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The Concomitant Effects of Phrase Length and Informational Content in Sentence Comprehension

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Recent evidence suggests that phrase length plays a crucial role in modification ambiguities. Using a self-paced reading task, we extended these results by examining the additional pragmatic effects that length manipulations may exert. The results demonstrate that length not only modulates modification preferences directly, but that it also necessarily changes the informational content of a sentence, which itself affects modification preferences. Our findings suggest that the same length manipulation affects multiple sources of constraints, both structural and pragmatic, which can each exert differing effects on processing.

Much of the work in the comprehension literature has been concerned with ambiguity resolution. The central issues in this work concern identifying factors involved in resolving ambiguous strings and determining how these factors interact. One such factor, phrase length, has received recent attention in the literature, with a number of proposals suggesting that it is crucial to processing (Fodor, 1998; Gibson, 1998; MacDonald, 1999). Interestingly, these proposals differ significantly in their details, but all predict that sentence processing should be more difficult when grammatical dependencies are separated by intervening material, and will be easier when dependent elements are adjacent.

These length-based proposals make specific predictions regarding a number of linguistic phenomena. One such area is research on modifier ambiguities. Thornton and MacDonald (1999) tested length-based predictions by examining two-site verb phrase modification ambiguities, as in (1):

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(1) a. VP1 attachment:
She [VP1 taught the sixth and seventh grade kids [VP2 to dive] [PP in a single afternoon]]

b. VP2 attachment:
She [VP1 taught the sixth and seventh grade kids [VP2 to dive [PP into the deep end]]]

In this construction, the PP (*in a single afternoon*/*into the deep end*) is temporarily ambiguous, as it can potentially modify either the distant VP, as in (1a) or the local VP, as in (1b). In examining this ambiguity, many researchers have noted a strong preference for the modifier to attach to the local site. This observation has been taken as evidence that some sort of recency principle (e.g. late closure, Frazier & Clifton, 1996) initially handles these ambiguities.

The length-based accounts, however, predict that any recency effect should be modulated by the distance between the two potential attachment sites. On this view, when there is substantial length between the two sites, as in (1), a local attachment preference should be observed. When the distance between the sites is reduced, however, in examples such as (2), any local attachment preference should be greatly reduced.

(2) a. VP1 attachment:
She [VP1 taught the kids [VP2 to dive] [PP in a single afternoon]]

b. VP2 attachment:
She [VP1 taught the kids [VP2 to dive [PP into the deep end]]]

The results of Thornton and MacDonald's (1999) two self-paced reading experiments support the length-based predictions. In their long condition, RTs at the disambiguation were significantly longer for the distant attached versus local attached items, indicating a local attachment preference. In their short condition, however, there was no significant difference between local and distant attachment. These results indicate that as the distance between the potential attachment sites increases, the preference for local modification increases as well. When the potential sites are close together, there was no local attachment preference.

One question that has not been address thus far, however, is what ancillary effects length manipulations might have on experimental stimuli. In much of the work on length effects, phrase length is treated as independent of other variables. This work typically assumes that everything can be held constant except for length in order to determine what effects length has on processing. This might be a dangerous assumption, however, because length manipulations usually involve adding words, and consequently more information, to the sentence. The current study extends the work on length effects to consider what pragmatic consequences length manipulations might have on stimuli and in what way might these possible pragmatic differences modulate modification preferences.

Recent work has suggested that changes in the informational content of a phrase affect modification preferences. Specifically, Thornton, MacDonald, and Gil (in press)

demonstrated that by adding information to a noun phrase, you decrease its modifiability, that is, the felicity of it taking further modification. They used both English and Spanish examples like (3), and manipulated the relative specificity of the local NP:

(3) a. The plumber by an enamel sink with...
b. The plumber by our kitchen sink with...

In (3a), *an enamel sink* is relatively unspecific, as there are lots of enamel sinks in the world, so that NP needs further modification to be uniquely identified. Conversely, in (3b), *our kitchen sink* is very specific, as people usually only have a single kitchen sink, so it needs no more modification (see Altmann & Steedman, 1988; Spivey-Knowlton & Sedivy, 1995, for further discussion). They found that, for both languages, RTs were longer when the ambiguous modifier, beginning with *with*, was disambiguated as attaching to the local NP in (3b) than in (3a), reflecting the infelicity of further modifying an already heavily modified noun.

Although Thornton et al. (in press) controlled phrase length across conditions, rather than explicitly manipulating it, it is possible that variations in phrase length might affect modification preferences in a manner similar to the effect of their modifiability manipulation. Length manipulations necessarily add material to stimuli, which changes the overall information content of a sentence. Consequently, length might not only have a primary effect on the materials, but the concomitant pragmatic consequences of the manipulations might also influence modification preferences. Researchers might sidestep this problem by avoiding adding material to either of the potential attachment sites; Thornton and MacDonald (1999) did this by adding material between attachment sites, rather than by varying the length of one of the potential sites. It might be interesting, however, to examine what effect adding material to a potential attachment site will have in order to determine the pragmatic consequences of increasing phrase length.

The current experiment had two main goals. First, we wanted to explore the possible pragmatic consequences that differences in phrase length might have, by examining whether or not a length manipulation would affect the modifiability of a potential attachment site. Additionally, we wanted to provide further evidence of the role of phrase length on modification ambiguities, by testing the length-based predictions in a different construction.

The construction we employed was the mixed-phase modification ambiguity, which consists of a VP, followed by an NP, and a PP, which could possibly modify the VP (the distant site) or the NP (the local site). We used a subset of the items used by Spivey-Knowlton and Sedivy (1995). In their study, Spivey-Knowlton and Sedivy (1995) found a significant VP-attachment preference at the attachment disambiguation, when the NP was definite. In the current experiment, this would be reflected by longer RTs for the VP-attached items than for the NP-attached items at the disambiguation in the short condition. A strictly length-based account predicts that, in the long condition, the RT advantage for the VP-attached items should be decreased or ameliorated, as there is more material separating the VP-site from the modifier. A strict modifiability account predicts the opposite. Because

the length manipulation has added extra information to the NP, modifying it should be even less felicitous, so the VP modification advantage in the short condition should be even stronger in the long condition. This would be reflected by an even larger RT advantage at the disambiguation in the long condition for the VP-attached items over the NP-attached items.

Method

Participants

Sixty-nine University of Southern California undergraduates were paid $5 each for participation. All were native speakers of American English. Five participants were excluded from analysis for either low comprehension question accuracy (less than 75% when 50% is chance) or excessively high reading times (overall RTs more than two standard deviations above the grand mean for all participants on all items). This left sixty-four participants.

Materials and Design

The experiment used a 2 x 2 design with the length between the potential attachment sites (short versus long) and attachment disambiguation (VP-attached versus NP-attached) as independent variables. Our short condition used the sixteen definite items from Experiment 5 of Spivey-Knowlton and Sedivy (1995). These items were of the structure VP-NP-PP, for which the PP could modify either the VP or the NP. For our long items, we added three prenominal adjectives to the NP. Thus, the distance between the VP and the modifier is greater in the long condition than in the short condition, whereas the distance between the NP and the modifier is the same in both the short and long conditions. A sample item is presented in Table 1. A list of all of the experimental materials can be obtained at http://gizmo.usc.edu/ thornton/abstracts/npl99abs.html.

Four lists were created with equal numbers of items from each condition. Each item appeared in each condition across lists and only once in a single list. These items were combined with six practice and forty-one filler items to create four counterbalanced presentation lists. The practice items were always presented first, followed by the experimental and filler items, which were intermixed and presented in a different random order for each participant. A Yes/No comprehension question was composed for each item, for half of which the correct answer was “yes”.

Procedure

An IBM compatible computer was used to present the materials and the MicroExperiemntal Laboratory (MEL, Schneider, 1988) software package was used to control presentation and collection of reaction times. A single word, self-paced reading task was used (Just, Carpenter, & Woolley, 1982). For each trial, one or more lines of dashes appeared on the screen, with each dash representing a character in the sentence. Participants then pressed the space bar with their dominant hand to get each word of the sentence. The words

Table 1: Sample Materials from the Experiment.

Short NP conditions
VP attachment disambiguation:
The salesman glanced at the customer with suspicion and then walked away
NP attachment disambiguation:
The salesman glanced at the customer with ripped jeans and then walked away
Long NP conditions
VP attachment disambiguation:
The salesman glanced at the amazingly rude young customer with suspicion and then walked away
NP attachment disambiguation:
The salesman glanced at the amazingly rude young customer with ripped jeans and then walked away

appeared in a non-cumulative manner, so that when a word was presented, the previous word became dashes again. The keypress that ended a trial triggered the comprehension question for that item. Participants were instructed to answer the questions by pressing keys marked either "yes" or "no" and were given feedback on screen about their accuracy. On average, the experimental session took approximately 30 minutes.

Results and Discussion

RTs were length-adjusted for two reasons: (1) to be able compare RTs across conditions of unequal length and (2) to normalize reading times across participants, in order to be able to trim RTs by each condition as well as by word. This procedure involved calculating a regression equation across all experimental items and fillers in order to determine a length-adjusted reading time for each word (Ferreira & Clifton, 1986). To ensure that a few outlying values did not grossly skew the equation, all raw reading times greater than 2500 ms were classified as participant or equipment failures and excluded from analysis. This procedure affected 64 out of the 68949 total observations (about 0.09%) and only 19 of the 15848 experimental observations (less than 0.12%). Overall, participants answered 94.2% (SD=6.3%) of the comprehension questions correctly and no subject had an error rate greater than 20%. Error rates on the comprehension questions did not vary significantly by condition. Items answered incorrectly were excluded from analysis.

For the purpose of analysis, reading times were grouped together into three critical regions: (1) the preposition that began the ambiguous modifier (*with*), (2) the rest of the PP, consisting of the disambiguating material (e.g. *suspicion/ripped jeans*) and (3) the rest of the sentence. Regions whose values were more than two standard deviations from the cell mean for its region and condition were excluded, which affected less than 3.5% of all

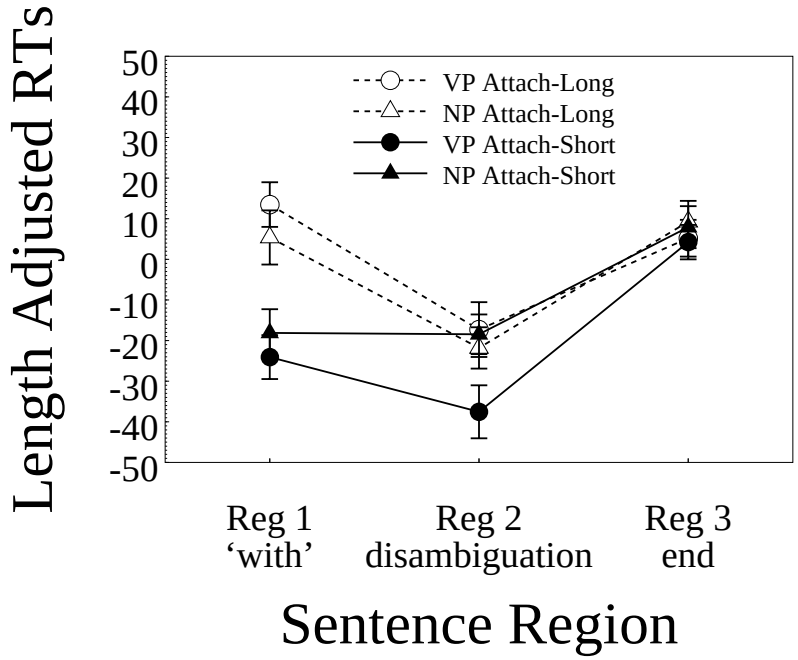

Figure 1. Mean length-adjusted reading times in milliseconds, with standard error bars computed across participants, for both the short and long conditions in both the VP- and NP-attachment disambiguation conditions.

observations.

The results are presented in Figure 1. ANOVAs were performed on each sentence region, including both length and attachment disambiguation as independent variables. In Region 1, there was a main effect of length, F_1 (1, 63) = 25.29, $p < .001$; F_2 (1, 15) = 18.02, $p < .001$, such that RTs were shorter for the short condition than for the long condition. No other effects were significant in the region. In Region 2, neither main effect (length or attachment disambiguation) approached significance, but the interaction between them was significant, F_1 (1, 63) = 4.58, $p < .05$; F_2 (1, 15) = 4.59, $p < .005$. Pairwise comparisons confirmed the nature of this interaction: in the short condition, RTs were shorter for the VP-attached items than for the NP-attached items, F_1 (1, 63) = 8.12, $p < .01$; F_2 (1, 15) = 2.80, $p = .12$, whereas in the long condition, there were no significant RT differences between the NP- and VP-attached items F_1 (1, 63) = 0.26, $p > .6$; F_2 (1, 15) = 1.26, $p > .25$. In Region 3, there was no main effect of either variable and their interaction did not approach significance.

Our results are consistent with the findings of Spivey-Knowlton and Sedivy (1995). Our short condition used the definite items from their Experiment 5, and we observed the same effect they found: RTs were significantly shorter for the VP-attached items than for the NP-attached ones at the disambiguation.

Our results are also generally consistent with the length-based predictions outlined

in the Introduction. At the disambiguation (Region 2), RTs were longer for the VP-attached items in the long condition than in the short condition. Thus, greater processing difficulty is observed when the VP-site is farther away from the modifier than when it is closer.

In Region 1, RTs were significantly longer for the long condition than for the short condition. This difference suggests that in the long condition, additional modification of either site is infelicitous. The length effects work against VP attachment and the modifiability effects work against NP attachment. The effects of infelicitous modification carry over to the disambiguation: RTs for both the VP- and NP-attached items do not significantly differ with the dispreferred NP-attachment in the short condition.

An alternative explanation of the length effect at Region 1 is that RTs are increased in the long condition versus the short condition because processing is slower after a more complex NP. Although we did not run a control condition to completely rule out this possibility, which might have been to include a phrase other than a modifier immediately following the NP, the results at Region 2 suggest that this was not the case. The clear interaction in this region indicates that RTs were not simply shifted; in the short condition, there is a significant VP-attachment preference, which is erased in the long condition. Thus, the results minimally indicate that the VP-attachment preference is greatly reduced by the length manipulation, consistent with length-based predictions. They further suggest that the pragmatic consequence of manipulating the length of the NP, decreasing its modifiability, makes additional modification of this site in the long condition infelicitous as well.

Conclusions

The data presented here offer two important results. First, this study provides additional evidence that phrase length plays a significant role in modification ambiguities. RTs at the disambiguation were significantly shorter for VP modification in the short condition than in the long condition. Thus, as the distance between the VP site and the modifier increases, the preference to modify the VP decreases.

The second important result is the demonstration that phrase length manipulations not only directly modulate modification preferences, but they also exert an additional pragmatic effect on the sentence, which itself affects modification preferences. By manipulating the length of a potential attachment site, that site's modifiability was decreased, thereby reducing the acceptability of further modification. Accordingly, our data indicate that the same length manipulation can affect multiple sources of constraint, which can have differing, even opposing, effects on modification preferences. Thus, our results provide a cautionary note for researchers investigating length effects in sentence processing. We suggest the best way this confound can be obviated is by avoiding manipulating the length of a potential site. Length manipulations will still likely change the informational content of the overall sentence, but changes in the modifiability of the individual sites can hopefully be minimized.

The present results demonstrate that it is important for researchers to consider not only their primary manipulations, but to also contemplate the possible ancillary effects experimental manipulations might have. Consequently, this work adds to be body of work

stressing the importance of considering the influence of multiple constraints on processing (e.g. MacDonald, 1993; Trueswell, Tanenhaus, & Garnsey, 1994).

References

Altmann, G. T. M., & Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition*, *30*, 191-238.

Ferreira, F., & Clifton, J., C. (1986). The independence of syntactic processing. *Journal of Memory and Language*, *25*, 348-368.

Fodor, J. D. (1998). Learning to parse? *Journal of Psycholinguistic Research*, *27*, 285-319.

Frazier, L., & Clifton, J., C. (1996). *Construal.* Cambridge, MA: MIT Press.

Gibson, E. (1998). Syntactic complexity: Locality of syntactic dependencies. *Cognition*, *68*, 1-76.

Just, M. A., Carpenter, P. A., & Woolley, J. D. (1982). Paradigms and processes in reading comprehension. *Journal of Experimental Psychology: General*, *111*, 228-238.

MacDonald, M. C. (1993). The interaction of lexical and syntactic ambiguity. *Journal of Memory and Language*, *32*, 692-715.

MacDonald, M. C. (1999). Distributional information in language comprehension, production, and acquisition: Three puzzles and a moral. In B. MacWhinney (Ed.), *The emergence of language* (pp. 177-196). Mahwah, NJ: Lawrence Erlbaum Associates.

Schneider, W. (1988). Micro experimental laboratory: An integrated system for IBM PC compatibles. *Behavioral Research Methods, Instruments, & Computers*, *20*, 206-217.

Spivey-Knowlton, M. J., & Sedivy, J. C. (1995). Resolving attachment ambiguities with multiple constraints. *Cognition*, *55*, 227-267.

Thornton, R., & MacDonald, M. C. (1999). *The role of phrase length in modification ambiguities.* Manuscript submitted for publication.

Thornton, R., MacDonald, M. C., & Gil, M. (in press). Pragmatic constraint on the interpretation complex noun phrases in Spanish and English. *Journal of Experimental Psychology: Learning, Memory and Cognition*.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic disambiguation. *Journal of Memory and Language*, *33*, 285-318.