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The Interpretation of Inverse Scope in Korean*

William O'Grady & Sunyoung Lee
University of Hawai'i at Manoa

1. Introduction

A standard assumption in work on syntactic processing is that sentences are interpreted one word at a time from 'left to right' (e.g., Frazier 1998:126, Hagoort, Brown, & Osterhout 1999:275, Pickering 1999:124, and O'Grady 2005). Williams (2006:71) puts it this way:

> The most salient point to come out of sentence processing research over the last few decades, and perhaps the only point on which there is widespread agreement, is that sentences are interpreted in a highly incremental fashion.

Nonetheless, a great deal remains to be learned about precisely how linear processing works. The phenomenon of quantifier scope helps illustrate this point.

As is well known, English permits two readings for sentences such as the following.

(1) Someone loves everyone.

- the surface scope interpretation (someone > everyone):
  'A particular person loves everyone.'
- the inverse scope interpretation (everyone > someone):
  'Everyone is loved by someone, but not necessarily the same person.'

A preference for the surface scope interpretation in these patterns has been reported in various psycholinguistic experiments (Kurtzman & MacDonald

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1993, Tunstall 1998, Anderson 2004, O'Grady 2006). For instance, in Anderson's experiment 6, subjects were presented with potentially ambiguous sentences such as the following.

(2) An experienced climber scaled every cliff.

Each test sentence was followed by a query such as *How many climbers scaled cliffs?*, with a choice of answers:

One	Several
[surface interpr]	[inverse interpr]

The answer 'one' signals the surface scope reading ('There is a particular climber who scaled every cliff'), whereas the response 'several' implies the inverse scope interpretation ('Every cliff was scaled by an experienced climber, but not by the same climber.')

Anderson analyzed the reading times according to the subjects' answers to the comprehension question. As Figure 1 shows, the sentence was read significantly more slowly when subjects assigned it an inverse scope interpretation (broken line) than when they computed the surface scope reading (solid line)

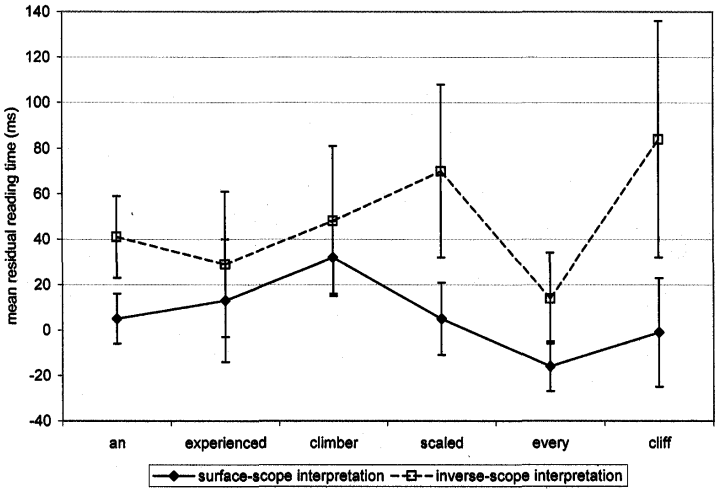

Figure 1 Results of Anderson's self-paced reading task (Anderson 2004:104)
An experienced climber scaled every cliff.

A possible explanation for this is outlined by O'Grady (2006), following Fodor (1982:143-45) and Kurtzman & MacDonald (1993:257). The key idea is that as the processor proceeds through the sentence from left to right, it initially interprets the indefinite NP as referring to a single entity ('the single reference principle').

(3) *After computation of the first NP:*
[An experienced climber] ...
↓
one climber

In order to derive the inverse scope ('multiple climbers') reading upon encountering the universally quantified NP, the processor must abandon its normal linear course and recompute the reference of the previously interpreted indefinite NP—at significant computational cost.

(4) *Derivation of the inverse scope interpretation*:
[An experienced climber] scaled [every cliff] *every > a*
↓
~~*one climber*~~
↓
several climbers

Although Anderson's results support the marked character of inverse scope, they are not particularly revealing when it comes to the question of whether scope is interpreted incrementally. This is because the second quantified NP (a prerequisite for scope) appears at the END of the sentence. Thus even if there were a significant increase in reading time at this point, it would not be clear what to make of it—is it a sign that scope is interpreted incrementally (at the first opportunity), or is it a sign that scope is interpreted at the end of the sentence?[1]

[1] In fact, although Anderson's graph shows an increase in reading time at the final position in the sentence, only the difference in the overall reading time of the two sentences is significant.

What is clearly needed here is information about how the second quantifier is processed in sentences where it does not occur in the final position. Korean provides an interesting opportunity to investigate scope interpretation in just such patterns.

2. Scope in Korean

It is widely held that Korean permits only the surface scope interpretation for indefinites in the sorts of simple transitive patterns we have been considering. The following sentence is from Kim (1989:366), cited by Marsden (2004:240); see also Yang (1992:15) and many others.[2]

(5) Nwukwunka-ka nwukwuna-lul salangha-n-ta.
someone-Nom everyone-Acc love-Prs-Decl
'Someone loves everyone.'
(surface scope interpretation: 'There is a particular person who loves everyone.')

In fact, though, with certain quantifiers, Korean does appear to permit inverse scope. The following sentence is a case in point since at least some Koreans permit the inverse scope reading in which different people bought the various loaves of bread.

(6) Ppangkakey-eyse **nwukwunka-ka** kuphakey **kakkak-uy** ppang-ul sa-ss-ta.
bakery at someone-Nom hurriedly each-Gen bread-Acc bought
'Someone hurriedly bought each loaf of bread at the bakery.'

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[2]As in English, the pattern in which the grammatical relations of the quantifiers are reversed is ambiguous.

(i) Nwukwuna-ka nwukwunka-lul salangha-n-ta.
Everyone-Nom someone-Acc love-Prs-Decl
'Everyone loves someone.'

Our investigation focuses on two questions relating to this type of sentence. First, is it possible to determine experimentally whether such sentences do in fact allow the inverse scope ('multiple bread-buyers') interpretation? And second, if the inverse scope reading is possible, at what point is it computed—at the point where the second quantified NP is encountered, or at the end of the sentence?

2.1 An Experiment

In order to explore these questions, we decided to modify a technique pioneered by Anderson (2004) in her experiment 5.

Participants

Twenty-six subjects (all students at the University of Hawai'i at Manoa and all native speakers of Korean).

Procedure

Self-paced region-by-region reading task, and truth-value judgment task

Method and materials

Our test items consisted of 24 ambiguous doubly quantified sentences containing *nwukwunka* 'someone' in subject position and *kakkak* 'each' in direct object position. Each test sentence was preceded by a context that biased it toward either the surface scope or the inverse scope interpretation.

Sample context favoring the surface scope interpretation: (translation)

> A new family is moving into the neighborhood next to Younghee's apartment. Sitting on the chair on her patio, she watches big boxes being delivered. There is a tall guy outside the truck and three big boxes on the truck. *The guy is carrying one big box at a time with difficulty*. Younghee feels that because of the new family moving in, things look hectic around the apartment.

> Aphathu aph-eyse nwukwunka-ka himtulkey kakkak-uy cim-ul nallassta.
> apartment front at someone-Nom with.difficulty each-Gen item-Acc deliver
> 'In front of the apartment, someone delivered each item arduously'

Sample context favoring the inverse scope interpretation: (translation)

A new family is moving into the neighborhood next to Younghee's apartment. Sitting on the chair on her patio, she watches big boxes being delivered. There are three tall guys outside the truck and three big boxes on the truck. *Each guy is carrying one big box by himself with difficulty*. Younghee feels that because of the new family moving in, things look hectic around the apartment.

Aphathu aph-eyse nwukwunka-ka himtulkey kakkak-uy cim-ul nallassta.
apartment front at someone-Nom with.difficulty each-Gen item-Acc deliver
'In front of the apartment, someone delivered each item arduously'

The subject's task was to indicate whether the test sentence is true, given the context that preceded it. A 'yes' response in the first context indicates that subjects have assigned the sentence the surface scope interpretation, while a 'yes' response in the second context implies that the sentence has been given the inverse scope reading.

The test sentences were presented in a self-paced reading format controlled by PsyScope software running on a Macintosh computer. The reading task begins with the appearance of an asterisk on the computer screen. By pressing on the space bar, the participant reveals the first region of the sentence (containing *aphatu aph-eyse* 'in front of the apartment') in the example above. Pressing on the key again reveals the second region and causes the preceding region to disappear. The participant proceeds in this manner until reaching the end of the sentence, marked by a period. The test sentences were divided into regions as follows.

Region 1 *2* *3* *4* *5* *6*
Aphathu aph-eyse / nwukwunka-ka / himtulkey / kakkak-uy / cim-ul / nallassta.
apartment front at someone-Nom with.difficulty each-Gen item-Acc deliver
'In front of the apartment, someone delivered each item arduously'

The 24 sets of items were distributed in a Latin Square design, creating two lists.[3] There were also 48 fillers, which contained sentences of various

[3] In this design, each list contained an equal number of inverse scope and surface scope contexts, but only one version of each test item. Thus subjects would encounter a

structures and length. Each subject read a total of seventy-two sentences from one of two lists; the order of the sentences in each list was randomized.

Our design had three dependent variables. The first was the response ('true' or 'false') by the subjects to a question about whether the test sentence was true, given the context that preceded it. This allowed us to determine whether the subjects permitted the inverse scope interpretation—if they did, they would treat the sentence as true when it was preceded by the inverse scope context.

A second variable involved the time needed for the truth value judgment. In particular, does it take longer to provide a judgment about the truth of the inverse scope interpretation than it does to provide a judgement about the truth of the surface scope interpretation?

The third variable had to do with response latencies in the course of reading the test items. Because inverse scope is known to be marked and to increase the burden on the processor (see the earlier discussion of Anderson's findings), its computation can be expected to trigger a spike in processing time. Of special interest in this regard is region 4 (see above), where the second quantifier makes its appearance. An increase in reading time in this region in the inverse scope context compared to the surface scope context could signal an attempt to compute inverse scope at that point—an indication not only that scope is computed incrementally in Korean (i.e., as the sentence is being built), but that contextual information is integrated into the early stages of the relevant interpretive process.

2.2 Results

The means and analyses presented below are based on twenty-two of the original twenty-six subjects because one subject stopped in the middle of the experiment and three subjects showed low accuracy on filler items.[4]

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particular test item in either the surface scope context or the inverse scope context, but not both.

[4] We excluded extreme RTs of 2000 ms or more and excluded outliers more than two standard deviations above or below the subject group's mean per condition and replaced them with the mean value plus (or minus) two standard deviations. This procedure was done for the first word through the sixth word but separately for the sentence judgment, and affected around 4.2% of the data. Reading times at each region and truth value judgment of each sentence were entered into a repeated-measures ANOVA, with scope (surface and inverse) as the within-subjects factor.

Truth-value judgments

Table 1 summarizes the results for the truth-value judgment portion of our experiment.

Table 1 Mean percentages of True or False responses

Context	T	F
Surface (someone > each)	**91.2%**	8.8%
Inverse (each > someone)	**47.3%**	52.7%

As can be seen here, our subjects accepted the truth of the test sentence in the inverse scope context 47.3% of time. This indicates that at least some Korean speakers permit this reading at least some of the time. Indeed this rate of acceptance is very close to the rate obtained for English (53%) by Anderson (2004:62) in her experiment 2.

Moreover, as in Anderson's experiment, the proportion of 'true' responses showed a main effect for scope. That is, subjects were more likely to accept the surface scope reading than its inverse scope counterpart (91.2% versus 47.3%). This difference is statistically significant at the $p < .0001$ level on both a subject analysis ($F1 (1, 21) = 46.677$) and an item analysis ($F2 (1, 23) = 148$).

Judgment times for the truth-value judgments

Judgment times were numerically slower in sentences with an inverse scope interpretation (1584 ms, compared to 1458 ms for sentences with a surface scope reading), but the difference was not significant in either a subject or item analysis.

Reading times (RTs)

Data analyses by subjects and by items were conducted on the reading times associated with the two truth-value judgement responses.

Table 2 Mean reading times by context

	R1	R2	R3	R4	R5	R6	Total (ms)
Surface context	501.52	674.04	602.56	616.49	589.53	625.46	601.60
Inverse context	514.94	706.97	632.57	706.36	719.37	731.23	668.58

At region 2, which contained *nwukwunkaka* 'someone,' the difference in reading times was significant by subjects but not by items ($F1(1, 21) = 4.52$, $F2(1, 23) = 2.09$, $p < .05$). At region 4 the difference in reading times was significant both by subjects and by items ($F1(1, 21) = 12.39$, $p<.05$; $F2(1, 23) = 13.37$, $p < .05$). Significant reading time differences were also observed in region 5 ($F1(1, 21) = 6.65$, $p<.05$; $F2(1, 23) = 13.95$, $p<.05$) and in region 6 ($F1(1, 21) = 22.12$, $p<.05$; $F2(1, 23) = 4.93$, $p<.05$)—possibly reflecting a 'spill-over' effect (i.e., a delayed effect of the processing difficulty occasioned by the second quantifier).

In sum then, there is reason to think that the processor makes at least a preliminary attempt to construct the inverse scope interpretation at the first opportunity—i.e., upon encountering the universal quantifier *kakkak*. This explains the increase in reading time in region four in the inverse scope context compared to the surface scope context.

The relationship between reading times and truth value judgments

Table 3 summarizes the reading times for each region, contingent on subjects' truth value judgments in the inverse context condition.

Table 3 Mean reading times by judgment type in the inverse context condition

	R1	R2	R3	R4	R5	R6	Total (ms)
F	505.96	709.60	629.13	698.98	715.54	720.49	663.28
T	523.12	702.97	635.48	713.66	721.62	742.17	673.17

Interestingly, when we compare the reading times for test items in the inverse scope condition that were judged to be true with the reading times for test items

in the same condition that were judged to be false, we found no significant difference at any region.[5]

In order to understand this, it is first necessary to distinguish between the computation of a potential inverse scope interpretation and the evaluation of a sentence's truth. If the view adopted in this paper is correct, the (initial) computation of inverse scope takes place immediately upon exposure to the distributive universal quantifier *kakkak* 'each' when the context supports an interpretation in which that element has scope over the indefinite subject NP to its left. Because inverse scope is marked, this in turn leads to an increase in processing time at *kakkak*, as shown in table 2.

Crucially, however, it is impossible for a judgment of the sentence's truth to be generated at this point. At the very least, that must await the end of the sentence, where all the constituents relevant to assessing the sentence's meaning and truth (including of course the verb) have been assembled and processed. There is therefore no reason to expect the subjects' reading times at the second quantifier to reflect their eventual judgment of the sentence's truth.

The inverse scope interpretation that is tentatively computed upon encountering the universal quantifier may well lose out to the surface scope reading that is far more commonly associated with indefinite subjects in Korean, leading to a judgment of falsity. Or it may be maintained, leading to a judgment of truth. Our point is simply that this is a separate matter and should not obscure the fact that inverse scope is computed, at least tentatively, at the earliest opportunity—upon exposure to the universal quantifier.

3. Discussion and Conclusion

In sum, we are able to report two key findings, one having to do with the interpretation of the test sentences and the other having to do with the manner in which this interpretation is processed.

First, our subjects appeared to select the inverse scope interpretation of the test sentences about half the time, as indicated by the rate at which they acknowledged the truth of our test sentences in contexts calling for an inverse

[5] A similar comparison for test items in the surface scope context is not practical because of the very small number of such sentences that were judged to be false—see table 1.

scope reading. As noted above, this corresponds roughly to the rate at which English speakers accept the truth of the inverse scope interpretation of comparable sentences in English. This allows us to conclude that Korean does in fact permit inverse scope in the particular type of multiply quantified sentences we have been considering.

Second, subjects' reading times were significantly slower in region 4 (the position of the universal quantifier *kakkak* 'each') in the inverse scope interpretation than in the surface scope interpretation. This suggests that readers make at least a preliminary calculation of scope upon exposure to the universally quantified direct object in our test sentences, taking into account the previously read context. Thus there is an increase in reading time at *kakkak* in the inverse scope context because, as already noted, inverse scope is marked and places extra demands on the processor.

This in turn suggests that quantifier scope is interpreted incrementally (i.e., as the processor moves through the sentence, one word at a time). Moreover, it appears that the processor makes quick use of information provided by the discourse context in building its interpretation. That is why processing at the site of the second quantifier takes longer when the context supports the more difficult inverse-scope reading.

Beyond this, though, very little can be said, and many questions remain. At what point is the computation of the inverse scope interpretation completed—at the head of the second NP, at the verb, at the end of the clause? Is the surface scope interpretation computed as a back-up possibility even when it is not favored by the context? Does it sometimes subsequently over-ride the inverse scope interpretation even when context favors the latter, as Anderson reports for English? These and many other questions deserve careful attention in future research.

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William O'Grady & Sunyoung Lee
Department of Linguistics
University of Hawai'i at Manoa
Honolulu, HI 96822
ogrady@hawaii.edu; sunyoung@hawaii.edu