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Errors of Omission in English-Speaking Children's Production of Plurals and the Past Tense: The Effects of Frequency, Phonology, and Competition

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Abstract

How do English-speaking children inflect nouns for plurality and verbs for the past tense? We assess theoretical answers to this question by considering errors of omission, which occur when children produce a stem in place of its inflected counterpart (e.g., saying "dress" to refer to 5 dresses). A total of 307 children (aged 3;11–9;9) participated in 3 inflection studies. In Study 1, we show that errors of omission occur until the age of 7 and are more likely with both sibilant regular nouns (e.g., *dress*) and irregular nouns (e.g., *man*) than regular nouns (e.g., *dog*). Sibilant nouns are more likely to be inflected if they are high frequency. In Studies 2 and 3, we show that similar effects apply to the inflection of verbs and that there is an advantage for "regular-like" irregulars whose inflected form, but not stem form, ends in *d/t*. The results imply that (a) stems and inflected forms compete for production and (b) children generalize both product-oriented and source-oriented schemas when learning about inflectional morphology.

Keywords: Inflectional morphology; Language acquisition

1. Introduction

One of the holy grails of cognitive science is the explanation of linguistic productivity: a model of the language system that allows people to store what they hear and creatively reuse it to novel ends.

There has been extensive debate concerning how one should carve apart storage and combinatorial use, with some who have favored a strict division between the concrete representation of lexical items and their combination in terms of abstract categories (e.g., Chomsky, 1965) and others who have argued that storage is more pervasive and associative in nature, making it the very stuff from which abstract combinatorial schemas may first arise (e.g., Langacker,

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1987). Inflectional morphology has long been the favored test case for these contrasting views of language. The intense research in this field offers a particularly rich set of explanatory alternatives that we explore here from a developmental perspective.

Research into the acquisition of inflectional morphology has tended to concentrate on the phenomenon of overregularization—the application of a regular inflection to an irregular stem or inflected form, for example, *mouses* or *mices.* Depending on one's point of view, such errors of commission have been taken as the quintessential demonstration that children either acquire abstract rules or generalize schemas. Far less attention has been paid to the errors that occur when children simply do not inflect a word at all—for example, saying "mouse" to refer to five mice. Yet these errors of omission can shed considerable light on the acquisition process and can potentially pull apart differing theoretical accounts of inflectional morphology.

The dual-route model of inflection (Clahsen, 1999; Clahsen, Aveledo, & Roca, 2002; Clahsen, Rothweiler, & Woest, 1999; Marcus, 1995a, 1995b; Marcus et al., 1992; Pinker, 1999; Pinker & Prince, 1988; Pinker & Ullman, 2002) proposes that irregularly inflected words (e.g., *mice*) are stored in an associative memory, whereas the inflection of regular words (e.g., *houses*) is computed by a default rule (e.g., "add *-s*" for English plurals) that combines a symbol for a stem with a symbol for a suffix. Before the default rule is acquired, if a child does not have an appropriate inflected form in memory, then she or he will be forced to utter a bare stem in its place (Pinker, 1999), and therefore, errors of omission may occur prior to the acquisition of a rule. On learning the rule (as evidenced by the production of overregularizations), errors of omission should disappear, and the child should inflect consistently, albeit with overregularized forms for unknown irregulars (e.g., *mouses*). However, the dual-route model allows for analogies to be made between irregular nouns/verbs that form phonological subgroups, allowing a certain degree of erroneous productivity (e.g., *bring-brang* by analogy to *sing-sang, ring-rang*). Thus, any subsequent errors of omission could only be explained if one were to argue that the word in question was mistaken to be a "no change irregular" (e.g., *cut-cut*) by virtue of being a close phonological neighbor of such irregulars. When this is not the case, errors of omission are not predicted.

Usage-based or schema models (Bybee, 1985, 2001; Bybee & Slobin, 1982; Dąbrowska, 2001, 2004; Köpcke, 1998) propose that both regulars and irregulars are handled by the same storage and processing mechanisms. In a sense, schema models are also dual-route models in that a given inflected form may be arrived at either by retrieving the whole form from memory or by accessing a stem and adding appropriate affixes, which are represented as schemas (Bybee, 2001, p. 113). The difference is that the choice of route is determined by the frequency of the form, not its regularity. The higher the frequency of the inflected form, the more likely it is that it will be retrieved whole from memory (whether it is regular or irregular). Bybee and Slobin (1982) proposed that children form *product-oriented* schemas, which are generalizations about properties of inflected forms (e.g., "past tenses tend to end with *-ed*") as well as *source-oriented* schemas, which are generalizations about how an inflected form is composed of a stem and an inflection (e.g., "to make a past tense, take a verb stem and add *-ed*"). Adult-like mastery is achieved by balancing product-oriented schemas with source-oriented generalizations about suffixation and irregular idiosyncrasies. The early development of product-oriented schemas predicts that children will make more errors of omission with nouns and verbs whose stem ending already resembles the inflected schema (e.g., *dress* already ends in

-s). This account does not predict that errors of omission should stop once errors of commission (productive suffixation) begin. Rather, the developmental process is seen as a gradually refined balancing act that is sensitive to the token frequency of the individual words being inflected (be they regular or irregular) and the type frequency of the inflection(s) being schematized.

Connectionist models have generally been compatible with schema models in that they propose the same storage and processing mechanisms for regulars and irregulars (e.g., Joanisse & Seidenberg, 1999; MacWhinney & Leinbach, 1991; Plunkett & Juola, 1999; Plunkett & Marchman, 1991, 1993, 1996; Rumelhart & McClelland, 1986; Westermann, 1998). These models show signs of schema-induced errors of omission (e.g., making more errors of omission with the /-id/ inflection required for verbs whose stem already ends in *d*/*t*), although these errors are not very frequent and are often argued to be due to analogy with no-change irregulars (*cut- cut*) rather than due to the implicit generalization of a product-oriented schema. Connectionist models more generally demonstrate neighborhood effects whereby items that fall into densely populated neighborhoods, for example *drink-drank* and *sink-sank,* tend to be inflected similarly by virtue of analogy (which can mean they are especially resistant to overregularization errors).

Comparison of connectionist models with Bybee's (2001) schema account is, however, limited because most connectionist models map from a stem to an inflected form rather than from an intended meaning to a past-tense form, which is how production is conceived in usage-based models such as Bybee's (2001). One exception to this is Cottrell and Plunkett's (1994) model that maps from verb semantics (units that uniquely identify a given verb and its tense) to phonological form. The model has difficulty learning the epenthesized regular inflection (/-id/, e.g., *wan**ted***), making more errors of omission with this allomorph, and does not overregularize no change verbs whose stem and inflected form are both identical and both end in *-t* (e.g., *cut*). Interestingly, the model also makes errors of omission with "vowel change" irregulars (e.g., *strike*). When given the semantics of a vowel change irregular and the past tense, it sometimes produces the present tense (stem) form. One might explain these errors in terms of competition between the stem, an overregularization and the irregular form. If an irregular form and an overregularization are in direct competition, then a well-attested stem form that is partially semantically adequate (i.e., has the correct verb semantics but not tense) might occasionally win out. This model therefore predicts that errors of omission are more likely with (a) words whose stem already resembles the schema for an inflected form (e.g., a singular noun that ends in *-s*) and (b) irregular words, which are by their nature subject to more competition effects.

One final type of model to consider is referred to as the parallel dual-route race model (Baayen, Dijkstra, & Schreuder, 1997). In this model, both whole inflected forms and decomposed stems and inflections are activated and race for selection. The higher the frequency of the inflected form, the more likely the whole form is to be used and not the decomposed forms. This model is thus similar to Bybee's (2001) model we described previously but has a more specified processing architecture that includes steps for the activation of segments, the licensing of their composition, and the composition of their meaning. This architecture is proposed to explain adult comprehension. Consequently, it is difficult to make any strong predictions about errors of omission in child production. However, the pervasive storage assumed by the model would presumably predict fewer errors of omission for words whose inflected form is higher frequency. The logic here is that inflected forms that are high-frequency are more likely to be retrieved as a whole than to be formed from a stem and a separate inflection. Errors of omission would not occur if the whole form is retrieved directly but might occur is the stem is retrieved but then not combined with an inflection. The model also predicts that the inflected form of a word should be easier to process if that word is encountered relatively more often in its inflected form than in its uninflected form (when total stem + inflected form frequency is held constant). Taking the example of English nouns, the word *cloud* is often encountered in the plural form and is thus termed *plural dominant,* whereas *ceiling* rarely occurs in the plural and is thus is *singular dominant.* New, Brysbaert, Segui, Ferrand, and Rastle (2004) found that adults were quicker to process plural dominant plurals such as *clouds* than singular dominant plurals such as *ceilings.* Applying this reasoning to acquisition, we might predict that for words of overall equivalent frequency, those that occur more often in the inflected form will be less susceptible to errors of omission than those that occur more often in the singular (see also Bybee, 2001; Hay, 2001).

To summarize, the following six major factors have been identified as potentially affecting the rate of errors of omission in child English:

1. The child's ability to inflect productively (possession of a rule/schema).
2. The phonological similarity of the stem ending to a relevant inflection schema.
3. The phonological neighborhood of the item to be inflected (i.e., the number of other phonologically similar stem-inflected form pairs, e.g., *sing-sang; ring-rang*).
4. The regularity of the word (potential for competition effects).
5. The overall token frequency of the word.
6. The relative frequency of the inflected form to the stem.

The different theoretical models we have reviewed make contrasting predictions with respect to these six factors. The dual-route model would predict errors of omission to disappear (or at least dramatically diminish) once the child can apply the relevant inflectional morpheme productively. Indeed, evidence of productivity (overgeneralization errors) is taken to mean that the child has realized that past-tense marking is obligatory (Marcus et al., 1992). In this case, errors of omission should only occur for items that share a close phonological neighborhood with no-change nouns/verbs and should not be affected by other phonological or frequency factors (although both frequency and phonological neighborhood density may affect the extent to which irregulars are produced correctly or in an overregularized form). Schema models such as that of Bybee (2001) would predict that once a child can inflect productively, errors of omission will gradually decrease with experience. The phonological similarity of the stem ending to the relevant inflectional schema should have a strong effect on errors of omission as should the overall frequency of the inflected form and the frequency of the inflected form relative to its stem. Effects of word regularity are not directly predicted by this account. Cottrell and Plunkett's (1994) model makes the same predictions as the schema model except that it predicts that irregular words will be more susceptible to errors of omission due to competition effects. To the extent that the parallel, dual-route race model can be applied to acquisition, we assume that it would also make predictions similar to those of the schema model. In particular, it would predict fewer errors of omission with words whose inflected form is high-frequency relative to its stem.

A number of studies in the acquisition literature have already suggested that similarity of a stem to the relevant inflection schema affects the rate of errors of omission. In her "wug test" experiment, Berko (1958) noted that children often gave unmarked plural forms, for example, confidently pronouncing "one tass, two tass" (see also Cazden, 1968). That these uninflected forms were most frequent with sibilant nonce nouns supports the idea of a product-oriented plural schema. Reanalyzing Berko's data, Köpcke (1998) found the probability of the 6- and 7-year-olds leaving a form uninflected was clearly related to its degree of similarity to canonical plurals. Similarly, Bybee and Slobin (1982) found that preschoolers were able to productively inflect verbs for the past tense but often failed to apply the *-ed* suffix to verbs whose stem already ended in *d* or *t.* This was the case whether the verbs were regular (leading to errors of omission) or irregular (leading to fewer overregularizations for the no change irregular subgroup, e.g., *cut*). Marchman (1997) replicated this effect with the past tense and also found that errors of omission were more likely if the stem, rather than the past tense, contained a dominant vowel (e.g. the *o* in *throw;* cf. Stemberger, 1993) but less likely if the item in question came from a large phonological neighborhood (e.g., *throw, blow, grow*).

The effects of the other outlined factors on errors of omission have received less investigation and have shown less consistent results. Graves and Koziol (1971) found a considerable time lag between children's mastery of, for example, real /-iz/ plurals (e.g., *glasses, badges*) and their nonce counterparts (e.g., *tasses, radges*). This could be taken as an extreme example of how low-frequency (nonce) words are less likely to be inflected than high-frequency words, particularly if the stem in question resembles a schema. In line with this logic, Stemberger and MacWhinney (1986) found that adults performing a past-tense elicitation task under time pressure were less likely to inflect regular verbs whose stem ended in *d/t* if they were low-frequency than if they were high-frequency. However, Marchman (1997) found no effect of frequency on the rate of errors of omission with the past tense. The effect of frequency thus bears further investigation, especially becasue this factor might affect some phonological subgroups (e.g., verbs whose stem ends in *t/d*) but not others.

The principle aim of these studies was to gain a clearer picture of the extent to which the previously outlined factors affect children's errors of omission to assess different theoretical accounts of inflection. We used stimuli sets specifically designed to address the issue, basing our frequency analyses on counts from corpora of child-directed speech. Using such counts made it difficult to manipulate the relative frequency of inflected as compared to stem forms while holding cumulative or inflected frequency constant. However, we did manage to achieve this for high-frequency, irregular nouns. Thus, in Study 1, we investigated the effect of phonological form, regularity, overall frequency, and relative frequency on the inflection of English nouns for plurality. In Study 2, we investigated the effect of phonological form, regularity, and overall frequency on the inflection of English verbs for the past tense. In Study 3, we investigated the effects of phonology and frequency on different subgroups of irregular verbs.

In all three studies, we tested children aged between 4 and 8 years. Our reasoning was that English-speaking children typically begin to produce plural and past-tense overgeneralization errors between 2 and 3 years of age, and these errors have been observed to persist well into the 4th year (Maratsos, 2000; Maslen, Theakston, Lieven, & Tomasello, 2004). By age 4, we thus assume that errors of omission are not due to a simple absence of any productive knowledge of inflection, which could account for such errors in some children at younger ages. Our aim was to establish for precisely how long these errors would persist before children would reach ceiling across the board on our inflection tasks.

2. Study 1: Inflecting English nouns for plurality

In study 1, we elicited the plural form of three types of noun: irregulars, regulars (inflected with /-s/ and /-z/), and sibilant regulars (inflected with /-iz/). For each group, half of the nouns were high-frequency and half were low-frequency.

2.1. Method

2.1.1. Participants

We tested 114 children (61 girls, 53 boys) at their primary school in Bolton, United Kingdom. The children ranged in age from 4;4 to 8;11 and were divided into five age groups (4-year-olds: $N = 18$, M age = 4;8; 5-year-olds: $N = 24$, M age = 5;7; 6-year-olds: $N = 26$, M age = 6;6; 7-year-olds: $N = 26$, M age = 7;7; 8-year-olds: $N = 20$, M age = 8;7). All children were normally developing, monolingual English speakers.

2.1.2. Materials and design

We made picture cards to represent referents for each of the 36 nouns shown in Table 1. We either hand drew the pictures on the cards or selected them from a Web-based image search. All the images were easily described by the children. We divided the test nouns into three

Table 1
Parental frequencies for singular and plural nouns in the CHILDES database

	Noun Type								
	Irregular			Regular			Sibilant		
	Noun	Singular	Plural	Noun	Singular	Plural	Noun	Singular	Plural
High frequency	Man	1,994	212	Doll	329	210	Horse	938	182
	Mouse	440	61	Grape	106	60	Box	1,342	73
	Knife	140	29	Tail	280	30	Dress	338	26
	Child	854	865	Shoe	345	834	Dish	91	128
	Tooth	83	470	Wheel	351	405	(Shoe)lace	16	48
	Foot	547	535	Eye	296	613	Bush	38	35
Low frequency	Wolf	107	5	King	124	5	Cross	145	5
	Scarf	65	0	Map	20	1	Prince	34	1
	Woman	156	37	Beard	87	1	Church	127	0
	Elf	6	23	Eyebrow	9	24	Branch	16	17
	Hoof	2	2	Prawn	2	2	Hedge	1	3
	Louse	0	0	Igloo	1	1	Sledge	3	0

within-subjects conditions according to inflection type. There were 12 nouns that had an irregular plural form, 12 were regularly inflected with the allomorphs /-s/ and /-z/, and 12 sibilants were inflected with the allomorph /-iz/. We further subdivided these noun groups into two within-subjects categories on the basis of the frequency of the plural form (*high* and *low*) as defined by the parental frequency count available on the CHILDES database (MacWhinney, 2000).[1] As far as possible, we matched the frequency of the plural forms across noun groups (e.g., *men, dolls,* and *horses* are roughly equally frequent). Finally, we were able to form two relative frequency conditions for the high-frequency irregular nouns while holding overall frequency (singulars + plurals) roughly constant. The nouns *man, mouse,* and *knife* occurred more frequently in the singular form than the plural form (singular > plural condition). The nouns *child, tooth,* and *foot* occurred equally or more frequently in the plural form than in the singular form (plural > singular condition).

2.1.3. Procedure

We designed an inflection game in which children were asked to help name objects. The game proceeded in the following order.

1. *Naming phase:* We first presented the children with pictures of single objects in random order and we asked them to say what they saw. If a child could not name the object on the screen with the singular form, we provided help until all the nouns were familiar from their pictures.
2. *Warm up phase:* We gave the children a demonstration and practice run of the inflection game with mass nouns. For example, the children would see a picture of a pile of mud and the experimenter would say "This is some mud." Then a picture of several piles of mud would be presented, and the experimenter would say "This is some more mud." The children would then have a turn with, for example, piles of sand. This helped to ensure that the children had understood the task without uttering any plural forms.
3. *Elicitation of plural forms:* We again showed the children the singular picture for each object (and given a reminder of the singular form if necessary) followed by a picture corresponding to the noun's plural form. For each picture depicting a plural noun, we asked the children "What are these?"

Children were always congratulated for their responses and were never given any corrective feedback.

2.1.4. Coding

We transcribed responses during the testing session and made an audio recording of the test session. We coded responses as *uninflected, correctly inflected, over-regularized,* or *other.* We coded double marked responses (e.g., *mices*) as overregularizations. A second coder (D. Matthews) checked and coded 10% of the audio recordings. Agreement was very high: Cohen's $\kappa = 0.96$.

2.2. Results

We analyzed the results in terms of mean percentage of nouns inflected, regardless of whether inflections were correct or overregularizations (denominator: inflected forms +

stems). A summary of the mean inflection rates for each condition is given in Table 2. The results for each individual noun are given in Appendix A.

The children made gradually fewer errors of omission as age increased. A one-way analysis of variance (ANOVA) on the proportion of nouns inflected in each of the five age groups revealed a significant effect of age, $F(4, 109) = 15.47$, $p < .001$. A steady increase in the proportion of nouns inflected is revealed in a significant correlation with age ($N = 114$; $r = 0.57$, $p < .001$). We further analyzed the irregular nouns for age effects because they are subject to two kinds of errors: omission and overregularization. There was a significant correlation with age for both types of error as a proportion of overall responses for both high- and low-frequency nouns (high-frequency: $r = –0.51$, $p < .001$, $N = 114$; low-frequency: $r = –0.45$, $p < .001$, $N = 114$), revealing that older children made fewer errors of both types than younger children. However, when we examine errors of omission as a proportion of total errors only (omissions + overregularizations), we observe a different relation with age. There is a correlation between age and the rate of errors of omission as compared to overregularizations such that younger children produce proportionally more stem errors, whereas older children produce proportionally more overregularization errors for both high- and low-frequency nouns (high-frequency: $r = –0.46$, $p < .001$, $N = 106$; low frequency: $r = –0.42$, $p < .001$, $N = 110$).

Because there was no variance for some cells (where the children were at ceiling), we analyzed the data with Friedman tests and Wilcoxon tests as appropriate. To test whether the rate of inflection was affected by noun type (irregular, regular, sibilant), we ran one Friedman test for each age group. We observed a significant effect of noun type at 4, 5, 6, and 7 years but not 8 years: 4 years $\chi^2(2, N = 18) = 13.3$, $p = .001$; 5 years $\chi^2(2, N = 24) = 22.4$, $p < .001$; 6 years $\chi^2(2, N = 26) = 16.8$, $p < .001$; 7 years $\chi^2(2, N = 26) = 7.2$, $p = .027$ (see Fig. 1). Wilcoxon tests showed that the 4- and 5-year-olds inflected regular nouns more than irregular nouns ($Z = 2.6$, $p = .01$; $Z = 2.9$, $p = .002$, respectively) and in turn, irregular nouns more than sibilant nouns ($Z = 2.0$, $p = .049$; $Z = 2.4$, $p = .017$, respectively). The 6- and 7-year-olds inflected regular nouns more than both irregular nouns ($Z = 3.3$, $p = .01$; $Z = 2.4$, $p = .016$, respectively) and sibilant nouns ($Z = 3.2$ $p = .001$; $Z = 2.6$, $p = .01$, respectively).

To check whether noun type effects would differ for high- and low-frequency verbs, we ran equivalent Friedman and Wilcoxon tests for each overall frequency group separately. Fried-

Table 2
Mean percentage of nouns inflected as a function of age, noun type, and frequency

	Noun Type					
	Irregular		Regular		Sibilant	
Age (Years)	HF	LF	HF	LF	HF	LF
4	59	62	79	69	53	45
5	70	78	90	82	66	55
6	90	93	98	99	91	84
7	93	93	100	96	95	91
8	100	97	100	99	99	98

Note. HF = High Frequency; LF = Low Frequency.

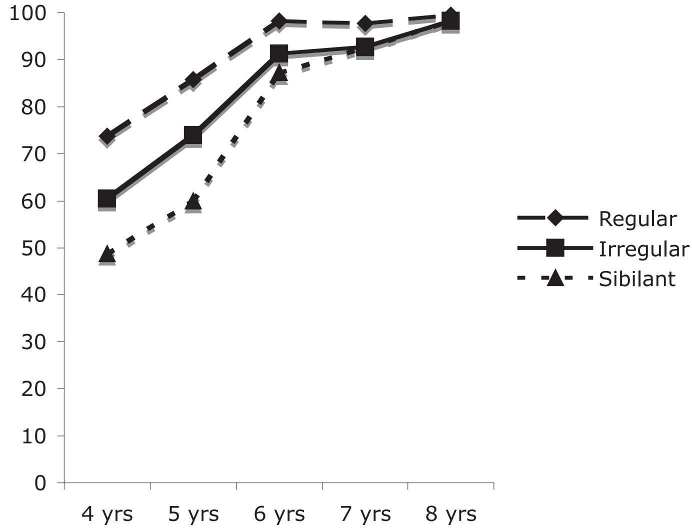

Fig. 1. Mean proportion of nouns inflected as a function of age and noun type.

man tests revealed a significant effect of noun type on high-frequency verbs at 4, 5, 6, and 7 years: 4 years $\chi^2(2, N = 18) = 6.5$, $p = .031$; 5 years $\chi^2(2, N = 24) = 13.0$, $p = .001$; 6 years $\chi^2(2, N = 26) = 8.8$, $p = .013$; 7 years $\chi^2(2, N = 26) = 7.3$, $p = .026$. High-frequency regulars were inflected significantly more than high-frequency irregulars at all ages except 8 years (4 years: $Z = 2.4$, $p = .015$; 5 years: $Z = 2.7$, $p = .008$; 6 years: $Z = 2.8$, $p = .005$; 7 years: $Z = 2.3$, $p = .024$). High-frequency regulars were also inflected significantly more than high-frequency sibilants at 4, 5, and 6 years (4 years: $Z = 2.5$, $p = .012$; 5 years: $Z = 3.2$, $p = .001$; 6 years: $Z = 2.5$, $p = .013$). Friedman tests revealed a significant effect of noun type on low-frequency verbs at 4, 5, 6, and 7 years: 4 years $\chi^2(2, N = 18) = 7.0$, $p = .03$; 5 years $\chi^2(2, N = 24) = 22.4$, $p < .001$; 6 years $\chi^2(2, N = 26) = 14.1$, $p = .001$; 7 years $\chi^2(2, N = 26) = 6.3$, $p = .042$). Low-frequency regulars were inflected significantly more than low-frequency irregulars at 6 years only ($Z = 2.5$, $p = .013$). Low-frequency regulars were inflected significantly more than low-frequency sibilants at 4, 5, 6, and 7 years (4 years: $Z = 2.6$, $p = .011$; 5 years: $Z = 3.4$, $p = .001$; 6 years: $Z = 3.1$, $p = .002$; 7 years: $Z = 2.4$, $p = .016$). Low-frequency irregulars were inflected significantly more than low frequency sibilants at 4, 5, and 6 years (4 years: $Z = 2.2$. $p = .028$; 5 years: $Z = 3.4$, $p = .001$; 6 years: $Z = 2.3$, $p = .02$).

To test whether the rate of inflection was affected by noun frequency (high- vs. low-frequency), we ran five Wilcoxon tests (one for each age group). A significant effect was observed at 8 years only ($Z= 1.9$, $p = .05$) such that high-frequency nouns were inflected more than low-frequency nouns (with similar borderline effects at 5 years: $Z = 1.8$, $p = .065$; and 7 years: $Z = 1.7$, $p = .088$). When we ran equivalent Wilcoxon tests for each noun type separately, we found that the 5-, 6- and 7-year-olds all inflected high-frequency sibilants more than low-frequency sibilants (5 years: $Z = 2.3$, $p = .024$, 6 years: $Z = 2.3$, $p = 0.024$, 7 years: $Z = 2.1$, $p = .031$). The 5-year-olds also inflected high-frequency regulars more than low-frequency regulars ($Z = 2.0$, $p = .045$). The 8-year-olds inflected high-frequency irregulars more than low-frequency irregulars ($Z = 2.0$, $p = .046$).

To test whether the relative frequency of plural forms as compared to singular forms affected inflection rates, we analyzed the rate of inflection of the high-frequency irregular nouns. Half of these nouns (*man, mouse,* and *knife*) were by far more frequent in the singular form. The other half (*child, tooth,* and *foot*) were either equally frequent in the plural and singular forms or more frequent in the plural form. We conducted Wilcoxon tests for each age group separately and compared the rate of inflection of singular dominant irregular nouns as compared to plural dominant irregular nouns. This revealed that the 5-year-olds inflected irregular nouns significantly more often if their plural form was relatively more frequent than the singular form ($Z = 2.6$, $p = .009$).[2]

To summarize, we observed a clear effect of noun type such that regular nouns were generally inflected significantly more than both irregular and sibilant nouns, with sibilants showing the greatest disadvantage. The 5-, 6- and 7-years-olds were more likely to inflect sibilant nouns if they were high-frequency. An advantage for high-frequency nouns was also observed for regular nouns at 5 years and irregular nouns at 8 years. Finally, the 5-year-olds were more likely to inflect irregular nouns if the plural form is relatively more frequent than the singular.

2.3. Discussion of Study 1

The results of Study 1 are not in line with the dual-route prediction that once children have a plural rule, errors of omission should essentially disappear. Even the youngest children tested all frequently produced overregularized plurals (the 4-year-olds overregularized a mean of 2.89 of the six irregulars), yet errors of omission were frequently recorded up until the age of 8. The strong effects of phonology (sibilant compared to nonsibilant regulars) are consistent with the findings of Berko (1958) and Graves and Koziol (1971) and with the theoretical account of Bybee (2001). The effect of regularity (irregulars compared to regulars) on errors of omission is consistent with the predictions of Cottrell and Plunkett (1994).[3] The effects of frequency observed were more sporadic but consistently in the direction predicted by usage-based accounts. Frequency effects were most clear for the subgroup of sibilant nouns. The 5-year-olds also showed an effect of relative frequency, suggesting that advances in the inflection of irregular nouns may first be made with plural dominant nouns.

One potential criticism of this study is that the elicitation of the singular form (to check children knew the word) might have primed the stem form and made it an artificially likely response type. Even if this were the case, any such priming would not directly predict the effects of noun type and frequency we noted previously. Nonetheless, when testing the inflection of verbs for the past tense in Studies 2 and 3, we adapted the familiarization phase so that the verb was presented in the present progressive. In this case, errors of omission could not be due to direct priming of the stem.

3. Study 2: Inflecting English verbs for the past tense

In Study 2, we elicited the past-tense forms of three types of verb: irregulars, regulars (inflected with /-t/ and /-d/), and "*t*/*d* regulars" (inflected with /-id/). For each verb group, half of the verbs were high-frequency and half were low-frequency.

3.1. Method

3.1.1. Participants

We tested 104 children (49 girls, 51 boys) at their primary school in the Manchester region of the United Kingdom. The children ranged in age from 3;11 to 9;4, and we divided them into five age groups (4-year-olds: N = 22, M age = 4;9; 5-year-olds: N = 21, M age = 5;7; 6-year-olds: N = 21, M age = 6;8; 7-year-olds: N = 21, M age = 8;1; 8-year-olds: N = 20, M age = 9;2). All children were normally developing, monolingual English speakers.

3.1.2. Materials and design

We made picture cards to represent the 24 verbs shown in Table 3. We took pictures from Web-based image searches and tested them in pilot sessions. We changed any pictures that systematically elicited alternative verbs. We never used two cards representing mental state verbs (*guess* and *want*) as the very first test card, as they were particularly difficult to illustrate. We divided the 24 verbs into three within-subjects conditions according to inflection type. The eight regular verbs are regularly inflected with the allomorphs /-t/ and /-d/. The eight regular *t/d* verbs have stems that end in *d/t* and are inflected with the allomorph /-id/. The eight irregular verbs are irregularly inflected but are like regulars in that their stems do not end in *d/t,* whereas their inflected forms do. We then further divided these verb groups into two frequency conditions (high and low). We formed the frequency conditions on the basis of counts of the past tense form in the Child Directed Speech (CDS) of 12 mothers in the Manchester Corpus available on the CHILDES database (MacWhinney, 2000; Theakston, Lieven, Pine, & Rowland, 2001). This database contains approximately 1.4 million words tokens, with approximately 15,000 word types. We used this database so as to obtain accurate frequency counts of the different verb forms for British English and to allow us to differentiate verbal and nominal uses of the words on the MOR (morphological) line. As far as possible, we matched the frequency of the past-tense forms across verb groups.

Table 3
Verb frequencies for present stem + progressive and past-tense forms in the Manchester corpus

	Verb Type								
	Regular			Regular *t/d*			Irregular		
	Verb	Present	Past	Verb	Present	Past	Verb	Present	Past
High frequency	Use	508	147	Want	7,453	219	Tell	1,435	232
	Crash	239	61	Start	307	53	Catch	187	53
	Try	932	45	Mend	139	41	Keep	637	51
	Wash	280	44	Sort	96	19	Hear	360	45
Low frequency	Poke	35	4	Collect	34	4	Sell	37	4
	Guess	28	3	End	31	3	Sweep	28	3
	Cough	28	1	Load	20	2	Kneel	24	0
	Follow	16	1	Twist	16	1	Creep	17	0

3.1.3. Procedure

We designed a game that would allow children to inflect the test verbs. As the meanings of these verbs were harder to depict visually than was the case for the nouns in Study 1, we followed a different procedure. First, we showed a picture of an elephant spraying water to the children, and the experimenter said "This elephant is always spraying water. Look! There he is spraying water! Yesterday he did the same thing. So yesterday he. …" We then required the child to complete the sentence. If she or he had difficulty doing so, then the experimenter simply completed the sentence for this first example verb. Piloting demonstrated that one such example sufficed for children to understand the task. The test session continued in the same manner as for the example verb except that the experimenter did not complete the sentence if the child did not respond. If the verb was followed by any other material (e.g., a prepositional phrase or a direct object), then we constructed the script such that this did not start with a *d* or *t*. We took this precaution to aid transcription accuracy because the difference between, for example, *go to the shops* and *goed to the shops* is not as easily detected as the difference between *go home* and *goed home.* We showed the pictures representing the test verbs to the child in random order.

Piloting demonstrated that children sometimes gave the past-progressive form, for example, "He *was spraying*" (in fact, 10% of responses were of this form). We decided that if children gave three consecutive progressive responses, the experimenter would remind them of the game by showing them the training picture and saying "Do you remember how we did this one? We said …" and repeating the example sentence once.

3.1.4. Transcription and coding

We transcribed responses during the test session. We made an audio recording to check any queries. As was the case in Study 1, we coded responses as uninflected, correctly inflected, overregularized, or other. Double-marked responses were coded as overregularizations. We categorized progressive forms (e.g., *washing* or *was washing*) as other. A second coder (D. Matthews) checked and coded 10% of the audio recordings. There was 100% agreement between the first and the second coder.

3.2. Results

We analyzed the results in terms of mean percentage of verbs inflected for the past tense regardless of whether inflections were correct or overregularizations. A summary of the mean percentages for each condition is given in Table 4. The results for each individual verb are presented in Appendix B. A one-way ANOVA on age and proportion of verbs inflected was not significant, $F(4, 100) = 1.57$, $p > .05$. This probably reflects the fact that the children were approaching ceiling in their performance.

We ran five Friedman tests, one for each age group, to test whether the rate of omission errors was affected by verb type (irregular, regular, regular *d/t*). We observed a significant effect of verb type was observed at 4 and 7 years: 4 years $\chi^2(2, N = 22) = 7.5$, $p = .024$; 7 years $\chi^2(2, N = 21) = 12.1$, $p = .002$). At 4 years, regular verbs were inflected significantly more than regular *d/t* verbs ($Z = 2.4$, $p = .017$). At 7 years, irregular and regular verbs were inflected significantly more than regular *d/t* verbs ($Z = 2.4$, $p = .017$; $Z = 2.5$, $p = .011$, respectively). These results are

Table 4
Mean percentage of verbs inflected as a function of age, verb type, and frequency

	Noun Type					
	Irregular		Regular		Regular *d/t*	
Age (Years)	HF	LF	HF	LF	HF	LF
4	99	99	96	100	93	91
5	96	98	98	99	94	91
6	93	93	98	97	94	93
7	100	96	100	100	96	80
8	100	97	100	100	100	99

Note. HF = High Frequency; LF = Low Frequency.

illustrated in Fig. 2. When we ran equivalent tests on high-frequency and low-frequency verbs separately, it revealed that the previous pattern of results held for low-frequency verbs, whereas there were no significant effects when we compared only high-frequency verbs.

To see whether verb frequency affected rates of omission errors, we ran Wilcoxon tests for each age group comparing the rate of inflection for high and low frequency verbs (collapsing across verb types). This revealed a significant effect of frequency on the rate of inflection at 7 years (Z = 2.4, p = .018) such that high-frequency verbs were inflected more than low-frequency verbs. When we ran equivalent Wilcoxon tests for each age and verb type separately, they showed that the effect of frequency at 7 years held only for *d/t* regular verbs (Z = 2.4, p = .017).

To summarize, the 4- and 7-year olds were worse at inflecting regular verbs whose stem already ends in /-d/ or /-t/. For the 7-year olds, this difficultly was compounded when the verb

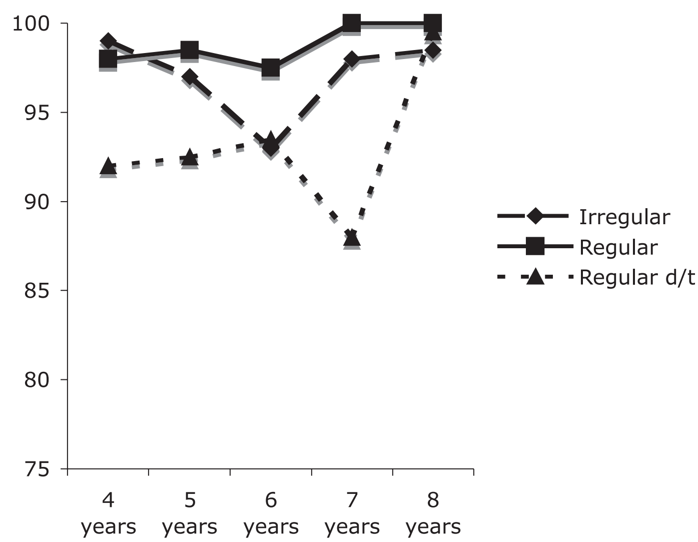

Fig. 2. Mean proportion of verbs inflected as a function of age and verb type.

was low-frequency. This latter effect of frequency on errors of omission with regular *d/t* verbs replicates equivalent findings for adults (Stemberger & MacWhinney, 1986).

3.3. Discussion of Study 2

The children were clearly approaching ceiling for the verb inflection task, and it is therefore not surprising that we found limited effects of our test variables. There was a clear, if sporadic, effect of phonology on inflection rates but no observed effect of verb regularity as there had been for nouns. This might be because all the irregulars were regular-like in that the present form did not end in a /-d/ or /-t/, whereas the inflected form did.[4] It might be that this similarity to regulars increased the irregulars' chances of inflection (either correctly or as an overregularization). To investigate this further, we conducted a third study in which children were required to inflect irregular verbs of the following three types: (a) regular-like irregulars in which the stem does not end in /-d/ or /-t/, but the inflected form does; (b) *d/t* irregulars in which both the stem and the inflected form end in *d/t;* and (c) non-*d/t* irregulars—in which neither the stem nor the inflected form ends in /-d/ or /-t/. We predicted that these three groups of irregular verbs would be inflected differently. Specifically, we expected the *d/t* irregulars and non-*d/t* irregulars to be inflected less often than regular-like irregulars, with the strongest disadvantage being for *d/t* irregulars.

4. Study 3: Irregular verb subgroups

4.1. Method

4.1.1. Participants

We tested 89 children (39 girls, 50 boys) at their primary school in the London regions of the U nited Kingdom. We excluded an additional 30 children from the study due to (a) lack of attention, (b) consistent use of nontest verbs, or (c) consistent use of the past progressive. The children ranged in age from 4;5 to 9;9, and we divided them into five age groups (4-year-olds: N = 18, M age = 4;9; 5-year-olds: N = 17, M age = 5;7; 6-year-olds: N = 18, M age = 6;8; 7-year-olds: N = 18, M age = 7;9; and 8-year-olds: N = 18, M age = 8;9). All children were normally developing, monolingual English speakers.

4.1.2. Materials and design

We made picture cards to serve as prompts for the 24 verbs shown in Table 5. We took pictures from Web-based image searches and tested them in pilot sessions. We changed any pictures that systematically elicited alternative verbs. Because the verb *to mean* was particularly difficult to represent pictorially, we never used the card used as a prompt for this verb as the very first test card. We divided the 24 verbs into three within-subjects conditions according to the following inflection types: (a) regular-like irregulars—stem does not end in /-d/ or /-t/, but the inflected form does; (b) *d/t* irregulars—stem and the inflected form end in *d/t;* and (c) non-*d/t* irregulars—neither the stem nor the inflected form ends in /-d/ or /-t/. We then further divided these irregular verbs groups into two frequency conditions (high and low). We formed

Table 5
Verb frequencies for present- (stem + progressive) and past-tense forms in the Manchester corpus

	Verb Type								
	Regular Like			*t/d* Irregular			Non-*t/d* Irregular		
	Verb	Present	Past	Verb	Present	Past	Verb	Present	Past
High frequency	Tell	1,435	232	Find	1,683	215	Fall	829	225
	Leave	592	123	Sit	1,910	95	Break	419	111
	Mean	462	86	Eat	1,850	84	Throw	599	70
	Catch	187	53	Stand	155	34	Know	4,116	60
Low frequency	Sell	37	4	Bend	56	2	Shake	48	2
	Sweep	28	3	Fight	53	2	Steal	33	2
	Kneel	24	0	Light	119	2	Swing	57	2
	Creep	17	0	Spit	21	1	Spin	41	1

the frequency conditions on the basis of counts of the past tense form in the CDS of 12 mothers in the Manchester Corpus available on the CHILDES database (MacWhinney, 2000; Theakston et al., 2001). As far as possible, we matched the frequency of the past tense forms across verb groups.

4.1.3. Procedure, transcription, and coding

We used the same procedure, transcription, and coding methods as for Study 2. A second coder (D. Matthews) checked and coded 10 % of the transcripts, and Cohen's $\kappa = 0.98$.

4.2. Results

We first analyzed the results in terms of mean percentage of verbs inflected regardless of whether inflections were correct or overregularizations. A summary of the mean percentages for each condition is given in Table 6. The results for each verb are presented in Appendix C. A one-way ANOVA for the five age groups (dependent variable: proportion of verbs inflected) revealed a significant effect of age on errors of omission, $F(4, 92) = 2.45$, $p = .05$. A significant

Table 6
Mean percentage of verbs inflected as a function of age, irregular verb type, and frequency

	Regular Like		Irregular *d/t*		Non-*d/t* Irregular	
Age (Years)	HF	LF	HF	LF	HF	LF
4	91	90	75	78	93	88
5	94	95	85	68	89	91
6	100	98	88	94	93	99
7	99	97	89	81	95	91
8	99	100	96	94	99	99

Note. HF = High Frequency; LF = Low Frequency.

correlation between age and the proportion of verbs inflected shows that the children produced fewer stem responses as age increased (r = .30, p < .01; N = 97). This result tended to hold when we considered each subgroup of verbs separately.[5] However, when we examined errors of omission as a proportion of total errors (omissions + overregularizations), a more interesting relation with age emerged for low-frequency, regular-like irregulars. There was a correlation between age and the rate of errors of omission and overregularization such that younger children produced proportionally more omissions, whereas older children produced proportionally more overregularization errors (r = –.23, p = .041; N = 75). This suggests that for the subgroup of verbs that are most like regulars, children became increasingly more likely to add an inflection one way or another (correct irregular of overregularization) as age increased.

We ran five Friedman tests, one for each age group, to test whether the rate of omission errors was affected by irregular verb type (regular-like, irregular *d/t,* non-*d/t*). We observed a significant effect of verb type at 4, 5, 6, and 7 years but not 8 years: 4 years $\chi^2(2, N = 18) = 6.7$, p = .035; 5 years $\chi^2(2, N = 17) = 6.2$, p = .044); 6 years $\chi^2(2, N = 18) = 8.9$, p = .011; 7 years $\chi^2(2, N = 18) = 8.9$, p = .012). The 4-, 6- and 7-year-olds were significantly more likely to inflect regular-like verbs than *d/t* irregulars (4 years: Z = 2.7, p = .007; 6 years: Z = 2.3, p = .024; 7 years: Z = 2.6, p = .011). The 5-year-olds were significantly more likely to inflect regular-like verbs and non-*d/t* irregulars than *d/t* irregulars (Z = 2.4, p = .01; Z = 1.9, p = .05, respectively). These results are illustrated in Fig. 3. When we ran equivalent tests on high- and low-frequency verbs separately, the previous pattern of results held for low-frequency verbs (except at 6 years when there were no significant effects). There were no significant effects for high-frequency verbs.

To test for an effect of verb frequency on rates of inflection, we ran Wilcoxon tests at each age (collapsing across verb types). This revealed that high-frequency verbs were inflected significantly more often than low frequency verbs at 5 years (Z = 2.4, p = .015). Running equivalent Wilcoxon tests for each verb type separately revealed that this effect of frequency at 5 years held for *d/t* irregular verbs only (Z = 2.4, p = .018).

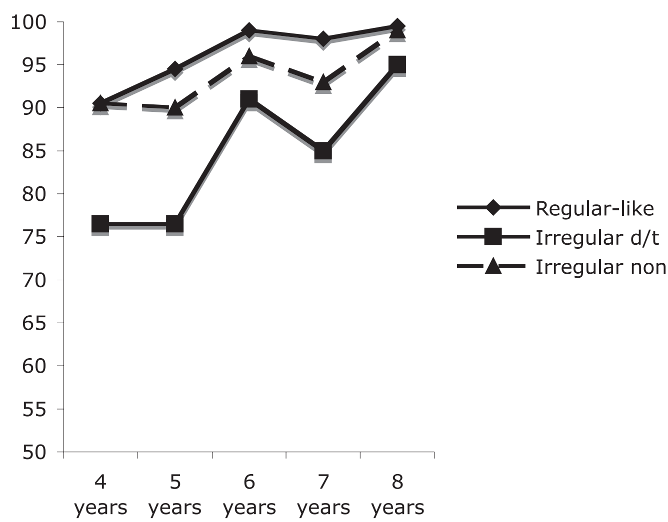

Fig. 3. Mean proportion of verbs inflected as a function of age and irregular verb type.

To summarize, all but the oldest children were less likely to inflect the *d/t* irregulars than regular-like irregulars. For the 5-year-olds, this difficulty with inflecting *d/t* stems was compounded when the verb was low-frequency. Interestingly, and in contrast to Marchman (1997), *d/t* irregulars were less susceptible to errors of overregularization than were regular-like irregulars at 4, 5, and 7 years of age (4 years: $Z = 2.96$, $p < .01$; 5 years: $Z = 3.06$, $p < .01$; 7 years: $Z = 3.19$, $p < .001$).

4.3. Comparison of Studies 2 and 3

Our motivation for Study 3 was to investigate whether children successfully inflected the irregular verbs in Study 2 because they have a similar style of inflection to regular verbs. Given that children do indeed appear to have an advantage for inflecting regular-like irregulars, it makes sense to test for effects of verb type by comparing inflection rates for regular verbs with those of the different irregular verb categories. We achieved this by comparing rates of inflection in Studies 2 and 3. First, we compared the rates of inflection for irregular verbs in Study 2 and regular-like irregulars in Study 3. If our comparison is to be valid, these rates of inflection should be equivalent—because they are essentially the same verb groups (in fact, most of the verbs we tested were the same in each study, and the others did not differ greatly in frequency). Mann–Whitney tests for each age group revealed no significant differences for the rate of inflection for these equivalent verb groups. This justifies our comparison of the rate of inflection of regular verbs in Study 2 with the rate of inflection of different irregular verb groups in Study 3. We ran Mann–Whitney tests comparing regular verbs with regular-like irregulars, *d/t* irregulars, and non-*d/t* irregulars for the five age groups, collapsing across verb frequency conditions. These revealed that regular verbs were inflected significantly more than *d/t* irregulars at 4, 5, and 7 years, with a borderline effect at 8 years (4 years: $Z = 2.8$, $p = .005$; 5 years: $Z = 2.8$, $p = 0.006$; 7 years: $Z = 3.3$, $p = .001$; 8 years: $Z = 1.9$, $p = .061$). Regular verbs were inflected significantly more than non-*d/t* irregulars at 4 years and 7 years, with a borderline effect at 5 years (4 years: $Z = 2.6$, $p = .01$; 5 years: $Z = 1.7$, $p = 0.084$; 7 years: $Z = 2.2$, $p = .029$).

To summarize, both *d/t* irregulars and non-*d/t* irregulars were less likely to be inflected than regular verbs for certain age groups. The lower rate of inflection for non-*d/t* irregulars indicates that verb inflection was not only affected by the presence of a *t/d* at the end of the stem. These results echo those for plurals in Study 1 in which we observed both an effect of a product-oriented schema and an effect of noun regularity.

4.4. Discussion of Study 3

The studies of verb inflection revealed a similar pattern of results as the study of noun inflection, although this pattern was somewhat fainter due to ceiling effects. Children clearly had more difficulty inflecting verbs that ended in *t/d,* be they irregular or regular. This problem has now been well established in the literature (Bybee & Slobin, 1982; Marchman, 1997) and is persistent even at 7 years of age. The combined analysis of Studies 2 and 3 also suggests that children are better able to inflect regulars and regular-like irregulars (e.g., *think* > *thought*) than *d/t* irregulars (e.g., *eat* > *ate*) and non-*d/t* irregulars (e.g., *see* > *saw*). This could be taken to imply that children form fairly broad source-oriented generalizations about the relation between stems and inflected forms (i.e., that to make a past tense form, you take a stem and add an inflection) and that verbs that fit with this generalization are more likely to be successfully inflected. Alternatively, one might argue that inflected forms that end in a *t/d,* whether they are regular or irregular, fit better with a product-oriented schema (that past-tense verbs should end in *d/t*) and are thus produced more easily than irregular forms (which contradict this schema) and *d/t* verbs (for which both the stem and the past-tense form fit the schema). Further cross-linguistic research would no doubt prove useful in assessing the relative contributions of source- and product-oriented schemas. It is worth noting, however, that the presence of such source-oriented schemas is not incompatible with the models we discussed previously in which stems and inflected forms are represented in the same network level. For example, although Cottrell and Plunkett's (1994) model maps from meaning units to form units, the form units have additional intralevel connections that map between present- and past-tense phonology. These mappings could capture source-oriented generalizations.

5. General Discussion

In these studies, we set out to test which factors would affect errors of omission in children's production of plurals and past tenses with the aim of differentiating accounts of acquisition on this basis. We found that errors of omission were more frequent with irregular nouns and verbs and with specific phonological groups of regular nouns and regular and irregular verbs. The dual-route model has difficulty handling these results. First, errors of omission are not predicted to occur once the relevant default rule has been mastered. All the children in these studies gave overregularized responses on occasion and so could be considered to have such a rule. Yet errors of omission were commonplace, particularly for some subgroups of regulars and irregulars, even at 7 years of age (see Maslen et al., 2004, for a similar criticism with respect to overgeneralization errors). So, long after children are presumed to have understood the obligatory nature of plural and past-tense marking, factors of frequency and phonology (and potentially semantics; Shirai & Andersen, 1995) continue to affect inflection. Even if one were to assume that the default rule is prone to failure on occasion, it is not clear why this should be the case more for some types of noun and verb than others, especially in the case of regulars. One of the advantages of the dual-route model was proposed to be its separation of morphology from phonology, with the latter applying downstream of the former (Pinker & Prince, 1988). It is therefore difficult to explain why the rule should apply less often to nouns that end in sibilants and verbs whose stems end in alveolar plosives, unless adding an extra syllable is simply too demanding. It might be possible to argue that some stems are mistakenly assumed to be irregular and inflected by analogy to no-change irregulars (*cut, put, sheep,* etc). However, this explanation seems unlikely for three reasons. First, because no-change nouns, unlike verbs, do not form a phonologically homogeneous group, it would seem that only a semantic analogy (e.g., animals in a group) could induce errors of omission for nouns. Any such semantically based analogy would not predict the observed effects of phonological form. Second, it is not obvious why the subgroup of no-change verbs should have such a large impact on errors when other subgroups have so little effect (we only observed one vowel-change error, which might indicate an influence of analogy across phonological subgroups of verbs across all the children in Studies 2 and 3). Third, in Study 3, no disadvantage was observed for irregular verbs (such as *sit*) that share a phonological neighborhood with no-change verbs (e.g., *hit, split*) in comparison with those that do not (e.g., *find* and *stand*). Moreover, the *d/t* regular verbs in Study 2 were also susceptible to errors of omission, but none shared a close phonological neighborhood with no-change verbs. This suggests that if errors of omission are due to analogy with no-change verbs, then this analogy applies very broadly. Consequently, recovery from this error would require learning each verb and its inflection individually for both regular and irregular verbs, which would seriously undermine the need for any additional rule.

Schema models are better placed to explain the effect of phonology on errors of omission, as these are directly predicted as a consequence of the use of a product-oriented schema. In this case, errors of omission reflected the use of the stem in place of an inflected form rather than the "zero inflection" of a stem via analogy with no-change irregulars. Schema models predict that the effect of such a schema would be weaker for nouns and verbs that are more frequent as was observed. However, future work is needed to establish precisely how schematic generalizations would contribute to errors of omission. This is problematic because both the stem and the inflected form of, for example, *dress,* fit a broad, product-oriented plural schema. We therefore need to explain why children should favor the stem over the inflected form. One possibility is that although both the stem and the inflected form fit the schema, the stem has the stronger representation (by virtue of its higher frequency) and so wins out. Another possibility is that the stem conforms to a more frequent subschema, in the case of plurals, /-s/, and the inflected form conforms to the less frequent subschema, /-iz/. The weaker representation of the /-iz/ allomorph would disfavor its production and lead to the production of the stem. It is possible that both of these explanations apply to varying degrees for different words and paradigms.

Further clarification of the schema model is needed to explain the fact that more errors of omission occurred for irregular than regular nouns and verbs (when the stem did not resemble a prototypical inflected form).[6] There was a clear effect of regularity on the rate of inflection of nouns for all but the eldest children and a similar effect for verbs at 4 and 7 years of age. A schema model might explain this by proposing that the inflected forms of regular nouns and verbs are easier to acquire by virtue of the high type frequency of the regular inflection. In this case, regularly inflected forms would be easily identified in the input, more rapidly learned, and thus more resistant to error.

The observed difference in inflection rates between regular and irregular forms could also be explained if we assumed an architecture similar to that of Cottrell and Plunkett's (1994) model in which stems, schemas, and irregular forms essentially compete for expression. This occasionally leads to the production of a stem in place of an irregular form. Stemberger (2002) argued that this kind of model, in which the base and inflected forms are derived in the same network and may compete, is necessary to explain adult overtensing errors. It would also help to explain the relative frequency effects observed for high-frequency irregular plurals: If the inflected form is relatively more frequent than the stem, then it is more likely to win out, making errors of omission less likely. More generally, a network in which stems directly compete for production with inflected forms is well placed to explain why errors of omission are so pervasive. (In contrast, a network that passes from stem to inflected form phonology would only explain errors in terms of analogy with no-change irregulars). It is likely that models that naturally predict errors of omission will also be more helpful in explaining why these errors are so prevalent in children with specific language impairment (Rice, Wexler, & Hershberger, 1998).

Finally, we should note that phonologically problematic subgroups aside, there were surprisingly few frequency effects found in this data. We observed consistent frequency effects for sibilant nouns and *t/d* verbs. However, frequency effects in the other subgroups were sparse (although always in the direction of an advantage for higher frequency words). It appears that the children were sufficiently familiar with all the nouns, verbs, and inflections to inflect one way or another so long as schema or competition effects (for irregulars) did not directly run against this. This raises three issues. First, it is possible that we would find stronger frequency effects if we examined younger children's use of noun and verb inflections, especially given the ceiling effects observed in our data. Carrying out such studies can be problematic in a number of ways (establishing that children have productive knowledge of inflection, finding sufficient stimuli that children are able to label due to their smaller vocabularies, and so forth) but may provide greater insights into the factors that affect rates of inflection. Second, frequency counts are always made over some qualitative category, and thus, attention to how these categories are formed is essential. In this case, token frequency only appeared to be a good predictor of omissions for phonologically problematic subgroups such as sibilant nouns. Similarly, Dąbrowska (2004) argued that one cannot accurately assess the effect of type frequency until one understands how words are clustered together as being of the same type on phonological and semantic grounds (see also Baayen & Moscoso del Prado Martín, 2005; Ramscar, 2002; Shirai & Andersen, 1995). Third, it is clearly important to specify precisely what kind of frequency measures one expects to have an effect on inflection (e.g., type, token, relative frequency; see Moscoso del Prado Martín, Kostiç, & Baayen, 2004, for a discussion of information theoretical measures used to explain adult inflection) and where one expects to see these effects (in errors of omission, commission, reaction times, etc.). To the extent that we were able to assess relative frequency with this factorial design, this certainly seems to be a promising predictor of errors of omission.

To conclude, this data strongly suggests that a traditional dual-route model of inflection is not viable. A more promising model would (a) store both regular and irregular forms, (b) represent stems and inflected forms such that their phonological forms may influence one another, and (c) yield product- and source-oriented schemas. The major task for future research is to provide a more precise processing model that fits with these experimental findings and the broader language development picture.

Notes

1. The total number of lexical items in this parental corpus is approximately 2.6 million word tokens (about 24,000 word types, counting all inflected forms of a word as separate types). See http://childes.psy.cmu.edu/topics/parentfreq.doc for more information.
2. The 4-year-olds showed this effect with regular nouns in that regulars that are more frequent in the inflected form (*shoe, wheel,* and *eye*) were inflected significantly more than regulars that are more frequent in the singular (*doll, grape,* and *tail;* $Z = 2.5$, $p = .013$), although this may be due to the higher overall frequency of these noun types.

3. Although two of the irregular nouns are sibilant irregulars (*mouse* and *louse*), the children's performance on these items is not solely responsible for the poor performance observed in the children's production of plural forms with irregular nouns. There is a more pervasive effect of irregularity that lends support to the suggestion that competition effects are responsible for errors of omission with this group of nouns.
4. Only five of the irregular nouns bear this resemblance to regulars in that the singular does not end in *-s,* but the plural form does.
5. There was a significant correlation with age for the rate of omissions for high- and low-frequency, regular-like, and *d/t* irregulars (high regular-like $r = -.22$, $p = .03$, $N = 93$; low regular-like $r = -.25$, $p = .02$, $N = 91$; high *d/t* $r = -.29$, $p = .004$, $N = 96$; low *d/t* $r = -.22$, $p = .036$, $N = 93$), which shows that for regular-like and *d/t* verbs, children made fewer errors of omission with age. In addition, there was a significant correlation with age for the rate of overregularizations for high- and low-frequency regular-like, *d/t,* and non-*d/t* verbs, which shows that the proportion of overregularizations decreased with age for all verb subgroups (high regular-like $r = -.53$, $p < .001$, $N = 93$; low regular-like $r = -.54$, $p < .001$, $N = 91$; high *d/t* $r = -.44$, $p < .001$, $N = 96$; low *d/t* $r = -.44$, $p < .001$, $N = 93$; high non-*d/t* $r = -.57$, $p < .001$, $N = 94$; low non-*d/t* $r = -.45$, $p < .001$, $N = 93$).
6. Adherents of the dual route model might explain this by arguing that irregulars could block the application of a rule but subsequently allow the production of a stem. This would still not explain the interacting effects of phonology and frequency on the inflection of regulars, however.

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Appendix A
Percentage Nouns Inflected in Study 1

Noun	4 Years	5 Years	6 Years	7 Years	8 Years
Man	56	63	73	92	100
Mouse	56	50	96	92	100
Knife	69	74	100	96	100
Child	67	92	92	96	100
Tooth	44	64	79	81	100
Foot	56	74	96	96	100
Wolf	63	83	96	92	100
Scarf	71	91	96	92	100
Woman	65	79	92	79	80
Elf	56	78	92	96	100
Hoof	67	78	92	100	100
Louse	39	54	85	92	100
Doll	72	79	100	100	100
Grape	61	96	96	100	100
Tail	78	96	100	96	100
Shoe	76	79	96	100	100
Wheel	94	100	100	100	100
Eye	89	92	96	100	100
King	61	92	100	96	100
Beard	82	88	100	96	100
Map	61	79	92	96	100
Eyebrow	75	83	100	96	100
Prawn	56	63	100	96	100
Igloo	78	79	100	96	95
Horse	50	63	96	96	100
Box	44	58	85	92	95
Dress	72	65	85	92	100
Dish	44	75	92	96	100
Shoelace	65	63	96	96	95
Bush	44	67	92	92	100
Cross	56	54	92	92	95
Prince	39	46	73	88	100
Church	50	58	81	85	95
Branch	44	67	92	96	100
Hedge	39	52	92	88	100
Sledge	41	48	69	88	95

Appendix B
Percentage Verbs Inflected in Study 2

Verb	4 years	5 years	6 years	7 years	8 years
Twist	100	87	64	69	100
Load	83	83	100	82	100
End	100	100	93	93	100
Collect	73	80	82	68	95
Poke	100	94	94	100	100
Cough	100	100	93	100	100
Follow	100	100	100	100	100
Guess	100	100	100	100	100
Sweep	93	88	94	93	86
Creep	100	100	93	100	100
Kneel	100	92	92	92	100
Sell	100	100	92	94	100
Sort	81	92	83	87	100
Mend	92	85	100	92	100
Want	93	100	94	86	100
Start	100	100	100	100	100
Crash	100	93	100	100	100
Use	100	100	92	100	100
Wash	95	100	100	100	100
Try	94	100	100	100	100
Catch	100	100	87	100	100
Hear	100	94	93	100	100
Tell	100	100	100	100	100
Keep	93	100	92	100	100

Appendix C
Percentage Verbs Inflected in Study 3

Verb	4 Years	5 Years	6 Years	7 Years	8 Years
Tell	94	93	100	100	100
Leave	87	100	100	100	100
Mean	83	100	100	100	93
Catch	87	100	100	95	100
Sell	88	86	94	95	100
Sweep	87	100	94	100	100
Kneel	94	100	100	94	100
Creep	93	100	100	95	100
Find	65	79	93	89	100
Sit	73	92	100	94	100
Eat	86	93	95	89	100
Stand	69	75	95	82	88
Light	88	75	94	86	89
Spit	75	71	95	81	89
Bend	76	80	95	86	100
Fight	78	69	94	67	94
Fall	94	92	100	90	100
Break	71	93	94	100	94
Throw	89	94	95	95	100
Know	100	79	93	95	100
Swing	71	92	100	95	100
Steal	100	93	100	90	100
Spin	93	93	94	94	94
Shake	100	93	100	95	100