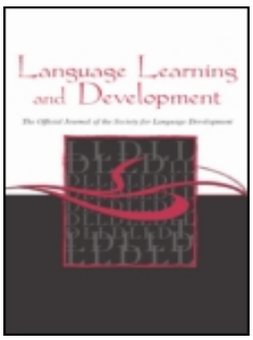

Language Learning and Development

ISSN: 1547-5441 (Print) 1547-3341 (Online) Journal homepage: http://www.tandfonline.com/loi/hlld20

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To cite this article: Inbal Arnon & Eve V. Clark (2011) Why Brush Your Teeth Is Better Than Teeth – Children's Word Production Is Facilitated in Familiar Sentence-Frames, Language Learning and Development, 7:2, 107-129, DOI: 10.1080/15475441.2010.505489

To link to this article: https://doi.org/10.1080/15475441.2010.505489

Language Learning and Development, 7: 107–129, 2011

ISSN: 1547-5441 print / 1547-3341 online
DOI: 10.1080/15475441.2010.505489

Psychology Press
Taylor & Francis Group

Why *Brush Your Teeth* Is Better Than *Teeth* – Children's Word Production Is Facilitated in Familiar Sentence-Frames

Inbal Arnon
Department of Linguistics & English Language, University of Manchester

Eve V. Clark
Department of Linguistics, Stanford University

Adult production is influenced by the larger linguistic contexts in which words appear. Children, like adults, hear words in recurring linguistic contexts, but little is known on the effect of that context on their speech. We look at the production of irregular plurals in English (e.g., *mice, feet*) to argue that children attend to the larger phrases words appear in and make use of that distributional knowledge in production. We assess the role of linguistic context by comparing irregular plurals elicited with a general question (*What are all these?*) versus a lexically specific frequent frame (e.g., *Three blind —*). In study 1, 4;6 year-olds produced many more correct irregulars after lexically specific frequent frames (72%) than after a general question (32%). Corpus data on spontaneous speech offered analogous findings: Children did not overregularize irregular plurals after lexically-specific frames. In study 2, we confirm children's sensitivity to the relation between particular words and phrases: A familiar frame (*So many)* enhanced production (52%) but not as much as the lexically specific frames in Study 1. Children's word production is affected by the larger patterns words appear in. Consequently, studies of lexical and morphological acquisition need to take linguistic context into account when assessing children's abilities. This has implications for models of both lexical and morphological acquisition.

INTRODUCTION

When speakers talk, they rarely produce words in isolation. Instead, they combine words, often in ways that are predictable for native-speakers (e.g., *disappearing ink* but *vanishing cream*; Bolinger, 1976) but difficult for non-native speakers to anticipate. Even though there are numerous ways words can be combined, knowing the subtle ways they actually do is one marker of native-speaker fluency in speech (Fillmore, 1979; Pawley & Syder, 1983; Wray, 2002). Adult word production is also sensitive to larger distributional patterns. Adult speakers are faster to produce words when they appear in more predictable (and frequent) contexts (Bybee & Scheibman, 1999; Bell et al., 2003, 2009; Jurafsky et al., 2001). For instance, adult production of the

Correspondence should be addressed to Dr. Inbal Arnon, Department of Linguistics & English Language, University of Manchester, Oxford Road, Manchester M13 9PL, UK. E-mail: inbal.arnon@manchester.ac.uk

word 'don't' is shorter when it appears inside a frequent phrase like 'I don't know' (Bybee & Scheibmann, 1999). In producing words, adults demonstrate their sensitivity to larger contexts and to the predictive relations between words and phrases. To become native-speakers, children have to develop a similar sensitivity, yet there is little research asking how children's word production is affected by the larger contexts that words appear in. Here, we ask whether children's production of irregular plurals in English is facilitated following more frequent (and predictive) frames.

Several lines of research support the prediction that children's production of words will be affected by linguistic context. Children, like adults, generally hear words embedded in larger phrases. Studies looking at the properties of child-directed speech have highlighted the prevalence of multi-word utterances in general, and repeated frames in particular, in what children hear. Adults direct words in isolation to them in only about 10% the time (Aslin et al., 1996; Brent & Siskind, 2001; Fernald & Simone, 1984; Fisher & Tokura, 1996; Cameron-Faulkner, Lieven, & Tomasello, 2003; Mintz, 2003). While these one-word utterances may play some role in assisting segmentation and learning new vocabulary items (Brent & Siskind, 2001), most of the time adult use the words children hear embedded in larger utterances.

These larger utterances recur frequently. One corpus study, for example, showed that half the utterances in a sample of child-directed speech (CDS) began with one of 52 simple frames, such as *Look at the —* or *Where's the —* ? Of the remaining frames, many were repeated in daily routines (feeding, bathing, dressing, etc.), making them frequent before specific nouns (e.g., *Wash your —* before *hands*, *Have a —* before *bath*) (Cameron-Faulkner et al., 2003; Ferrier, 1978). Frames such as these are also used when adults introduce children to unfamiliar words, e.g., *That's a —*, *Those are —*, *This is called a —* (Clark & Wong, 2002; Estigarribia & Clark, 2007) and may help learners to extract information about syntactic categories (e.g., Mintz, Newport, & Bever, 2002; Mintz, 2003; Weisleder & Waxman, 2010). The language children hear illustrates the co-occurrence relations between frames and single words.

Moreover, children seem to be sensitive to such distributional relations from early on. Many studies have documented children's early sensitivity to distributional patterns at various levels of linguistic analysis and their use of such information in language learning (e.g., Saffran, Aslin, & Newport, 1996; Saffran, Newport, & Aslin, 1996; Swingley & Aslin, 2002). For instance, infants can use transitional probabilities to break into the speech stream (e.g., Saffran, Aslin, & Newport, 1996); young children are better at learning and producing novel words when they conform to more frequent phonotactic patterns (e.g., Maekawa & Storkel, 2006; Zamuner, Gerken, & Hammond, 2004); they can use information about the kinds of subjects verbs take (animate vs. inanimate, say) to make syntactic generalizations (e.g., Goodman, McDonough & Brown, 1998). In short, children can (and do) make use of distributional information in a variety of ways as they are learning to talk.

One recent finding is that young children also attend to the frequency of larger linguistic chunks or multiword phrases. In one study of two- and three-year-olds, children were asked to repeat four-word phrases such as *'a cup of tea'* and *'a cup of milk'*. These phrases differed in chunk frequency but were matched for part frequency (the frequency of the constituent words, bigrams, and trigrams). Children's repetitions of the frame *a cup of* were faster and more accurate for highly collocated phrases like *'a cup of tea'* than for their less frequent counterparts like *'a cup of milk'* (Bannard & Matthews, 2008). The children produced more frequent phrases with greater precision and ease: their production of phrases reflected their knowledge about the words that tend to follow them.

Even though children (like adults) generally hear words embedded in larger phrases (e.g., Aslin et al., 1996), and even though children can (and do) attend to co-occurrence information in language (e.g., Saffran et al., 1996; Mintz, 2003), most studies of lexical and morphological acquisition have paid little or no attention to the effect of linguistic context on word production. Children's ability to produce words is (implicitly) assumed to be independent of the linguistic context. Their knowledge of the correct word form, or the correct inflection, is typically assessed in isolation (e.g. object naming) or in a context assumed to be neutral.

Here, we ask if children's ability to produce the appropriate word form is affected by the larger patterns words appear in: Are children more accurate when they produce words after frames they often co-occur with? We focus in particular on the production of irregular plurals, a domain where children have considerable difficulty. If children's word production, like that of adults, is sensitive to the larger patterns words appear in, they should be more accurate in linguistic contexts that occur more frequently. For example, the plural form *teeth* should be easier to produce after hearing 'Brush your —' than after hearing 'Show me your —'. Such a finding would (a) show that children attend to larger distributional patterns and rely on such linguistic information in production, (b) imply a more gradient characterization of children's lexical knowledge where their ability to produce the correct form depends (among other things) on the immediate linguistic context, and (c) highlight the need to take linguistic contexts into account when looking at children's emerging abilities in production.

Irregular Plurals in English

Children have difficulty acquiring irregular plural nouns in English (Berko, 1958; Cazden, 1968). Although they make sporadic use of a few correct irregular plural forms quite early, children then typically overregularize irregular forms and, for several years, waver between overregularized forms and the correct irregular forms (e.g., Cazden, 1968; Marchman, Plunkett, & Goodman, 1997; see also Kuczaj, 1977; Slobin, 1978). They produce overregularized forms such as '*mouses'* or '*foots'* with the regular *–s* plural inflection, both in spontaneous speech (Marcus et al., 1992; Maslen et al., 2004) and in experimental elicitation tasks (Arnon & Clark, 2008; Gordon, 1985; Matthews & Theakston, 2006; Ramscar & Yarlett, 2007), even though they never hear such forms in adult speech.

Children make fewer errors on more frequent nouns, e.g., *teeth*, compared to less frequent ones, for example, *mice* (Maslen et al., 2004). Their errors are also affected by phonological form. They make more errors in production when the singular noun resembles a plural — when it ends in a sibilant, for example, *horse, lens* (Bybee & Slobin, 1982) or when it resembles other plural nouns, for example, singular *lens* alongside plural *fens, pens, wrens*, and so forth. They also err more when the irregular noun fits an existing plural schema, for example, irregular *ox* /oks/ in the plural schema [— s] (Köpcke, 1998).

These errors, and children's plural formation more generally, have been used to address a variety of theoretical issues: the role of word frequency in acquisition (e.g., Maslen et al., 2004), rule-based vs. rote learning (e.g., Berko, 1958; Pinker, 1999), and the choice of single-system versus dual-system models for representing regular and irregular inflections (e.g., Rumelhart & McClelland, 1986; Pinker & Prince, 1988). The acquisition of irregular forms offers one window on how children learn, organize, and access linguistic information.

Yet studies of irregular plurals have long exhibited a strong single-word focus. Children are asked to produce plurals in a linguistic environment assumed to be "neutral" and held constant across all the items elicited. For instance, after seeing a picture of one *wug* (depicted as a small bird-like creature) and then being shown a picture of two of them, they hear a phrase sicj as *Now there are two —*, with unfinished intonation, as a prompt to fill in the missing word (Berko, 1958). Many other studies have relied on the same elicitation technique (e.g., Arnon & Clark, 2008; Graves & Koziol, 1971; Matthews & Theakston, 2006; Miller & Ervin, 1964; Ramscar & Yarlett, 2007). However, this procedure pays no attention to the possible influence of linguistic context on production, and although corpus studies allow one to investigate multiple variables simultaneously, researchers here too have focused on single words or morphemes. When Maslen and his colleagues (2004) showed that children's production of irregular noun and verb forms is influenced by token frequency, type frequency, and the type/token ratio, they ignored any influence of linguistic context (Maslen et al., 2004; Marcus et al., 1992).

Irregular plurals, then, make a good test case for examining the role of linguistic context on word production. Children produce many errors in elicitation tasks, leaving much room for improvement. Four-year-olds produce irregular plurals correctly in English only about 30% of the time (Arnon & Clark, 2008; Ramscar & Yarlett, 2007). While error-rate has shown to be influenced by such factors as noun frequency and phonological form, no one has looked at the role of linguistic context in children's error rates. Here, we manipulate the previous linguistic context to see whether, and how, this affects children's ability to retrieve the appropriate irregular plural form for production. If children are sensitive to the phrases that words often occur with, and if their online production reflects such knowledge, they should be better at producing irregular forms in frames they often co-occur in (e.g., *Brush your* before *teeth)* than in frames where they occur less frequently.

1: Is the production of irregular plurals facilitated after lexically specific frames?

We used a picture-naming task to compare children's production of irregular plurals in two conditions: (1) after a labeling-question (*What are all these called?*) and (2) in completion of a two-word lexically specific frame. A lexically specific frame is one that frequently precedes specific nouns, such as *Brush your* before *teeth* or *Three blind* before *mice*. In both conditions the child produces only the irregular form, and in both conditions the form is a felicitous continuation of the prompt. Only the lexically specific condition, however, reflects co-occurrence patterns found in spontaneous speech. If children are sensitive to these patterns, they should be better at producing the irregular forms in the lexically specific condition.

We selected lexically specific frames on the basis of raw frequency and chose the frame that preceded each irregular form most often. There are other (more sensitive) ways to assess the relation between frame and noun. In particular, predictability (how surprising a form is given the preceding material) is emerging as an important predictor of linguistic behavior (Altman & Mirkovic, 2009; Hale, 2001; Jaeger, 2006; Jurafsky, 1996, 2003; Levy, 2008). Words are phonetically reduced in more predictable semantic and syntactic environments (Jurafsky et al., 2001; Gahl & Garnsey, 2004; Tily et al., 2009); complementizers are omitted when the relative clause is more predictable (Levy & Jaeger, 2007). While the effect of frequency is well-documented in acquisition, the effect of predictability has been less studied. The two factors are often correlated but can be distinguished. For example, a word such as *cream* may be relatively infrequent but highly predictable in the phrase *face cream*. Here, we investigate the effect of both frame frequency and frame predictiveness (how predictable the word is given the frame) by conducting a detailed item-analysis in the lexically-specific condition.

METHOD

Participants

Twenty-four children (12 boys and 12 girls) participated in the between-subjects study, with 12 children in each condition. Their mean age was 4;6 (range 4;3–4;10) across the experiment and within each condition. All the children were learning English as their first language, and were developing normally.

Materials

We elicited seven irregular plural nouns: *children, feet, fish, geese, mice, sheep,* and *teeth*, all irregular nouns familiar to children aged 4;6.

Frames

To identify lexically specific frames, we extracted frames from a 6 million word subset of the American English portion of the CHILDES database (MacWhinney, 1995). This corpus included all speech spoken to and produced by nonimpaired children between the ages of one and six. To ensure that the resulting three-word utterances (frame + noun) sounded natural, we limited our search to instances where the resulting three-word sequence could appear as an independent utterance. For example, we excluded sequences such as *and the children*). For each of the seven target nouns we selected the frame(s) that appeared most often, excluding all frames that appeared less than three times. For the relatively more frequent nouns (*children, feet, mice,* and *teeth*) we were able to select two frames, while for the less frequent nouns only one frame met our criterion. We also looked separately at the frequency of the frames in child speech vs. adult (child-directed) speech and found high agreement.

For each noun+frame combination selected, we also calculated its predictiveness: how surprising the word is given the frame (-log(P(word|frame). This measure takes into account the number of times the frame occurs independent of the noun. It also reflects the incremental nature of speech: children heard the frame before producing the word. We can then ask whether accuracy within the lexically specific condition varies as a function of the frequency and/or predictiveness of the frame. Table 1 shows the lexically-specific frames for each target noun, together with their joint frequency, and their predictability measure.[1]

[1]There are other measures of the relation between the noun and the frame that could influence production. In particular, how many different frames a noun can occur with. The effect of preceding linguistic context may be weaker for nouns that appear with many different frames (we thank an anonymous reviewer for this observation). We set out to look at the effect of noun flexibility (how many different frames a noun appears with) and frame predictability (how predictable is the lexically-specific frame given the particular noun) on our results. But both measures were highly correlated with important control variables (noun flexibility with noun frequency, and frame predictability with frame frequency), making it hard to discern what independent effect they had. We think these are important issues for future investigation using items that systematically vary along the relevant dimensions

TABLE 1
Lexically Specific Frames Used as Prompts: Raw Frequency and Predictability

Noun	*Frames*	*Raw Freq*	*Frame Freq*	*Noun Freq*	*Predictability: Word|Frame*[a]
Children	*All the* children,	46	3885	1025	.011
	The little children	20	1809		.011
Feet	*On your* feet,	56	2955	2049	.018
	On my feet	25	1748		.014
Fish	*Lots of* fish	7	913	2519	.007
Geese	*Buy some* geese	3	155	70	.019
Mice	*Three blind* mice,	22	22	248	1
	Afraid of mice	3	87		0.03
Sheep	*Count some* sheep	3	3	709	1
Teeth	*Brush your* teeth,	110	178	1417	.62
	Brush my teeth	40	65		0.61

[a]For ease of understanding we give the P(Word|Frame). For statistical analysis we used the corresponding surprisal measure: -log(P(Word|Frame) where higher numbers mean lower predictability.

Filler Items

In both conditions the children completed a color-naming task in addition to the plural production task. They saw pictures of colored balloons and had to name each color in response to: *'What color is this?'* In the frame-completion condition, children also completed ten filler-frames in which the word to be supplied was a regular singular noun. For example, the child saw a picture of a red book and had to complete the frame *The red* — produced by the experimenter with a high unfinished intonation.

Procedure

Children were tested in a quiet room at the nursery school. They were first asked to name single instances of all the target referents to make sure that they recognized them and used the label we intended. If they produced a different label at this stage (e.g., *lamb* for *sheep* or *kid* for *child*), the experimenter offered the intended term instead (*Right! But can we also call it a sheep?*). This was done to reduce the number of nontarget nouns at the plural-elicitation stage. The single-noun elicitation was followed by plural-noun elicitation, prompted either with a labeling-question, or with a lexically specific frame, depending on the condition.

What differed between the two conditions was the linguistic context for the target irregular plural nouns. In the labeling-question condition, children produced each irregular noun in response to the question *'What are all these called?'* In the lexically specific condition, they completed two-word sentence frames produced with rising 'unfinished' intonation by a puppet (voiced by the experimenter). Each noun was matched to a frame it frequently co-occurs in, in spontaneous speech (e.g., *brush your* — for *Brush your teeth*; *on your* — for *On your feet*).

The experimenter began by showing two practice pictures. The first depicted a single house, the second five houses. To emphasize the plurality of the objects, the child was asked first to name the single object (*What is this called?)* and then the set of objects (*and what are all these called?)*. In the frame-completion condition the puppet was introduced after the two practice items. The experimenter asked the child to help the puppet describe the pictures: the puppet would start a description and the child was to finish it. Children then had two further practice trials with nonplural nouns to make sure they understood the task (*It's a — hat, It's a — ball)*.

Coding

Responses were coded for accuracy by a research assistant blind to the predictions of the study. They were coded as Correct if the child produced the correct irregular plural, and Incorrect if the child produced an overregularized plural or a singular form. Incorrect forms were further classified into three types: (a) *s*-addition (adding an 's' to a singular form, e.g., *mouses*), (b) *s*-plural-addition (adding an 's' to the irregular plural form, e.g., *mices*), and (c) singular-form alone (e.g., *mouse*). Finally, nontarget labels for the pictures (e.g. *lambs, kids*) were coded as Other.

RESULTS AND DISCUSSION

Children gave responses in all of the elicitation trials. Their responses, when asked for an irregular plural form, fell into five main categories: Correct, Added *–s* on singular, Added *–s* on plural, Singular alone, or Other. We excluded children who produced Other responses more than one third of the time (more than one SD from the mean Other response rate) since this left too few correct and incorrect forms for reliable comparison. There were only three such children. The proportion of responses for the remaining children is shown in Table 2.

We predicted that children's production of irregular plurals should be better after a lexically specific frame than after a labeling-question. Figure 1 presents correct productions of the irregular plural forms for each condition excluding Other responses (their rate did not differ between the conditions).

We used a mixed-effect logistic regression model to analyze our results. These models allow us to control simultaneously for subject and item effects (see H. Clark, 1973; Baayen, Davidson, & Bates, 2008). They also allow us to look at the effect of linguistic context while controlling

TABLE 2
Percentage of Each Response-type Elicited for Irregular Nouns (Computed Over All Trials)

Condition	*Correct*	*Singular + added -s*	*Plural + added -s*	*Singular*	*Other*
Labeling-question	30	37	2	24	7
Lexically specific frame	68	2	0	23	7

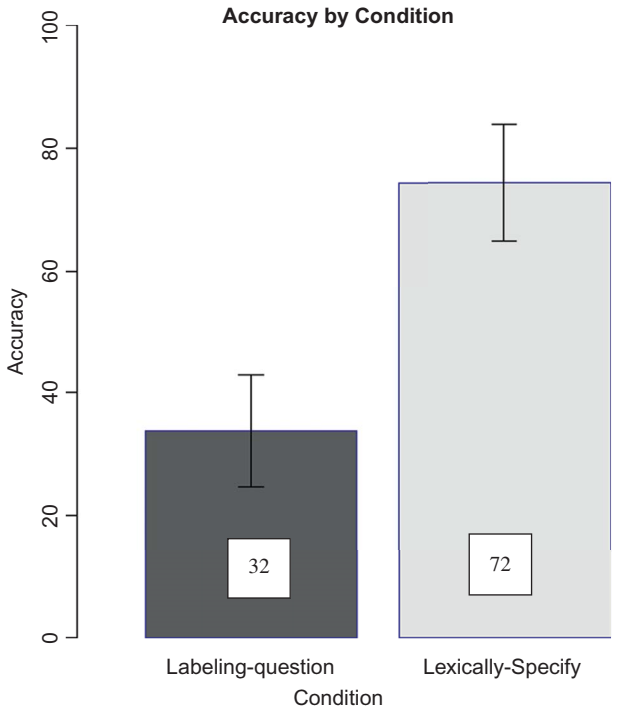

FIGURE 1 Percentage of correct responses by condition in Study 1 (averaged across trials).

for any effect of the frequency of the target nouns themselves. We ran a mixed-effect model with accuracy (correct vs. incorrect) as the predicted variable, linguistic context and log (frequency) as fixed effects, and subject and item as random effects. We calculated the frequency of the nouns using the same 6 million-word corpus we had used to select the frames.

Comparing the Conditions

As predicted, children did significantly better in the lexically specific frame condition than in the labeling-question condition, B = 2.9 (SE = .42), $p < .001$. They were more accurate when the target noun was "introduced" with a lexically specific frame (72% correct) than when it was elicited with a labeling-question (32% correct). Performance in the lexically specific condition was twice as good as in the question condition, even though fewer than half the lexically specific prompts contained linguistic cues to plurality (e.g., *all, three*) like those in the labeling-question (*What are all these called?)*. Performance was also twice as good as previously reported for four-year-olds (e.g., Arnon & Clark, 2008; Ramscar & Yarlett, 2007). As in previous studies, children were more accurate with more frequent nouns, B = 1.49 (SE = .42), $p < .001$.

Differences in accuracy cannot be attributed to knowledge of the relevant singular noun forms. Children successfully labeled singular objects before both plural elicitation conditions: They were correct on 65% of singulars in the labeling-question condition and on 66% in the lexically

specific condition, B = −0.002 (SE = .37), $p > .9$. In the remaining trials, children sometimes produced a nontarget noun (e.g., *kid* for *child* 30% of the time) or, in very few cases, used a plural form (5% of the time). Overall, though, children in both conditions were equally familiar with the objects depicted in the pictures, and with the singular forms of the relevant nouns.

Item-Analysis in the Lexically Specific Condition

The results show that production is improved after lexically specific frames. But what about the frame-noun combinations facilitated their production? The combinations varied both in frequency and in predictability. For example, in *Three blind mice,* the frame is highly predictive — it only occurs before *mice.* In *lots of fish,* the frame is less predictive because it occurs before many other nouns, too. The predictability of the correct form is higher following *Three blind–* than following *Lots of –*. Given the variability in frequency and in predictability in our lexically specific frames, we wanted to see if we could tease apart the effects of those two factors.

To do this, we conducted a mixed-effect regression on the responses only in the lexically specific condition. We ran a model with accuracy (correct vs. incorrect) as the predicted variable, log(word-frequency), log(frame-frequency), and word-predictability (-logP(word|frame)), as fixed effects, and subject as a random effect (we did not include item as a random effect since we were interested in the specific properties of the frames). Some nouns appeared with two different frames (e.g., *Three blind mice* and *Afraid of mice*). Since the frames could (and did) differ in their predictiveness we calculated word-predictability for each frame-noun combination (so the accuracy for *mice* in *three blind mice* was predicted by the probability of (mice| three blind) while the accuracy of the same noun in *afraid of mice* was predicted by the probability of (mice| afraid of).

Word-predictability emerged as a significant predictor when controlling for noun frequency and frame-frequency: Accuracy was higher following more predictive frames, B = –.45, (SE = .15), $p = .008$ (we expect a negative coefficient because the lower the surprisal, the more predictable the word). Frame-frequency, in contrast, was not significant, B = −.65 (SE = .39), $p > .1$. As in the previous analysis, noun-frequency was significant, B = 2.11 (SE = 52), $p < .001$. Children's accuracy within the lexically specific condition increased as a function of predictability: more predictable words were produced more accurately. We return to these findings in the general discussion.

These results clearly demonstrate an effect of linguistic context on children's production of inflected words. Children were more accurate when they produced irregular plurals after sentence-frames that were more predictive. This suggests that they are sensitive to co-occurrence relations between words and phrases and that this knowledge influences their own production. If these results reflect how linguistic knowledge is organized and accessed, children should display similar patterns in everyday conversation, and may produce fewer over regularization errors for irregular plurals after lexically specific phrases there, too.

Irregular Plurals in Spontaneous Conversation

We can look at spontaneous errors to see if this pattern holds. We wanted to see if children were less likely to make errors after the lexically-specific frames used in Study 1 than after

other two-word sentence frames. To do this, we extracted all the child-produced speech in the 6 million-word corpus we had used to select frames. This reduced the corpus to 1.7 million words. Using CLAN (MacWhinney, 1995), we extracted all the correct and incorrect plural uses of the target nouns (*children, feet, fish, geese, mice, sheep,* and *teeth)*, together with the utterance that each use occurred in, plus the two immediately adjacent utterances (preceding and following). We expected to find two kinds of errors: addition of the regular *'–s'* plural marker (a) to the singular form (e.g., *mouses*), and (b) to the irregular plural form (e.g., *mices*). Both error-types were attested in our experimental data. We therefore searched the corpus for all the following forms as well: *childs, childrens, fishes, gooses, geeses, mouses, mices, tooths, teethes, sheeps, foots,* and *feets*.

As in previous corpus studies (e.g., Marcus et al., 1992), we ignored errors of omission where children used a singular form in lieu of a plural. The reason for this was that, without detailed contextual information, it is impossible to tell whether the child made a singular-for-plural error or was actually focusing on just one of the entities in the relevant set. The corpus data available did not allow us to make this distinction (see also Clark & Nikitina, 2009).

We found 102 overregularization errors. Of these, 75% (n = 77) consisted of adding '*–s*' to the singular form and 25% of adding '*–s*' to the irregular plural form. Table 3 lists all the correct productions and errors for each irregular plural noun. Averaged across nouns, the error rate was 4.5%. However, the actual rate differed from one noun to the next, from a low of 1% for *teeth* to a high of 21% for *mice*. These figures are consistent with previous studies of overregularization errors (e.g., Maslen et al., 2004; Marchman et al., 1997; Marcus, 1995; see also Maratsos, 2000).

As predicted, children seem to make fewer errors after lexically-specific frames. Of the 102 errors, 58 were produced after a two-word frame (in addition, 15 overregularizations were produced as one-word utterances, or as the first word of an utterance, and 29 were preceded by just one word.) Children produced irregular plurals following two-word frames 1,503 times. Error rate was 4% overall but dropped to zero after the lexically specific frames. Children did not produce utterances such as *Brush your teeths*. They did produce lexically specific frames followed by an irregular plural noun (79 times), and in every case the irregular form was produced correctly. While we do not want to draw strong conclusions from this limited corpus sample, these findings are consistent with our prediction that children's production of irregular forms is improved after frequent frames in spontaneous speech just as in elicited production and highlight the need to take linguistic context into account in corpus studies.

TABLE 3
Number of Correct and Erroneous Plurals for Irregular Nouns Produced in Spontaneous Conversation

Noun plural	*Correct uses (n)*	*Errors in use (n)*	*Error rate (%)*
Children	205	5	2
Feet	478	31	6
Fish	840	32	4
Geese	25	2	7.5
Mice	73	20	21
Sheep	123	7	5
Teeth	374	5	1
Total	2118	102	4.5

So far, we have seen that children's production accuracy goes up after lexically specific frames compared to after a labeling-question. However, this improvement might be caused by the mere presence of the frame rather than by its lexical content or distributional relation to the target nouns. Answering a question might simply be harder than completing a sentence-frame. Children's production could also benefit simply from the presence of a familiar frame. Frames that often introduce the target words in conversation facilitate word recognition in young children at 1;6. They recognize familiar target words faster when these are introduced in a frame such as *Look at the —* (*Look at the mouse*) than when they are introduced with an attention-getter followed by the target term as in *Look. The —* (Fernald & Hurtado, 2006). Children's experience with a frequent frame may make it easier to process, thereby freeing up resources for dealing with the following word.

If production follows a similar pattern, then children's accuracy might improve after any frame that is frequent before nouns in their input, compared to after a labeling-question. To investigate this, in Study 2 we look at children's production of irregular plurals after a frame that is frequent before nouns but rarely appears before our irregular plural nouns. We compare their accuracy in this condition to the two conditions tested in Study 1. If children's production is aided by the overall familiarity of a frame, they should do better after such a frame than after a labeling-question. If they are also sensitive to the linguistic contexts of specific words, they should still do better after lexically specific frames than after frames that are merely familiar.

2: Is the production of irregular plurals facilitated after a familiar-frame?

Participants

Twelve children (6 boys and 6 girls) participated. Their mean age was 4;6 (range 4;3–4;10). All the children were learning English as their first language and were developing normally.

Materials

We used the same seven irregular plural nouns (*children, feet, fish, geese, mice, sheep,* and *teeth*) and the same picture-naming task.

Familiar Frame

We used the same 6 million-word corpus to find a frame that was frequent before nouns but rarely or never appeared before the target irregular plurals. We chose the frame *So many*: It occurred 278 times but rarely preceded any of the test nouns. It preceded *children* 3 times (the lexically specific frames for *children* occurred over 20 times) and did not precede any of the other target nouns. Like the labeling-question, it contains a linguistic cue to plurality (*many*).

Filler Items

Children also completed a color-naming task in addition to the plural production task. We used the same fillers in the plural elicitation as we had in the lexically-specific condition in Study 1.

Procedure

The procedure was identical to the lexically specific condition, as was the coding of the responses children gave.

RESULTS AND DISCUSSION

Children gave responses in all of the elicitation trials. Their responses, when asked for an irregular plural form fell into the same five main categories found in Study 1: Correct, Added *–s* on singular, Added *–s* on plural, Singular alone, or Other. None of the children in this study had an Other response rate that fulfilled the exclusion criteria applied in Study 1 (more than 1 SD from the mean Other rate), and so none were excluded. We predicted that children's production of irregular plurals should be better after a familiar frame than after a labeling-question but worse than after lexically specific frames. To test this, we compare children's performance in this study to that of the children in Study 1. Figure 2 presents correct productions of the irregular plural forms for each condition excluding Other responses (which did not differ between the conditions).

As in the previous study, we used mixed-effect logistic regression models with accuracy (correct vs. incorrect) as the predicted variable, and noun-frequency (log (noun-frequency)) as fixed

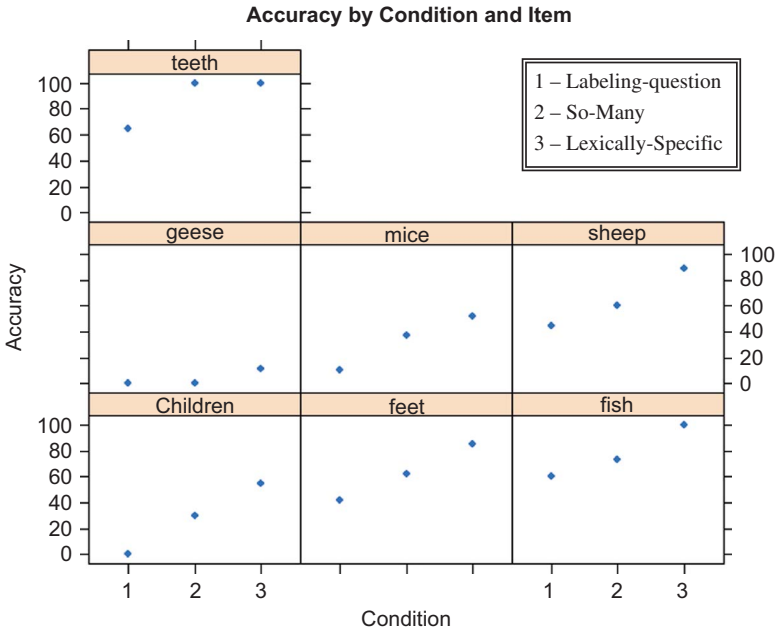

FIGURE 2 Percentage of correct responses in three conditions (averaged across trials).

effects, and subject and item as random effects, to compare each of the two conditions. Children did significantly better in the familiar-frame condition compared to the labeling-question condition, B = 1.51 (SE = 46), $p < .01$, but significantly worse compared to the lexically specific condition, B = −1.30 (SE = 51), $p < .05$. In all three conditions, children were more accurate with more frequent nouns (p's < .001). As predicted, they did better in producing irregular plurals when the target noun was introduced with the familiar frame *So many* (53% correct) than with a labeling-question (32%) but worse than when the target noun was introduced with a lexically specific frame (72%).

The *so-many* condition and the lexically-specific condition differed in the number of unique frames children were exposed to — 11 in the lexically specific condition versus only one in the *so-many* condition. Could their performance be worse in the *so-many* condition (compared to the lexically specific one) only because the frame became less effective over time? To rule out this possibility, we compared performance in the first and second half of the experiment. If the effect of frame diminished over time in the *so-many* condition, we would expect performance to be worse in the second half of the experiment compared to the first. This was not the case: Performance in the *so-many* condition did not decrease in the second half of the experiment, B = .43 (SE = .49), p > .4. If anything, it was numerically better (47% correct in first half vs. 57% in second half). A similar pattern is found for the lexically specific condition where performance was somewhat better in the second half of the experiment (67% vs. 76%) but not significantly so, B = .17 (SE = .68), p > .7. The difference between these conditions cannot be attributed to the different number of frame-types used.

Children's accuracy on the singular forms of the target nouns also did not differ significantly across the three conditions (65% of singulars in the labeling-question condition, 57% in the familiar-frame condition, and on 66% in the lexically-specific condition). We ran two logistic regressions comparing the added condition (*so-many*) to the ones from Study 1 (labeling-question vs. *so-many*, B = .–6 (SE = .36), $p > .09$, lexically specific vs. *so-many*, B = −.6 (SE = .33), $p > .06$).

The plots in Figure 3 present children's mean accuracy by item in each condition. While the baseline accuracy differs for each noun (higher frequency nouns such as *teeth* are produced accurately more often than lower frequency ones such as *geese*), the general pattern is the same across items. Children were least accurate for irregular plurals after a labeling-question, better after a familiar frame, and better still after a lexically specific frame.

Why was performance also enhanced (though less so) after a familiar but less highly collocated frame, namely '*So many —*' ? As in word recognition (Fernald & Hurtado, 2006), word retrieval and production may benefit when the preceding context is more familiar and hence easier to process. However, there may be another explanation that is tied to the *so-many* frame we used here. This frame rarely preceded any of the test nouns in the corpus we drew on, so there is little evidence for any sequential link between this frame and any irregular plural nouns. There is a link between the frame and the notion of plurality.

The frame *So many* appeared more than 200 times and was followed by a plural noun 77% of the time (n = 155). (In the remaining cases, this frame appeared in utterance final position with no following word, e.g., *I got so many*, *there are so many*.) Even though the frame *So many —* was followed mainly by *regular* plural nouns (90% of the time), the fact that it is generally followed by plurals may have helped children retrieve irregular plural nouns there as well. The correct form might therefore be easier to retrieve in a linguistic context that calls for a plural

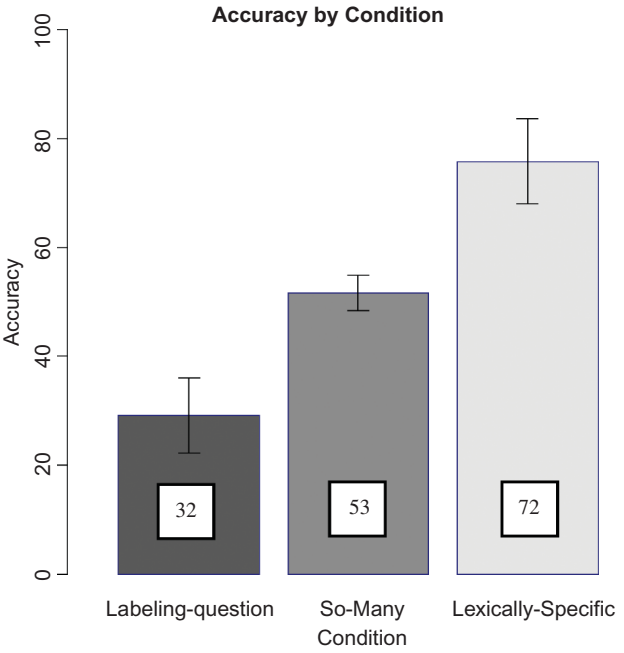

FIGURE 3 Accuracy for item by condition (averaged across trials).

form (Ramscar & Yarlett, 2007). In predictability terms, *so many* made the notion of plurality more expected.

Predictability of the plural may also explain why children's error distribution was somewhat different in the experimental manipulation and in naturalistic speech. In natural conversation, 25% of children's errors were of the form: irregular plural + s (e.g., *mices*). Such errors were infrequent (∼2%) in the experiments. One explanation is that the activity of naming objects may be more predictive of singular nouns than plurals: The pragmatic context of picture description is more frequently associated with singular forms, making errors of irregular plural + s less likely.[2]

Another factor might play some role in children's improved performance after frames. The two frame-completion conditions differed from the labeling question in prosody (two unfinished utterances vs. a question) as well as in the nature of the responses they elicited (a word in utterance-final position vs. single-word answer). However, the prosodic characteristics of the linguistic context alone cannot account for the difference we found between frame-types: Children's production was better after a lexically specific frame than after a frequent frame (*So many*), even though both provided the same prosodic context (an "unfinished" intonation contour). Nevertheless, prosody may have contributed to the general improvement children showed in the frame-conditions.

[2]We thank an anonymous reviewer for this suggestion.

This point receives some support from episodic theories of lexical access (Goldinger, 1996, 1998; Roediger & McDermott, 1993). In such models, "[. . .] groups of detailed traces collectively represent individual words" (Goldinger, 1996, p. 1166). These traces include fine-grained acoustic information about the voice of the speaker (Goldinger, 1996, 1998; Hintzman et al., 1972; Schacter & Church, 1992) and the intonation contour a word was produced with (Church & Schacter, 1994) that can be used in lexical access. For instance, speakers recognize words faster when they are spoken in the same voice as a previous production (Goldinger, 1996).

This suggests that children may be better at producing (and recognizing) words when they occur in more familiar prosodic environments. Because words are more likely to appear as parts of larger utterances than as single-word utterances, this might explain why children did better after hearing a frame than in answering a question — the prosodic context the frame supplied may have facilitated retrieval for production. We can re-interpret the finding that children's word recognition is enhanced after a familiar frame (Fernald & Hurtado, 2006) in this light: Children may be faster to recognize words when they appear after the familiar frame *Look at the bunny* compared to the semantically equivalent frame *Look! The bunny,* not only because of the lexical difference between them but also because of the different prosodic contours in which they are presented. Further research is needed to investigate the role that frame-prosody may play in lexical access.

The two frame conditions allow children to anchor the word forms they have to produce by linking them to familiar linguistic contexts — the lexically specific frame and the frequent frame, both familiar as plural contexts, and hence able to act as prompts for the target plural forms. This prompt function may be particularly effective where children have already established strong syntagmatic associations among co-occurring words (e.g., Entwisle, Forsyth, & Muus, 1964). Unlike the two frame conditions, the question condition requires that children generate an answer, a single word, unanchored to any phrase just produced, and so less securely linked to any preceding linguistic context. In short, children may be better at producing words when they occur in more predictable lexical and prosodic environments. Because words are more likely to appear as parts of larger utterances than as single-word utterances, children should do better after hearing a frame than in answering a question.

GENERAL DISCUSSION

We set out to investigate whether children's production of irregular plurals is affected by the preceding linguistic context. Children did poorly when they produced irregular plurals in isolation, with only 32% correct. They did rather better when produced these plurals after hearing a familiar frame, with 53% correct, and did even better, with 72% correct, when they produced these irregular plural nouns after hearing lexically specific frames highly collocated with the target nouns. This level of performance (72%) is twice as high as in previous elicitation studies with the same age and language population.

This pattern of production held across items and persisted when noun frequency was controlled for. It cannot be attributed to differences in cues to plurality in the three conditions since children did best with lexically specific frames even though fewer than half of these contained any explicit cues to plurality (terms such as *some* or *all*, or numerals such as *three*), while the

prompts for elicitation in the other two conditions did contain such cues (*What are all these called?, So many —).*

This is a first demonstration that linguistic context affects children's accuracy in producing morphologically inflected words. Their irregular plural production was affected not only by properties of the words themselves (the token frequency of the nouns) but also by the preceding linguistic material. They were more accurate when they produced the irregular plural after a highly predictive frame. Our findings highlight the importance of taking features of the linguistic context into account in studies of morphological acquisition. Simply asking children to produce words with a neutral prompt (the labeling-question) does not uncover the range of factors that affect the developmental path of 'natural', context-bound, word production.

The Units Children Learn

For children to be differentially affected by the three frame-types, they must be attending to larger patterns in the language, here, the phrases containing the target words. Our current findings show that children attend to the phrases that words co-occur with: They were more accurate in producing irregular plural nouns when these followed lexically specific frames. This facilitation follows naturally if children, like adults, are sensitive to distributional information at multiple levels of analysis. Adult production is sensitive to co-occurrence patterns at many grain-sizes: from sound combinations (Colman & Pierrehumbert, 1997) through single words (Jescheniak & Levelt, 1994) to multiword phrases (Bybee & Scheibman, 1999), and syntactic constructions (Bock, 1986; Gahl & Garnsey, 2004). Like adults, children rely on such information in production and show a gradient effect of predictability: Words are easier to produce when they are more expected given the preceding context.

To accommodate these findings, we need to expand the inventory of linguistic units that language users attend to for production — not only words on their own but also units of varying sizes and levels of abstraction. Such a view is argued for, and naturally accommodated by usage-based approaches to grammar where linguistic knowledge contains form-function pairings of various sizes (Bybee, 1998; Goldberg, 2006; Langacker, 1988; Tomasello, 2003). Similarly, we need to modify what we think children learn — not only words but also a whole inventory of linguistic patterns, and the relations among them. One model that may be especially suited to capture the effects of context on children's production is that presented by Chang, Dell, and Bock (2006). This model is naturally sensitive to generalizations and co-occurrences at different levels. However, it has not yet been applied to irregular morphology.

The Units Children Learn From

Phrases and sentences may provide important building blocks for constructing utterances. If children learn language from stored utterances, as suggested in usage-based and exemplar models of learning (e.g., Abbot-Smith & Tomasello, 2006; Bod, 1998; Tomasello, 2003), then linguistic units larger than words must play a crucial role: They allow children to discover relevant co-occurrence patterns and grammatical relations. In word learning, larger units tell children about the linguistic contexts for different words. Might children then rely on larger units not only in production, as we have shown for irregular plurals, but also in learning?

In learning a first language, children rely on three general processes. First, they need to store in memory any relatively fixed chunks corresponding to utterance-level prosodic units. Given the nature of child-directed speech (Fisher & Tokura, 1996), these should include single words, certain multiword units (e.g., article-noun combinations), and short utterances. Second, they start work early on segmenting their initial inventory using prosodic, distributional, and semantic cues to extract grammatical and referential regularities. Third, over time, they build up a more and more extensive inventory of linguistic units together with conditions on their use. At any one point in time, this inventory will include their accumulated distributional information about the relations between different-sized units as well semantic and grammatical information.

The four-year-olds in our study have already accumulated a considerable inventory of linguistic units and conditions on their use: They produced irregular plural forms better after a frame because they were sensitive to the co-occurrence of frame and word. The three processes proposed above could be investigated further by looking at any effects of frames and phrases on word production in still younger children. Early on, words may be so closely linked to the frequent phrases they appear in, that hearing a phrase would strongly enhance word production. But a subsequent shift in focus to segmentation and analysis might weaken these links: As children develop more flexibility and learn to use words in more contexts, phrases frequent in child-directed speech might become less facilitative than they were and less facilitative than they will become. As children are exposed to more language, they will expand their knowledge of the contexts that words tend to appear in beyond those that are particularly frequent in child-directed speech. Longitudinally, children may pass through a temporary phrase of decreased reliance on phrases.

Rules Versus Connections

The source of children's over-regularization errors has long spurred heated debate: Do they reflect the application of a regular rule (e.g., Marcus et al., 1992)? Or do they reflect higher activation of the more frequent regular plural overall (e.g., Plunkett & Joula, 1999)? This debate has been pursued in experiments (Arnon & Clark, 2008; Matthews & Theakston, 2006; Ramscar & Yarlett, 2007), corpus studies (Marcus et al., 1992; Maslen et al., 2004), and simulations (Plunkett & Marchman, 1993). However, researchers have not looked for linguistic context effects nor considered how such effects could be accommodated.

The current results have implications for the debate over the acquisition of irregular forms. They go beyond previous findings in showing that accuracy can be boosted by the immediate linguistic context of the target word. This presents a challenge for both types of model. For activation-based accounts, the challenge is a practical one. Existing implementations do not incorporate any linguistic contexts (Plunkett & Marchman, 1993; Plunkett & Juola, 1999; Rumelhart & McClelland, 1986). They model children's productions with units that roughly correspond to words. To account for the current findings, such models will have to incorporate information about the larger patterns in which words appear. This may be possible to do in a simple recurrent network (Elman, 1991). Such networks have been used successfully to model local-coherence effects (Tabor, Juliano, & Tanenhaus, 1997) and thematic fit effects (Tabor & Tanenhaus, 1999), both of which require keeping track of distributional contexts. Effects of linguistic context on word production could likewise be modeled by tracking larger sequential

chains. However, there are no existing connectionist simulations of irregular plural use that set out to capture such relations.

The findings also present a challenge to rule-based accounts of inflection. Recent rule-based models have accommodated irregular token frequency by arguing that the application of a default regular rule is more easily blocked when the irregular form in question is more frequent (Pinker & Ullman, 2002; Walenski & Ullman, 2005). To account for the effects of different linguistic contexts, such models would also have to allow rule-application to be modulated by the larger linguistic context that words appear in, that is, by elements external to the unit (the word) that the rule operates over. To allow this would mean that the rule no longer operates over clearly defined grammatical units (like Verb and Noun). Since error rates are also affected by phonological and semantic features (Köpcke, 1998; Matthews & Theakston, 2006; Ramscar, 2002), rule application would have to incorporate stochastic information about nongrammatical features of the target form and its surrounding linguistic context.

Language as Prediction

In conversation, speakers develop expectations about the topics, words and syntactic constructions that will be used. These expectations are an important factor in language use: They influence production choices and affect how sentences are comprehended (Altman & Mirkovic, 2009; Hale, 2001; Jaeger, 2006; Jurafsky, 1996, 2003; Levy, 2008; Levy & Jaeger, 2007; McDonald & Schillcock, 2003). They reflect fine-grained information about the way linguistic elements co-occur with one another, and with events in the world.

Even though predictability plays an important role in adult language, it has not been studied in children. In looking at how input patterns influence first language learning, researchers have highlighted the role of frequency but not of predictability. Our findings demonstrate an effect of predictability on children's production: Variation in accuracy was affected by the predictability of the word, not by the overall frequency of the chunk. Children produced irregular forms more accurately in highly predictive frames, underlining the potential importance of predictability in child language more generally.

While both frequency and predictability probably influence child language use (as is the case for adults), predictability offers a more functional explanation for why distributional information plays a crucial role in language learning. Children are not just "counting up" how many times forms appear. Instead, they are trying to make sense of the world around them by developing their ability to predict what will happen next. Knowing which words tend to appear after which phrases may help direct children's attention to the relevant objects, and free up resources to retrieve the correct form. More generally, viewing the child's task as one of prediction (Elman, 1991, 1993; Ramscar et al., 2010), opens up new ways of thinking about the relation between what children hear (i.e., their input) and what they say (i.e., their output).

Next Steps

Our results are limited to irregular plural nouns. First, these findings need to be extended to other domains of word production to determine if the effects of linguistic context are widespread and,

if so, how widespread. If the facilitation we found reflects the way linguistic information is organized in memory, children's word recognition should also benefit from the presence of lexically specific frames. Second, we only looked at the effect of context on accuracy: Forms were either correct or incorrect. Our findings might receive further support from more subtle measures of production such as voice-onset time and duration: the preceding linguistic material may affect not only accuracy (whether the correct form is retrieved) but also the speed and fluency of correct forms as well. Third, we used sentence-frames produced by adults (or a puppet) to prompt children's production. While the corpus data show the same pattern when children produce the entire utterance, it would be useful to find a way to elicit whole utterances as well as single words.

Finally, our results highlight the role of prediction in children's production, but they do so based on a limited set of measures (frequency and probability of noun given frame). There are many other ways to think about the relation between words and phrases (e.g., how flexible a noun is, how semantically similar are the words following the frame), and exploring them could shed light on the kind of information children rely on in learning and using language. The growing evidence for subtle predictability effects in adult language makes the study of similar patterns in child language a compelling area of research.

SUMMARY

We have shown in this study that children are sensitive to the linguistic contexts that words appear in: they are better at producing irregular plurals following a frame that often precedes these words in actual speech. Our findings demonstrate that children attend to the relations between words and phrases, and draw on this knowledge in production. More broadly, they demonstrate children's sensitivity to the co-occurrence relations between words and phrases in the process of lexical and morphological acquisition.

ACKNOWLEDGMENTS

We thank Kimberley Chu for her help in collecting and analyzing the data; the children at Bing for all their cooperation; Virginia Marchman for kindly making some additional data available to us; and Virginia Marchman and Nola Stephens for commenting on an earlier version of the paper.

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