Context and the Real-time Comprehension of Scope Ambiguity

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Abstract: Two self-paced reading experiments investigated the real-time comprehension of doubly quantified sentences. The results showed that perceivers experienced processing difficulty in assigning inverse-scope interpretations to the quantified sentences, not only when the quantified sentence appeared in isolation, but also when the preceding context supported the inverse-scope interpretation and when the quantified sentence was unambiguously inverse scope. I conclude that the cost of assigning inverse scope arises from the greater syntactic complexity of the inverse-scope representation, as a structure-driven model of the human sentence processing mechanism would predict.

Keywords: quantifier scope ambiguity, sentence comprehension, self-paced reading

1. Introduction

A sentence that contains more than one quantified expression is ambiguous. This paper describes a set of psycholinguistic experiments investigating the real-time comprehension of ambiguous doubly quantified sentences such as (1).

(1) A climber scaled every cliff.

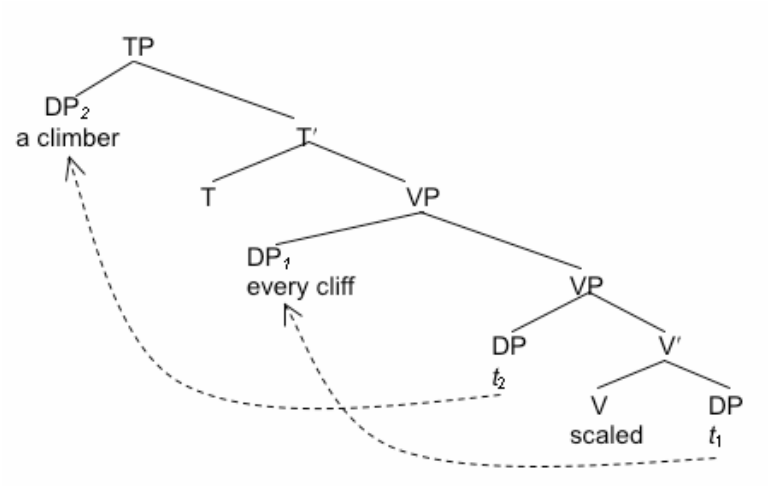
The linguistic account of the ambiguity of such sentences postulates that the two possible interpretations arise from the two possible configurations of the quantified expressions (*a climber* and *every cliff* in (1)) at LF, the level of the syntax that is interpreted by the semantics.

May (May 1977; 1985) proposed that a quantified expression that cannot be interpreted in object position for reasons of semantic type composition (Montague 1974) undergoes Quantifier Raising (QR), a syntactic operation that moves the quantified phrase covertly to an LF position where it can be interpreted. The QR account provides a natural explanation for the ambiguity of doubly quantified sentences, namely, that the two interpretations result from the two possible LF landing sites of the object phrase.

In the example derivations that follow, I use Heim & Kratzer's (1998) modernized version of May's theory, which takes advantage of the VP-internal subject hypothesis (Kitagawa 1986; Kuroda 1988; Koopman and Sportiche 1991), whereby a verb's subject argument originates inside the VP and moves to a position higher in the tree for case or agreement purposes. If the DP *every cliff*

undergoes the shortest possible QR move it is still inside VP at LF, as shown in (2), while *a climber* must move out of VP to the appropriate subject position.

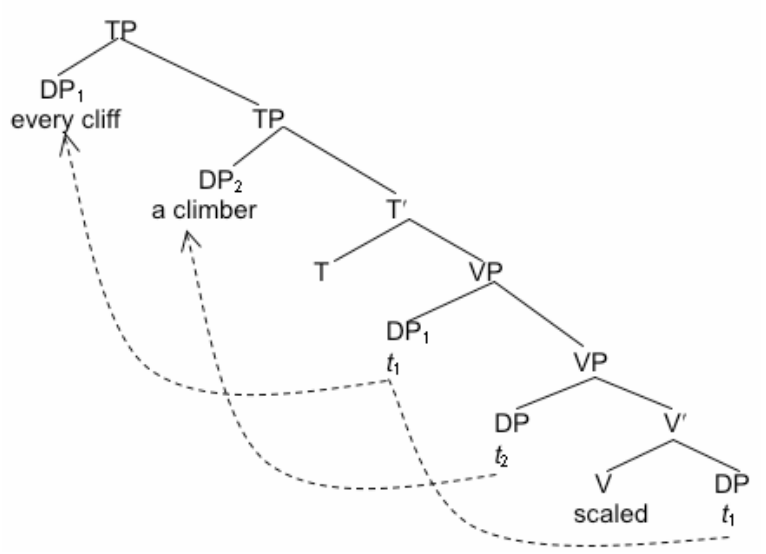
(2)



In this position, *every cliff* is interpreted inside the scope of the DP *a climber*, giving rise to the interpretation where a single climber scaled all the cliffs. This is known as the **surface-scope interpretation**, since the quantifiers have the same configuration at LF as they do in the surface syntax.

On the other hand, if an additional QR move raises the object DP *every cliff* to a position higher than *a climber*, as shown in (3), *every cliff* is interpreted with wider scope than *a climber*, which leads to the **inverse-scope interpretation** where each cliff is scaled by a possibly different climber.

(3)



A model of sentence processing in which the parser has an inherent preference for simpler structural configurations (e.g., Frazier and Fodor 1978; Ferreira and Clifton 1986; Frazier 1987, 1990; Frazier and Clifton 1996) would predict that assigning the inverse-scope interpretation to a quantified sentence would be more difficult than assigning the surface-scope interpretation, because of the greater structural complexity of the inverse-scope configuration. On the other hand, a constraint-based model of sentence comprehension (e.g., MacDonald 1994; Trueswell and Tanenhaus 1994; Trueswell 1996; Spivey and Tanenhaus 1998; Tanenhaus, Spivey-Knowlton and Hanna 2000) would attribute processing difficulty to competition between two representations that the parser considers in parallel. In one such model (Crain and Steedman 1985; Altmann and Steedman 1988), competing analyses are evaluated in parallel for plausibility with respect to the discourse context. Since the parser prefers the analysis that "carries fewer unsupported presuppositions" (A&S 1988: 203), accommodating additional presuppositions (such as the existence of multiple climbers) leads to processing difficulty.

The results of the experiments presented here show that perceivers experience processing difficulty when they assign inverse scope to a doubly quantified sentence, not only when the sentence is in isolation, but also when the discourse context supports the inverse-scope interpretation and when the sentence is

unambiguous inverse scope. The results indicate that this processing difficulty is not attributable merely to competition between alternative parses or to referential complexity, but to the structural complexity of the inverse-scope configuration. I conclude that computing quantifier scope relations in real time crucially involves syntactic processing, not just general conceptual inferencing.

2. Experiment 1

Experiment 1 obtained a baseline for perceivers' comprehension of doubly quantified sentences by presenting them in isolation, without any surrounding context. Thirty-two Northwestern University undergraduates participated in a word-by-word self-paced reading task on a computer. Before each item appeared on the computer screen, a set of dashes showed the position of the item on the screen. Participants pressed the space bar on the computer's keyboard to make each region of text appear. As each region of text was displayed, the previous region reverted to dashes. Participants were instructed to press the space bar at a rate that allowed them to read at their normal speed. The computer recorded the length of time that each region of text was displayed on the screen.

Participants read 24 stimulus sentences like example (1), with an existentially quantified subject and universally quantified object. After each sentence, the computer presented a comprehension question of the form shown in (4):

(4) How many climbers scaled cliffs?
One. Several.

The participant pressed a key to select one of the two answers to the question. The answer *One* corresponded to the surface-scope and *Several* to the inverse-scope interpretation. The experiment also included 76 distractor sentences that contained a variety of different kinds of ambiguities.

2.1 Results

All results reported here are residual reading times (Ferreira and Clifton 1986) which provide individually corrected estimates of participants' expected reading times for regions of differing lengths. Negative numbers represent faster reading times than expected and positive numbers represent slower reading times than

expected for a region of that length. In Experiment 1, reading times were significantly longer for items to which perceivers gave the inverse-scope response (333 ms) than for items to which they gave the surface-scope response (-28 ms) ($t1(63)=2.5$, $p<0.02$; $t2(43)=2.1$, $p<0.05$).

2.2 Discussion

Experiment 1 showed that perceivers experienced processing difficulty when assigning an inverse-scope interpretation to a doubly quantified sentence. This could be a result of the greater structural complexity of the inverse-scope representation. However, it could also be the case that this processing difficulty arises simply because the inverse-scope interpretation is dispreferred (whether because it is less frequent or because it introduces more presuppositions than the surface-scope interpretation) and therefore the processor consumes more resources in activating this representation highly enough to select it. It is also possible that the observed processing difficulty indicates that the two interpretations are equally weighted and are competing with each other for activation (cf. Kurtzman and MacDonald 1993).

3. Experiment 2

Experiment 2 investigated the effect of discourse context on perceivers' comprehension of doubly quantified sentences by embedding the same 24 sentences from Experiment 1 in paragraphs that supported either the surface-scope or the inverse-scope interpretation. Examples (5) and (6) illustrate the two contexts for one of the stimulus items:

(5) With the increased popularity of adventure sports, the cliffs outside Campbellton were becoming a popular destination. One weekend, the climbing equipment shop sponsored a show to demonstrate the sport. While an announcer described the techniques, an experienced climber scaled every cliff. The shop owner did, too. The shop's sales increased the following weekend.

(6) With the increased popularity of adventure sports, the cliffs outside Campbellton were becoming a popular destination. One weekend, the climbing equipment shop sponsored a race between climbing enthusiasts. While an official timed the event, an experienced climber scaled every cliff. The shop owner did, too. The shop's sales increased the following weekend.

Two unambiguous control conditions were also included, with an unambiguous surface-scope sentence appearing in the surface-scope context (7) and an unambiguous inverse-scope sentence (8) appearing in the inverse-scope context.

(7) The climbing expert scaled every cliff.

(8) A different climber scaled every cliff.

The experiment thus had a 2x2 design, with two kinds of context and two levels of ambiguity. Each paragraph was followed by a comprehension question as in Experiment 1.

Twenty-four NU undergraduates were randomly assigned to four conditions in a Latin Square design such that each participant saw six items in each of the four conditions. The list of stimuli also included 24 distractor paragraphs that did not contain quantifier scope ambiguities. The perceivers completed a phrase-by-phrase self-paced reading task, where the measures of interest were the reading time for the quantified sentence and the response to the comprehension question.

3.1 Results

The residual reading times for the quantified sentence, shown in Table 1, showed a significant main effect of context ($F1(1,23)=18$, $p<0.001$; $F2(1,23)=17$, $p<0.001$). Sentences in the inverse-scope contexts (both ambiguous and unambiguous) were read more slowly than those in the surface-scope conditions.

Table 1

Reading times for quantified sentence, Experiment 1

Condition	Mean residual reading time (ms)
unambiguous surface scope	-62
ambiguous surface scope	97
unambiguous inverse scope	326
ambiguous inverse scope	351

This same pattern holds when we examine perceivers' reading times with respect to the answer that they gave to the comprehension question. When perceivers gave the response "*One*" after reading the ambiguous quantified sentence in the surface-scope context, the mean residual reading time was 3 ms. But when they gave the response "Several" after reading the ambiguous quantified sentence in the inverse-scope context, the reading time was 504 ms. Again, the effect of context was significant ($F1(1,46)=7.2$, $p<0.01$; $F2(1,46)=6.4$, $p<0.01$). Clearly, perceivers read the quantified sentence more slowly when they assigned it an inverse-scope interpretation, even when that interpretation was supported by the context.

3.2 Discussion

The results of Experiment 2 show that the cost of assigning an inverse-scope interpretation observed in Experiment 1 persists even when that interpretation is supported by the preceding context. This fact suggests that the cost is not simply that of activating a lower-ranked or dispreferred interpretation, as a constraint-based model might predict. If that were the case, then we should expect the cost to be mitigated by a discourse context that supports the dispreferred interpretation and contributes to its activation, but in Experiment 2 we observe the cost even with a supporting context.

Furthermore, the unambiguous baseline condition shows that the inverse-scope interpretation incurs a cost even when it is the only possible interpretation. As Table 1 shows, the quantified sentence was read just as slowly when it was unambiguous inverse-scope as when it was ambiguous in an inverse-scope context. This fact is compelling evidence against Kurtzman and MacDonald's (1993) parallel processing model. In their model, processing difficulty arises when the two representations are equally weighted thanks to the input of the various competing constraints that govern interpretive processes. Because both representations are equally activated, the processor has difficulty committing to one of them. In the unambiguous inverse-scope condition, no other interpretation was possible for the quantified sentence. There should be no competition between representations, and thus no reason to predict processing difficulty. But in fact

perceivers did experience significant processing difficulty at the unambiguous inverse-scope quantified sentence, difficulty which could not have arisen from competition with an alternative representation.

Experiment 2 therefore provides further evidence to support the idea that the cost of assigning inverse scope is a structural cost, arising from the greater complexity of the syntactic configuration of the inverse-scope representation.

4. General Discussion

The results of both experiments showed that perceivers experienced processing difficulty when they assigned an inverse-scope interpretation to a doubly quantified sentence. Experiment 1 established that the cost of inverse scope arises during the processing of the sentence that receives the dispreferred inverse-scope interpretation by showing slower reading times for sentences to which perceivers assigned inverse scope.

In Experiment 2, the cost associated with assigning inverse scope was observed even for sentences following an inverse-scope supporting context that introduced multiple entities into the discourse context. It is therefore unlikely that the cost can be attributed merely to the effort required to constructing a discourse model that includes multiple entities, as (Crain and Steedman 1985; Altmann and Steedman 1988) would predict.

Experiment 2 showed, furthermore, that even an unambiguous inverse-scope quantified sentence incurs a processing cost, contrary to the predictions of a parallel-processing model (Kurtzman and MacDonald 1993) where processing difficulty indicates competition between representations.

Taken together, all of these facts point to an account of quantifier scope comprehension that predicts a cost for interpreting quantifiers with a scope configuration that is not isomorphic with the surface configuration. The results demonstrate that the on-line comprehension of an inverse-scope quantified sentence gives rise to difficulty beyond what can be explained by extra-grammatical factors. I conclude, therefore, that processing quantifier scope is a

crucially grammatical operation, and that the human sentence processing mechanism is sensitive to syntactic complexity.

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