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Productive use of the English past tense in children with focal brain injury and specific language impairment

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Abstract

In this study, 22 children with early left hemisphere (LHD) or right hemisphere (RHD) focal brain lesions (FL, $n = 14$ LHD, $n = 8$ RHD) were administered an English past tense elicitation test ($M = 6.5$ years). Proportion correct and frequency of overregularization and zero-marking errors were compared to age-matched samples of children with specific language impairment (SLI, $n = 27$) and with typical language development (TD, $n = 27$). Similar rates of correct production and error patterns were observed for the children with TD and FL; whereas, children with SLI produced more zero-marking errors than either their FL or TD peers. Performance was predicted by vocabulary level (PPVT-R) for children in all groups, and errors did not differ as a function of lesion side (LHD vs. RHD). Findings are discussed in terms of the nature of brain–language relations and how those relationships develop over the course of language learning.

Keywords: Specific language impairment; Focal brain injury; Morphology; English past tense; Plasticity; Overregularization

1. Introduction

English-speaking children typically begin to mark plural or past tense forms before their second birthday and often do so appropriately for both regular (e.g., "Daddy *walked*") and irregular forms (e.g., "Johnny *took* my blocks," "I *won*!"). Later, inappropriate uses of inflectional morphemes (e.g., *taked*, *winned*) begin to be observed. These errors persist well into the school-age period, however, their frequency gradually diminishes as children's production of both regular and irregular forms approaches an adult-like pattern. It is generally assumed that these errors reflect progress in the development of productive language use, i.e., the hallmark human ability to generate words or sentences that have not been heard in the input (Berko, 1958; Bybee & Slobin, 1982; Cazden, 1968; Kuczaj, 1988).

In recent years, the details of this achievement and the precise mechanisms guiding its development have been the subject of considerable study, refinement, and debate. It has become clear that a simple stage-like account is inadequate and does not account for the complex developmental pattern that has emerged in more recent studies (e.g., Marchman, 1997; Marcus, Pinker, Ullman, & Hollander, 1992; Plunkett & Marchman, 1991). Children do not enter a period in which the regular rule is applied across-the-board. Instead, past tense forms of some irregular verbs are produced correctly at the same time that others are being overregularized. Although it is rare to find a child who never produces overregularizations (Marchman, 1997), errors typically reflect only a small portion of children's irregular verb use (e.g., less than 15% reported by Marcus et al., 1992). Finally, while overregularizations are the most oft-cited evidence that children have abstracted systematicities that are inherent in the language, other types of productions also occur, including zero-markings (e.g., "he *sit*") and vowel changes (e.g., "she *brang*"). Analyses have shown that these errors are systematic (Marchman,

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1997; Marchman, Wulfeck, & Weismer, 1999), predicted by frequency, and phonological similarities that exist across sub-clusters of irregular verbs (Pinker & Prince, 1988).

While the facts have been refined, the standard interpretation remains true to the conclusion that overregularizations signify the emergence of grammatical rule-based knowledge. The ability to generalize the regular pattern to irregular forms is seen as evidence that the child has abstracted the regular pattern and stored it in a symbolic, rule-based format that can apply to any verb, regardless of its phonological or surface characteristics (Marcus et al., 1992). This symbolic encoding of linguistic regularity is crucial to the child's acquisition of grammatical rules and is independent of the statistically based lexical-learning system that is required to master the exceptions to those rules (Marcus et al., 1992; Pinker, 1991; but see Christiansen & Curtin, 1999; Seidenberg, 1999). Support for this dual-mechanism view is based in studies of naturalistic productions (Marcus et al., 1992), acceptability judgments (Kim, Marcus, Pinker, & Hollander, 1994; Prasada & Pinker, 1993), cross-linguistic analyses (Clahsen, Rothweiler, Woest, & Marcus, 1992), and neuroimaging (Jaeger et al., 1996). More recently, studies have shown that infants as young as 7 months of age can discriminate novel sequences of nonsense words that adhere to a rule-based pattern (e.g., "ga ti ga") versus those that do not (Marcus, 2001; Marcus, Vijayan, Bandi Rao, & Vishton, 1999). As Marcus et al. state "infants possess at least two distinct tools for learning about the world and attacking the problem of learning language: one device that tracks statistical relationships and another that manipulates variables, allowing children to learn rules" (1999, p. 79).

Adopting a more unified view of the language faculty, other researchers have suggested that the mechanisms involved in processing statistical regularities allow language learners to master lexically based mappings as well as encode the regularities that occur across them (e.g., Elman et al., 1996; Seidenberg, 1997). In connectionist models of past tense acquisition (Plunkett & Marchman, 1991, 1993), both learning tasks are inextricably linked, suggesting that size of lexicon should be a strong predictor of the onset of generalization behavior. Marchman and Bates (1994) tested this prediction in a large sample of children using a parent report measure of vocabulary production and use of correct and overgeneralized English verbs. As in the models, overregularizations were rare in children with small verb vocabularies, and tended to increase in frequency as vocabulary sizes exceeded a particular level. Such strong continuity across lexical and grammatical development is consistent with a host of findings that have established strong links between lexical and grammatical acquisition more generally (e.g., Bates et al., 1988; Fenson, Dale, Reznick, & Bates, 1994; Rollins & Snow, 1998). Further, this view has implications for the nature of the representations underlying lexical and grammatical development and processing (Akhtar & Tomasello, 1997; Bates & Goodman, 1997) and the origins of grammatical categories in lexically based terms (Goldberg, 1995; MacDonald, Pearlmutter, & Seidenberg, 1994).

Debates regarding the origins of productive language use have also received considerable attention from researchers interested in disordered populations. For example, children with Specific Language Impairment (SLI) show general delays in expressive language abilities that place them below expectations based on age- and cognitive-level. However, a hallmark characteristic of SLI in English-speaking children is a disproportionate difficulty with grammatical morphology. It is consistently reported in the literature that children with SLI tend to omit grammatically inflected forms in obligatory contexts more frequently than their typically developing (TD) counterparts, producing more zero-marked (or "unmarked") plural or past tense forms (e.g., "he walk") compared to their peers (Bishop, 1997; Marchman et al., 1999; Rice, Wexler, & Cleave, 1995; Oetting & Horohov, 1997). While TD children will also produce unmarked forms, errors tend to persist later in development in children with SLI. In addition, children with SLI are more likely to avoid target inflected forms in elicitation tasks, choosing instead to produce a non-past form (e.g., "he is walking") or a filler phrase (e.g., "I don't know") (Marchman et al., 1999).

Some accounts of SLI propose that these children have particular difficulties at the level of representations of linguistic structures (Gopnik & Crago, 1991; Rice & Wexler, 1996; Ullman & Gopnik, 1999; van der Lely & Christian, 2000; van der Lely & Sloowerck, 1997; van der Lely & Ullman, 2001). For example, Gopnik and Crago (1991) studied a three-generation British family (ranging from 2 to 74 years of age), in which half of the members presented a serious form of language impairment. Following a dual-mechanism view, Gopnik and Crago (1991) suggested that the affected family members had a language-specific deficit that precluded their ability to apply grammatical rules productively. Correctly inflected forms were produced via an item-based mechanism utilized for memorizing individual lexical items. However, the specificity of the language deficits observed in individuals with language impairment is controversial. When Vargha-Khadem and colleagues (Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995) conducted follow-up assessments on the family members, results indicated a general impairment of IQ in some affected family members (e.g., IQ scores below 85), as well as broader language impairments in domains such as word repetition, prosody, and manipulation of word order. Further, upon re-testing with an expanded set of items, family members displayed the same level of difficulty producing both regular and irregular forms, contrary to the selective deficit pattern reported in the original study.

Further questions have been raised concerning the language-specific nature of SLI. These questions arose as a result of a growing number of studies reporting below-age level performance in non-linguistic skills such as reduced processing capacity and the ability to encode temporal characteristics of auditory stimuli (Bishop, 1994; Leonard, 1994; Leonard, 1995; Norbury, Bishop, & Briscoe, 2001; Tallal, Merzenich, Miller, & Jenkins, 1998; Tallal, Stark, & Mellits, 1985). A general processing account of SLI is also consistent with the proposal that the problems with inflectional morphology that are observed in these children may arise from the same mechanisms that are responsible for difficulties in lexical learning. Marchman et al. (1999) found that the errors produced by children with SLI were similar in nature to those produced by younger children with TD and that characteristics of individual items (e.g., frequency) predicted which items were more likely to be produced as errors for both groups. It was further proposed that the difficulties observed in children with SLI are related to their protracted lexical development early in acquisition. English-speaking children with SLI frequently have a history of lexical delays, including late onset of first words and slower rates of vocabulary growth in the preschool period. Recent proposals have specifically implicated the protracted acquisition of verbs as one possible reason why grammatical morphology is an area of persistent difficulties in this population (Jones & Conti-Ramsden, 1997; Norbury et al., 2001).

Interestingly, studies of children with early focal brain injury (FL) also have revealed delays in the achievement of early language development milestones, including late onset of babbling and use of first words (e.g., Bates et al., 1997; Eisele & Aram, 1995; Marchman, Miller, & Bates, 1991; Thal et al., 1991; Vicari et al., 1999). Much of what is known comes from a large-scale longitudinal study of children with pre- and perinatal (before 6 months of age) unilateral focal brain injury (for a review, see Stiles, Bates, Thal, Trauner, & Reilly, 1998). To date, studies of this population have provided researchers with a unique opportunity to examine development in brains that are forced into alternative patterns of organization, and to test and refine models of brain plasticity and specialization.

Following (Bates et al., 1997), the adult model of language processing, derived mainly from the study of aphasia and confirmed by modern imaging techniques (for a recent review, see Brown & Hagoort, 1999), is a logical starting point from which to formulate hypotheses about the development of children with focal lesions (FL). This model clearly points to a privileged role for the left hemisphere in language processing, and to the limited possibility of extensive recovery and reorganization of language functions in adults (Damasio & Damasio, 1992; Geschwind, 1972). To this end, the contrast between adult aphasics and children with early focal lesions allows us to compare the outcome of brain damage on relatively stable and organized systems to neurologically immature systems that have not yet acquired language. However, the emerging profiles in these children are in contrast to what would be expected based upon studies of adults with comparable but late-onset lesions. For example, studies of language acquisition in children with early lesion onsets reveal that deficits are common to children with right hemisphere damage (RHD) as well as children with left hemisphere damage (LHD) (Bates et al., 1997). Also, studies of 10-to-17-month-old infants indicate that the right hemisphere might play a crucial role in early language comprehension and gestural communication.

Further, there is evidence for considerable plasticity in this population (see Bates & Roe, 2001; Bates, Thal, Finlay, & Clancy, 2002; Bates, Vicari, & Trauner, 1999; Eisele & Aram, 1995; Stiles, 1995; Stiles et al., 1998). Contrary to the persisting deficits observed in adults with aphasia, children with early brain injury often show remarkable recovery in a wide range of domains (e.g., Aram, 1988; Basser, 1962; Bates et al., 1997; Feldman, Holland, Kemp, & Janosky, 1992; Lenneberg, 1967). In many cases, language functioning is found to fall within the normal range by the school-age years. For example, Reilly, Bates, and Marchman (1998) examined morphological and syntactic abilities using a naturalistic narrative production task (Mercer Mayer's "The Frog Story"). Reilly et al. reported that children with focal brain injury were more likely to make morphological errors compared to their non-brain-injured peers. However, this effect was considerably stronger in the younger children (5–7 years of age), while older children performed within the normal or low-normal range. Moreover, Reilly et al. report few differences in the use of these grammatical morphemes as a function of lesion side. That is, children with RHD were just as likely to produce errors of grammatical morphology as children with LHD and both groups showed similar degrees of recovery by school-age.

More recently, Bates and colleagues (Bates et al., 2001) used age-corrected z-scores to allow a direct comparison of language production in adults and children with brain injuries. The analyses conducted on the elicited speech samples confirmed that the performance of children with unilateral lesions did not differ significantly from that of normal age-matched controls. Also, no effect of lesion side was observed when children with RHD and LHD were compared directly. In contrast to these results, the brain-injured adults showed reliable hemisphere effects, with left-hemisphere damaged patients performing below right-hemisphere damaged patients. Even though the children with brain damage showed remarkable recovery (evident when their z-scores were compared to those of adult aphasics), morphology was singled out as an area of particular difficulty. On a measure of morphological productivity, children with FL performed significantly below their controls, but still above the limits that would qualify them as language impaired.

Owing to their prospective nature, these studies examine relationships between lexical and grammatical development in systems that were undergoing considerable recovery and reorganization. Bates et al. (1997) report individual variation in the degree of delays in both lexical and grammatical skills. These data are consistent with the proposal that lexical delays in children with early brain injury may indeed be related to their later difficulties with grammatical morphology.

In sum, children with early focal brain injury appear to demonstrate deficits in both lexical and grammatical development, as well as considerable recovery in the later preschool years. The results to date indicate remarkable language development that are in sharp contrast to patterns of impairment seen in adult aphasics. However, these studies did not specifically examine productive use of grammatical morphemes, an area that has been shown to be particularly vulnerable in children with SLI. That is, even though children with FL show remarkable recovery in grammar more generally, it is possible that more subtle deficits may be observed when inflectional morphemes are applied productively in a structured context.

This leads us to the contrast between children with FL and children with SLI. Here, we compare systems that approach the same task (learning language for the first time) with very different neurological conditions. While children with FL are defined by their lesions, children with SLI are not, by definition, neurologically impaired. For the most part, it has been assumed that these children have no frank neurologic impairment, even though little direct evidence is presented to confirm normal neurodevelopment. Paradoxically, studies of children with SLI reveal persistent problems with grammatical morphology that are more in line with the patterns of grammatical vulnerability seen in adults with aphasia. However, with the exception of a handful of studies identifying a range of neurodevelopmental abnormalities including structural abnormalities, anomalous asymmetries of prefrontal cortical regions and excessive neurologic "soft signs" (Gauger, Lombardino, & Leonard, 1997; Jernigan, Hesselink, Sowell, & Tallal, 1991; Plante, 1996; Plante, Swisher, Vance, & Rapcsak, 1991; Trauner, Wulfeck, Tallal, & Hesselink, 2000; Tuchman, Rapin, & Shinnar, 1991), the field lacks detailed examination of the neurologic status of children with SLI. This lack of attention to neurologic status is remarkable considering the extent and persistence of language impairment in these children and the fact that the etiology of SLI continues to elude us, a topic to which we will return. Comparative studies of the developmental patterns of FL and SLI children can help shed light on the nature of the constraints that underlie language learning.

In this study, we conduct a detailed examination of English past tense production in school-aged children with FL, SLI, and TD. Following previous studies, we use an elicitation task in which children are required to produce the past tense forms of both regular and irregular English verbs. Previous findings would predict that children with FL should show considerable grammatical skill by school-age. Yet, difficulties might nevertheless be observed in past tense performance in light of their history of early lexical delays and recent studies have shown that this area might be particularly vulnerable in this population (Bates et al., 2001). Answers to the following questions can contribute to our understanding of the nature of recovery in children with FL, as well as begin to address why plasticity seems to be limited in children with SLI:

1. Do children with FL demonstrate difficulties in past tense production, similar to those observed in children with SLI? Or, are overall accuracy rates similar for children with TD and FL?
2. Are children with FL using language productively in the same ways as children with TD? Or, do error patterns align more with those observed in children with SLI?
3. Is there more evidence of recovery in the use of past tense forms in older children with FL compared to their younger FL counterparts?
4. What is the relationship between past tense production and vocabulary knowledge? Does performance on standardized tests of language skill predict past tense use in these samples of children?
5. Is there evidence that recovery of productive language skills is related to lesion location? Do children with LHD experience particular difficulties with past tense usage? Do their error patterns align more with those observed in children with SLI?

2. Materials and methods

2.1. Participants

Seventy-six monolingual English-language speaking children from the Center participated in this study. Before being recruited for the study, children underwent careful screening to insure that they had hearing and vision (corrected) within normal limits, adequate speech sound production abilities at least at the single-word

Table 1
Neurological information for individual participants with focal brain injury

Participant	Gender	Age at test (years)	Side of lesion	Lobe(s) involved	Sub-cortical	Seizures history
1	M	7	L	F, T, P, O	Y	N
2	M	6	L	T	Y	N
3	F	8	L	F	Y	Y
4	M	10	L	F	Y	N
5	M	10	L	F, T, P, O	Y	N
6	F	8	L	T	N	N
7	M	7	L	T,P	Y	Neo
8	M	4	L	T, P, O	Y	Y
9	F	6	L	F, T, P, O	Y	N
10	F	6	L	Na	Y	N
11	M	4	L	F	Y	N
12	F	8	L	F, T, P, O	Y	N
13	F	4	L	F,T	Y	Na
14	M	11	L	F, T, P	Na	Na
15	F	8	R	T, P	Y	Neo
16	M	10	R	F, P	Y	N
17	M	12	R	F, P, O	Y	N
18	F	12	R	F, T, P	Y	Y
19	M	6	R	F, T, P, O	Y	N
20	F	4	R	T, P	Y	N
21	M	7	R	T, P	N	Na
22	M	15	R	P, O	Na	Na

Note. M: male, F: female; L: left, R: right; F: frontal, T: temporal, P: parietal, O: occipital; Y: yes, N: no; Neo: neonatal; Na: not available.

level and met specific selection criteria for their group.[1] All children with complete language assessment batteries (described below) and codable responses on at least 50% of the items on the past tense elicitation task (described below) were included.

The SLI group consisted of 27 children (22 males, 5 females) with documented language impairment recruited from area speech–language pathologists, psychologists, and physicians. They met the following selection criteria: (1) performance IQ (PIQ) of 80 or higher; (2) no major neurologic abnormalities; (3) expressive language composite score 1.5 or more standard deviations below the mean using the Clinical Evaluation of Language Fundamentals—Revised (CELF-R) (Semel, Wiig, & Secord, 1987); and (4) absence of known developmental disorders such as mental retardation or autism.

The FL group included 22 children (13 males, 9 females) who presented with a unilateral focal brain injury in the right-hemisphere (RHD, $n = 7$) or left hemisphere (LHD, $n = 14$). All lesions were identified by a clinical neurological examination of MRI, CT scan or both. In all cases, lesion onset occurred prenatally or prior to 6 months of age. For each participant, it was determined whether lesion involvement appeared in the left (LHD) or right (RHD) hemisphere and in each of the four lobes: frontal, parietal, temporal, and occipital. Table 1 lists each of the participants with FL, age at test and lesion information.

The TD group consisted of twenty-seven children (19 males, 8 females) who were selected from a larger pool of participants. The children were reported to have a normal health history with no indications of language or motor difficulties or developmental delays and were performing at grade level in a regular classroom at the time of testing.

Table 2 summarizes the number and chronological age (CA) of participants in each group and standardized test scores. A one-way ANOVA indicated no significant differences in age across these three groups. At the time of testing, all children were given at least one standardized test of non-verbal cognition including the WPPSI-R (Wechsler, 1989), the WISC-R (Wechsler, 1974), or the Leiter International Performance Scale (Leiter, 1969). All children in the TD and SLI groups performed within the normal range (standard score range 85–130). An independent samples t test indicated no group differences in mean cognition score for children in the TD and SLI groups. FL children were included in the study regardless of their scores if their participation in the experimental task met the criteria for inclusion (as noted above). Six FL children scored one standard deviation below the mean, resulting in a generally lower mean cognitive score for children in the FL vs. TD and SLI groups. However, a one-way ANOVA showed no significant difference in mean cognition scores across the three groups.

[1] A subset of the TD and SLI children reported on here were included in an earlier study of past tense production (Marchman et al., 1999).

Table 2
Mean (SD) age and test scores for participants in different groups

Group	Age in years	Non-verbal cognition[a]	Receptive language PPVT-R[b]	Receptive language (RLS)[c]	Expressive language (ELS)[c]
TD ($n = 27$)	7.6 (2.2)	104.8 (9.4)	110.3 (11.3)	104.1 (11.3)	94.6 (13.6)
FL ($n = 22$)	7.9 (2.9)	96.2 (17.9)	101.3 (19.7)	83.9 (18.3)	76.1 (18.3)
SLI ($n = 27$)	8.9 (2.5)	101.3 (12.2)	86.6 (11.4)	70.4 (18.5)	64.9 (18.5)
All participants ($N = 76$)	8.2 (2.6)	101.1 (13.6)	99.3 (17.3)	86.4 (21.6)	78.8 (18.7)

[a] Standardized assessment of non-verbal cognition based on WPPSI-R, WISC-R or Leiter International Performance Scale (see text).
[b] Peabody Picture Vocabulary Test—Revised standard scores.
[c] Receptive and expressive language composite scores on the CELF-R. Scores were not available for 2 children in the FL group.

Table 2 also presents group scores from three language measures used to assess receptive and expressive language abilities. All children in the TD group performed within the normal range on each of the language measures. All children in the SLI group scored outside the normal range (one or more SDs below the mean) on one or more of these measures, with the majority scoring substantially lower than this cutoff ($n = 13$ below on 2 measures; $n = 11$ below on 3). Performance on the language tests was not used as an exclusionary criterion for the children in the FL group. Some children with FL ($n = 5$) performed in the normal range on all measures, however, other children fell below the cut-off on 1 ($n = 7$), 2 ($n = 6$) or three ($n = 3$) of the language assessments.

More specifically, all children participated in standardized assessments of receptive language skills using the Peabody Picture Vocabulary Test—Revised (PPVT-R) (Dunn & Dunn, 1981). A main effect of group was observed, $F(2, 73) = 18.9$, $p < .001$, with post-hoc comparisons indicating that the SLI group scored significantly lower than both the TD and FL groups ($p < .001$). Receptive (RLS) and expressive (ELS) language scores from the CELF-R (Semel et al., 1987) were obtained for all children, with the exception of 2 children in the FL group. Main effects of group for RLS, $F(2, 73) = 29.5$, $p < .001$, and ELS, $F(2, 71) = 31.9$, $p < .001$, were observed. For both measures, post-hoc comparisons indicated that the SLI group scored significantly lower than children with TD and with FL ($p < .01$). Further, the FL group scored significantly lower, on average, than children in the TD group ($p < .01$).

2.2. Procedure

Each child, tested individually, was administered a production task to elicit past tense forms. Children were shown black-and-white drawings representing everyday activities (e.g., a boy walking, a girl eating an apple), and were asked to complete a target sentence. For example, the experimenter said: "This boy is walking. He walks everyday. Yesterday, he....?" and the child responded with "walked." All scenarios depicted an action which required a third person singular noun in subject position, in order to avoid confusion between possible zero-marking errors (e.g., "Yesterday he walk"), and present tense forms (e.g., "They walk," "I walk"). Three practice items were administered. During testing, the experimenter responded with non-contingent but supportive praise regardless of the grammaticality or pronunciation of the child's response. If the child provided a non-past tense response (e.g., "he was walking," "I don't know"), the item was re-prompted by the experimenter. If the child's response included a verb other than the one included in the prompt (e.g., "he ran far"), the experimenter re-prompted with "Can you use the same word as I do?" If more than two prompts were required, the experimenter went on to the next item. The test session was video-taped for later transcription.

2.3. Items

The production task was identical to that used in Marchman et al. (1999) and included 52 English monosyllabic verbs. Items were selected so that they would be familiar to children across a broad range of ages and abilities, while covering a range of frequency values (Hall, Nagy, & Linn, 1984; Kucera & Francis, 1967; Moe, Hopkins, & Rush, 1982). Items were classified as regular (suffixed with /ed/; $n = 25$) or irregular ($n = 27$) based on the conventions of Standard American English (Pinker & Prince, 1988). Irregular verbs formed the past tense through zero-marking (e.g., hit ⇒ hit), vowel change (e.g., ring ⇒ rang), and blend (e.g., feel ⇒ felt). Approximately one-third of the stems (12 irregular; 5 regular) ended in an alveolar stop consonant (/t/ or /d/).

2.4. Transcription and coding

All responses were orthographically transcribed from the video-taped recording of the session. Responses were scored as correct (i.e., appropriate past tense forms) or as falling within one of four error categories. In the case of self-correction, the final response was coded.

1. *Non-valid*: Non-valid responses included non-responses (e.g., "I don't know"); present tense forms (e.g., "he walks"); past/present progressive (e.g., "he was walking"), or past participle (e.g., "he had walked," "it rung") forms, or responses with a non-target verb (e.g., "he went home").
2. *Suffixation*: Responses were coded as suffixations if a child added a suffix to the stem or produced a stem-final suffix plus vowel change (e.g., "the bell ringed" or "the bell ranged"). This category also includes use of incorrect suffixes on regular verbs, according to the conventions of American English (e.g., "he spilt it," "he leanded against the wall").
3. *Zero-marking*: Zero-marked forms were reproductions of the stem, involving no change of stem and no addition of a suffix (e.g., "she hold the baby").
4. *Vowel change*: Change of stem-internal vowel with no addition of a suffix (e.g., "the river flew" for *flowed*; "he brang" for *bring*). Only productive vowel changes were included, as past participles with or without auxiliary (e.g., "it rung") were scored as non-valid.

2.5. Reliability

All sessions were transcribed and coded by at least two research assistants. Taking a random sample of 10% of the participants, we computed reliability estimates as the number of discrepancies divided by the number of opportunities for agreement. Inter-rater reliability prior to resolving discrepancies was 99.8% for transcription (7 discrepancies of 3952 opportunities) and 99.9% (1 of 3952) for coding. All transcription and coding discrepancies were resolved by the first author.

3. Results

3.1. Overall performance

Fig. 1 displays correct production of past tense forms for children in the three groups. Correct forms were produced by most children on the majority of trials with an overall $M = 68.1\%$ ($SD = 22.2$). At the same time, only 1 child (of 76, 1.3%) produced all forms correctly (age 12 years, FL). Thus, the correct production of irregular and regular past tense forms is difficult for most children throughout this age range.

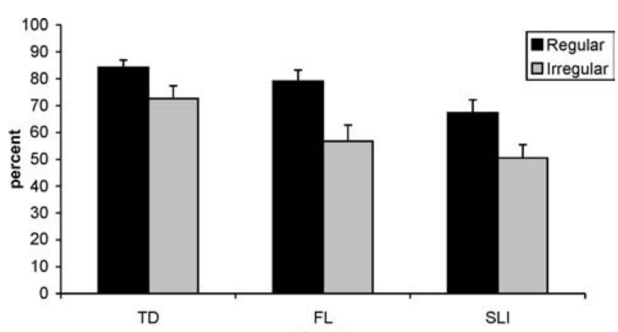

Fig. 1. Percent correct as a function of group and verb type.

Further analyses utilized a mixed multivariate ANOVA on percentage of correct past tense forms with group (SLI vs. FL vs. TD) as a between-subjects factor and verb class (regular vs. irregular) as a within-subjects factor. This analysis indicated a significant main effect of group, $F(2,73) = 5.9$, $p < .004$. Univariate post-hoc comparisons with a Tukey correction indicated that children with SLI were less likely to produce correct past tense verb forms than the TD group ($p < .001$), but their correct production did not differ significantly from that of the children in the FL group. In addition, children in the FL group did not produce significantly fewer correct past tense forms than children in the TD group, on average.

The multivariate analysis also indicated a main effect of class, $F(1,73) = 49.1$, $p < .001$. This effect is due to the fact that children were more likely to produce the correct past tense forms of regular ($M = 76.7\%$, $SD = 21.1$) than irregular ($M = 60.1\%$, $SD = 27.7$) verbs, on average. As illustrated in Fig. 1, no group-by-verb class interaction was observed, suggesting that the regular advantage held to the same degree for children in all three groups, on average.

3.2. Error analyses

Turning now to error types, we first note that approximately 8.2% of all responses were coded as non-valid, e.g., "I don't know" or the production of a non-target verb. Based on Marchman et al. (1999), we expected that children with SLI would be more likely to produce non-valid responses than their TD peers. Further, this tendency could be more evident on irregular rather than regular verbs. A mixed multivariate ANOVA was conducted with group (SLI vs. TD vs. FL) as a between-subjects factor and item type (regular vs. irregular) as a within-subjects factor. While the data reflect a general tendency in the appropriate direction, no significant main effects or interactions were obtained. Children with SLI ($M = 10.5\%$, $SD = 10.2$) were not significantly more likely to produce a non-valid response than the children with TD ($M = 5.8\%$, $SD = 7.3$) or FL ($M = 8.0\%$, $SD = 8.7$). In addition, no difference was observed in the rate of non-valid responses between the FL and TD groups. Further, non-valid responses were equally likely on regular ($M = 4.2\%$, $SD = 4.9$) and irregular ($M = 3.9\%$, $SD = 4.4\%$) verbs for children in all groups. Non-valid responses are excluded from all subsequent analyses.

Our next analysis evaluates distribution of errors produced by our groups for regular and irregular verbs, restricted to only those responses in which children made legitimate attempts at producing a past tense form of a target verb. Figs. 2 and 3 show error patterns, broken down into suffixation, zero-marking, and vowel change responses, for irregular and regular verbs.

Turning first to the errors on irregular verbs (Fig. 2), suffixation errors represented the most frequent error types in groups. However, in the SLI group, zero-marking errors were also quite frequent. A series of univariate analyses compared the frequency of these error types as a function of group (SLI vs. FL vs. TD). Results indicated that the proportion of suffixation errors on irregular verbs did not differ significantly across the three groups, $F(2,73) = 0.7$, $p = .49$. However, consistent with previous findings, group differences were observed in the proportion of zero-marking errors, $F(2,73) = 8.6$, $p < .001$. Post-hoc analyses with a Tukey correction indicated that children with SLI were significantly more likely to produce zero-marking errors than children in both the TD and FL groups ($p < .002$). The frequency of zero-marking responses produced by the FL group, in contrast, did not differ significantly from that of the children with TD ($p = .99$). Vowel change responses represented a relatively small portion of the errors on irregular verbs for children in all three groups ($M = 11.6\%$, $SD = 24.3$), especially the SLI group.

Fig. 3 overviews the pattern of errors produced on regular verbs as a function of group. Note that vowel change errors were the least frequent error type for all children ($M = 6.8\%$, $SD = 19.3$). As expected, zero-marking was the most frequent error type, representing approximately half of the errors on average ($M = 54.5\%$, $SD = 41.8$) across all groups. A univariate ANOVA on proportion zero-marking errors with group as a between-subjects factor indicated no significant group differences. Thus, when errors were produced on regular verbs, children in all groups were equally likely to zero-mark these forms. In addition, no group differences were observed in the rate of suffixation errors. Suffixation errors on regular verbs are those responses in which some type of suffix was applied, but the form did not match the adult target, e.g., "lented." These inappropriate suffixations were observed on nearly one-fifth of the errors that were produced on regular verbs ($M = 22.4\%$, $SD = 32.4$), and this tendency did not differ across the groups.

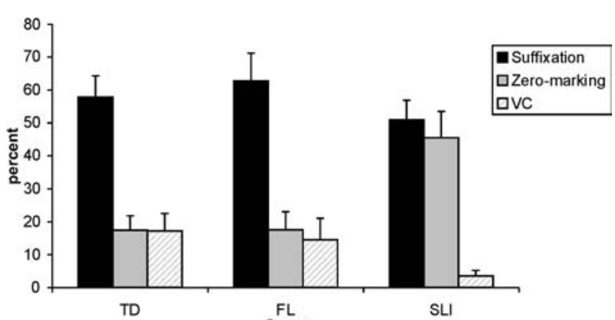

Fig. 2. Errors on irregular verbs as a function of group.

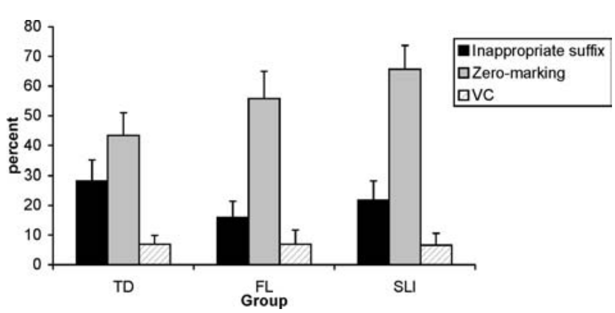

Fig. 3. Errors on regular verbs as a function of group.

3.3. Developmental trends

We would expect that correct past tense production would be more likely in older than younger children for all groups. Indeed, strong positive correlations were observed between age and correct past tense production for the children in the TD ($r = .73$, $p < .0001$), SLI ($r = .66$, $p < .001$) and FL ($r = .55$, $p < .001$) groups.

An error analyses revealed that children in the SLI group were more likely to zero-mark irregular forms than their TD peers. However, the patterns of errors produced by the children in the FL group were very similar to those of children with TD. Recall that Reilly et al. (1998) reported that delays in language were considerably less pronounced in older children with FL. In order to evaluate age-related changes in pattern of usage of past tense inflectional morphology, we grouped children into two age groups: "young" (at or under 7 years, $n = 35$) and "old" (older than 7, $n = 41$). Table 3 presents the number of participants, non-verbal cognitive test score, and age in years of the children in the young and old groups for each of the three populations. While there is some suggestion that older children in the FL group had lower cognitive scores, on average, than children in the TD and SLI groups, no significant group differences were observed.

Table 3 also lists the overall percent correct on the past tense elicitation task for the two age groups. Looking first at the younger children, a univariate ANOVA indicated a significant difference in overall correct performance across the groups, $F(2,32) = 6.9$, $p < .003$. Post-hoc comparisons with a Tukey correction indicated that percent correct did not differ significantly between the children with FL and TD ($p = .79$). Instead, the main effect was attributable to the lower overall correct performance by the children with SLI. Children with SLI performed lower, on average, than children in both the TD ($p < .003$) and FL ($p < .02$) groups.

Table 3
Mean (*SD*) of age and test scores for participants in three groups as a function of age group

Group	Young[a]				Old[a]			
	n	Age in years	Non-verbal cognition[b]	% correct	*n*	Age in years	Non-verbal cognition[a]	% correct
TD	14	5.9 (1.1)	104.3 (9.0)	68.1 (20.2)	13	9.4 (1.5)	105.5 (10.3)	88.9 (9.0)
FL	11	5.5 (1.3)	98.8 (15.6)	63.3 (13.9)	11	10.2 (2.2)	93.6 (20.5)	71.5 (25.5)
SLI	10	6.4 (0.5)	100.6 (10.5)	40.4 (20.7)	17	10.5 (1.9)	101.6 (13.4)	69.2 (17.8)

[a] Young, 7 years and younger; old, older than 7 years.
[b] Standardized assessment of non-verbal cognition based on WPPSI-R, WISC-R or Leiter International Performance Scale (see text).

Turning to the older children, Table 3 indicates that children in all groups are producing the majority of the past tense forms correctly, on average. However, a one-way ANOVA indicated that group differences are still evident, $F(2,38) = 4.8$, $p < .02$. While older children with SLI have clearly made substantial gains in overall correct performance, post-hoc comparisons with Tukey correction indicated that performance, on average, was still reliably lower than that of the children with TD ($p < .02$). Interestingly, children with FL did not reliably differ from either the children in the TD or SLI groups at the $p < .05$ level, suggesting that at least some of these older children with FL may still be lagging behind their age-matched peers. This effect may be due, in part, to the fact that non-verbal cognitive scores for some of the older children with FL were in the lower range. In general then, both the younger and older children with FL performed similarly to their TD peers in overall past tense production.

Next we investigate whether the similar relative distribution of suffixation to zero-marking errors in the FL and TD groups is apparent at both the younger and older ages. Fig. 4 shows the proportion of suffixation and zero-marking responses on irregular verbs for children in the two age and three participant groups. Note that the pattern of error types is strikingly similar in the TD and FL groups at both age levels. In contrast, it is the young children with SLI who show the distinct pattern of overuse of zero-marking. This trend is reversed in the older children. Indeed, no significant differences in rate of zero-marking or suffixation errors were observed in the older groups. This indicates that the overall pattern of error production is similar across all groups for children in this older age range. Thus, there is evidence for some improvement in the performance of children with SLI, as well as of children with early focal brain injury.

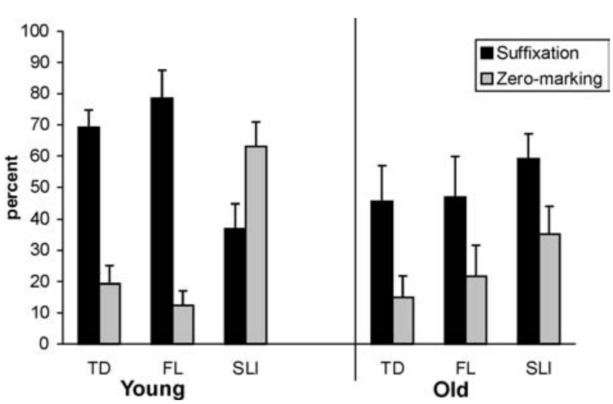

Fig. 4. Proportion of errors on irregular verbs as a function of group and age.

3.4. Role of vocabulary knowledge

Above and beyond these age effects, it is of interest to determine the degree to which non-syntactic language skills are predictive of performance on the past tense elicitation task. Table 4 presents partial correlations between standardized tests of expressive and receptive language and the frequency of past tense errors. Note that in all three groups, scores on the PPVT-R composite were significantly correlated with correct past tense production. Performance on the ELS composite was also significantly correlated in the TD and SLI groups, and approached significance in the FL group. However, the correlations between the RLS composite and past tense performance were low and non-significant in all three groups. In contrast to the receptive vocabulary focus of the PPVT-R, these standardized tests sample a range of syntactic and non-syntactic language skills. Thus, these data indicate a significant relationship between correct past tense production and vocabulary knowledge for children in all groups and demonstrate a striking similarity in the pattern of relationships across the three groups.

3.5. Lesion location

Finally, we examine past tense performance in our children with FL as a function of side of lesion. We first note that there was some suggestion that more correct past tense forms were produced by children with RHD (overall $M = 76.2\%$, irregular $M = 73.0\%$, regular $M = 89.1\%$) compared to children with LHD (overall $M = 62.4\%$, irregular $M = 53.5\%$, regular $M = 73.8\%$). However, these differences were not statistically reliable,

Table 4
Correlation between performance on language assessments and percent correct on past tense task by group controlling for age in years

Group	Receptive language (PPVT-R)[a]	Receptive language (RLS)[b]	Expressive language (ELS)[b]
TD	.52**	.30	.54**
FL	.57**	.23	.42+
SLI	.45*	.09	.58**

[a] Peabody Picture Vocabulary Test—Revised standard scores.
[b] Receptive (RLS) and expressive (ELS) composite scores on the CELF-R. Scores were not available for two children in the FL group.
* $p < .05$.
** $p < .01$.
+ $p < .07$.

$p > .10$. Our confidence in similar levels of performance for children in the LHD and RHD groups is strengthened by the fact that children with RHD were more than two years older at time of test ($M = 9.3$, $SD = 3.7$) than children in the LHD group ($M = 7.0$, $SD = 2.3$). Thus, the possibility for an RHD advantage is likely a reflection of the differences in average age of two groups. At this point, therefore, we must conclude that the children with FL in our sample have undergone considerable improvement in the ability to productively use past tense forms and that lesion side does not have a particularly strong impact on the extent of plasticity by this age.

4. Discussion

The purpose of this study was to evaluate the productive use of English verbal inflections in children with FL, SLI and their typically developing peers. Consistent with previously reported results, school-aged children were quite accurate in producing correct past tense forms. Older children were more likely to produce correct past tense forms than younger children, reflected in strong inverse relationships between frequency of past tense errors and age. In addition, performance on the past tense elicitation tasks was significantly predicted by performance on standardized assessments in all three groups. These relationships were most robust in tests of vocabulary knowledge, the PPVT-R, suggesting that production of correctly inflected past tense forms is linked to level of vocabulary skill (e.g., Marchman & Bates, 1994).

At the same time, these children were likely to produce a variety of errors on both regular and irregular verbs. Children from all groups produced both the classic suffixation (“add -*ed*”) error, as well as zero-marked forms on irregular and regular verbs. Consistent with previous studies, children with SLI were significantly more likely to produce zero-markings on irregular verbs than age- and cognitive-matched controls. This effect was considerably more pronounced in the younger children with SLI.

Analyses indicated striking similarities in both the rate and pattern of errors for children in the FL and TD groups. Children in the FL group were not more likely than typically developing children to produce past tense errors in general, and both groups were more likely to produce errors on irregular verbs. Children with FL produced both overregularizations and zero-marked past tense forms to the same degree as children from the TD group. In contrast to the SLI group, children with FL displayed a pattern of productive language use that was clearly in line with their typically developing peers. Performance of these children, as a group, suggests that the achievement of normal-range grammatical abilities that have been observed in other studies is also reflected in the specific productive language skills under investigation here. Finally, no significant differences in the production of past tense errors were observed in the FL group as a function of lesion side. Thus, children with early unilateral lesions of the LH or RH were able to display past tense usage that followed a typical developmental trajectory.

Why do we see age-level performance in children with brain injury and not in children with SLI? Why are children with lesions that involve the “language areas” doing better than children whose brains are apparently intact? While children with SLI are clearly making progress over the period studied, as noted by the error patterns in the older children with SLI, this progress is considerably less pronounced than that observed in other populations. What is preventing the young children with SLI from using their plastic systems to solve the problem of language learning? This problem is complicated by our incomplete understanding of the neurological processes that characterize normal development, or the development of children with early focal lesions. A number of scenarios could result in normal functioning in the case of a lesion. For example, electrophysiological data from adult left hemisphere stroke patients suggest a “shift” to the right hemisphere for language processing (Papanicolaou, Moore, Deutsch, Levin, & Eisenberg, 1988; Thomas, Altenmüller, Marckmann, Kahrs, & Dichgans, 1997), but considerable intrahemispheric reorganization for motor areas (Benecke, Meyer, & Freund, 1991). Either pattern, or a combination of the two, could be taking place in children with FL. In other words, obtaining a clearer picture of plasticity at work in normally developing and lesioned brains seems to be the necessary premise in order to understand why language is prevented from taking off and flourishing in apparently healthy children. Hopefully, new insights will be obtained from fine-grained studies using non-invasive imaging techniques currently underway.

As mentioned earlier, although there is a rich literature on language profiles of SLI children, far less attention has been directed at their neurologic status. Nevertheless, the small neurodevelopmental literature on SLI as well as studies of adolescents and adults with reading problems (i.e., dyslexia) and language deficits contain numerous reports of neuroanatomical abnormalities that are instructive as we consider hypotheses formulated to account for failure of plasticity in SLI. Abnormalities that have been observed include anomalous asymmetries of the plana temporale (Dalby, Elbro, & Stødkilde-Jørgensen, 1998; Galaburda & Aboitiz, 1986; Galaburda, Sherman, Rosen, Aboitiz, & Geschwind, 1985; Gauger et al., 1997; Plante et al., 1991), diffuse cortical microlesions (Galaburda et al., 1985), volume reduction in the cortical and sub-cortical left posterior perisylvian region (Jernigan et al., 1991), structural abnormalities of the frontal lobe (Vargha-Khadem et al., 1998) and ventricular enlargement, central volume loss, and white matter abnormalities (Trauner et al., 2000). One possibility is that the damage might be limited to the areas that normally subserve language acquisition, and that it might be subtle enough to allow sub-optimal functioning of those areas, and prevent drastic reorganization in healthy tissue (Galaburda et al., 1985). This hypothesis is supported by studies that related lesion size and learning abilities in adult animals (Irle, 1990), and found that animals with either large or small lesions performed better than animals with middle-size lesions. This U-shaped function of performance versus lesion size has been observed in the language of children with FL (Thal et al., 1991), but the pattern failed to reach significance in a subsequent study that included a larger group of children (Bates et al., 1997).

One alternative hypothesis is that language impairment might be caused by widespread involvement across a broad area of cortical tissue, too subtle to be detected by conventional imaging methods, but pervasive enough to prevent normal brain organization. Galaburda et al. (1985) related the neuronal ectopias and dysplasias they observed on dyslexic autopsy patients to the lesions produced in animals when the pattern of neural migration to the cortex is disrupted. Finally, it is also possible that abnormalities in sub-cortical structures might prevent normal language learning. For example, Eisele and Aram (1995) report more severe language deficits in children with lesions to the basal ganglia. The cerebellum and brain stem have been involved in the disorders of communication observed in people with Williams Syndrome (Bellugi, Mills, Jernigan, Hickok, & Galaburda, 1999) or Autism (Courchesne, 1997).

In sum, the results from this study offer evidence that, in general, children with early brain injury can achieve age-level skill in one of the hallmark skills of language, productive use of inflectional morphology. In addition, we corroborate previous findings about the pattern of productive language use in children with SLI, and demonstrate that older children with SLI also approach the typically developing level. While we are still far from reaching definitive answers to the complex reasons for these different developmental patterns, such cross-population studies of children with different neurodevelopmental profiles can provide useful information regarding the nature of brain–language relations and how those relationships change over the course of language learning.

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