Implicit Prosodic Priming and Autistic Traits in Relative Clause Attachment

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Abstract

Using the structural priming paradigm, the present study explores predictions made by the Implicit Prosody Hypothesis by testing whether an implicit prosodic boundary generated from a silently-read sentence influences attachment preference for a novel, subsequently read sentence. Results indicate that such priming does occur, although the patterns are highly dependent on individual differences in listeners' "autistic" traits.

Index Terms: Implicit Prosody, non-restrictive RC, autistic traits, prosodic disambiguation, AQ

1. Introduction

1.1 Implicit Prosody in Relative Clause Attachment

In a sentence such as (1), it is ambiguous whether the relative clause (RC) modifies NP1 *the servant* (high attachment) or NP2 *the actress* (low attachment):

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

Although the details of attachment preference are language-specific ([2],[3]), it is known that, cross-linguistically, attachment decisions are sensitive to the sentence's prosodic characteristics, including the location of a prosodic boundary ([4], [5], [6], [7], [8]). This fact has been used to support the Implicit Prosody Hypothesis (IPH; [2], [9]), which states that, in silent reading, a default prosodic contour is projected onto the sentence, influencing syntactic ambiguity resolution. Other things being equal, the parser favors the syntactic analysis associated with the most natural (default) prosodic contour for the construction. Fodor and colleagues claimed that speakers interpret a prosodic break before an RC as a marker of a stronger syntactic boundary, which prompts high attachment. This suggests that the human sentence parser would favor low attachment when the RC forms a single prosodic phrase with NP2, but favors high attachment when a prosodic break directly precedes the RC.

1.2 Accessing Implicit Prosody

An important question is how implicitly-generated prosody can be investigated. Fodor and colleagues (e.g., [10],[6],[11],[7]) assumed that implicit prosody is equal to explicit, or overt, prosody such as that associated with an out-of-the-blue reading. However, recent production studies ([12],[13],[14]) suggest that this is not necessarily the case. These studies found that a majority of English speakers produced a large prosodic boundary directly before the RC, despite English's status as a language with a low-attachment bias. Thus it appears that implicit prosody is not easily accessible via the investigation of overt prosody.

If implicit prosody is not reliably studied by way of overt prosody, it may be possible to study it more directly, by influencing implicit prosody itself and observing the effects on processing. One possible way to accomplish this is to manipulate visual cues that impose implicit boundaries in reading materials. For example, recent studies examining individual differences in attachment preference show working memory capacity to be positively (e.g., [15], [16] for on-line data) or negatively (e.g., [17] for off-line data) correlated with high attachment responses when the target sentence is presented on a single line. However, when the sentence is displayed on two lines, i.e., visually chunked so that the RC is separated from the two head nouns (i.e., …NP1 NP2 // RC...), working memory plays a weaker role and subjects prefer high attachment, regardless of their working memory capacity. This suggests that visual cues, such as visual discontinuity, may influence attachment by imposing implicit prosodic juncture in reading.

Another approach to the manipulation of implicit prosody would be to try to "prime" it using overt prosody. In recent work ([18]), we carried out an experiment intended to do just this, using a novel prosodic adaptation of the structural priming paradigm ([20], [21], [22]). In particular, listeners were auditorily presented with ambiguous RC-sentences that contained a prosodic boundary either before or after NP2, and then had to read another, also ambiguous RC target sentence. Subjects then made attachment decisions about the silently read target. If the overt prosody in the prime sentence influenced the implicit prosody generated during the reading of the target sentence—and implicit prosody influences attachment—this would be observable in attachment decisions.

In fact, a certain subset of listeners were influenced by the primes as predicted by the IPH; after hearing sentences with a boundary after NP2, these subjects were more likely to interpret the silently read target as having a high-attaching RC. Interestingly, this group of subjects consisted of those with prominent "autistic" traits along the "communication" dimension (indicating poorer, more autistic-like communication skills), as measured by the Autism Spectrum Quotient ([23]). At present it is unclear why these individuals should be especially sensitive to prosodic boundaries in this way, although high scores on this dimension (indicating poorer, more autistic-like communication skills) have been shown inversely related to the use of pragmatic information in sentence processing (e.g., [23], [24]), and, similarly, to the accentual patterns that typically encode such information ([25]). (For further discussion of the individual sensitivity to prosodic structure, and its consequences for sentence parsing, see [19]).

The results of the experiment just described indicate a correlation between the use of a prosodic boundary and attachment of an RC in a way that supports the basic prediction of the IPH. A question remains, however: what was the mechanism? That is, although a boundary separating the RC and the two head nouns was (for subjects with more prominent autistic traits) associated with high attachment, it is unclear whether this happened as a result of syntactic structure priming or prosodic structure priming. In the first case, the overt prosody of the primes would have influenced the syntax assigned to the primes themselves, at which point that syntactic structure could be re-used to parse the target sentence. This is syntactic priming in the typical sense ([20]). In the second case, however, the overt prosody would have influenced the targets more directly, by influencing the implicit prosody generated for those targets. However, both of these scenarios are possible in the experiment just described, it is unclear which is the correct one.

This is the matter that we attempt to better understand in the present study. In the experiment presented below, native English speakers took part in a more traditional (i.e., reading only) structural priming task, involving targets containing an RC with ambiguous attachment, such as in (1) above. However, prime sentences were designed not to have RCs with one or the other attachment possibilities, but to have RCs that modified a head noun restrictively or non-restrictively. The reason for this was that this contrast—orthogonal to the attachment ambiguity—is distinguished primarily by the presence versus absence of a prosodic boundary before the RC in speech; it is represented visually by the presence versus absence of a comma in orthography. An example of the contrast is shown in (2a) and (2b):

(2) a. Restrictive RC in the prime sentence:
The newspaper reporter phoned the secretary who was annoyed.

b. Non-restrictive RC in the prime sentence:
The newspaper reporter phoned the secretary, who was annoyed.

If the implicit prosody (of targets) can be influenced by the implicit prosody (of primes), we expect targets like (1) to be parsed differently depending on whether they are read following a sentence with a restrictive versus non-restrictive RC. In particular, because the non-restrictive RC in the primes contains a boundary before the RC (cued by the comma), it should increase the probability that a boundary will be inserted before the RC in the targets. Based on the results of previous studies (e.g., [27], [17]), we predict that this will induce a greater likelihood of high attachment responses. Based on [18, 19], we also predict this effect to depend somewhat on autistic traits. As described above, autistic traits are measured in the neurotypical population using the AQ, a self-report questionnaire; this measure is composed of five subscales measuring *social skills*, *attention to detail*, *attention switching*, *communication skills*, and *imagination*. Rather than the entire score combined, in our own work, we have found scores on the communication subscale to be inversely related to the use of prosodic prominence in speech [26], and directly related to a sensitivity to prosodic boundaries [18, 19].

This was tested in the experiment presented below in Section 2; a discussion and conclusion based on the results follows in Section 3.

2. Experiment

2.1. Method

2.1.1. Stimuli

Sixteen sentences containing RCs of medium length (4-6 syllables) were created to serve as target sentences to be read by participants. These sentences, based on sentences used in previous studies (e.g., [28], [29], [30], [31], [32], [33]), were designed to lack any grammatical or semantic bias towards high or low attachment. An example of such a sentence is shown in (1), with some additional examples listed in Appendix I.

Prime sentences, to be presented and read immediately before the targets, were based on 30 sentences of similar length. Like the targets, primes contained RCs that were 4-6 syllables in length, but they differed from targets in two ways. First, the RCs in primes followed a single head noun, and so they had unambiguous attachment to that head noun. Second, there were two versions of each prime, one which was to be interpreted as having a restrictive RC, and the other which had a nonrestrictive RC. The non-restrictive RC was marked by the standard orthographic convention, i.e., a comma preceding the RC; the restrictive RC versions lacked any such comma. An example of each version is shown in (2); five additional examples are listed in Appendices II and III.

2.1.2. Participants

Participants were 120 native speakers of American English, mostly undergraduate students at the University of California, Los Angeles. None of the participants reported any speech or communication disorders, and all received either course credit or monetary compensation.

2.1.3. Procedures

Participants read the prime and target sentences, and answered attachment questions, at their own pace. A MATLAB script was used to present participants with the sentence materials on a computer screen. On each experimental trial, the script selected one of the 16 target sentences and three prime sentences from one of the two prime conditions; the order of presentation of primes was randomized on each trial. The subject then proceeded through these four sentences, first the three primes, then finally the target, at their own pace, pressing a computer key to remove one sentence and display the next. Following a key press after the target sentence, however, a question appeared, asking the participant the standard RC-attachment question (e.g., Who was on the balcony? In the case of (1), above), presenting the two possible head nouns as the options "A" and "B". Whether the high attachment response (i.e., NP1) appeared on the left as "A" or on the right as "B" was counterbalanced for each participant.

Filler trials (consisting of 28 filler targets and 30 filler primes) proceeded in the same manner as experimental trials, with the following exception. On filler trials, a question appeared for one of the three prime sentences, selected at random. This was to prevent participants from knowing exactly which sentence in a trial (i.e., every fourth sentence presented to them) would be the one requiring the answering of a question.

Participants carried on through all experimental and filler trials (randomized for each participant), and the assignment of a particular target sentence to a prime condition (restrictive vs. non-restrictive RC) was counterbalanced across subjects. The task took participants approximately 15-20 minutes. Following the reading task, participants completed the AQ ([23]), a 50-item self-report questionnaire, requiring an additional 10 minutes.

2.2. Results

Two rounds of mixed-effects logistic regression modeling took place; the first was aimed at a simple, overall test of the effect of primes, without considering possible individual differences related to autistic traits. The second round of modeling included AQ scores.

Results of the first model, shown in Table 1, indicated that primes did in fact influence how participants interpreted the ambiguous targets; as predicted, participants chose high attachment significantly more often after reading sentences in the non-restrictive RC condition that contained a comma than in the restrictive RC condition that did not contain a comma (see Figure 1). That is, the implicit prosody of primes influenced the implicit prosody of the targets, which then influenced the attachment resolution, thus supporting the IPH. Additionally, the significant effect of trial indicated that, as the experiment went on, high attachment responses became more likely overall.

A second model of mixed effects logistic regression included the participants' scores on each of the subscales of the AQ (Communication, Social Skills, Attention to Detail, Attention Switching, and Imagination), in addition to the factors in the first model. The results of the model (see Table 2) showed significant interaction between Prime Type and AQ-Communication scores. As shown in Figure 2 (next page), the influence of primes was stronger for individuals with higher scores on this subscale (indicating more autistic-like communication skills).

There was also a significant main effect for scores on the AQ-Attention Switching subscale; as shown in Figure 3, higher scores in AQ-Attention scale were associated with a greater likelihood of a "high attachment" response. Finally, the significant effect of trial found in the simpler model also held here, indicating high attachment was more likely on later trials.

Table 1. *Estimates, standard errors, z- and p-values for the first model testing the effect of primes on high attachment responses. Positive estimates indicate the amount of increase in log-odds relative to the intercept.*

Fixed effects:	*β*	*SE*	*z*	*p*
(Intercept)	-.389	.213	-1.83	.068
Trial	.009	.003	2.55	**.011**
PrimeType(*nonrestrictive*)	.220	.104	2.11	**.035**

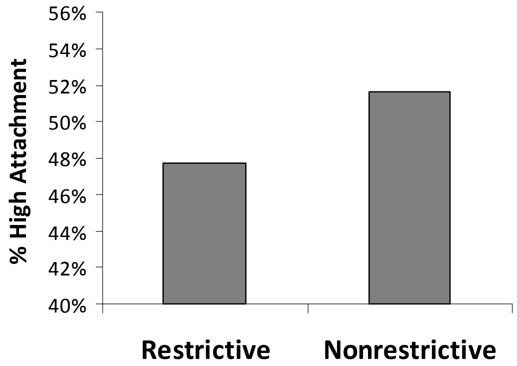

Figure 1: High attachment responses to target sentences in the two prime conditions, based on RC-type.

Table 2. *Estimates, standard errors, z- and p-values for the second model of high attachment responses, adding AQ subscales.*

Fixed effects:	*β*	*SE*	*z*	*p*
(Intercept)	-1.797	.933	-1.93	.054
Trial	.009	.004	2.45	**.014**
AQ-Attention Switching	.096	.036	2.70	**.007**
AQ-Communication	-.052	.036	-1.45	.147
PrimeType(*nonrestr.*)	-.932	.511	-1.82	.068
PrimeType(*nonrestr.*) × AQ-Communication	.060	.026	2.30	**.021**

3. Discussion and Conclusion

The structural priming experiment presented above was intended to test a basic prediction of the Implicit Prosody Hypothesis ([2], [9]), which says that a strong prosodic boundary generated implicitly during reading influences the attachment of a relative clause. In particular, a strong prosodic boundary directly before the RC is predicted to encourage a high attachment parsing of the RC. Our prime sentences were designed to manipulate the presence versus absence of such a boundary. In fact, results showed that, after reading primes with a boundary, participants were more likely to attach the RC high in a novel, structurally ambiguous sentence. First, and significantly, this suggests that implicit prosodic structure, like syntactic structure, can be primed; second, in relation to our main goal, it demonstrates that silently-generated prosodic boundaries influence attachment—supporting the IPH.

The results also confirm previous findings that autistic traits in the neurotypical population are relevant to predicting sensitivity to prosody in sentence processing ([26]). In particular, the communication subscale of the AQ seems to be correlated with sensitivity to prosodic boundaries ([18, 19)]. Participants with higher AQ-communication scores (e.g., those who are not good at social chit-chat, or are slower in understanding the point of a joke), chose more high attachment responses for targets following non-restrictive RC primes than those following restrictive RC primes. Though the mechanisms underlying this tendency require further study, we hypothesize that individuals with high AQ-communication scores, rather than incorporating the prosodic boundary to attachment, might have been disrupted by the juncture, prompting closure at the location of boundary.

On the other hand, a second finding, not previously reported, is also related to autistic traits. Namely, high scores on the attention-switching subscale of the AQ (i.e., worse attention-switching abilities) were associated with higher overall rates of high attachment. The relation between attachment preference and attention-switching therefore resembles the one between attachment preference and verbal working memory capacity ([16], [17]), possibly because both of these reflect similar general processing resources. That is, those who lack attention shifting abilities and those who have lower working memory capacity might both have difficulty integrating multiple sources of information. This may be supported by the main effect of trial, which indicated that, as the experiment went on (and participants possibly became more fatigued), high attachment decisions became more likely. Again, further research is needed to understand the processing mechanism underlying the performance of individuals with more prominent autistic traits.

In sum, the present study provides crucial evidence for the Implicit Prosody Hypothesis with respect to the relation between implicit boundaries in reading and attachment preferences. Further, we have shown that implicit prosodic structure, like syntactic structure, can be primed, and that the details of this priming depend on autistic traits in the neurotypical population.

4. Acknowledgements

The authors thank Henry Tehrani for his help in writing the MATLAB script and undergraduate research assistants Katie Brown, Sewon Na, and Hannah Kim for help running the experiment. Work on this project was facilitated by a UCLA Faculty Research Grant to Sun-Ah Jun.

5. Appendices: Example Stimuli (part)

I	**Example Target Sentences**
1	Jennifer blackmailed the boss of the clerk that was dishonest.
2	Susanna was dating the cousin of the artist that was a veteran.
3	The lady mended the sleeve of the shirt that had been stained.
II	**Example Prime Sentences (Restrictive, without comma)**
1a	The inspector photographed the boat's cover that was yellow.
2a	The coach looked at the varsity players who were very happy.
3a	The picky journalist hated the soldiers who were sitting down.
III	**Example Prime Sentences (Non-restrictive, with comma)**
1b	The inspector photographed the boat's cover, which was yellow.
2b	The coach looked at the varsity players, who were very happy.
3b	The picky journalist hated the soldiers, who were sitting down.

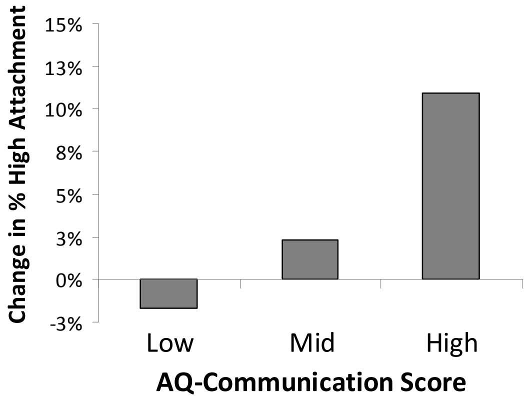

Figure 2: *Increase in high attachment responses to targets in the non-restrictive RC prime condition (relative to the restrictive RC prime condition) as a function of AQ-Communication scores. The three levels of AQ refer to the group distribution: "Mid" are subjects scoring within 1 SD of the mean, the "Low" and "High" levels below or above 1 SD.*

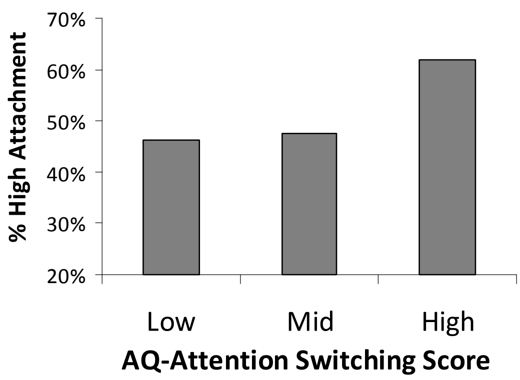

Figure 3: *High attachment responses as a function of scores on the Attention-Switching subscale of the AQ. The three levels refer to the group distribution: "Mid" are subjects scoring within 1 SD of the mean, the "Low" and "High" levels below or above 1 SD.*

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