Syntactic Ambiguity Resolution: Effects of Prosodic Breaks and Prosodic Length

Hyekyung Hwang, Moti Lieberman, Heather Goad, and Lydia White
McGill University

1. Relative clause attachment ambiguities

The question of how speakers resolve ambiguities when parsing sentences has motivated a great deal of research in sentence processing. A well-known example is provided by the case of relative clause (RC) attachment. As shown in (1), the relative clause (*who was on the balcony*) can be interpreted as belonging to either the first NP (NP1, *the servant*) or the second NP (NP2, *the actress*) within the constituent that forms the direct object of the verb.

(1) Someone shot the servant of the actress who was on the balcony.

Languages are known to differ in attachment preferences for relative clauses (Cuetos & Mitchell, 1988). A language is said to exhibit a high attachment (HA) preference when the RC is more commonly attached to the first NP, whereas a low attachment (LA) preference is shown when the RC is usually interpreted with the second NP. Examples of languages that show a high attachment preference include Spanish (Cuetos & Mitchell, 1988), Dutch (Brysbaert & Mitchell, 1996), French (Zagar, Pynte, & Rativeau, 1997), German (Hemforth, Konieczny, Scheepers, & Strube, 1998), and Japanese (Kamide & Mitchell, 1997), whereas languages showing a low attachment preference include Arabic (Quinn, Abdelghany, & Fodor, 2000), English (Frazier & Clifton, 1996), and Norwegian, Romanian, and Swedish (Ehrlich, Fernández, Fodor, Stenshoel & Vinereanu, 1999), among others.

In all of these languages, both attachment sites for the RC are in fact available; in other words, such sentences are potentially ambiguous. The strength of the preference for one type of attachment over the other varies across languages. For instance, Spanish exhibits a strong HA preference, opting for HA about 80% of the time (Cuetos & Mitchell, 1988), whereas English shows a rather weak preference for LA of only about 60% (Fodor, 2002). The ultimate choice of interpretation can be influenced by a wide variety of factors (e.g., syntax, semantics, pragmatics, prosody, working memory), and it is often difficult to choose between them. In this paper, we aim to isolate the contribution of prosody (as distinct from syntax), by investigating the potential influence of the Same Size Sister Constraint (SSSC) (Fodor 1998).

To illustrate the influence of various factors on ambiguity resolution, consider first the semantic or pragmatic content of the RC, which can heavily bias which of the attachment sites is appropriate for a given sentence, as illustrated in (2) below:

(2) The boy admired the label of the bottle that...
    a. was written in Korean.
    b. was filled with orange soda.

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Depending on the content of the RC, the attachment can either be forced to be high, as with the continuation in (2a), or forced to be low, as in the continuation in (2b). The semantic content may well be the strongest of the different factors that influence resolution of the ambiguity.

The prosodic phrasing of a sentence can also help signal its interpretation. In the case of relative clause attachment, if a boundary follows NP1, then the listener will be pushed towards attaching the RC low, whereas if the boundary appears following NP2, the listener will prefer high attachment (e.g., Fodor, 2002; Jun, 2003; Maynell, 1999, 2000). Thus, for the sentence in (3a), where the prosodic boundary, indicated by the # sign, is placed after *servant*, the listener is likely to opt for LA, interpreting the RC as modifying NP2, whereas HA should be preferred in (3b), where the boundary appears after *actress*.

(3) a. Someone shot the servant # of the actress who was on the balcony.
b. Someone shot the servant of the actress # who was on the balcony.

Another factor that has been argued to influence RC attachment is the length of the relative clause (e.g., Colonna, Pynte, & Mitchell, 2000; Fernández & Bradley, 1999; Fernández, Bradley, & Taylor, under revision; Fodor, 1998, 2002; Pynte & Colonna, 2000). According to Fernández et al. (under revision), relative clauses are privileged syntactic constituents in that they can attract a prosodic boundary immediately preceding them when they are long. In other words, long RCs tend to be separately phrased, which makes them more likely to be interpreted as attaching high. Thus, sentences like (4a) should show a preference for high attachment, whereas sentences like (4b) should bias towards low attachment.

(4) a. The professor read the review of the poem that was published at the end of the magazine.
b. The professor read the review of the poem that just came out.

On the other hand, Fodor (1998: 302), noting the existence of "considerable evidence in the phonological literature that prosodic phrasing favors balanced structures in which sister constituents are roughly equal in prosodic weight (a function of length and also stress, etc.)", proposes the Same Size Sister Constraint (SSSC), which states: "Find a sister of your own size". Fodor (1998) suggests that RC attachment should be one of the phenomena subject to the SSSC; as such, a longer RC should prefer to be attached to the longer of the two NPs in question, whereas a shorter RC should prefer to go with the shorter one, regardless of the position of the longer or shorter NP, as NP1 or NP2. Thus, the SSSC would predict high attachment in (5a), but low attachment in (5b), depending on which of the two NPs is longer.[1] Colonna, Pynte, and Mitchell (2000) tested visually-presented French sentences similar to (5) in an eyetracking study and showed the preference patterns expected by the SSSC.

(5) a. The detective pursued the fashionably dressed bride of the prince that watched tennis at Wimbledon last year.
b. The detective pursued the bride of the fashionably dressed prince that watched tennis at Wimbledon last year.

Considering the variety of factors that can potentially influence which interpretation (high versus low) is ultimately chosen, it is perhaps surprising that no single study to date that we are aware of has attempted to control for all of the factors mentioned above that have been shown to influence resolution of the ambiguity. A further open question is how much work is done by the syntax versus the prosody in the resolution of the ambiguity. Prosodic boundaries tend to align with syntactic boundaries; if we again consider the sentences in (3), the prosodic boundary in (3a) lies at the right edge of NP1, while the prosodic boundary in (3b) lines up with the onset of the RC. The relative

1. We recognize that NP1 will, in fact, necessarily always be longer than NP2 since, structurally, NP1 contains NP2. However, it is common practice in the parsing literature to consider only the linear relationship of the two NPs. For the purpose of this research, we assume that a heavier NP2 can prosodically behave as separate from NP1.

importance of each of the cues is thus unclear. To tease these apart, we propose to investigate Fodor's (1998) Same Size Sister Constraint. Since the length of a constituent has no effect on where that constituent attaches syntactically, the SSSC, which equalizes the length of prosodic sisters, should provide a tool by which the relative importance of the syntax and prosody can be measured. These issues are explored in the experiment described below.

2. Methodology

2.1. Design

Three factors were manipulated in our task: (i) the length of the RC; (ii) the relative lengths of NP1 and NP2; and (iii) the placement of the prosodic boundary. Test items were constructed accordingly. The RC was classified as short if it contained four syllables or less, including the complementizer, whereas it was long if it had more than seven syllables, with the average of the long RCs being 10.7 syllables. For the two NPs, the longer one was always 6-7 syllables (4 PWds), and the shorter was 2-3 syllables (2 PWds). Finally, the prosodic boundary, marked by a falling boundary tone and phrase-final lengthening followed by a pause, was placed either after NP1 or between NP2 and the RC. By varying the length of the two NPs as well as the RC, we are able to test the predictions of the SSSC for RC attachment preferences. The predictions for each of the four possible variations are given in (6).

(6) a. Long NP1 + Short NP2 + Long RC → HA
b. Short NP1 + Long NP2 + Long RC → LA
c. Long NP1 + Short NP2 + Short RC → LA
d. Short NP1 + Long NP2 + Short RC → HA

It is important to note that these predictions, made on the basis of the SSSC, differ from predictions based on RC length alone. From the perspective of RC length, a long RC will bias towards high attachment, regardless of the relative length of the NPs, while a short RC will tend towards low attachment. In contrast, the SSSC predicts that short RCs will be interpreted with whichever of the two NPs is short, and that long RCs will attach to the longer of the two NPs.

There were 24 target items, in a 2 x 2 x 2 design, manipulating high attachment (HA) vs. low attachment (LA) prosody, short vs. long RC, and short vs. long NP1 and NP2, across 8 different conditions. All items were also controlled for possible semantic bias, so that there would be no reason to prefer one NP over the other as an attachment site based merely on the RC being a more appropriate modifier of one of the two NPs. Items were distributed evenly across 8 lists in a Latin Square design, mixed with 48 fillers, and presented to participants in a pseudo-randomized order, to ensure that the same types of items were not presented sequentially. An example of a full set of stimuli is shown in (7), with prosodic boundaries indicated by the # sign. It can be seen that, in some cases, the predictions made by considering position of the prosodic breaks alone (prosody) and the predictions based on length of the NPs interacting with length of the RC (SSSC) coincide, forming the match conditions (namely, 7b, 7c, 7e, 7h), whereas in other cases they differ, forming the mismatch conditions (7a, 7d, 7f, 7g).

(7) a. LA prosody - HA SSSC (Long NP1/Short NP2 - Long RC)
The bartender served the cheerful outgoing cousin # of the actor that always ordered peanuts with his beer.

b. HA prosody - HA SSSC (Long NP1/Short NP2 - Long RC)
The bartender served the cheerful outgoing cousin of the actor # that always ordered peanuts with his beer.

c. LA prosody - LA SSSC (Short NP1/Long NP2 - Long RC)
The bartender served the cousin # of the cheerful outgoing actor that always ordered peanuts with his beer.

d. HA prosody - LA SSSC (Short NP1/Long NP2 - Long RC)
The bartender served the cousin of the cheerful outgoing actor # that always ordered peanuts with his beer.

e. LA prosody - LA SSSC (Long NP1/Short NP2 - Short RC)
The bartender served the cheerful outgoing cousin # of the actor that ate peanuts.

f. HA prosody - LA SSSC (Long NP1/Short NP2 - Short RC)
The bartender served the cheerful outgoing cousin of the actor # that ate peanuts.

g. LA prosody - HA SSSC (Short NP1/Long NP2 - Short RC)
The bartender served the cousin # of the cheerful outgoing actor that ate peanuts.

h. HA prosody - HA SSSC (Short NP1/Long NP2 - Short RC)
The bartender served the cousin of the cheerful outgoing actor # that ate peanuts.

The wave forms and pitch contours of two example sentences are given below. Figure 1 shows sentence (7e) with a prosodic boundary characterized by a falling boundary tone on NP1 and phrase-final lengthening which is followed by a substantial pause. Figure 2 displays sentence (7f) with a prosodic boundary following NP2 and preceding the relative clause.

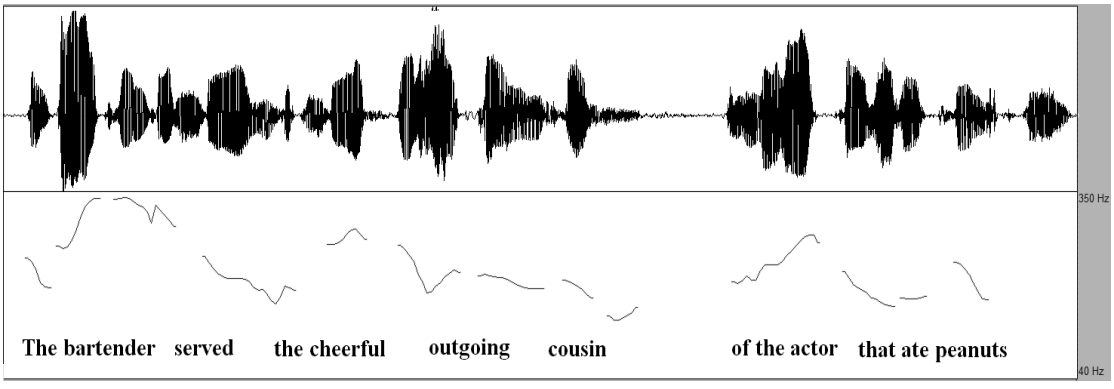

Figure 1: Sample pitch contour with acoustic wave form for (7e)
(Prosodic boundary in front of the preposition *of*)

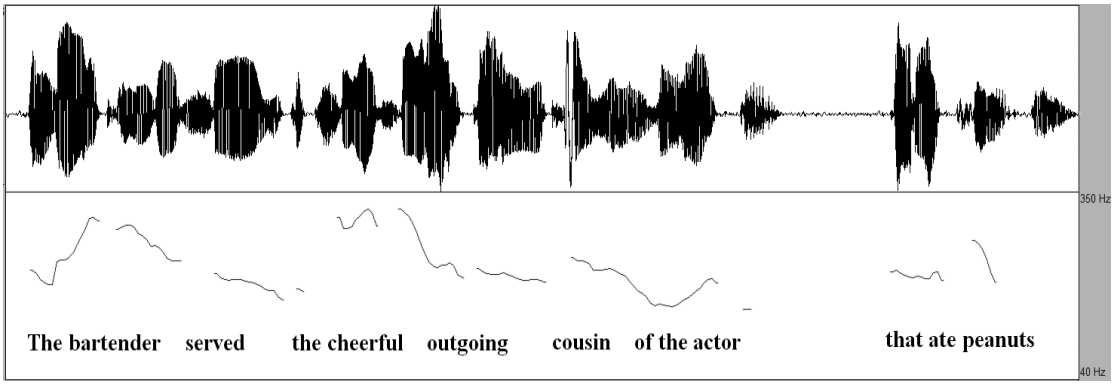

Figure 2: Sample pitch contour with acoustic wave form for (7f)
(Prosodic boundary immediately preceding relative clause)

All items were recorded in Praat (Boersma & Weenink, 2009) by a native English speaker; production was consistent across items for the relevant prosodic factors. All items, both targets and fillers, were followed by comprehension questions to be answered by pressing a button on the keyboard; for the targets, the options were always NP1, NP2 or *don't know*. Thus, for the examples in (7e-h), the participant would be asked *Who ate peanuts?* with the possible answers of *the cousin*, *the*

actor, or *don't know*. Participants were instructed to answer right away, to keep them from concentrating on the ambiguity and potentially changing their preferences.

2.2. Participants

56 native speakers of North American English with no greater than beginner's proficiency in any other language participated in the study. Most were undergraduate students at McGill University. The mean age of participants was 21.9. All participants were compensated for their time.

2.3. Predictions

If the SSSC plays a role in the resolution of RC ambiguity, we expect an interaction effect between the prosodic phrasing and the NP/RC length factors. When the prosodic phrasing and the SSSC both point to the same attachment site, we predict a higher proportion of responses favouring that attachment site. On the other hand, when the prosodic boundary and the SSSC conflict, favouring differing attachment sites, no clear preferences should be observed for either HA or LA. As mentioned above, prosodic breaks coincide with syntactic boundaries, so either prosody or syntax (or both) may determine attachment preferences in such cases, whereas constituent length is a prosodic issue rather than a syntactic one. Hence, if the SSSC turns out to play a role, we have stronger evidence in favour of the importance of prosodic factors in determining ambiguity resolution.

3. Results

In line with the results from previous studies on English, we found a weak LA preference, with participants choosing to attach the RC to NP2 58% of the time. No significant difference was found between the eight lists (*p*s>.1), so all lists are collapsed in the presentation of the results. The percentage of HA responses from each subject were subjected to a 2 x 2 x 2 repeated measures ANOVA with Prosody (HA prosody with a break before RC vs. LA prosody with a break before *of*), SSSC (HA vs. LA), and RC length (Long vs. Short RC) as within-subjects factors. Of the manipulated factors, prosodic boundary cues proved the strongest factor, with a significant main effect of Prosody shown both by participant and by item ($F1(1,55) = 204.771$, $p < .001$; $F2(1, 23) = 257.071$, $p < .001$).

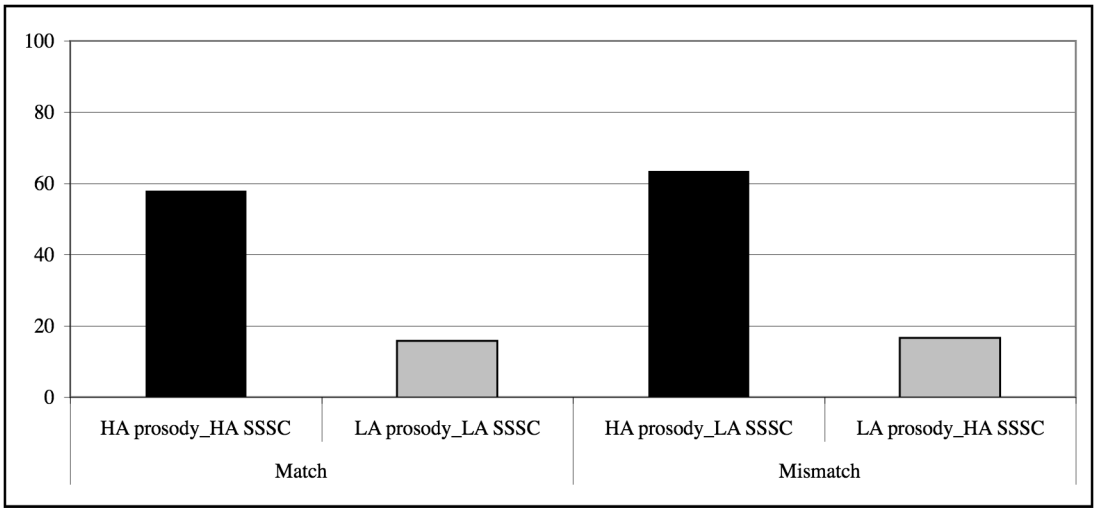

Figure 3: Prosodic phrasing influence on attachment, % HA responses (NP/RC length collapsed)

Figure 3 shows the percentage of high attachment responses with the NP/RC length factors collapsed. For the cases where the prosodic boundary cues and the SSSC cues match, as well as when they mismatch, a significantly higher percentage of the sentences are given an HA interpretation when

the prosodic cues point that way. The differences between the HA and LA prosody conditions are similar for both the match and mismatch conditions, which also demonstrates the relative strength of the prosodic boundary as a cue for disambiguation.

A main effect of RC length was also observed by participant, but not by item ($F1(1, 55)=5.482$, $p<.03$; $F2(1, 23)=2.457$, $p>.1$). However, there was no significant interaction effect between Prosody and RC length ($F1(1, 55)=1.409$, $p>.1$; $F2(1, 23)=2.343$, $p>.1$).

Figure 4 shows the percentage of high attachment responses, broken down by NP length and RC length. For each pair of conditions, a significant difference is observed in both the match and the mismatch cases. For the match case with HA prosody, a long NP1 and long RC combination yields a higher rate of HA responses than its short counterpart ($ps<.01$). This trend holds for the LA prosody pairs in the match case ($ps<.02$) and the mismatch case ($ps>.05$) even though the percentage of HA responses is much lower; the overall number of HA responses may be less for these sentences, but there remains more of a tendency to opt for high attachment when RCs are long. In sharp contrast, for the mismatch case with HA prosody, the short NP2 and short RC combination shows significantly more HA responses ($ps<.01$). Although the interaction of RC length with Prosody was not significant, these results might seem to support the claim of Fernández et al. (under revision) for RC-privilege, i.e. that added length in the RC leads to a prosodic boundary being located at the left edge of the RC, which in turn results in increased rates of high attachment independent of the left context.

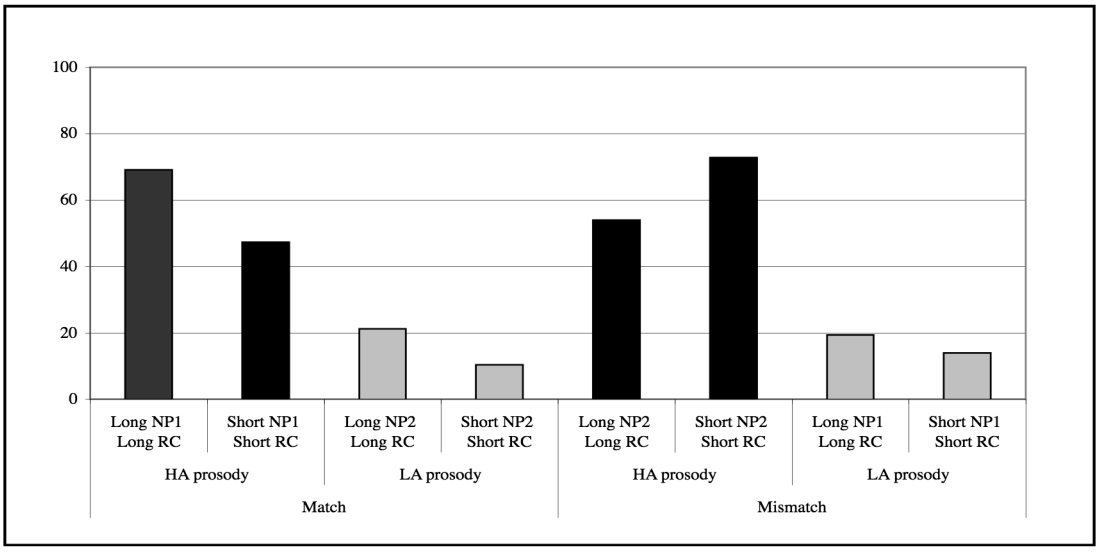

Figure 4: RC and NP length by prosody, % HA responses

Let us now turn to whether the predictions made regarding the SSSC were borne out. Recall that if the SSSC helps guide ambiguity resolution, then there should be a significant interaction effect between prosodic phrasing and the SSSC; where the prosodic boundary cues match the SSSC, we should see a clearer preference for whichever attachment site is favoured than where there is a mismatch. However, no significant interaction effect was found between the SSSC and Prosody, either by participant or by item ($F1(1, 55)=2.197$, $p>.1$; $F2(1, 23)=2.657$, $p>.1$). At first glance, then, it would appear that the SSSC does not help guide RC attachment ambiguity resolution.

However, if we look at paired comparisons of match versus mismatch conditions, there is some evidence that the SSSC may be playing a role after all. The match condition, with the prosodic boundary before a long RC together with a long NP1, yields a significantly higher rate of HA interpretations than the mismatch condition with the same prosodic phrasing but with a long NP2 ($ps<.001$), suggesting that sisterhood does make a difference: there is a 'pull' towards low attachment in the latter case, as predicted in (6b). This significant difference between the two long RC conditions with HA prosody cannot be captured by Fernández et al.'s claim of RC-privilege. A similar trend can be found with the LA prosodic phrasing in the match condition where a short NP2 is matched with a

short RC, as compared to its corresponding mismatch condition, where a short NP1 and a short RC are found. In the match condition, the RC is more likely to be interpreted as LA, although this is not significant. There is a significant result for the other HA prosody comparison, between a short NP1 and short RC combination in the match condition and a short NP2 and short RC combination in the mismatch condition; however, here, the opposite trend is shown, with the mismatch case showing a significantly stronger HA preference ($ps<.001$), a result for which we do not at this time have an explanation.

To conclude, the results are promising but not altogether straightforward. The SSSC does not appear to have the effect we predicted on RC ambiguity resolution, as we failed to find strengthened attachment preferences for cases when the prosodic phrasing cues and the NP/RC length match pointed in the same direction. However, on closer inspection, some cases do indeed suggest that the SSSC plays a role in biasing interpretation in the predicted fashion. Our results are not consistent with the RC-privilege account either. While neither of the prosodic length-related accounts wins out, a hint of length effects on RC attachment preferences does emerge in this study. That is, constituent length matters in sentence processing, but the question of how it triggers prosodic phrasing remains unclear.

Further inspection of the role that the SSSC plays in regard to other factors in ambiguity resolution and sentence parsing is called for.

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