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The Structure of Children's Linguistic Knowledge

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A recurring theme in arguments from the poverty of the stimulus concerns children's knowledge of linguistic structure. Nativists point to the extensive gap between what children know and what they could have learned from experience, even given optimistic assumptions about children's abilities to extract information from the environment, and to form generalizations. This squib looks at children's knowledge of linguistic structures that involve the semantic property of downward entailment, allowing us to address a recent critique of children's knowledge of structure offered by Lewis and Elman (2002).

1 Structure Dependence and Poverty of the Stimulus

An example of structure-dependent linguistic principles deals with question formation. This phenomenon was originally described by Chomsky (1971), who questioned the extent to which the primary linguistic data could lead children to form the correct generalizations relating declarative sentences and their yes/no question counterparts (see also Chomsky 1980 and discussion in Piattelli-Palmarini 1980).

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Consider the declarative sentences in (1) and the corresponding yes/no questions in (2).

(1) a. The boy who is sitting on the rug is hungry.
b. The boy is sitting on the rug that is being vacuumed by his mother.

(2) a. Is the boy who is sitting on the rug _____ hungry?
b. Is the boy _____ sitting on the rug that is being vacuumed by his mother?

Even these simple examples suffice to illustrate that structure-blind operations will have a difficult time accounting for question formation in English.

The role of structure dependence in question formation by children was investigated by Crain and Nakayama (1987), who used an elicited-production task in several experiments to evoke yes/no questions from young children. In one experimental trial, children were shown a picture depicting one man who was beating a donkey and a second man who was not beating a donkey. Then children were invited to pose a question to a puppet, Jabba the Hutt. The input to children contained two auxiliary verbs: for example, *Ask Jabba if the man who is beating the donkey is mean*. The experiment was designed to see whether children would ask adultlike questions like (3) or whether, instead, they would ask incorrect questions like (4), where the first auxiliary verb was ''moved'' from its position in the request they had just heard.

(3) Is the man who is beating the donkey mean?

(4) *Is the man who beating the donkey is mean?

Observing that no child ever produced questions like (4), Crain and Nakayama (1987) concluded that children entertain structure-dependent operations in forming yes/no questions, not structure-independent ones, despite the lack of overt evidence in the input.

This conclusion was recently challenged on two counts. Pullum and Scholz (2002) argue that Crain and Nakayama (1987) make the unwarranted assumption that children cannot rely on the input in order to learn the correct question forms. They contend that there is sufficient available evidence to support learning (but see Crain and Pietroski 2002, Lasnik and Uriagereka 2002, Yang 2003). Taking a different tack, Lewis and Elman (2002) constructed a simple recurrent network to model question formation in English. The network was trained in a three-stage process, such that the degree of complexity of the input was increased at each stage. The network was presented with yes/no questions with a single auxiliary verb (e.g., *Is the big dog in the car scary?*), but not ones with two auxiliaries (e.g., *Is the farmer who is beating the donkey mean?*). Lewis and Elman (2002:364) maintain that ''the network does not make the predictions corresponding to the ungrammatical [question, such as (4)]—*i.e.*, the network does not predict [a gerund] following '*who*'.'' In other words, the network con-

sistently predicts that a substring like (5) should be followed by an auxiliary verb, despite the absence of such strings in the training sessions.

(5) Is the boy who _____

Lewis and Elman (2002) observe, further, that if the network *is* presented with a substring with an auxiliary verb following *who*, as in (6), it predicts the occurrence of a third auxiliary, thereby modeling the kind of ungrammatical questions that children produced in Crain and Nakayama's study (e.g., *Is the man who is beating his donkey is mean?*).

(6) Is the boy who is smoking _____

Lewis and Elman (2002:368–369) remark that ''the most prominent and persistent of the errors is the prediction of an auxiliary following the participle, i.e., '*is the boy who is smoking is*' ''—so the network models the kind of ungrammatical questions reported by Crain and Nakayama.

Despite these claims, it is hard to see what the network really learned. We gather that one thing the network learned is that a sequence like *who smoking* is unacceptable whereas *who is smoking* is acceptable. This is not a desirable result, however, since questions like (7) are well formed despite the occurrence of the sequence of words *who smoking*.

(7) Is the boy who smoking offends still here?

Furthermore, it is misleading to claim that the network models children's mistakes documented by Crain and Nakayama (1987). These researchers indeed collected sentences containing three occurrences of *is*. However, they concluded that those forms could not be used to distinguish between the application of a structure-dependent rule and the application of a structure-independent one. Therefore, they modified the experimental protocol in a follow-up study, in order to elicit questions containing an auxiliary like *be* and a modal like *can*. Parsimony suggests that Lewis and Elman should have implemented the same maneuver. For example, they should have investigated the network predictions for sequences with an auxiliary like *be* and a modal like *can*, as in (8).

(8) Can the boy who is smoking _____

Finally, Lewis and Elman need to explain how the same abstract notion underlies several different linguistic phenomena. Assuming that the results they have documented show that a neural network can model question formation, it still remains to be shown that the same network would converge on any principle that is also relevant for other linguistic phenomena. After all, no one has ever suggested that structure dependence is construction specific. Indeed, there is abundant empirical evidence that children apply structure-dependent operations across different linguistic phenomena, as we will now demonstrate.

2 Structure Dependence and Downward Entailment

Structure dependence figures prominently in several linguistic phenomena that involve the semantic property of downward entailment (see Ladusaw 1979). Consider the examples in (9)–(11). The sentences in (9) show that negation only licenses inferences from a set to its subsets for NPs in its c-command domain. The same contrast holds for the licensing of several negative polarity items (NPIs), as shown in (10); and it is crucial for the interpretation of the disjunction operator *or*, which receives a conjunctive interpretation when it is in the scope of negation, as shown in (11), as in one (direction of one) of De Morgan's laws.

(9) a. The boy who majored in linguistics did not learn a Romance language.
⇒ The boy who majored in linguistics did not learn French.
b. The boy who did not major in linguistics learned a Romance language.
*⇒ The boy who did not major in linguistics learned French.

(10) a. The boy who majored in linguistics did not learn any Romance language.
b. *The boy who did not major in linguistics learned any Romance language.

(11) a. The boy who majored in linguistics did not learn French or Spanish.
⇒ The boy who majored in linguistics did not learn French and the boy who majored in linguistics did not learn Spanish.
b. The boy who did not major in linguistics learned French or Spanish.
*⇒ The boy who did not major in linguistics learned French and the boy who did not major in linguistics learned Spanish.[1]

The role of c-command in constraining children's assignment of the conjunctive interpretation to the disjunction operator *or* was studied

[1] Higginbotham (1991) refers to the phenomenon illustrated in (11) as the ''conjunctive'' interpretation of disjunction. We will adopt Higginbotham's terminology for convenience. However, it should be clear that, strictly speaking, the interpretation of the disjunction *or* is simply the inclusive-*or* interpretation, proposed by classical logic (see Horn 1989). In other words, the meaning of *or* is not different in downward- and upward-entailing environments. Possible differences in the entailment patterns originate from the *interaction* between *or* and other operators. A more accurate, though less reader-friendly, way of capturing the scheme in (11) would be to say that sentences containing disjunction in the scope of a downward-entailing operator entail the validity of the sentences in which the same operator has scope over one of the disjuncts (i.e., $OP_{DE}(A \textit{ or } B)$ entails $OP_{DE}(A)$ as well as $OP_{DE}(B)$).

by Crain et al. (2002), who investigated whether the structure-dependent notion of c-command constrains downward entailment in child language, using a truth-value judgment task. The aim was to see if 4- and 5-year-olds know that the relevant operator must c-command disjunction to license the conjunctive interpretation of disjunction, as in (11a), while linear precedence does not suffice, as in (11b). The experiment employed the prediction mode.[2]

In one trial of Crain et al.'s study, children were told a story about two girls who had each lost a tooth. The girls knew that the Tooth Fairy would come during the night to reward them, in exchange for their lost tooth. One girl decided to go to bed right away, while the other girl decided to stay up late to see what the Tooth Fairy looked like. Then, the Tooth Fairy arrived, with two jewels and two dimes. At this point, the story was interrupted so that a puppet, Merlin the Magician, could make a prediction about what would happen in the remainder of the story. One group of children heard (12), in which negation both precedes and c-commands the disjunction operator *or*, while the second group heard (13), in which negation precedes but does not c-command *or*.

(12) The girl who stayed up late will *not* get a dime *or* a jewel.

(13) The girl who *didn't* go to sleep will get a dime *or* a jewel.

At this point, the story was resumed. As events ensued, the Tooth Fairy gave a dime and a jewel to the girl who was sleeping, but the Tooth Fairy was disappointed to see that the other girl was still awake. The little girl explained that she had decided to stay up to see what the Tooth Fairy looked like. Then, the Tooth Fairy decided to give this girl a jewel, but not a dime. Following the completion of the story, Merlin reminded the child subjects of his prediction:

(14) I said that the girl who stayed up late would *not* get a dime *or* a jewel.

(15) I said that the girl who *didn't* go to sleep would get a dime *or* a jewel.

Because of the interaction between downward entailment and c-command, the two sentences generate different entailment patterns. In particular, only (12) licenses the conjunctive interpretation, which requires that the girl under consideration did not get a dime and that she did not get a jewel. By contrast, (13) is true in the context set up by the story. The finding was that children rejected sentences like (12) 92% of the time, but they accepted ones like (13) 87% of the time. Thus, the findings indicate that children distinguish between the entailment patterns associated with *or* in the two sentences.

[2] This choice was dictated by the desire to avoid the infelicity of using the scalar term *or* in a context that warranted the computation of scalar implicatures (see Chierchia et al. 1998).

The findings documented by Crain et al. (2002) show that linear precedence is not a sufficient condition to establish a downward-entailing environment. That said, we decided to extend Crain et al.'s study to address a potential confound. In that study, the two test sentences differed in the number of words that intervened between negation and disjunction: these operators were closer in (12) than in (13). If linear precedence is a domain-general cue that children pay attention to, it is possible that ''distance'' played a role in children's interpretation.

3 Experimental Design

To investigate the role of linear distance in child grammar, we conducted two experiments employing the truth-value judgment task (Crain and McKee 1985, Crain and Thornton 1998). In Experiment I, children were presented with sentences in which the disjunction operator *or* was preceded and c-commanded by negation, but these two operators were further from each other than in the corresponding condition in Crain et al.'s study. In Experiment II, children were presented with sentences in which the disjunction operator *or* was preceded but not c-commanded by negation, and these two operators were closer to each other than in the corresponding condition in Crain et al.'s study.

3.1 Experiment I

Experiment I was designed to determine whether children's interpretation of disjunction in the scope of negation was affected by the distance between the two operators. Recall that c-command was confounded with proximity in Crain et al.'s study. To rectify this, we conducted an experiment in which the structural relations were not altered, but the distance between negation and disjunction was manipulated in the target sentences. To minimize the differences between our study and Crain et al.'s, we used the prediction mode of the truth-value judgment task, as Crain et al. did. Thirty children participated in the experiment. The children ranged in age between 3;08 and 6;05, with a mean age of 4;09. Each child was presented with two target trials, one warm-up, and one filler trial. One of the target trials is described in (16).

(16) ''This is a story about Winnie the Pooh, Eeyore, and Arthur. Eeyore is very sad, and Winnie the Pooh says, 'You need something to cheer you up. Let's go to Arthur's. He always has lots of good food!' When they arrive at Arthur's store, Arthur shows them some goodies: a strawberry, a cookie, and a cake.''

At this point, the storyteller interrupted the story to ask Merlin the Magician to predict what would happen next. Merlin made the following prediction:

(17) I know what will happen. Winnie the Pooh will not let Eeyore eat the cookie or the cake.

Then the story resumed, as in (18).

(18) ''Winnie the Pooh invites Eeyore to eat the strawberry because it is very healthy, but Eeyore says, 'Well, I know that the strawberry is very healthy, but I really need something sweet,' to which Winnie the Pooh responds, 'OK, you can have the cookie then, but not the cake, because that's too much sugar for you!' ''

Following the completion of the story, Merlin reminded the child of his prediction.

(19) I said that Winnie the Pooh would not let Eeyore eat the cookie or the cake.

Let us spell out our predictions. Negation precedes and c-commands disjunction in (19). Thus, the preferred reading of the target sentence, for adults, is that Winnie the Pooh would not let Eeyore eat the cookie and he would not let Eeyore eat the cake. This interpretation makes the sentence false, because Winnie the Pooh did allow Eeyore to eat the cookie.[3] In short, the conjunctive interpretation of disjunction arises despite the linguistic material intervening between negation and disjunction.

Against this background, recall that children's behavior documented by Crain et al. (2002) could have been dictated by the distance between negation and disjunction. If so, children could fail to assign the conjunctive interpretation to the disjunction operator *or* in the present study; then, they would accept the target sentences. By contrast, if children's interpretation was governed by structural relations between *not* and *or*, they should reject the target sentences, without regard to the distance between the two logical operators. This is exactly what happened. The child subjects rejected the target sentence on 51 out of 60 trials (85%). As controls, a group of 10 undergraduates participated in a videotaped version of the experiment. This control group rejected the target sentences 95% of the time.

These findings show that c-command is a sufficient condition for the application of the familiar entailment pattern. When disjunction is c-commanded by a downward-entailing operator like negation, children, like adults, apply the relevant De Morgan's law, regardless of the distance between the logical operators. Moreover, children assigned the conjunctive interpretation to disjunction in our experiment to the same extent as in Crain et al.'s (2002) experiment, despite the difference in distance between the two operators in the sentences em-

[3] As in Crain et al.'s study, we controlled for the order of the disjunct that made the sentence false. In other words, in one trial the target sentence was false because the sentence containing the first disjunct was false, as in the story just described, and in the other trial, the sentence was false because the sentence containing the second disjunct was false.

ployed in the two experiments (see (17) and (12)).[4] Thus, the relative proximity of negation and disjunction is not necessary for the conjunctive interpretation of disjunction. To determine whether it is a *sufficient* condition, we turn to the next experiment.

3.2 Experiment II

Experiment II was designed to determine whether children in Crain et al.'s (2002) study refrained from assigning the conjunctive interpretation of disjunction (in the relevant condition) because of the words that intervened between the two operators in that study. Crain et al. report that children did not assign a conjunctive interpretation to the disjunction operator *or* when interpreting (13), thereby showing that linear precedence by negation alone did not license such an interpretation in child grammars. Notice, however, that there is considerable distance between negation and disjunction in (13). In particular, the distance between the two logical operators is greater than that in the target sentences used by Crain et al. in the c-command condition (see (12)). Hence, the possibility arises that children did not assign a conjunctive interpretation to disjunction in (13) because the relevant operators were further apart in (13) than in (12).

To investigate this possibility, children were presented with sentences in which negation and disjunction occurred at the same distance as in (12), but negation did not c-command disjunction. As in Crain et al.'s study, the experiment employed the prediction mode of the truth-value judgment task. Thirty-five children participated in the experiment. The children ranged in age between 3;05 and 6;05, with a mean age of 4;11. Each child was presented with two target trials, one warm-up, and one filler trial. Here is the protocol of one of the target trials:

(20) ''This is a story about a Karate Man and two Pooh Bears, one very big and the other smaller. The Karate Man has just finished his training and is about to eat his after-training snack: some honey, a doughnut, and a strawberry. When the Pooh Bears arrive, the Karate Man starts bragging about how strong he is and says, 'I bet I am so strong that I can lift each one of you! In fact, I promise that I will give some of my food to whoever I cannot lift.' The Pooh Bears accept the bet and the small Pooh Bear walks in front of the Karate Man. The Karate Man looks at him and easily lifts him. Then, the Karate Man looks at the bigger Pooh Bear and says, 'Hmm, this is going to be tough. Maybe I made a mistake. Well, let's see.' He tries to lift the Pooh Bear but he fails. He walks around the Pooh Bear and looks for an easier grip but he fails again. At this point he says, 'Well,

[4] Recall that children in Crain et al.'s (2002) study rejected sentences like *The girl who stayed up late will not get a dime or a jewel* 92% of the time.

it looks like I lost my bet with you, big Pooh Bear. Now I have to give you some of my food!' ''

As in Experiment I, the storyteller stopped at this point in the story to ask Merlin the Magician to guess what would happen next. Merlin made the following prediction:

(21) I know. The Karate Man will give the Pooh Bear he cannot lift the honey or the doughnut.

Then the story resumed.

(22) ''The Karate Man looks at his food and says, 'Maybe I should give him some honey because I know that's what bears like, but I am sure he already had some honey today. Well, I could give him the doughnut, then, but I will keep the strawberry because that's what makes me strong!' and gives the big Pooh Bear the doughnut.''

At this point, Merlin reminded the child of the prediction he had made.

(23) I said that the Karate Man would give the Pooh Bear he could not lift the honey or the doughnut.

Notice first that the substring of (23) . . . *he could not lift the honey or the doughnut* is composed of local construction types that permit the conjunctive reading of the disjunction operator *or*. Thus, if children encode linguistic expressions like this into construction types, they might be expected to assign the conjunctive interpretation to *or* in such sentences (see Crain and Pietroski 2002:174). However, if children assign a structural representation to such sentences, this will ensure that negation does not c-command the disjunction operator, so the conjunctive interpretation will not be possible. In addition, notice that negation and disjunction are closer to each other in the target sentences in the present study than in Crain et al.'s study. If proximity were a sufficient condition for assigning a conjunctive interpretation to disjunction, then children should resort to such an interpretation in response to the test sentences, such as (23). On this scenario, children should assign the conjunctive interpretation to disjunction in (23), and reject it, on the grounds that the Karate Man had not given the honey to the Pooh Bear that he had not been able to lift. By contrast, if children take into account the structural relationship between the two operators, the absence of intervening words should be irrelevant to their interpretation of disjunction. If so, the conjunctive interpretation of disjunction will not be assigned, since negation fails to c-command the disjunction operator, regardless of linear distance or the local well-formedness of the sequence of words.[5]

[5] As in Crain et al.'s study, on half of the trials, only the first disjunct needed to be parsed in order for subjects to decide the truth or falsity of the test sentences. However, on half of the trials, the truth or falsity of the sentence could only be decided if subjects parsed the entire disjunction, since the second disjunct was crucial for deciding the truth of the test sentences.

This is exactly what happened. The children who participated in the experiment accepted the target sentences on 56 out of 70 trials (80%).[6] A group of 12 undergraduates participated as controls; they always accepted the target sentences. Thus, children did not assign the conjunctive interpretation to the disjunction operator *or*, despite the proximity between negation and disjunction, and despite the similarity of the local construction types to other linguistic expressions for which the conjunctive interpretation is imposed. Moreover, children refrained from assigning the conjunctive interpretation to the disjunction operator *or* to the same extent for the target sentences of our experiment and for the target sentences used by Crain et al. (2002), even though the distance between negation and disjunction differs in the two sentences (see (23) and (13)).[7] This shows that proximity between these two operators is not relevant for children's interpretation of disjunction; structure is what matters for children.

4 Conclusion

This squib focused on structure dependence in child language. We reviewed the findings of an experiment by Crain et al. (2002). We noted a possible confound in that study, and we eliminated the confound in two follow-up experiments. These experiments investigated children's knowledge of the interaction between downward entailment and the structure-dependent notion of c-command. The experimental results corroborate the findings of previous research and resist explanation by accounts that do not attribute knowledge of structure-dependent principles to young children. The semantic property of downward entailment was used in these experiments to test children's adherence to structure dependence by considering how children interpret sentences that do not differ in the possibility of occurring in their environment (see Pullum and Scholz 2002). The findings show that children, just like adults, do not assign scope using a structure-independent notion such as linear precedence (see also Lidz and Musolino 2002). The findings are consistent with the view that children base their interpretation of sentences on abstract syntactic properties and do not entertain the kind of shallow linguistic representations that figure prominently in conservative learning models, such as the one proposed by Tomasello (2000). Finally, because no overt marking of these abstract properties is available in the primary linguistic data, children's sensitivity to

[6] A reviewer points out that our interpretation of the results fails to take into account that children rejected the target sentence 20% of the time. We would point out that of the 14 cases of acceptance, in 7 cases children's explanations suggested they were failing to assign a relative clause structure. For instance, children sometimes rejected (23) by saying that in the story it had not been established whether Pooh could lift the honey or the doughnut. In our view, this kind of response could arguably be excluded. If so, then the rate of acceptance would be 89% (56/63).

[7] Recall that children in Crain et al.'s study accepted sentences like *The girl who didn't go to sleep will get a dime or a jewel* 87% of the time.

abstract properties such as c-command adds to the nativist's arguments from the poverty of the stimulus.

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