The Role of Distributional Cues in the Acquisition of Verb Argument Structures

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Meesook Kim. 2003. The Role of Distributional Cues in the Acquisition of Verb Argument Structures. *Language and Information 7.1*, 87–99. This paper investigates the role of input frequency in the acquisition of verb argument structures based on distributional information of a corpus of utterances derived from the English CHILDES database (MacWhinney 1993). It has been widely accepted that children successfully learn verb argument structures by innate language mechanisms, such as linking rules which connect verb meanings and its syntactic structures. In contrast, an approach to language acquisition called "statistical language learning" has currently claimed that children could succeed in acquiring syntactic structures in the absence of innate language mechanisms, making use of distributional properties of the input. In this paper, I evaluate the feasibility of the statistical learning in acquiring verb argument structures, based on distributional information about locative verbs in parental input. The naturalistic data allow us to investigate to what extent the statistical learning approach can and cannot help children succeed in learning the syntax of locative verbs. Based on the results of English database analysis, I show that there is rich statistical information for learning the syntactic possibilities of locative verbs in parental input, despite some limitations in the statistical learning approach. (**Sangji University**)

Key words: statistical learning approach, locative verbs, distributional information, corpus

1. Introduction

The question of how children are able to learn adult-like knowledge of their native language in spite of the apparent lack of adequate feedback has long been a puzzling one. It is clear that the learning process is driven both by the children's innate linguistic knowledge and by the children's exposure to language. Nevertheless,

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the fundamental questions are what the nature of these sources of information is and to what extent each plays a role in language learning.

The standard approach in linguistics has suggested that humans possess a "universal grammar" (UG), which is an innate set of mechanisms that is required for language learning (Gold 1967, Baker 1979, Chomsky 1981). That is, UG plays a crucial role for children to entertain and evaluate input sentences during language learning. The important idea of this view is that the input to the children is simply a sequence of valid sentences, and statistical properties of this input are generally overlooked or thought to be little relevant to language learning.

In recent literature, in contrast, an approach to language acquisition called "statistical language learning" has arisen independently in many of the subfields studying natural language, including not only language acquisition, but also sentence processing and computational linguistics (Bowerman 1982, Elman 1993, Allen 1997, Seidenberg 1997, Rohde and Plaut 1999). According to the statistical learning approach, the learnability problem can be solved by a mechanism that relies heavily on statistical evidence in the input. For instance, children could succeed in acquiring syntactic structures in the absence of explicit negative feedback, and in the absence of innate learning mechanisms, by using distributional properties of the input. If some sentences or syntactic frames are more frequent than others, then distributional properties of the input could generate language. Accordingly, if a particular syntactic frame is not observed during finite period of exposure, children will assume that it is not part of the language. With more exposure, the probability of making errors decreases.

In addition, recent studies of linguistic input taken from the CHILDES database (MacWhinney & Snow 1985) have shown that the statistical features of input corpora provide rich information for the induction of grammatical categories and other linguistic structures. More specifically, recent empirical studies of infants' and children's learning from input structured solely in terms of statistical information have shown that they are surprisingly good at acquiring such information (Brent 1996, Morgan & Saffran 1995, Saffran, Newport, & Aslin 1996).

The goal of this paper is to evaluate the possibility of statistical learning mechanisms in the acquisition of verb argument structures, focusing on distributional information about the use of locative frames in a corpus of parental utterances derived from the English CHILDES database. Specifically, I investigate to what extent the statistical learning approach can and cannot help children succeed in learning the syntax of locative verbs. The discussion is organized as follows: Section 2 introduces previous studies on the general phenomenon of locative verbs. Section 3 discusses the results of the data analysis in detail. Section 4 and 5 summarize the results and present some important implications.

2. Background

It is well known that the learning of verb meanings and their associated syntactic possibilities poses many difficult problems for children. Despite a variety of different solutions to the problem of how children successfully learn verb meanings and verb argument structures, most accounts rely on the existence of consistent syntax-

semantics linking rules, which cause verbs with similar meanings to have similar syntactic possibilities (Grimshaw 1981, Landau and Gleitman 1985, Pinker 1989, Gleitman 1990, Gropen et al. 1991a,b)

It has been suggested that locative verbs provide an example of reliable syntax-semantics mappings (Rappaport and Levin 1988, Pinker 1989, Glopen et al. 1991a.b, etc.). As discussed by Pinker (1989) and Kim (1999), locative verbs in English fall into at least five syntactic classes, as shown in (1-5). There are two classes of Non-Alternating verbs. The figure verbs in (1) allow only figure frame syntax, in which the NP describing the moving object occupies direct object position. Other locative verbs with similar syntax to *pour* like *dribble* and *spill* have semantic features in common with *pour* in that they semantically describe a manner-of-motion meaning. The ground verbs in (2) allow only ground frame syntax, in which the NP describing the location occupies direct object position. What other locative verbs with similar syntax to *fill*, such as *cover*, *decorate*, and *bandage*, all have in common, is that they semantically describe a change-of-state meaning.

(1) a. John poured water into the glass. Figure-frame
b. *John poured the glass with water. *Ground-frame
other verbs: dribble, drip, spill, shake

(2) a. *John filled water into the glass. *Figure-frame
b. John filled the glass with water. Ground-frame
other verbs: cover, decorate, bandage, soak

Alternating verbs all allow both the figure and ground frames, but they in fact fall into three different syntactic groups, by virtue of whether or not the PP argument is optional (see Kim 1999 for more details). The figure alternating verbs in (3) only allow PP-omission in the figure frame. The ground alternating verbs in (4) only allow PP-omission in the ground frame. Finally, the pure alternator verbs in (5) allow PP omission in either the figure or the ground frame.[1]

(3) a. John piled the books (on the shelf).
b. John piled the shelf *(with books).
other verbs: sow, heap, spread, rub, dab

(4) a. John painted varnish *(onto the wall).
b. John painted the wall (with varnish).
other verbs: stuff, cram, jam

(5) a. John loaded the apples (onto the truck).
b. John loaded the truck (with apples).
other verbs: pack, spray

[1] According to Pinker (1989: 125), Alternating verbs can be divided into two basic verb classes, based on a PP-omission test: Figure Alternators which have primary manner-of-motion meanings and Ground Alternators which have primary change-of-state meanings. However, Kim (1999) pointed out some problems of Pinker's classification. Instead, she suggests three subclasses of Alternating verbs, based on the same PP-omission test.

We have seen that there are reliable syntax-semantics linking regularities in English locative verb classes. Accordingly, it has been widely assumed that children are aided by the existence of these innate linking regularities for learning locative verbs' meanings and their argument structures. Nevertheless, in this paper I do not demonstrate what children can and cannot learn by using a innate learning strategy based on syntax-semantics correspondences (see Kim 1999 for more details). Instead, I focus on the role of distributional properties of the input in learning the syntax of locative verbs, in the absence of innate learning mechanisms.

In contrast with innate learning mechanisms, a number of researchers have paid attention to the importance of the distributional properties of the input in learning (Bowerman 1982, Elman 1993, Allen 1997, Seidenberg 1997, Rohde and Plaut 1999). For example, Bowerman (1982, 1990) suggests that children acquire verbs' syntactic structures individually entirely from the input, without relying on innate and universal linking patterns between syntax and semantics. Interestingly, it has been widely reported that English-speaking children overgeneralize figure frame syntax to Ground verbs like *fill* and *cover*, and produce ungrammatical sentences like "she filled the water into the glass" (Bowerman 1982, Pinker 1989, Gropen et al. 1991a,b). In order to explain English-speaking children's syntactic errors with Ground verbs like *fill* and *cover*, Bowerman (1982) suggests that their overgeneralization errors are due to the frequency of the input available to them. More specifically, since the figure syntactic frame is more dominant than the ground syntactic frame for expressing English locative events in parental speech, they may generalize the figure frame to all locative verbs. Therefore, frequency effects may lead to children's well-known syntactic errors with "fill"-type verbs.

By contrast, based upon Rappaport & Levin's (1985) verb type frequency and Francis & Kucera's (1982) token frequency analyses, Gropen et al. (1991a) claim that Bowerman's input frequency effect cannot explain children's syntactic errors with Ground verbs like *fill*, For instance, Rappaport & Leven's (1985) type frequency analysis shows that among 125 locative verbs in English, the Non-alternating verbs (92) overwhelmingly outnumber the Alternators. Among the Non-Alternating verbs, Ground verbs (73) overwhelmingly outnumber Figure verbs (19). In addition, Francis & Kucera's token frequency analysis based on a million-word corpus shows that the Non-Alternators (1295) outnumber the Alternators (658), and that among Non-Alternators, Ground verbs (944) outnumber the Figure verbs (351) in English. Therefore, Gropen et al. claim that since Ground verbs obviously outnumber Figure verbs in English, in terms of token frequencies as well as type frequencies, Bowerman's input frequency effect cannot be true. Therefore, one part of this study is to evaluate Bowerman's argument and Gropen et al.'s argument about the input frequency effect in verb learning, based on the corpus analysis of utterances derived from the CHILDES database.

In addition to Bowerman and Gropen et al.'s argument, a recent statistical learning approach suggests that learning the syntax of locative verbs may be possible in the absence of learning mechanisms like innate linking rules, based on distributional properties of the input. Accordingly, I present results from an analysis of maternal speech from all of the English CHILDES database, to find out

whether maternal speech is enough for children to learn the syntactic structure of locative verbs. More specifically, I investigate whether verb classes can be reliably distinguished based on distributional properties of parental speech to children.

3. Data Analysis

I searched through all English-speaking mothers' speech in CHILDES database-corpus (MacWhinney 1993), based on all locative verbs selected from Pinker's (1989) list. A statistical learning approach claims that verbs with similar statistical distributions or similar meanings are assumed to have the same syntactic possibilities. Accordingly, I first investigate how many different verbs were used in the maternal input, and how frequently figure and ground syntactic frames were used in the input. Second, I examine how reliable the input is. Finally, I explore the distributional patterns of locative verb syntax in the parental input.

In order to determine whether or not locative verbs were used with an appropriate argument as direct object, I excluded the following utterances in this analysis: (1) utterances which involve intransitive classes (e.g., Water spilled on the floor/ I painted on the floor); (2) utterances which do not have any internal arguments (e.g., I poured); (3) utterances where the context does not provide an appropriate argument as direct object (e.g., You poured it), making it impossible to classify the utterance as figure or ground frames.

3.1 Frequency Effects

When dealing with a statistical learning approach, the frequency effects of the input can be used in two different ways. First, the frequency effects of the input could be enough information for children to figure out the syntax of locative verbs in their target language, with no further evidence. Second, the frequency effects of the input could lead children to make overgeneralization errors. This is consistent with Bowerman's (1982) argument that children's overgeneralization errors with Ground verbs (e.g., *fill* and *cover*) are due to the fact that figure frames outnumber ground frames in the input. However, as I pointed out above, Gropen et al. (1991a) argue against Bowerman's input frequency account, based on evidence from both type and token frequencies in English.

The two kinds of frequency information need to be distinguished. On the one hand, there is token frequency, which refers to the number of times a particular verb is used in a particular frame; on the other hand, there is type frequency, which refers to the number of distinct verbs that occur in a particular frame.

Let us first investigate type frequency in the maternal input. Note that Pinker's (1989) list of Non-alternating locative verbs shows that there are at least 34 Figure verbs and 77 Ground verbs in English. However, in the maternal input 15 different types of Figure verbs and only 7 different types of Ground verbs were used, as shown in Table 1.[2]

[2] A lot of tokens of the Ground verb cover may be due to the frequent use of "cover your mouth" in the maternal input.

Table 1 Type Frequency of Non-Alternating Verbs in the Input

Non-Alternating Verbs	Numbers of Verbs	
	Pinker's list	Maternal Input
Figure Verbs	34	15
Ground Verbs	77	7

The data in Table 1 support Bowerman's argument that Figure frames are more dominant than Ground frames in the maternal input, regardless of whether locative verbs with ground syntax outnumber those with figure syntax in English.

Let us next consider token frequency in the maternal input. Even though 15 different types of figure verbs and 7 different types of grounds were used in the maternal input, a lot of verbs were used only once or twice with an appropriate argument as direct object. Table 2 shows the token frequency of Non-alternating verbs.

Table 2 Token Frequency of Non-Alternators in the Input

Non-alternating Verbs	Number of Uses
Figure Verbs	*total (500)*
pour	135
spill	194
hang	108
stick	63
Ground Verbs	*total (213)*
fill	33
cover	169
decorate	11

In considering token frequencies of figure and ground frames, figure frames seem to be more common than ground frames in the maternal speech, as shown in Table 2. Therefore, based on the results given in Table 1 and 2, it can be concluded that the results of the two kinds of frequency information, such as token frequency and type frequency, support Bowerman's argument that Figure frames are more frequent than Ground frames in parental speech.

3.2 Distribution of Frames of Locative Verbs

Let us now investigate the distribution of frames for the Non-alternating locative verbs in the maternal input. Note that verbs of the "pour"-class are grammatical only with figure frames, whereas verbs of the "fill"-class are grammatical only with ground frames. The four most frequent verbs from the "pour"-class and the three most frequent verbs from the "fill"-class were used in this analysis, as shown in Table 3:

Table 3 Distribution of Frames of Non-Alternating Verbs in the Input

Non-alternating Verbs	V-NP Only (PP-omission)	V-NP-PP	Error	Total (713)
Figure verbs	Figure-frame	Figure-frame	Ground-frame	total (500)
pour	96 (71%)	39		135
spill	163 (84%)	30	1(?)	194
stick	69 (63.9%)	39		108
hang	52 (82.5%)	11		63
Ground verbs	Ground-frame	Ground-frame	Figure-frame	total (213)
fill	30 (90.9%)	3		33
cover	157 (92.9%)	11	1 (?)	169
decorate	11 (100%)			11

First, let us look at the distribution of syntactic frames of the Non-alternating Figure verbs in the maternal input. Verbs like *pour*, *spill*, *stick*, and *hang* were predominantly used in the maternal input in a Figure frame without a PP argument. These verbs were also sometimes used in a Figure frame with a PP argument. However, these verbs were never used in the ungrammatical Ground frame (99.8% error-free).

Next, let us look at the distribution of frames of Non-alternating Ground verbs. Ground verbs like *fill*, *cover*, and *decorate* were predominantly used in the maternal input without a PP argument. However, it is much less clear whether children would hear these verbs in a ditransitive sentence. In particular, children might not know that the verb *decorate* occurs in a ditransitive sentence, if they are relying heavily on the use of the distribution of frames of the input. Nevertheless, these verbs were never used in the maternal input in the ungrammatical Figure frame (99.5% error-free).

Now consider the distribution of syntactic frames of Alternating verbs in the maternal input. Alternating verbs can be divided into three subclasses, depending on which argument is obligatory: (1) a Ground-Alternating verb class which allows optionality of a Figure PP argument; (2) a Figure-Alternating verb class which allows optionality of a Ground PP argument; (3) a Pure Alternating verb class which allows optionality of both Figure and Ground PP arguments.

Let us first investigate the distribution of frames of Ground-Alternating verbs in the maternal input. Verbs in the Ground-Alternating verb classes selected from the CHILDES database included *paint*, *rub*, *wrap*, and *stuff*. These verbs allow only Ground frames when a PP argument is omitted, although they all allow both Figure and Ground frames with PP arguments, as shown in (6).

(6) a. John stuffed the feathers into the pillow. Figure-frame
b. John stuffed the pillow with feathers. Ground-frame
c. *John stuffed the feathers. *Figure-frame
d. John stuffed the pillow. Ground-frame

The results of the analysis of the maternal input data for Ground-Alternating verbs are shown in Table 4. First, the verbs in Table 4 were predominantly used in the maternal input in a Ground frame without a PP argument. Interestingly, this seems to be very similar to what we have seen in Non-alternating Ground verbs like *fill* and *cover*. However, the verbs in Table 4 were also used in a Figure frame with a PP argument, which was never found in the distribution of frames of Non-alternating Ground verbs like *fill*.

Table 4 Distribution of Frames of Ground-Alternators in the Input

Ground-Alternators	V-NP only		V-NP-PP		Total
	Figure (error)	Ground	Figure	Ground	
paint	1	81	8	2	92
rub		15	8	1	24
wrap	2	36	11	2	51
stuff	1	3	8	1	13
Total	4 (2.3%)	135 (75%)	35 (19.4%)	6 (3.3%)	180

In addition, mother's speech is highly grammatical, as shown in Table 4. However, even this level of accuracy may not be enough because the grammatical Ground frame with a PP argument is no more frequent than the ungrammatical Figure frame without a PP argument. This finding poses the problem for a statistical learning mechanism: If learning is only driven by the statistical evidence in the input, how can children figure out which frames are grammatical and which frames are ungrammatical?

Now let us see the distribution of frames of Figure-Alternating verbs in the maternal input. Verbs of the Figure-Alternating verb classes in this analysis included *stack*, *spread*, and *sprinkle*. These verbs allow both Figure and Ground frames with a PP argument, but they only allow Figure frames when the PP argument is omitted, as shown in (7).

(7) a. John stacked books on the shelf. Figure-frame
b. John stacked the shelf with books. Ground-frame
c. John stacked books. Figure-frame
d. *John stacked the shelf. *Ground-frame

Table 5 shows the results of the analysis of the maternal input data for Figure-Alternating verbs.

Table 5 Distribution of Frames of Figure-Alternators in the Input

Figure-Alternators	V-NP only		V-NP-PP		Total
	Figure	Ground (error)	Figure	Ground	
stack	64		6	1	71
spread	18		2		20
sprinkle	3				3
Total	85 (90.4%)		8 (8.5%)	1 (1.1%)	94

One thing to notice is that these verbs were predominately used in the maternal input in a Figure frame with or without a PP argument. However, these verbs were never used in a Ground frame with a PP argument, which is grammatical.

Finally, let us examine the distribution of frames of verbs for which PP omission is optional in both syntactic frames. Verbs in this class included *load*, *pack*, *spray*, and *squirt*.

(8) a. John loaded the apples onto the truck. Figure-frame
b. John loaded the truck with apples. Ground-frame
c. John loaded the apples. Figure-frame
d. John loaded the truck. Ground-frame

The result of the analysis of the maternal input data is shown in Table 6:

Table 6 Distribution of Frames of "Pure"-Alternators in the Input

Pure-Alternators	V-NP only		V-NP-PP		Total
	Figure	Ground	Figure	Ground	
load	6	2	9	2	19
pack	8	12	2	2	24
spray		8	3	3	14
squirt	4	17	2	1	24
Total	18 (22.2%)	39 (48.1%)	16 (19.8%)	8 (9.9%)	81

Since PP omission with these verbs is optional in both Figure and Ground frames, there are no ungrammatical patterns in this class. An interesting finding is that both Ground frames and Figure frames were used without a PP argument in the maternal input. Therefore, based on the use of distributions of syntactic frames in the maternal input, children may conclude that these verbs are Alternators.

4. Discussion

So far we have examined the possibility of the statistical learning mechanism based on information about the use of locative verbs in the maternal input derived from the English CHILDES database. First, frequency counts based on both token and type frequencies showed that Figure verbs outnumber Ground verbs in the maternal input. It shows that the number of token and type frequencies derived from text corpora is different from that of token and type frequencies derived from a corpus of maternal speech. Therefore, this finding supports Bowerman's (1982) global frequency account.

Second, I found that mother's speech is highly grammatical, 99%+ error-free. However, the distribution of frames of Ground-Alternators in Table 4 showed that certain grammatical structures are more frequent than ungrammatical structures. As pointed out above, this finding poses the problem for a statistical learning mechanism. That is, if learning is only driven by the statistical evidence in the input, children will have some difficulties in figuring out what frames are grammatical and which frames are ungrammatical.

Third, the distribution of frames in the maternal input might provide children with sufficient information on the syntactic possibilities of basic Figure verbs and basic Ground verbs. For instance, both Non-alternating Figure verbs and Figure-Alternating verbs were predominantly used in a Figure frame without a PP argument, and both Non-alternating Ground verbs and Ground-Alternating verbs were predominantly used in a Ground frame without a PP argument. Based on the distribution of syntactic frames of the maternal input, the first thing that children could figure out easily is which verbs allow Figure syntax and which verbs allow Ground syntax. Therefore, this may explain how 3-4 year old children have basically figured out the syntactic possibilities for the different classes of locative verbs, without the help of consistent syntax-semantics mappings.

Although most verbs are used in most of the syntactic frames that they allow, this may not be enough. For example, the distribution of Non-alternating Figure verbs and Figure-Alternators is essentially identical, as shown in Table 7.

Table 7 Comparison between Figure-Alternators and Non-Alternating Figure Verbs in the Distribution of Frames in the Input

	V-NP only		V-NP-PP	
Figure-Alternators	Figure	Ground (error)	Figure	Ground
stack	64		6	1
spread	18		2	
sprinkle	3			
Non-Alternators				
pour	96		39	
spill	163		30	
stick	69		39	
hang	52		11	

If children only hear Figure-Alternating verbs with or without a PP argument, they may not distinguish these verbs from Non-alternating Figure verbs like *pour* or *spill*. Thus, it is not clear how the learning strategy based on the statistical evidence in the input can tell the children that Figure Alternating verbs like *stack* and *spread* are different from Non-alternating Figure verbs like pour and spill.

The remaining question I have to answer is how an approach based on a statistical analysis of the input data can explain children's overgeneralization errors with the verb *fill*, using only positive evidence. Based on the distributional properties of the input, we may assume that positive evidence can provide children with sufficient information that some verbs allow both Figure and Ground verbs, and that some other verbs allow either Figure or Ground frames. Based on this positive evidence, children can make constrained generalizations, and assume that verbs which have a similar meaning have the same syntactic properties. However, at an early stage children draw more broad distinctions of syntactic categories. For example, children can distinguish basic Ground verbs from basic Figure verbs, whereas they have not drawn the specific distinction between Non-alternating verbs and Alternators at some point. This may induce children's overgeneralization

errors. For example, at an early stage the Non-alternating Ground verb *fill* might be overgeneralized from a Ground-Alternator like *stuff*. However, as distributional syntactic categories are more finely differentiated over time, children can draw more distinctions. Therefore, the verb *fill*, which at an early stage might be overgeneralized from the Alternator *stuff*, could be distinguished from *stuff* later, by only adding new knowledge to children's distributional categories. That is, by adding new knowledge to the syntactic categories, the Non-alternating verbs can be distinguished from the Alternators. This account at least avoids the need to unlearn anything because this learning strategy does not require "change" in knowledge, and requires the addition of syntactic information, which is needed under Pinker's (1989) approach.

5. Conclusion

In this paper I examined whether there is enough statistical information in the parental input for children to learn verb argument structures, based on a corpus analysis of parental utterances derived from the English CHILDES database. The results reported here suggest that approaches based on a sophisticated statistical analysis of the input data probably do better than was once thought. That is, I found that there is rich statistical information in the parental input for children to learn verb argument structures, and that children can use the statistical learning mechanisms to extract this information during the acquisition of verb meanings and its syntactic structures, despite the existence of some limitations in these learning approaches. In particular, significant limitations in these statistical learning approaches are faced with cross-linguistic data. For example, PP-omission can be used to distinguish certain verb classes in English, whereas in Korean (also Japanese) it is irrelevant, because these languages allow liberal omission of arguments.

As part of on-going studies, I will investigate distributional information derived from the Korean CHILDES database as well as the Korean text corpora, to evaluate the feasibility of the statistical learning approach in learning verb argument structures.

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Submitted on: May 7, 2003
Accepted on: May 28, 2003