove/dived*. The 88 irregular verbs, drawn from Pinker and Prince (1988), excluded doublets, auxiliaries (*be-was/were*), prefixed irregulars (*forgo, override*), and no-change irregulars (*hit-hit*). No-change irregulars were eliminated because the COBUILD frequency counts do not include no-change past tense forms. In addition, *say-said* was eliminated because it was an outlier with respect to stem-past frequency differences in the Associated Press counts. Its raw (not log-transformed) past tense frequency was strikingly larger (475,234) than its stem frequency (24,021), a pattern which is not surprising for a frequency count based on press reports. Note that by eliminating *say-said* we weaken support for the hypothesis that irregular verbs have past tense frequencies as least as high as their stem frequencies.

Results and discussion

The results are reported in Table 9 in terms of stem (\bar{X}_{stem}) and past tense (\bar{X}_{past}) frequency means, the differences of these means ($\bar{X}_{stem} - \bar{X}_{past}$), the effect size, and the paired t test statistics and their associated p values. Given that the sample size is very large for the

Table 9. Mean stem (e.g., look, dig) and past tense (looked, dug) natural log-transformed frequencies of 5,047 regular and 88 irregular verbs

Frequency count	Regulars					
	\bar{X}_{stem}	\bar{X}_{past}	$\bar{X}_{stem} - \bar{X}_{past}$	Effect size	$t(5,046)$	p
Francis & Kucera	.70	.58	.12	.12	12.20	<.0001
Associated Press	2.38	2.10	.27	.13	17.22	<.0001
COBUILD	2.16	1.78	.38	.24	20.59	<.0001
Frequency count	Irregulars					
	\bar{X}_{stem}	\bar{X}_{past}	$\bar{X}_{stem} - \bar{X}_{past}$	Effect size	$t(87)$	p
Francis & Kucera	3.57	3.52	.05	.03	.70	.485
Associated Press	6.59	6.50	.10	.04	.98	.330
COBUILD	5.05	5.22	-.17	-.11	-2.03	.046

regular verbs, one could argue that statistical significance is “easy to achieve” for them, and therefore comparing t or p values between regulars and irregulars (whose sample size is much smaller) may be misleading. Therefore a measure of effect size is appropriate (reported in column 5 in Table 9). It was calculated as $(\bar{X}_{stem} - \bar{X}_{past})/\sigma$, where σ = the average of the standard deviations for stem and past tense frequencies. This effect size gives an index of the magnitude of the difference in the location of the stem frequency and past frequency distributions in terms independent of sample size.

The regular verbs had statistically significantly higher stem (*look*) than past tense (*looked*) frequencies, whereas this pattern did not hold for irregulars (columns 6 and 7 of Table 9). Moreover, this distinction between regulars and irregulars was supported by the effect size values, which were much larger for regulars than for irregulars (column 5). This important exception was found for the COBUILD irregular past tense frequencies, which were actually more frequent than their stems. These results suggest that stem-past relative frequency differences between regulars and irregulars might explain previously reported SLI patterns of greater success at the production of irregular than regular past-marked forms. If in contexts requiring inflection in the normal adult grammar people with SLI select forms according to conceptual selection, then one should find a relative frequency competition between past-marked and unmarked forms, and the ratio of selected unmarked to past-marked forms should be higher for regular than irregular verbs.

It is not surprising that stems of regulars are more frequent than their past tense forms. Bare stems are used in many more contexts (I *walk*, I did *walk*, I want to *walk*) than past tense forms. Why might irregulars not follow this pattern? If irregular past tense forms are memorized, then those of higher frequency are more likely to remain in the language than those of lower frequency, which should tend to be replaced by regular past tense forms (e.g., *gild-gilded*) (see Pinker, 1991; Pinker & Prince, 1988). Regression to the mean predicts that high frequency irregular past tenses should not have, on average, accompanying stems of higher frequency. That is, because high frequency past tense forms are presumably memorized irrespective of their stem frequencies, these stem frequencies should tend to regress to the mean stem frequency over all verbs, which is

lower than the high frequencies of irregular past tense forms. By analogy, although men are on average taller than their wives, a selected group of women over 6 feet 6 inches may have husbands that are not much taller (and may even be shorter) because the average height of men is less than 6 feet 6 inches.

ACKNOWLEDGMENTS

We would like to thank Hilary Bromberg, Harald Clahsen, Jenny Dalalakis, Heather Goad, Michel Paradis, Glyne Piggott, William Snyder, Heather van der Lely, Roumyana Izvorski, and Steven Pinker, in particular, for helpful insights and discussions; Joseph Locascio for his statistical perceptiveness and advice; Leaann Collins, Marie Coppola, Kathleen DeHaven, Suzy Fukuda, Cheryl McSweeney, and Sue Methe for their work in coding the data and making tables; and especially Catherine Rebellati for her phonetic analyses. An earlier version of this article appeared as a working paper in Matthews (1994). This work was largely carried out while Michael Ullman was a McDonnell-Pew Post-Doctoral Fellow in Cognitive Neuroscience at MIT and was supported by SSHRC grant #410-90-1744 for Myrna Gopnik. The research was also supported by funding to Ullman at Georgetown University from Army grant DAM-17-93-V-3018 and a McDonnell-Pew grant in Cognitive Neuroscience.

NOTES

1. Vargha-Khadem et al. (1995) argued that the KE family IQ data suggest a broad cognitive impairment. However, we dispute this interpretation. For the affected family members, they report a WAIS-R/WISC-R mean verbal IQ (VIQ) of 75 (range, 59–91), and a mean Performance IQ (PIQ) of 86 (71–111). The unaffected family members had a mean VIQ of 94 (82–111) and a mean PIQ of 104 (84–119). The authors point out that “six of the affected members and one of the unaffected members obtained performance IQ scores below 85: this is commonly considered an exclusionary criterion for classification of a subject having a specific language impairment” (p. 932). They concluded that “the cognitive impairment of the affected family members is not confined to morphosyntax. Rather, it appears to extend to the verbal domain in general, and, indeed, is just as great in the nonverbal domain” (p. 932).

There appear to be a number of problems with this conclusion. First, it is not clear why Pembrey (1992) found a mean WAIS-R/WISC-R PIQ score of 95 (80–112) for 13 affected family members, whereas the mean reported by Vargha-Khadem et al. (1995) for 13 affected family members, presumably the same people as those reported by Pembrey, was 9 points lower. It may be that this difference could be explained by nothing more than the general revision in Britain of the IQ norms, which lowered all scores by 4 to 8 points (Gopnik, Dalalakis, Fukuda, Fukuda, & Kehayia, 1996). Second, the affected family members' mean PIQ score is within the normal range, above the cutoff of 85. Moreover, this cutoff is high, given that 16% of the population falls below it. A more stringent cutoff, such as that used for determining failure in the past tense production task in the present study (scores in the lowest 0.33% of a population are treated as outliers) or even the more generous cutoff of an IQ score of 70 (2% of the population falls below this point), would fall below the PIQ scores for all tested family members, suggesting that all may be

within the normal range. Third, the 6 affected subjects whose PIQ scores fell below 85 constitute less than half of the 13 affected family members tested by the authors. Thus, more than half of the affected subjects had normal PIQ scores, even by the authors' criterion. Moreover, the range of the affected members' PIQ scores falls above 100, indicating that one or more affected family members have PIQ scores above the population mean. It is highly implausible to attribute these higher IQ subjects' language impairments to general cognitive difficulties. Unfortunately, PIQ scores for individual subjects were not reported, precluding the possibility of testing associations over subjects between PIQ scores and language scores from the present study. Fourth, at least one of the family members reported as unaffected had a PIQ score below 85, suggesting that the affected members' depressed PIQ scores might not be accounted for solely by the hereditary deficit. Fifth, it would not be surprising if a grammatical impairment caused some decrease in PIQ scores because PIQ tasks require language comprehension, which presumably involves grammar. Sixth, the authors claim that the affected members' poor VIQ scores suggest that the disorder extends to the verbal domain in general; however, a grammatical impairment alone could lower VIQ scores because VIQ tasks require language comprehension and production.

2. The test of the significance of the past tense frequency predictor was computed with a Wald χ^2 statistic (the square of the parameter estimate, divided by its standard error estimate), which is distributed as χ^2 with one degree of freedom, under the null hypothesis of no effect for the predictor. The standardized coefficient indicates the direction of the association. For example, a positive coefficient indicates a positive association between past tense frequency and the production rate of past-marked forms, holding stem frequency constant.
3. Intriguingly, affected family member AW produced no doubly inflected regulars (*lookeded*). Possibly he tended to analyze *-ed* suffixed forms retrieved from memory as already being past-marked. If such an analysis is based not on his use of an *-ed* suffixation rule but on some strategy (e.g., "ends with a 'd'"), then AW might be expected to produce unmarked forms for verbs whose stems might be misanalyzed as already having been past-marked, such as *stand* or *blend*. Although none of the stems of regular verbs in the past tense task ended in a [d] or a [t], five of the irregulars did. Indeed, of all the language-impaired subjects, AW had the highest percentage (75%) of [d]- or [t]-final unmarked forms, among all unmarked forms produced.
4. Because a given subset of observations came from the same person (i.e., all 16 regulars from each subject were included), the assumption of the significance test that observations be independent is violated, and therefore *p* values should be considered only approximate.
5. The phonetic analyses were carried out by Catherine Rebelatti (a native Canadian English speaker trained in phonology and phonetic transcription) and were verified by Heather Goad.

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