

The Role of Parental Input in the Acquisition of Tense-Aspect Morphology

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This study investigates the role of parental input in the acquisition of tense-aspect morphology. We report statistical analyses of the distributions of tense-aspect morphology with different verbs in parental input to children between ages 2;0 to 4;0. A total of 3,505 verb tokens from the English corpora of the CHILDES database were included in our analyses. All the verbs that occur with the tense-aspect morphemes *-ing*, *-ed*, and *-s* were classified according to the verb categories of Vendler (1957) and then simplified into processes, events, and states. The frequency of occurrence of each of the three verb types with each morpheme was computed to identify the distributional properties of tense-aspect morphology with verb semantics in parental speech. The analyses show that there is a strong association between lexical aspect of verbs and grammatical aspect of morphemes in parental speech, and more important, characteristics of the parental input change over time, reflecting that the associations become weaker as the child grows older. These characteristics mirror the developmental patterns in children's speech as reported in the literature. Our results provide strong evidence for the argument that the undergeneralization patterns in children's use of tense-aspect morphology stem from children's extraction of prototypical associations in parental speech. Implications of the results are discussed in terms of probabilistic learning mechanisms that are sensitive to the statistical properties of the input.

Introduction

In 1973, Roger Brown documented two interesting patterns on young children's acquisition of English inflectional suffixes. First, the earliest grammatical marker in children's speech, the progressive aspect marker *-ing*, appears to be used always correctly. In particular, children never use *-ing* incorrectly with state verbs; for example, they do not produce overgeneralizations like *knowing* or *wanting*. Second, English-speaking children first use past tense forms with only a small, semantically

coherent set of verbs, including dropped, slipped, crashed, and broke, “which name events of such brief duration that the event is almost certain to have ended before one can speak” (Brown, 1973, p.334). Some years after Brown’s findings, Bloom, Lifter, and Hafitz (1980) provided further evidence that confirms Brown’s analyses. They found that the inflections used by young English-speaking children (between ages of 1;10 and 2;4) correlated with the semantic types of verbs: -ing occurred almost exclusively with verbs such as play, ride, and write (durative, nonresultative), whereas the past tense forms occurred with verbs such as find, fall, and break (punctual, resultative). Brown and Bloom et al.’s data suggest a picture of early “undergeneralization” in the acquisition of inflectional morphology: rather than using tense-aspect markers with all types of verbs, as adults do, children use them more restrictively.

These two studies have had significant impact on research in the acquisition of tense and aspect in English. There have been simultaneously or subsequently many studies that examined similar problems in other languages, including Chinese (Li, 1990, 1993; Li & Bowerman, 1998), French (Bronckart & Sinclair, 1973), Italian (Antinucci & Miller, 1976), Polish (Weist, Wysocka, Witkowska-Stadnik, Buczowska, & Konieczna, 1984; Weist, Wysocka, and Lyytinen, 1991), Turkish (Aksu-Koç & Slobin, 1985), and other languages (see Li & Shirai, 2000 for a review of relevant crosslinguistic data). In general, data from these studies indicate that the use of imperfective or progressive aspect morphology in children’s speech is first associated with atelic, activity verbs, whereas that of perfective aspect/past tense morphology is associated with telic verbs. Some researchers also suggest a third association between the habitual -s and state verbs in children’s speech (e.g., Clark, 1996). Subsequent discussions on these empirical results have stimulated intense debates on how children acquire lexical semantics and grammatical morphology, and motivated theoretical accounts of children’s semantic and morphological development in general (see Li & Shirai, 2000, for an overview).

There are roughly two contrasting views on how we can explain the patterns observed by Brown, Bloom et al, and many others, in a variety of languages. The first view is that these patterns reflect young children's initial, perhaps universal predispositions or biases toward certain semantic or conceptual categories. This view is advocated most forcibly by Bickerton (1981, 1984, 1999) through the arguments of the Language Bioprogram Hypothesis.¹ Bickerton argued that certain semantic distinctions are biologically pre-programmed and emerge early in human language acquisition. Because the distinctions are hardwired ahead of time, the child learner simply needs to find out how they are instantiated in specific forms in the target language. Bickerton used the observations made by Brown (1973) in support of an innate specification of the distinction between process and state: young English-speaking children never overgeneralize the progressive marker -ing to state verbs because they are sensitive to the state-process bioprogram distinction. Similarly, Bickerton argued for the existence of the punctual-nonpunctual distinction in the bioprogram, on the basis of interpreting the observations by Antinucci and Miller (1976), Bronckart and Sinclair (1973), and Aksu-Koç and Slobin (1985) that young children use the past or perfective morphology to mark punctual events.

An opposing view to the above is the cognitive-functional approach to aspect acquisition, which has had many variants in the literature. An early explanation relied on the child's insufficient cognitive ability to account for the restricted temporal uses in child language (Bronckart and Sinclair, 1973; Antinucci & Miller, 1976).² Other investigators turned to the input hypothesis to explain the early associations between grammatical and lexical aspect (e.g., Stephany, 1981 for Modern Greek, Li, 1990 for child Mandarin, and Shirai 1991 for English). In second language acquisition, researchers use "aspect hypothesis" or the "prototype hypothesis" to explain similar patterns in L2 learning (Andersen & Shirai, 1994; Shirai, 1991, 1999). More recently, Li

and Shirai (2000) presented an integrated view of this approach in terms of ideas from both the prototype hypothesis and connectionist networks. They argue that in both L1 and L2, the learner's early associations between lexical meanings of verbs and grammatical morphology do not indicate innate specifications of semantic categories. Rather, these associations reflect the learner's sensitivity to (and recognition of) the statistical properties of the linguistic input, which in turn may reflect inherent constraints on linguistic communication and event characteristics. Moreover, the association patterns are probabilistic and not absolute, counter to what nativist proposals would assume. Depending on the structure of the target language, in some cases, learners retreat from the probabilistic associations and develop the more flexible patterns of use; in other cases, they hold onto these associations.

In previous studies of the acquisition of tense and aspect, only a few studies have examined the relationship between patterns in child language and in child-directed parental speech. In a study of children's tense and aspect marking in Modern Greek, Stephany (1981) looked at mothers' speech in some detail. She classified verbs in Modern Greek into three categories: statives (e.g., know, be cold), resultatives (e.g., fall, take), and non-resultatives (e.g., cry, read). According to her analyses, Modern Greek children's speech is characterized by the pattern that resultative verbs occur more frequently than non-resultative verbs with perfective aspect, whereas the reverse is true for imperfective aspect; in addition, stative verbs are exclusively combined with imperfective aspect. Stephany hypothesized that these patterns in child Modern Greek might be derived from patterns in the input language. Her analyses indicated that the distribution of verb categories with tense-aspect markers in children's language conforms surprisingly well to patterns found in the mothers' speech directed to children. To further verify her hypothesis, Stephany compared mothers' speech to children versus mothers' speech to adults to see if mothers specifically modify their speech only for young children.

This comparison showed that verb semantics and tense-aspect markers are associated much more strongly in child-directed speech than in adult-directed speech.

Another researcher who has examined parental input is Shirai (1991, 1994; also Shirai & Andersen, 1995). Shirai analyzed Brown's (1973) data and the data from Sachs (1983), showing that contrary to what Brown had originally claimed, children do occasionally overgeneralize -ing to state verbs (e.g., seeing light, loving Georgie, needing, having all these toys). Interestingly, the child (Naomi; Sachs 1983) who often used state verbs with -ing had a mother who did so too, in contrast to the two children (Adam and Eve) that Brown studied whose mothers never used stative progressives. Shirai (1991) and Shirai and Andersen (1995) also showed that the mothers of these children used past inflections most frequently with achievements, but progressive inflections most frequently with activities. On the basis of these analyses, they suggested that patterns in the development of tense-aspect morphology are at least partly determined by the verb-to-morphology distributions in mothers' speech.

More recently, in a study of the acquisition of Turkish, Aksu-Koç (1998) examined the correspondence of a mother's speech and her child's speech in the use of tense-aspect morphology and verb types. She found that the mother used the direct past form (-dı) most frequently with achievement verbs (70%), and the present/imperfective form (-iyor) most frequently with activity verbs (61%). Moreover, the inferential/perfect form (-miş) occurred more frequently with achievement verbs (51%) than with any other type of verbs. The same distributional bias was also observed in the child's speech, but the child's preference for a given verb type with each inflection was stronger than the mother's, consistent with the predictions of the input hypothesis.

The above studies, however, only looked at the patterns of parental input as a whole, but did not examine the developmental profiles

of parental speech as a possible guiding force for children's formation of prototypical associations of verbs and morphology. In this study, we take a further step in this direction to argue specifically for the consistency between children's speech and parental speech over time. In particular, we would like to see if there are "developmental" patterns even in the adult speech: would the parental input also display stronger associations between given verb types and given tense-aspect morphology when the child is younger, but then gradually move to more flexible patterns of associations when the child is older? Our objective is to explain the patterns observed in child language by showing that there is rich statistical information in the parental speech that the child can extract by using probabilistic learning mechanisms. To this end, we present a statistical analysis of a large-scale corpus of parental speech with respect to input characteristics.

Method

Materials

The primary data of the current study came from the CHILDES database (MacWhinney, 2000). The specific corpora that we used in our analyses are: the New England data (Ninio, Snow, Pan, & Rollins, 1994), the Post data (Demetras, Post, & Snow, 1986), the Sachs data (Sachs, 1983), the Snow data (MacWhinney, 2000), the Wells data (Wells, 1981), and the Wisconsin data (Miller & Chapman, 1983). The selection of these corpora rather than the 40 other English corpora was random. From these six corpora we extracted all the utterances of the parents, caregivers, and experimenters to form our "parental input" corpus. Although not all of these utterances are child-directed, they form a representative sample of the speech that children are exposed to (e.g., dinner table talks, activities of free plays, and storytelling). The total number of lexical items in this corpus is about 175,539 w

ands (tokens).

Procedure and Data Analyses

To analyze the above parental corpus, we identified all of the verbs that have occurred in the corpus. To do this, first, we used the "freq" command of the CLAN program (MacWhinney, 2000) to compute lexical frequencies of the corpus, which gives a list of all words in the data. From these words we extracted all the verbs according to the parts-of-speech tagging in the CELEX database (Baayan, Piepenbrock, & Rijn, 1995). Next, all the verbs that occur with the tense-aspect morphemes -ing, -ed, and -s were identified, roughly a total of 3,505 items (tokens) in our corpus. Finally, we classified each of these verbs according to the four lexical aspect categories of Vendler (1957): activities, accomplishments, achievements, and states.

According to Vendler, activity verbs encode situations as consisting of successive phases over time with no inherent endpoint, for example, walk, run, and swim. Accomplishment verbs also characterize situations as having successive phases, but they differ from activity verbs in that they encode a natural endpoint and often a change of state, for example, paint a picture and build a house. Achievement verbs, like accomplishments, also encode a natural endpoint, but they differ from accomplishments and activities in that they encode events as punctual and instantaneous, that is, as having no duration, such as in fall, crash, and reach the summit. Finally, state verbs, in contrast to the other three categories, encode situations as homogeneous, with no successive phases or endpoints, involving no dynamicity, such as know and love. Thus, state verbs cannot usually be combined with progressive aspect that marks change and development from one phase to the next (e.g., *John is knowing the story is odd).

To categorize each verb in our data according to Vendler's system, we followed the coding procedure developed by Shirai (1991, also Shirai

& Andersen, 1995). In particular, the procedure involves a step-by-step analysis of the temporal characteristics of each verb. For example, the first step is to determine if the verb is a state or non-state verb, and to do so, the researcher needs to ask if the verb has a habitual interpretation in simple present tense (“state” if no, and “non-state” if yes). The second step determines if it is an activity or non-activity verb, and the researcher needs to ask if “X is V-ing” entails “X has V-ed” (John was running entails that John ran, whereas John was running a mile does not entail that John ran a mile; hence the former is activity, and the latter accomplishment). The third step follows suit to determine if a non-activity verb is accomplishment or achievement, and so on (see Ch.5.2 of Shirai 1991; also Shirai & Anderson, 1995, p. 749).

In some linguistic analyses or philosophical traditions, Vendler’s four-way classification is simplified into a three-way contrast between processes (Vendler’s activities), events (Vendler’s accomplishments and achievements), and states (e.g., Mourelatos, 1981; Parsons, 1990). This simplification reflects a consideration of the inherent similarity between accomplishments and achievements – both are what linguists call “telic” verbs, indicating endpoints or end result; for some, “change of state” might be what is most important here (cf. Klein, 1994; Klein, Li, & Hendiks, 2000). This three-way terminology also reflects a consideration that the distinction between accomplishments and achievements is irrelevant or unnecessary to the semantics of English verbs (Parsons, 1990). In our data analyses, we find that accomplishments and achievements behave almost identically with respect to their occurrences with tense-aspect morphology. Thus, we adopt the three-way terminology in our discussion below, collapsing Vendler’s accomplishments and achievements in order to highlight the differences between activities on the one hand and accomplishments/achievements on the other. For terminological consistency we will use “processes” to refer to activities, “events” to accomplishments and achievements, and “states” to states.

Finally and most importantly, in our analyses, we computed how often each of the three verb types occurred with each grammatical morpheme, in order to identify the distributional properties of tense-aspect morphology and verb semantics in the parental corpus.

Results

In the following we present results from the distributional analysis of the co-occurrences between lexical aspect of verbs (processes, events, states) and grammatical aspect of morphology (-ing, -ed, -s) in the parental speech. Table 1 shows the aggregated results from the analysis of the corpora of New England, Post, Sachs, Snow, Wells, and Wisconsin. The numbers indicate the token frequencies of verbs with each grammatical morpheme.

Table 1

Co-occurrences of Verbs with Tense-Aspect Morphology in Parental Speech³

Verb Type	<u>-ing</u>	<u>-ed</u>	<u>-s</u>
Processes	2084 (95)	136 (18)	339 (61)
States	22 (1)	60 (8)	147 (26)
Events	97 (4)	549 (74)	71 (13)

Note. Numbers in parentheses indicate the percentages of verbs used with a given tense-aspect morpheme.

Our initial expectation about the associations between lexical aspect of verbs and grammatical aspect of morphemes in parental speech

has been confirmed in Table 1. Not only do children display strong associations between inherent meanings of verbs and tense-aspect morphology, as shown by previous empirical studies, but adults also display similar patterns in their speech to children. As can be seen from Table 1, of all the verbs that occurred with *-ing*, 95% were process verbs, and less than 1% were event verbs. In contrast, of all the verbs that occurred with *-ed*, only 18% were processes, and 74% were events. This shows the classic processes-imperfective and the events-perfective/past associations. These patterns are highly consistent with the empirical findings with children by Brown (1973), Bloom et al., (1980), Li and Shirai (2000), among many others. However, unlike the *-ing* and *-ed* markers, the morpheme *-s* shows no strong association with the state verbs; in fact, it is associated more strongly with the processes (61%) than with the states (26%).

A contingency table analysis with the chi-square statistic was run on the data in Table 1. The analysis yielded a significant effect of the interdependency between the two factors ($\chi^2(4) = 2226, p < .01$), showing that the associations between verb types and morphology are very strong and statistically significant.

One interesting finding from Table 1 is that although *-ing* was predominantly associated with process verbs in our parental corpus, it occurred with 22 state verbs. Even though this is only a very small number of cases (less than 1% of all the verbs that occurred with *-ing*), it shows that adults do use *-ing* with state verbs in speech addressed to children (e.g., *wanting*, *feeling*, and *liking* in our data). Recall that Brown found that the children he studied used no progressive marker with state verbs, a finding that many take as evidence to suggest an innate state-process distinction as part of the child's initial semantic organization. However, in a further analysis of Brown's data and data from Sachs (1983), Shirai (1991, 1994) showed that children do in fact occasionally overgeneralize *-ing* to state verbs (see earlier discussion). In addition, in

adult-to-adult conversations, some state verbs also appear in the progressive; for example, Robison (1995) reported that 5.4% of the progressive inflections used by a native English speaker are attached to state verbs in a sample of conversational data with 407 verb tokens (see also Smith, 1983, for a linguistic analysis of this type of combination).

Results from Table 1 also show that the majority of verbs in our parental corpus have occurred with *-ing* (63%), followed by *-ed* (21%), and then by *-s* (16%). This pattern probably indicates that overall, parental speech addressed to young children deals more with ongoing activities, and less with events that have happened or events that are habitual or routine.

Table 1 presents the patterns of aggregated results from all parental speech in our corpus, as is typically done in previous studies. Shirai (1991) and Li and Shirai (2000) have shown that strong associations (the "prototypical associations") between verb types and grammatical morphology are characteristic of early child speech, but they become weaker over time as the learner develops non-prototypical associations (e.g., using *-ing* more flexibly with event verbs).⁴ Thus, we would like to see if there are "developmental" patterns even in the adult speech. In other words, would the parental input display stronger associations between given verb types and given tense-aspect morphology when the child is younger, but then gradually move to more flexible patterns of associations when the child is older? By mapping the parental speech to children's speech across developmental stages, we hope to identify the role of parental input in the acquisition of tense and aspect more clearly.

To this end, we analyzed a subset of the corpus with respect to the age at which the child received the adult input (the "input age"). This subset contained the parental speech from the corpora of New England, Post, Sachs, and Snow.⁵ Table 2 presents the results of this analysis as the percentage of uses of verbs with morphemes, broken down by three input age groups: the periods when children received the input data before

age 2;0, between 2;1 and 3;0, and between 3;1 and 4;0.

Table 2

Percentage of Use of Tense-Aspect Morphology with Verb Types across Input Ages in Parental Speech

Verb Type	Input Age								
	Before 2;0			Age 2;1-3;0			Age 3;1-4;0		
	<u>-ing</u>	<u>-ed</u>	<u>-s</u>	<u>-ing</u>	<u>-ed</u>	<u>-s</u>	<u>-ing</u>	<u>-ed</u>	<u>-s</u>
Processes	69	32	32	65	35	38	67	55	55
States	0	5	29	4	5	23	2	6	25
Events	31	63	39	31	60	39	31	39	20
Item Totals	96	56	49	137	88	72	52	31	20

Note. Item totals are the total number of verb tokens that occurred with a given suffix. These numbers allow the calculation of the raw scores for each cell.

Examining each input stage separately, we found the same strong associations between lexical aspect and grammatical morphology as we did in Table 1. In general, the use of -ing was associated more strongly with process verbs, while the use of -ed was associated more strongly with event verbs. A chi-square analysis was run on the raw frequency data of each input age, which yielded statistical significance for each data set (Before 2;0: $\chi^2(4) = 77.17$, $p < .01$; Age 2;1-3;0: $\chi^2(4) = 44.56$, $p < .01$; and Age 3;1-4;0: $\chi^2(4) = 12.17$, $p < .05$). More important, these results also show that the patterns of association between verb types and grammatical morphology differ across input ages. That is, there seem to be "developmental" trends even in the parental input, in that the associations become weaker as the input age increases (i.e., as children become older).

This development is reflected most clearly in the use of -ed and -s forms. For example, at input age 3;1-4;0, the association between -ed and event verbs was weaker. In fact, at this stage -ed occurred with more processes (55%) than with events (39%), counter to the general pattern. This could be because some verbs in the parental speech started to have greater lexical diversity that allows more and more non-prototypical associations (e.g., process-perfective). With respect to -s, it occurred with more processes (55%) than with states (25%) or events (20%) at the last input age – note that in Table 1 we did not find any strong associations between -s and verb types. This strong -s-to-process association might be due to the increase of habitual references as the child becomes older (see Shirai, 1991).⁶

Finally, there was a clear lack of association of state verbs with -ing and -ed, as compared with -s. That is, states occurred primarily with -s and hardly with the other morphemes across input stages, which is consistent with the overall pattern as seen in Table 1. This pattern suggests the importance of the direction of association: although we may not find a one-to-one mapping from morphemes to verbs (e.g., -s-to-state only), we may still find strong associations from verbs to morphemes (e.g., state-to-s only) – this latter direction of associations can also result in the child's extraction of prototypical associations between a given verb type and a given grammatical morpheme (e.g., -s and states).

Discussion

Investigators of language acquisition have long recognized the important role of adult input (e.g., Snow & Ferguson 1977; Gallaway & Richards, 1994), but only a few previous studies have examined parental speech in the domain of tense-aspect acquisition (see review in Introduction). In this study we set out to examine the speech produced by

parents and caregivers in a large-scale corpus from the CHILDES database. Our goal is to explain the patterns observed in child language by reference to the existence of statistical information in parental speech that the child can extract. Our analyses of the CHILDES database indicate that parental input contains rich statistical information that children can explore. In particular, the patterns of association between lexical aspect of verbs and grammatical aspect of morphology, as claimed by Brown (1973), Bloom et al (1980), among many others, are already evident in the input speech. The results from our analyses show that parental use of -ing is strongly associated with process verbs, and their use of -ed is strongly associated with event verbs. In addition, our analyses indicate that the patterns of association in parental speech also change over time, along the same direction as in children's speech: as input age increases, the use of tense-aspect morphology becomes more diverse with different verb types (perhaps first with -ed forms, as Table 2 indicates).

There are two immediate questions that our research needs to address. First, why should parents modify their patterns in child-directed speech? Second, how does the match between parental speech and children's speech tell us about mechanisms of language acquisition?

To answer the first question, let us return to the concept of "prototypical associations". According to Shirai (1991, 1994) and Shirai and Andersen (1995), in the acquisition of tense-aspect morphology, children and adult second language learners start with the prototypical associations, associations that are most characteristic of the meaning of the morphological marker and the semantics of the verb. For example, the features of [+dynamic] and [-telic] of processes or activity verbs best fit the "action in progress" meaning of the progressive aspect and therefore, the process-progressive combination is a prototypical association, and children will find this combination easiest to comprehend and most comfortable to produce. Thus, the early strong association patterns in children's speech could reflect children's use of prototypes.

Parents or caregivers, however, should not have any difficulty with the use of either the prototypes or the non-prototypes at any given point. So, why do they turn to prototypes when addressing children? This must be due to communicative pressure rather than linguistic considerations. Our hypothesis is that prototypical associations facilitate communication, especially in the case of talking to young children and non-proficient second language learners. De Lemos (1981) showed, in a study of Brazilian Portuguese, that mothers often engage young children in typical "action format", where the mother models her use of tense-aspect markers to direct the child's attention to certain salient properties of the situation (e.g., end result). The action formats represent basic event perspectives and are characteristic of early mother-child interactions – they are the "focal instances for the presentation of events and event structure to infants" according to de Lemos. This explains why in talking to young children parents are likely to stick to prototypical associations between basic event characteristics (e.g., end result) and particular linguistic perspectives (e.g., perfective aspect). Finally, parents' reliance on prototypes is also consistent with the general view that child-directed input may be simplified (e.g., with respect to prosody, syntactic structure, or length of utterance) and that such simplifications may facilitate language acquisition (Gallaway & Richards, 1994). The use of prototypical rather than flexible associations in parental speech shows that early on adult speakers attempt to use an underspecified, simpler form of verb-morphology combinations when addressing to children.

Prototypical associations often reflect the most natural combinations between morphology and semantics. Some researchers argue that perfective aspect combines most naturally with event verbs, whereas imperfective or progressive aspect combines most naturally with process verbs. For example, Comrie (1976) showed that imperfective aspect is not compatible with some punctual verbs, because imperfective aspect presents a situation as having an internal structure (ongoing) whereas

punctual verbs encode a situation as a single point. By contrast, perfective aspect combines naturally with punctual verbs, because perfective aspect presents a situation as a whole without regard to its internal structure. On the other hand, perfective aspect conflicts with state verbs, given the nature of homogeneous continuous state that is inherently not a single whole. In Li (1990) and Li and Shirai (2000), we further argued that such natural combinations may in turn reflect relationships between language use and event characteristics. For example, many situations with an end result last for such a brief period of time that any comment on them will have occurred after its ending, such as situations denoted by event verbs like drop, fall, and crash (cf. Brown, 1973). Thus, it is rare for speakers to use the progressive aspect to describe the "ongoing-ness" of a telic event and it is more natural to describe such situations with the perfective aspect. In some languages, such non-prototypical associations (e.g., between progressive aspect and telic events) are not even encoded in the grammar – they are prohibited in the language altogether. For example, if we study adult input in Mandarin Chinese, we will find that the co-occurrence of the progressive marker zai and telic/resultative events would not just be less frequent (as in English), but non-existent (see Tai, 1984; Li, 1990). For children learning Chinese, they could never become flexible enough to use such non-prototypical associations because the language prohibits the associations (see Li & Shirai, 2000, pp. 186-190, for a discussion of how such crosslinguistic differences affect developmental patterns). Therefore, depending on the structure of the target language, in some cases (e.g., English), learners move from the prototypical associations to more flexible, non-prototypical associations; in other cases (e.g., Chinese), they have to hold onto the prototypical associations.

If the above analysis is correct, we need to further assume that the child is sensitive to the statistical properties of the input, and is capable of extracting systematic patterns from the input. Given this assumption, then, we do not need to presuppose, as nativists do, innate specifications of the

grammar or universal predispositions at the initial stages of language acquisition. Note that the associations between morphology and verbs in child language, even if they are very strong, are in most cases probabilistic rather than absolute (excluding the impossible associations discussed above). For example, although children's use of *-ing* is more strongly associated with process verbs, it also occurs with event verbs. The same holds for *-ed*: its use is strongly associated with event verbs, but it also occurs with process verbs in children's speech. Probabilistic rather than absolute associations present problems for nativists who look at the associations as either-or-none phenomena arising out of innate constraints (e.g., Bickerton, 1981), but are compatible with the prototype view because probabilistic associations allow learners to extract the most frequent patterns as the prototypes (Shirai, 1999; Li & Shirai, 2000).

What capacity allows the child to do the pattern extraction from the input, and how does it work? Put simply, if input is important to language acquisition, in which way does it play a causal role? Answers to these questions are relevant to the question of how the correspondence between adult input and children's speech speaks to mechanisms of language acquisition (the second question asked above). In this paper we have referred to "probabilistic learning mechanisms" as the mechanisms that the children have at their disposal during acquisition. Although it is beyond the scope of this paper to give a full account of the probabilistic mechanisms involved, we have argued elsewhere that children's distributional analyses of the input could be viewed from a computational/connectionist perspective: young children have the necessary computational ability to extract statistical regularities from the input (Saffran, Aslin, & Newport, 1996; Seidenberg, 1997; Seidenberg & MacDonald, 1999). In particular, we believe that connectionist learning principles might provide an answer in this regard. Li (2000) and Li and Shirai (2000) showed that a self-organizing connectionist network with Hebbian learning is able to learn on the basis of adult input, and is able to

derive patterns observed in child language. In our simulations, the network used word representations (phonology, semantics, and morphology) as input, and was trained to associate verb meanings with the corresponding phonological and morphological forms. The network established prototypical associations between given morphemes and certain types of verbs through the learning of staged input according to parental speech. During the course of learning, it progressed, like children, from prototypical associations (earlier phases of learning) to more flexible non-prototypical associations (later phases of learning). Interestingly, the network did not simply mimic the input patterns verbatim in its production; rather, it produced patterns of associations that were initially stronger than those in the input it received. Our simulation results matched closely with empirical findings in child language, capturing tense-aspect acquisition without making particular assumptions about the structure of innate semantic knowledge (see Li & Shirai, 2000, Chapter 7 for details of the model).

A final question regarding the role of parental input has to do with the direction in which input can impact the acquisition process. Olsen et al. (1998; also Olsen and Weinberg 1999) claimed that the role of linguistic input is minimal in leading children to establish the initial strong associations, but may play a causal role in helping the child relax the strong associations. Our analysis suggests that adult input helps the child both in establishing the strong associations and in retreating or diverging from these associations. The connectionist model in Li and Shirai (2000) gives a mechanistic account of how input-based learning can give rise not only to prototypes, but also to the transition from prototypes to non-prototypes, both of which are triggered by the system's analyses of distributional properties of the input.

To conclude, our study provides evidence that there is rich statistical information (even "developmental patterns") for the verb-to-morphology mapping in the parental input, and that the child can use probabilistic

learning mechanisms to extract this information in forming prototypical associations during the acquisition of verb semantics and morphology. Such probabilistic mechanisms can be most clearly characterized as connectionist learning principles that are sensitive to the statistical properties of the input. Our argument echoes strongly with recent computational perspectives on the statistical learning of linguistic regularities, especially in connectionist networks (Li, Burgess, and Lund, 2000; Seidenberg & MacDonald, 1999; Rhode & Plaut, 1999).

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Footnotes

¹ A somewhat different, but related view is advocated by Slobin (1985). Slobin proposed the Basic Child Grammar, which contains a pre-structured "semantic space" with universal semantic notions or categories. These semantic categories can act strongly to attract the morphological mapping from the input language. Result and Process are two such semantic categories that have to do with children's acquisition of tense and aspect morphology. However, because the issue of innateness is less fundamental to the Basic Child Grammar as to the Language Bioprogram Hypothesis, and because Slobin's (1997) recent reformulation is consistent with a functional-cognitive view, we do not consider the Basic Child Grammar as a nativist theory in this debate. See Li and Shirai (2000) for a more detailed analysis of Slobin's perspectives in the context of the nativist-functionalist debate in language acquisition.

² Note all language acquisition researchers agree that these association patterns exist cross-linguistically. For example, Weist and his colleagues argued against the proposal of Bloom et al. (1980). They showed that Polish children are able to understand and produce the basic contrast between perfective and imperfective aspect at an age as young as 2;6 (Weist, 1983; Weist et al., 1984; Weist et al., 1991). See Li and Shirai (2000) for a discussion of the relevant debate (pp. 40-47).

³ A potential problem with calling all of these morphemes "tense-aspect morphology" is that some of the -ing and the -ed forms might be the present or past participles (rather than true progressive or past/perfective forms). However, in many cases the participles also carry the corresponding aspect meaning, for example, in sentences like Now I'll stop you moving around (as opposed to Now I am concerned with moving to

another city where moving does not carry an aspectual meaning). Obviously, a more detailed analysis requires the examination of the use of each morpheme in each sentence context in the CHILDES database.

⁴ This developing pattern, however, does not hold for all languages in all cases. Li and Shirai (2000) gave a detailed analysis of the conditions under which learners do and do not move from prototypical to non-prototypical associations. We will briefly discuss this issue in the General Discussion section.

⁵ The Wells data have a wider age range (1;6 to 5;0) and the Wisconsin data are from children who are all around 1;6. Thus, these two data sets are not included in the subset analysis.

⁶ Shirai (personal communication) suggested this possibility. Simple present forms in English typically denote states with stative verbs, but habitual events with dynamic verbs (e.g., process verbs). Shirai (1991) reported an increase of habitual references in parental speech over time.