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Brief article

What infants know about syntax but couldn't have learned: experimental evidence for syntactic structure at 18 months

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Abstract

Generative linguistic theory stands on the hypothesis that grammar cannot be acquired solely on the basis of an analysis of the input, but depends, in addition, on innate structure within the learner to guide the process of acquisition. This hypothesis derives from a logical argument, however, and its consequences have never been examined experimentally with infant learners. Challenges to this hypothesis, claiming that an analysis of the input is indeed sufficient to explain grammatical acquisition, have recently gained attention. We demonstrate with novel experimentation the insufficiency of this countervailing view. Focusing on the syntactic structures required to determine the antecedent for the pronoun *one*, we demonstrate that the input to children does not contain sufficient information to support unaided learning. Nonetheless, we show that 18-month-old infants do have command of the syntax of *one*. Because this syntactic knowledge could not have been gleaned exclusively from the input, infants' mastery of this aspect of syntax constitutes evidence for the contribution of innate structure within the learner in acquiring a grammar.

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1. Introduction

Any theory of the human mind faces the question of how to relate experience to attained knowledge. This nature of the problem comes into sharp focus in examining language acquisition. In this domain, infant learners exposed to a finite set of sentences quickly

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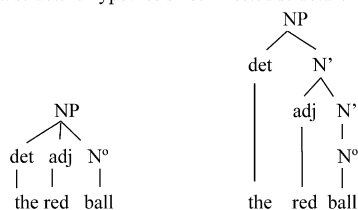
develop the capacity to produce novel sentences of the same character. The difficulty of mastering this capacity is highlighted by the discovery that the mental structures that constitute linguistic knowledge do not express themselves in a straightforward fashion in the surface form of a language (Chomsky, 1957, 1965). The question of how these structures are acquired, then, is more properly understood as the question of how a learner takes the surface forms in the input and converts them into abstract linguistic rules and representations. Answering this question requires balancing the structure derivable from the surface input with the structure inherent in the learner. On the traditional Chomskyan view, the input vastly underdetermines the linguistic representations of the adult grammar. This observed “poverty of the stimulus” tips the balance of the acquisition question in favor of mental structure inherent in the learner. It is this structure that supports linguistic representations beyond those that can be culled from the input (Chomsky, 1975; Crain, 1991; Hornstein & Lightfoot, 1981; Pinker, 1989).

This nativist perspective has been challenged directly, with the “poverty of the stimulus” argument recently taking center stage (Pullum & Scholz, 2002). Several researchers have countered that the linguistic input to children does contain sufficient information to account for their linguistic representations (Brent & Cartwright, 1996; Seidenberg, 1997), and moreover, that this information can be extracted by general purpose learning mechanisms (Elman, 1990; Saffran, Aslin, & Newport, 1996; Seidenberg, 1997). On this view, it is unnecessary to attribute so much structure to the learner because the input is argued to be sufficient to account for the acquisition of linguistic representations (Tomasello, 2000).

In this paper, we address these challenges to the nativist perspective. First, we articulate the logic of the argument, using the structure of the noun phrase (NP) as a case in point (Baker, 1978). Second, we analyze the input to children in order to show that the evidence which would lead the learner to the correct grammar is simply not a part of the language learning experience. Finally, we demonstrate experimentally that despite the poverty of support in the environment, infants know just what adults know about the structure of NP. We therefore conclude that although learners may use distributional analysis to acquire some aspects of their language, any such analysis must be subservient to the representational presuppositions of the learner (Lidz, Gleitman, & Gleitman, 2003; Lidz & Musolino, 2002).

One well-known illustration of the poverty of the stimulus argument concerns the hierarchical structure of NP and the anaphoric uses of *one* (Baker, 1978; Hamburger & Crain, 1984; Hornstein & Lightfoot, 1981; Lightfoot, 1982). Consider two hypotheses for the structure of NP, given in (1). Both would, in principle, be possible analyses of strings containing a determiner, adjective and noun.

- (1) a. Flat structure hypothesis b. Nested structure hypothesis



We know, on the basis of anaphoric substitution, that for adults (1b) is the correct representation (Baker, 1978). In (2), the element *one* refers anaphorically to the constituent [*red ball*].

(2) I'll play with this red ball and you can play with that one.

Since anaphoric elements substitute only for constituents and since it is only under the nested structure hypothesis that the string *red ball* is represented as a constituent (i.e. a single node containing only that string), it follows that (1b) is the correct structure.

Now, although we know that the nested structure hypothesis reflects the correct adult grammar, how children acquire this knowledge is more mysterious. Consider the following learning problem (Hornstein & Lightfoot, 1981). Suppose that a learner is exposed to small discourses like (2) in which *one* is anaphoric to some previously mentioned discourse entity and that the learner has recognized that *one* is anaphoric. In order to understand this use of *one*, the learner must know that it is anaphoric to the phrasal category N' , which is possible only under the nested structure hypothesis. However, the data to support this hypothesis are not available to the learner for the following reason. Every situation that makes $one = [N' \text{ red ball}]$ true also makes $one = [N^\circ \text{ ball}]$ true. Thus, if the learner had come to the flat structure hypothesis or to the hypothesis that *one* is anaphoric to N° and not N' , evidence that this is wrong would be extremely difficult to come by.

The right kind of evidence might be a situation in which (3) is uttered and Max has a blue ball.

(3) Chris has a red ball but Max doesn't have one.

In such a situation, the learner who posited that *one* was anaphoric to the $N^\circ \text{ ball}$, would have to conclude that he had built the wrong grammar (or that the speaker was lying) and thus be led to change the hypothesis. Now, in order for learners to build the correct grammar, such situations would have to be common enough for them to show up at levels distinguishable from noise in every child's linguistic environment. Since such situations are not likely to be so common, we conclude that neither the flat structure hypothesis nor the hypothesis that *one* is anaphoric to N° could be part of the hypothesis space of the learner. If they were, then some learners might never come upon the evidence disconfirming those hypotheses and would therefore acquire the wrong grammar. Since there is no evidence that English speakers actually do have that grammar, it simply must never be considered.

The logic of the argument is unquestionable; however, it is based on the crucial assumption that the evidence that unambiguously supports the nested structure hypothesis does not occur often enough to impact learning. In addition, because it is an argument based on what adults know about their language, it is missing the important step of showing that at the earliest stages of syntactic acquisition, children know that *one* is anaphoric to the phrasal category N' .

Hamburger and Crain (1984) in response to Matthei (1982) addressed the latter issue by testing 4- to 6-year-old children and found that they do represent the NP with a nested

structure and that they also know that *one* is anaphoric to the phrasal category N' . However compelling, evidence based on preschool-aged children cannot reveal the initial state of the learner or the mechanisms responsible for the acquisition of this syntactic structure. This type of evidence leaves open the possibility that learners begin the process of acquisition with a flat structure grammar, discover (based on the input) that this structure is wrong, and subsequently arrive at the nested structure grammar to better capture the input. We will address this concern by testing infants at the earliest stages of syntactic acquisition who are more likely to reveal the initial state of the learning mechanism. Before turning to the experiments, we will first address the question of the input to learners regarding the anaphoric properties of *one*.

2. Corpus analysis

To begin, we examined the empirical status of the assumption that the evidence that *one* is anaphoric to N' is unavailable to learners. In essence, we asked whether it is possible that children could learn on the basis of the input strings that they are exposed to whether *one* is anaphoric to N' . To answer the question, we examined the parental speech to the children Adam (Brown, 1973) and Nina (Suppes, 1974) in the CHILDES database (MacWhinney, 2000).¹ Adam's corpus contains approximately 20,000 adult utterances and Nina's approximately 34,800. Of these, 1129 contained the word *one*. The context surrounding each of these utterances was examined to determine whether this use was anaphoric and if so, what it was anaphoric to.

Of the sentences containing *one*, 792 were anaphoric uses. Other uses were numerals, impersonal pronouns (e.g. *where does one do that?*), or deictic (e.g. *look at this one* at the beginning of a discourse segment). We examined the anaphoric cases further to discover the structure of the antecedent. The structure of the antecedent is important because it has the potential to tell us whether *one* refers unambiguously back to an element of the category N' , or whether it might equally well refer to an element of the category N° . If in a high proportion of cases, *one* refers unambiguously to N' , then it is possible that infants might be able to learn about the syntactic properties of *one* from the input. This was not the case. In the vast majority of cases (750, approximately 95%) the antecedent had insufficient internal structure to be informative. These cases were uninformative either because the antecedent consisted only of a determiner-noun sequence (e.g. *the bottle*) or because the antecedent was itself a pronoun and had no internal structure. Among the remaining 42 cases, four (or 0.5% of the anaphoric uses) contained an ungrammatical use of *one*, which would constitute noise on either hypothesis. Only two (or 0.2% of the anaphoric cases) occurred in a context that unambiguously indicated that *one* is anaphoric to N' . In sum, anaphoric uses of *one* that are syntactically uninformative vastly outstrip the informative uses in the input, and the data that the infant would need in order to learn the syntax of *one* occur at a rate (0.2%) that is indistinguishable from noise in the input. Consequently, we can conclude that if infants have command over the syntax of anaphoric *one*, this syntactic knowledge could not have come from the input.

¹ These corpora were chosen because they are among the largest samples of child-directed speech in the CHILDES database.

3. Experimentation

We now turn to the acquisition question. Taking the ambiguity of the input as evidence that there must indeed be some innate syntactic structure in this domain, we ask whether infants know that *one* is anaphoric to the phrasal category N' and thus that the NP has a hierarchical (rather than a flat) structure. We predict that they do, and that they will therefore interpret *one* as anaphoric to the phrasal category N' .

To test this prediction, we examined infants' interpretation of sentences with *one*-substitution. Infants were tested using the intermodal preferential looking paradigm (Golinkoff, Hirsch-Pasek, Cauley, & Gordon, 1987; Spelke, 1979).

3.1. Method

3.1.1. Subjects

We tested 24 English-speaking children (12 male and 12 female) between the ages of 16m;23d and 18m;15d (mean: 18m;3d). We selected 18-month-olds because it is at this age that infants begin to produce utterances with more than one word, an achievement that is generally taken as clear evidence of the onset of syntactic development. Two children were taken out of the design because of failure to watch the video to completion.

3.1.2. Materials

The auditory stimuli consisted of sentences and questions recorded in a sound-proof recording chamber and saved in digitized format for use in the audio track of the video that infants heard during testing. The auditory stimuli were recorded by the last author in an infant-friendly voice. Durations of the sentences were matched so that the onset of the corresponding sentence across trials was aligned to within 1/30th of a second. The objects used in the experiment (a bottle, a car, a shoe, a bear) were chosen because their names are generally recognizable to infants aged 13 months and older according to the MacArthur Communicative Development Inventory norms (Fenson et al., 1994).

The visual stimuli were constructed using a computer drawing program. They were brightly colored and large so as to attract the infants' attention, yet designed to be of approximately equal salience. Split-screen displays were created in which the two objects appeared side by side using digital video production software. The individual pictures were 18 × 12 inches and were placed 20 inches apart from center to center.

3.1.3. Apparatus

A Sony TRV-240 Digital8 camcorder was attached to a Sony KP61V85 LCD Presentation Display (61 inch screen) and was used to present the audio-visual materials. A second camcorder was mounted above this display to record infant looking times and locations.

3.1.4. Procedure

Upon arrival at the lab, parents and their children were escorted to a playroom. There, the experimenter explained the procedure and asked the parent to sign a consent form and complete a vocabulary checklist. Once these were completed, the infant and parent were

escorted to a testing room where the infant was seated in a booster seat 80 inches from the television screen. The parent was seated in a chair behind the infant. The parent was instructed not to interact with the infant during the experiment. In addition, the parent wore a visor that blocked any view of the screen, so that the parent could not influence the infant's direction of gaze.

Each infant participated in four trials, each consisting of two phases. During the familiarization phase, an image of a single object (e.g. a yellow bottle) was presented three times, appearing in alternating fashion on either the left or right side of the television monitor. Each presentation was accompanied by a recorded voice that named the object with a phrase consisting of a determiner, adjective and noun (e.g. *Look! A yellow bottle.*). During the test phase, two objects appeared simultaneously on opposite sides of the television monitor (e.g. a yellow bottle and a blue bottle). Both objects were from the same category as the familiarization object, but only one was the same color. Infants were randomly assigned to one of two conditions which differed only in the linguistic stimulus. In the control condition, subjects heard a neutral phrase (*Now look. What do you see now?*). In the anaphoric condition, subjects heard a phrase containing the anaphoric expression *one* (*Now look. Do you see another one?*). On each of the four trials, the test phase lasted 8 seconds; the entire experiment lasted 3 minutes and 46 seconds.

3.1.5. Coding

For each subject, durations of looking time to the left or the right test image were coded off-line, frame-by-frame, by a single coder. An additional coder coded 25% of the data. Inter-coder reliability was 96%.

3.2. Predictions

The assumption in the preferential looking task is that infants prefer to look at an image that matches the linguistic stimulus, if one is available. Our predictions were as follows. In the control condition, where the linguistic stimulus does not favor one image over the other, we expected that infants would prefer the novel image (the blue bottle), as compared to the now-familiar image (the yellow bottle). In the anaphoric condition, infants' performance should reveal their representation of the NP. Here, there are two possible outcomes. If infants represent the NP with a flat structure, and therefore interpret *one* as anaphoric to the category N° , then both images would be potential referents of the noun (bottle). In this case, the linguistic stimulus is uninformative with regard to the test images, and so infants should reveal the same pattern of performance as in the control condition. However, if infants represent the NP with a nested structure, and interpret *one* as anaphoric to N' , then they should reveal a preference for the (only) image that is picked out by N' (the yellow bottle).

3.3. Results

As can be seen in Fig. 1, subjects in the control condition revealed the predicted preference for the novel image, devoting more attention to it than to the familiar image ($t(10) = 2.96, P < 0.01$). This preference was reversed in the anaphoric condition, where infants devoted more attention to the familiar than to the novel image ($t(10) = -4.70$,

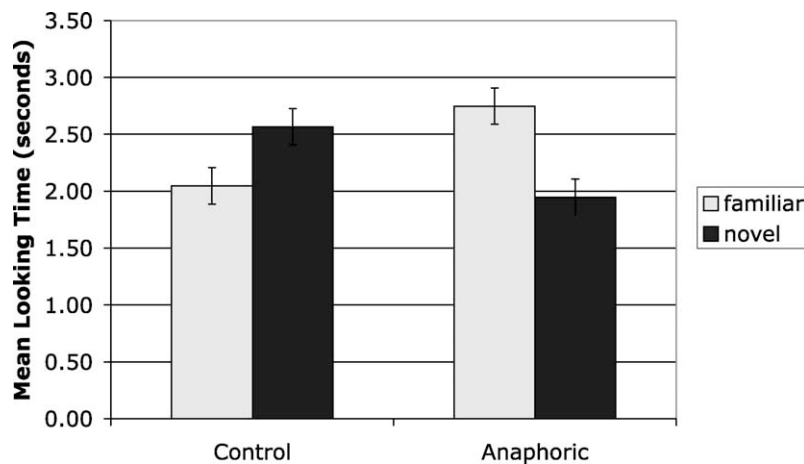


Fig. 1. Mean looking time (in seconds) to the two test images in each condition.

$P < 0.0008$). Looking times were entered into an analysis of variance (ANOVA) with two factors: direction of look (familiar vs. novel) and condition (anaphoric vs. control). There was no significant effect of direction or condition, but there was a significant interaction between these factors ($F(3, 40) = 10.26$, $P < 0.003$). That is, subjects in the anaphoric condition were more likely to look at the familiar image (i.e. the one labeled by the N') than were subjects in the control condition. These results show that by 18 months, infants interpret *one* as anaphoric to the category N' and thus that they represent the NP with a nested structure.

One possible interpretation of these results is that the infants treat *one* as anaphoric to N° but that when asked to find another instance of the category denoted by that N , they prefer the image that is most like the one they had seen during familiarization.

To address this possibility, we conducted a control experiment. The procedure was identical to that in the experiment proper, with one exception. At test, infants were presented with NPs whose content matched that of the two possible interpretations for *one*. Infants in the Noun condition ($n = 11$) heard a question containing only the noun presented during familiarization (e.g. “Do you see another bottle?”). Infants in the Adjective-Noun condition ($n = 11$) heard the adjective-noun combination presented during familiarization (e.g. “Do you see another yellow bottle?”). If infants’ behavior in the experiment proper reflected their interpreting *one* as referring only to the N , then infants in the Noun condition, like those in the experiment proper, should prefer the familiar object (e.g. the yellow bottle). However, if infants’ behavior in the initial experiment reflected their interpreting *one* as referring to the N' , then infants in the Noun condition should show no such preference. Rather, only infants in the Adjective-Noun condition should reveal a preference for the familiar object. As can be seen in Fig. 2, infants in the Noun condition revealed no preference for the familiar object ($t(10) = -1.52$, $P > 0.15$). Subjects in the Adjective-Noun condition, however, did show the predicted preference for the familiar object ($t(10) = 2.74$, $P < 0.03$). This outcome is consistent with the claim that infants treat *one* as N' .

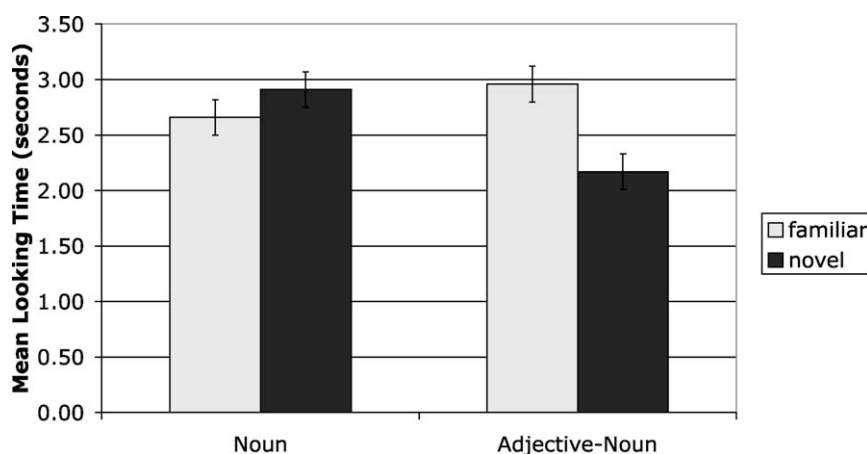


Fig. 2. Mean looking time (in seconds) to the two test images in the control experiments.

3.4. Discussion

These findings show that learners who are just beginning to combine words productively already have a very rich representational system for assigning syntactic structure to the exposure language. More importantly, they provide experimental support for the “poverty of the stimulus” argument. The current experiment shows that despite the paucity of relevant information in the input, knowledge of both the structure of NP and the anaphoric properties of *one* are in place at the very onset of syntactic development. This result strongly supports the view that learners approach the task of acquisition armed with linguistic structure, and that this structure guides the acquisition of syntax.

In the domain of anaphoric reference, learnability considerations lead to the conclusion that learners never consider the possibility that an element could be anaphoric to N° . Indeed, we know of no language with an element that is anaphoric to N° . This logical conclusion is now supported by corpus analysis and by experimentation with infants. We have demonstrated that infants at the earliest stages of syntactic production share with mature speakers of English the syntactic knowledge that the anaphoric element *one* refers to the category N' . This syntactic knowledge must derive from linguistic structure inherent in the learners themselves because, as we have shown, the input to which infants are exposed does not unambiguously support the linguistic representations that they create. Our results provide clear support for the argument that the learner’s innate linguistic structure guides language acquisition. This is not to say that there is no role for the input, for statistical learning or for distributional analysis in language acquisition.² Rather, in our view, a set of representational presuppositions inside the mind of the learner serves to structure the available input in such a way as to make learning possible.

² Indeed, it is only through distributional analysis that the learner could discover that *one* is an anaphoric expression and that it is not anaphoric uniquely to NP, as pronouns like *her* or *it* are. See Bloom (1990) for discussion.

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