

Individual Differences in Prosodic Strategies to Sentence Parsing

Jason Bishop¹, Adam J. Chong², & Sun-Ah Jun²

¹CUNY (College of Staten Island and The Graduate Center); ²UCLA
jbishop@gc.cuny.edu; ajchong@ucla.edu; jun@humnet.ucla.edu

ABSTRACT

This study investigated individual differences in the use of prosodic structure in the resolution of syntactic ambiguity in English, exploring listeners' sensitivity to the placement of prosodic boundaries in the parsing of relative clauses. Previous work, carried out in the context of the Implicit Prosody Hypothesis, has shown that variation in "autistic"-like personality traits in neurotypical individuals predicts the use of prosody for this purpose, although this work utilized silently-read materials. In the current study, we investigated the comprehension of auditorily-presented sentences and found such traits to only weakly predict syntactic parsing. We propose that autistic traits primarily influence sensitivity to accentuation (rather than phrasing) in sentence processing, affecting sensitivity to prominence in terms of both pitch accent status as well as pitch accent realization.

Keywords: prosody; sentence processing; individual differences; prominence; phrasing; intonation

1. INTRODUCTION

1.1. Prosody and syntactic ambiguity

Sentences such as (1) are syntactically ambiguous with respect to whether the relative clause (RC) "*who was on the balcony*" attaches high or low to one of the two preceding noun phrases (NPs):

- (1) *Someone shot the servant of the actress who was on the balcony.* [7]

In this English example, the RC can be parsed as attaching high in the syntactic structure to NP1 (modifying "*the servant*") or low to NP2 (modifying "*the actress*"). Such ambiguities have been of interest because native-speaking subjects do not make attachment decisions entirely randomly in sentence comprehension; rather, they are sensitive to a number of properties of the stimuli. One key property, the one of interest here, is the sentence's prosodic structure.

A long-standing observation about the relation between prosody and syntax holds that there is a preference for prosodic boundaries to be aligned with syntactic boundaries, although the relationship is by no means one-to-one [16,18,22]. According to the influential Implicit Prosody Hypothesis (IPH) [8], which makes a specific claim about the constructions

under consideration here, the presence of a prosodic boundary cues a higher syntactic boundary to the parser. Thus, assigning the prosodic structure in (2) rather than (3) to the sentence in (1) has different effects on attachment, i.e., the parsing of the RC:

- (2) Prosody for Low Attachment:
*Someone shot the servant //
of the actress who was on the balcony*
- (3) Prosody for High Attachment:
*Someone shot the servant of the actress //
who was on the balcony*

The IPH was developed in the context of psycholinguistic study of sentence disambiguation in reading. The basic idea, intended to explain cross-linguistic differences in attachment preference, was that native speakers of languages with a low attachment bias (like English) tend to generate the implicit prosody in (2) by default; native speakers of high attachment languages tend to project the structure in (3) in silent reading. In some cases [12,13], evidence from production studies have confirmed a correlation: speakers of a language with a high attachment bias, such as Korean, tend to produce a syntactically-equivalent sentence with a boundary separating the RC and the two NPs. However, native speakers of English also showed this tendency [9], even though such speakers are known to prefer low attachment in silent reading [7]. This suggests that either the IPH is incorrect, or that overtly-produced prosody in phonetic production studies does not accurately reflect the prosody readers generate when silently reading. The latter scenario was the preferred interpretation in [9], and this seemed to be consistent with other work showing that prosody elicited in the laboratory often does not encode syntactic and semantic structure [20,6]

1.2. The role of prominence in ambiguity resolution

In a recent study, [11] suggest that the discrepancy between the predictions of the IPH and the findings of production work on English may have more to do with the focus on phrasing, mostly to the exclusion of prominence (i.e., accentuation). They note that work from spoken sentence comprehension has shown that listeners attend to prominence patterns in order to make off-line attachment decisions. In particular, listeners tend to prefer attachment of an ambiguous RC to the more prosodically prominent of two preceding NPs—"Focus Attraction" [19], and a perceptual strategy that [15] claimed to be based on memory limitations rather

than a parsing mechanism per se. However, in their respective studies, the role of prominence was tested by holding boundary placement constant, presenting sentences where a boundary occurred late (after NP2) and the accent status of NP1 and NP2 was manipulated. These studies show a clear preference for the accented rather than the unaccented NP as an RC attachment site.

However, prominence patterns cannot be held constant when boundary locations vary. The phonological prominence of a head noun (i.e., its status as a prominent nuclear accent vs. a less-prominent pre-nuclear accent) is closely related to boundary location, since the last accented word in an Intermediate Phrase will bear the nuclear accent in English intonational phonology [2].

The matter is shown schematically in (4), where it is assumed that accent status is held constant for each of the two NPs (i.e., both are accented). Which of the two NPs bears the nuclear accent (shown in bold) will depend on the location of the boundary; when the boundary is late (after NP2) as in (a), NP2 will be nuclear, and NP1 will be pre-nuclear—rendering NP2 the structurally more prominent head noun. In the case where the boundary is early (after NP1) as in (b), however, NP1 is nuclear and NP2 is pre-nuclear, and so NP1 is structurally more prominent.

- (4)
- (a) **T*** **T*** T*
- (...NP1 NP2) // (RC)
- *Boundary placement favors high attachment of RC (to NP1), but nuclear accent placement favors low attachment (to NP2)*
- (b) T* T* T*
- (...NP1) // (NP2 RC)
- *Boundary placement favors low attachment of RC (to NP2), but nuclear accent placement favors high attachment (to NP1)*

Thus there is not one, but two “prosodic strategies” for the resolution of attachment ambiguity for these syntactic structures: one based on prominence structure (“Focus Attraction”), and one based on phrasal structure (i.e., as proposed by the IPH). Further, these two prosodic strategies can have completely different effects on parsing. We may therefore ask what the most important strategy in a given language might be.

1.3. Individual differences in prosodic strategies

Recent work by [11] suggests there may not be a single answer that applies broadly to entire groups. Still focused on the IPH, their study made use of a prosodic adaptation of the structural priming paradigm [5] in which listeners, before silently reading an ambiguous RC sentence, heard an auditory version of a different,

but structurally similar, prime sentence. The prosodic structure of this auditory prime varied, containing either an early boundary or a late boundary (as in (2) and (3), above), or no boundary (intended to serve as a control). They found subjects to comprehend silently-read target sentences differently depending on the primes. Notably, however, they found two basic kinds of subjects: those who seemed to be influenced by the primes’ prominence patterns, and those that were influenced by the primes’ boundary location. Interestingly, which of these strategies subjects seemed to follow correlated with scores on the Autism Spectrum Quotient (AQ), a measure of “autistic traits” in the neurotypical population [1]. Individuals with lower scores (reflecting fewer autistic-like traits) showed priming effects that were best explained by a prominence-based strategy; individuals with higher scores (reflecting more autistic-like traits) showed priming patterns best explained by a boundary-based strategy. In their discussion, [11] emphasize the individual differences in the encoding/ memory for prominence patterns, as such individual differences in priming effects have recently been demonstrated (though not in relation to autistic traits) by other researchers [21].

2. PRESENT STUDY

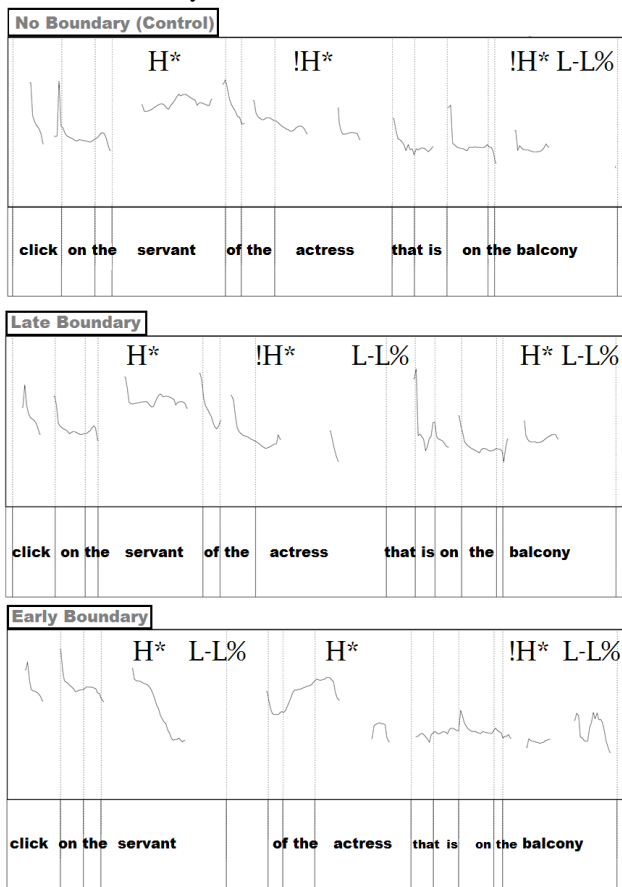
In [11] a rather elaborate priming task was used to explore implicitly-generated prosody in silent reading. What is difficult to discern from their study is whether the individual differences they observed—which they relate to divergent prosodic strategies—were in fact due to individual differences in attention to prosody (i.e., to the auditory primes)—or individual differences more specific to the encoding and/or generation of implicit prosody. In the present study we tested a large group of listeners in a more traditional task similar to that employed by [19] and [15], using auditory target sentences. We examined structures like the examples in (2), above, with the goal of examining individual differences (related to autistic traits) that may indicate attention to different aspects of prosodic structure.

2.1. Methods

2.1.1. Materials

A listening experiment was designed, based on the tasks used in [19,15], in which listeners were auditorily presented with productions of ambiguous RC sentences with different boundary locations. 24 sentences were constructed, each containing a syntactically-ambiguous RC. (e.g. “Click on the servant of the actress that was on the balcony”). Three recordings of each test sentence were produced by a female speaker of American English, forming the three prosodic conditions: an early boundary (after NP1), a late boundary (after NP2), and a control (no boundary) condition. An example test sentence in each of these three conditions is shown in Fig. 1.

Fig 1: Example RC test sentence in each of the three boundary location conditions.



For each of the test sentences, two visual scenes were constructed that corresponded to one or the other interpretations of the test sentences (i.e., a high or low attachment interpretation). Additionally, 36 filler sentences (each with two visual scenes) were created in the same manner as the test sentences. Like the test sentences, there were three prosodic conditions for the fillers that varied in the location of a prosodic boundary: early, or late in the sentence, or no boundary. However, the fillers, which contained an RC or an adjunct, lacked any syntactic ambiguity in attachment.

2.1.2. Participants

107 English-speaking listeners served as participants in the sentence comprehension task and AQ task.

2.1.3. Procedures

Sentence Comprehension Task: Participants sat in front of a computer screen and heard the 24 test and 36 filler sentences (randomized for each participant). After hearing each sentence, the participant used a mouse to click on the image on the screen that best fit their interpretation of the sentence.

AQ: Subsequent to the comprehension task, all participants completed the AQ, a 50-item, self-report questionnaire measuring autistic-like personality traits

in the neurotypical (i.e., non-clinical) population. Higher AQ scores indicate more prominent autistic traits in the individual. The AQ is composed of 5 separate subscales; here we focused on the Communication subscale, shown relevant to speech and sentence processing in previous work [3,4,10,17], and whenever “AQ” is referred to here, it is always this subscale only.

2.2. Results

We were interested in two primary questions: (1) is there an overall effect of boundary location for the whole group? and (2) are any such effects dependent on autistic traits (modelled as an interaction between boundary condition and AQ)?

Fig 2: Overall (i.e., group) rates of high attachment for test sentences in each of the three boundary location conditions.

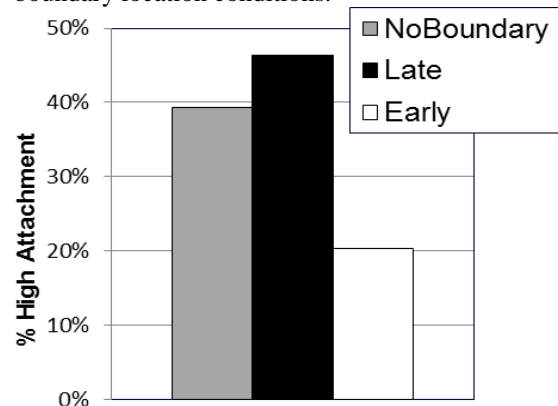
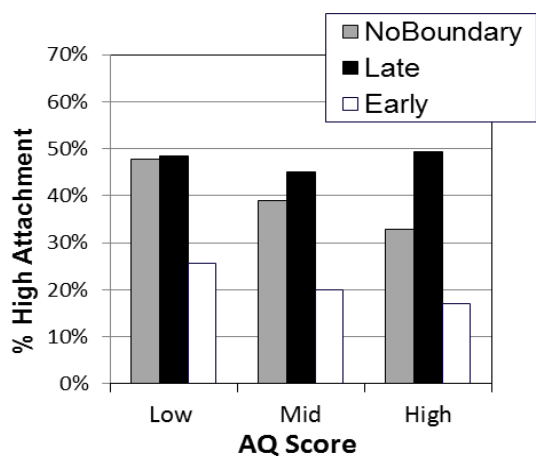


Fig 3: Rates of high attachment responses for each prosodic condition, broken down by scores on Autism Spectrum Quotient (AQ). “Mid” scores represent those 1 s.d. around the mean (N=71); “High” scores 1 s.d. above (N=19) and “Low” scores 1 s.d. below (N=17) the mean.



2.2.1. Overall effects of boundaries on attachment

Overall rates of high attachment for each prosodic condition are illustrated in Fig 2.; relative to the control condition, sentences with late boundaries prompted

more high attachment parsings, and those with early boundaries prompted more low attachment parsings—the pattern is the one predicted by the IPH. To test for statistical significance, high attachment responses were modelled using mixed-effects regression with *boundary location* as a fixed effect and participant and item as random effects; both were found to be significant (late boundary: $\beta = 0.40$, $z = 3.56$, $p < .001$; early boundary: $\beta = -1.20$, $z = -9.46$, $p < .001$).

2.2.2. Individual Differences

Fig. 3 shows rates of high attachment for each prosodic condition, broken down by AQ scores. Each group in the figure represents a different portion of the distribution of scores, ranging from one standard deviation around the mean (Mid) or above (High) or below (Low) that. To probe for effects related to AQ, a second mixed-effects model included scores on the communication subscale of the AQ, as well as the interaction between AQ and *boundary location*. The model showed the simple main effect of boundary location on attachment described above to be limited to early boundaries ($\beta = -1.82$, $z = -3.19$, $p < .01$), while there was no overall effect for late boundaries ($\beta = -0.57$, $z = 0.52$, $p > .1$). This was likely due to a marginally significant interaction between the late boundary condition and AQ ($\beta = 0.054$, $z = 0.03$, $p = .058$). As can be seen in Fig. 3, as participants' AQ increased, there was a larger difference between the late boundary condition and the control condition. Interestingly, this was chiefly due to a decrease in high attachment in the *control* condition as AQ increased (rather than an absolute increase in the late boundary condition). Also visible in the figure is a numerical decrease in high attachment for sentences with early boundaries as AQ increased; this trend was not significant ($\beta = .035$, $z = 1.11$, $p > .1$).

3. DISCUSSION AND CONCLUSION

In the experiment presented above, we used a direct listening/question-answering task to probe for individual differences in the use of prosodic boundaries in RC attachment. A major goal of this experiment was to determine whether we would find a pattern of results similar to that reported in [11], where auditory primes were heard but attachment decisions were about silently-read sentences (whose implicitly-generated prosody presumably matched the explicit prosody of the auditory primes). If the pattern of results here were similar, this would suggest that the individual differences related to autistic traits in [11] most likely reflected individual differences in attention to explicit prosody rather than in the generation of implicit prosody.

In fact, although the interaction with autistic traits here was not as statistically robust, we did replicate [11]'s basic pattern of results. In particular, relative to a no-boundary control condition, the expected effect of

a late boundary (which the IPH predicts to cue high attachment) actually increases as AQ increases. As can be seen in Fig. 3, this was primarily due to an inverse relation between high attachment and AQ in the control condition, rather than the late boundary condition itself. There are therefore two basic questions we wish to address: first, why did individuals with low AQ (indicating weak autistic traits) show a stronger preference for high attachment in our control condition? Second, why was this interaction between prosodic condition and AQ more marginal than in [11]'s priming study?

We believe the answer to the first question lies in the divergent prosodic strategies discussed in the introduction. There we described evidence that phonological prominence (accented vs. unaccented, or nuclear accented vs. prenuclear accented) attracts attachment, which [11] found to be stronger in low-AQ individuals. We think phonetic prominence in the form of pitch accent *type* (i.e., H* versus !H*) had a similar effect in our control condition in the present study. Recall the prosody employed in our control condition:

$$(5) \quad \begin{array}{ccc} \text{H}^* & \text{!H}^* & \text{!H}^* \\ (\dots\text{NP1} & \text{NP2} & \text{RC}) \end{array}$$

Unlike in the other two conditions, where one of the NPs carried a nuclear accent, neither of the NPs in the control condition carried a nuclear accent. However, even without such a difference in structural prominence, NP2 nonetheless bore a *less* prominent downstepped accent, and NP1 bore a full-fledged H*. We propose that low-AQ individuals were more sensitive to this difference in phonetic prominence, just as they were argued to be more sensitive to structural/phonological prominence in [11]. That is, the lower the individual's AQ, the more the NP1's phonetic prominence attracted attachment of the RC.

Second, although we found the same pattern as [11], AQ was not as highly significant as it was in [11]. We propose that this difference supports the claims of [15; see also 14] that the effect prominence on ambiguity resolution is a post-parsing, memory-based effect. We postulate that prominence's role was weaker here because the direct listening task made less use of phonological memory than [11]'s priming task. The result, then, is that individual differences in the sensitivity to prominence should, overall, be less evident in the present study.

In summary, we believe our results show evidence of multiple prosodic strategies to parsing ambiguous sentences. We have also shown that individuals may differ slightly in their sensitivity to a prominence-based approach, and it is necessary to consider structural prominence (presence of accentuation/status as nuclear vs. prenuclear), as well as phonetic prominence (pitch accent realization). More tentatively, we suggest that the size of the prominence-based effect in the present study may support [15]'s account of the mechanism by which prominence influences ambiguity resolution.

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