Delexicalised Auditory Priming of Implicit Prosody

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Abstract

This study used a cross-modal priming paradigm to investigate whether delexicalised auditory priming will influence relative clause (RC) disambiguation in silent reading. Two predictions of the Implicit Prosody Hypothesis were investigated: that an early prosodic break will lead to increased low attachment, and that longer RCs are more likely to attach high, known as an "antigravity effect." In each trial, subjects heard three different sentences that had been delexicalised into "fafafa speech." These were randomly selected from 9 primes with the same prosodic break (early, late, control) that matched the target sentence in RC length (short, long). The ambiguous visual target sentence appeared, followed by an attachment question with a two-alternative forced choice task between N1 or N2. Our initial hypothesis of a priming effect from delexicalised auditory stimuli on RC ambiguity resolution was confirmed, suggesting that prosody alone can influence attachment preference. Participants were significantly more likely to attach low after hearing primes in the early boundary condition. We also found a surprising interaction: when late boundary primes were combined with short RCs, subjects were significantly more likely to choose high attachment. Additional research is required to determine if the presence of either prosodic break has a similar effect.

Index Terms: implicit prosody, sentence processing, relative clause attachment, priming

1. Introduction

The aim of this study was to determine whether delexicalised auditory prosodic priming alone can influence the parsing of silently read ambiguous sentences, or if lexical/syntactic information is required as well.

Implicit Prosody has been shown to be affected by priming. Jun and Bishop [1] found an auditory priming effect on relative clause (RC) ambiguity resolution, but because their primes contained lexical and syntactic information, it was unclear if the effect was driven by prosodic or syntactic factors.

The Implicit Prosody Hypothesis posits that "the parser favors the syntactic analysis associated with the most natural (default) prosodic contour for the construction" [2], [3]. This leads to predictions based on two manipulations in English RC ambiguity resolution: the location of prosodic breaks and the length of the RC. Firstly, the IPH predicts that an early prosodic break between the noun phrases (NPs) promotes low RC attachment. A late prosodic break (after N2) may promote high attachment, but most auditory RC attachment studies have shown an asymmetric pattern in prosodic influence in disambiguation [4]. Secondly, short RCs are more likely to have low attachment, while longer, heavier RCs are more likely to attach high. This is known as an "antigravity effect." Fodor [3] suggests this is because very short RCs are unlikely

to be preceded by a prosodic pause and are integrated into the longer prosodic phrase. The current study investigated the hypothesis that delexicalized auditory priming will influence RC disambiguation in silent reading in accordance with these two predictions of the IPH.

2. Methods

2.1. Participants

Participants were 22 (11 female) adult native speakers of English who had not learned another language in childhood. They included speakers of American, Australian and British English, and importantly the relative clause disambiguation being investigated does not vary prosodically across these regions. No financial incentive was offered.

2.2. Stimuli

2.2.1. Visual Stimuli: Text

The visual target stimuli consisted of 18 sentences containing relative clauses (RCs) with ambiguous attachment. For example, in the sentence *Rob talked to the coach of the gymnast that was sick* the relative clause *that was sick* could attach to either N1 *the coach* (high attachment) or N2 *the gymnast* (low attachment). These sentences were based on the target sentences used in Jun and Bishop [1] but were modified to exclude perceptual and semi-perceptual verbs like "see" [5], [6] as well as implicit causality verbs like "hit" [7] which have been shown to influence attachment. Replacement sentences came from the prime sentences used by Jun and Bishop [1], as this study used their target sentences as both visual target sentences and delexicalised primes. Other minor changes were made to increase ambiguity based on the results of a pilot study. The target sentences were divided by relative clause length, with 9 containing short relative clauses (3-5 syllables) and 9 containing long relative clauses (6-9 syllables), as previous research has shown that relative clause length can influence attachment preferences [4]. Additionally, 18 filler sentences were created using the same structure but with unambiguous attachment (9 high, 9 low).

2.2.2. Primes: Delexicalised Speech

Auditory primes had the same structure as the visual target sentences but were disambiguated with prosodic breaks in the recording. Each sentence was recorded by a female native speaker of Yorkshire UK English using a Zoom H1 recorder. Three versions of each sentence were recorded: the disambiguated for low attachment version had a break after N1 (see Figure 1a), while the disambiguated for high attachment version had a break after N2 (see Figure 1b). A third control version had no prosodic break or extra emphasis (see Figure 1c).

The recordings were delexicalised into "Fafafa speech" [8]. This was accomplished using Praat by manually coding

voiced/unvoiced sounds in the textgrid of the original recording and substituting /ɑ/ for the voiced and /f/ for the unvoiced segments before concatenating them into a text string [9]. Next, the prosodic contour is extracted from the original recording and mapped onto the synthesized string, using a Praat script based on the Praat plugin developed by Dellwo [10].
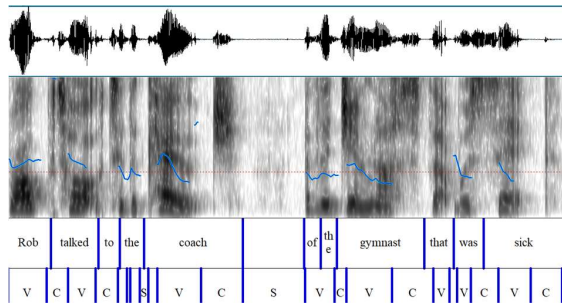

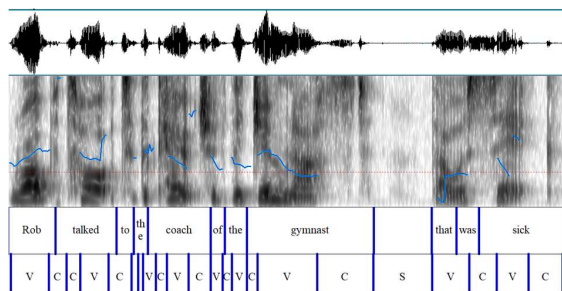Figure 1a: *Early boundary condition to promote low attachment*

Figure 1b*: Late boundary condition to promote high attachment*
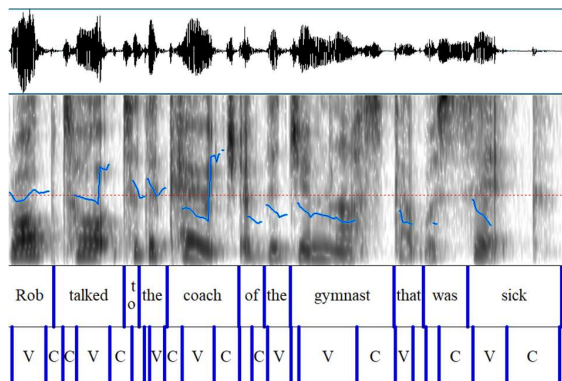

Figure 1c*: Control condition*

2.3. Procedure

The experiment was presented using PsychoPy [11] to participants wearing Bose QuietComfort 15 noise-cancelling headphones.

For each trial (see Figure 2), participants were presented with three delexicalised auditory primes. These primes were randomly selected from 9 primes with the same boundary location (early, late or control) that matched the target sentence in relative clause (RC) length (long or short). They were then shown a visual target sentence for 5 seconds (roughly the duration of the auditory primes) which disappeared and was replaced by an attachment question, followed by the two noun phrases (N1 or N2) which remained on the screen until the participant made a judgement decision by pressing the < or > key. < always indicated N1 while > always indicated N2. For example, after the sentence Rob talked to *the coach of the gymnast that was sick*, the attachment question would be *Who was sick?* The subject would then choose between N1, *the coach* or N2, *the gymnast*. For the unambiguous filler sentences, only plausible primes were presented (either matching the correct unambiguous attachment or control). 18 experimental trials and 18 filler trials were presented in random order.
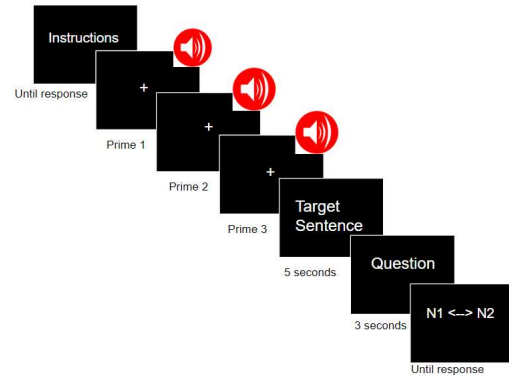

Figure 2: *Schematic image of the flow of each trial.. The only recorded response was the attachment choice (N1 or N2).*

3. Results

Because English is known to have a low attachment bias [3] high attachment is the less expected judgement. In order to see the likely effect of priming, we looked at the raw percentage of high attachment to get an idea of the overall shape of the results (Figure 3). The highest percentage of high attachment judgements were made after listening to the control prime (35%) followed by the high/late boundary prime (28%). Participants gave fewer high attachment judgements after hearing a low/early boundary prime (20%).
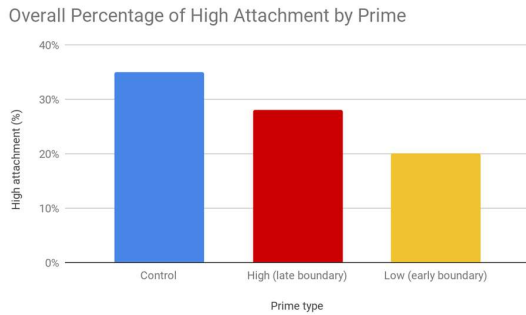
Figure 3: *Percentage of high-attachment responses as a function of prime type.*
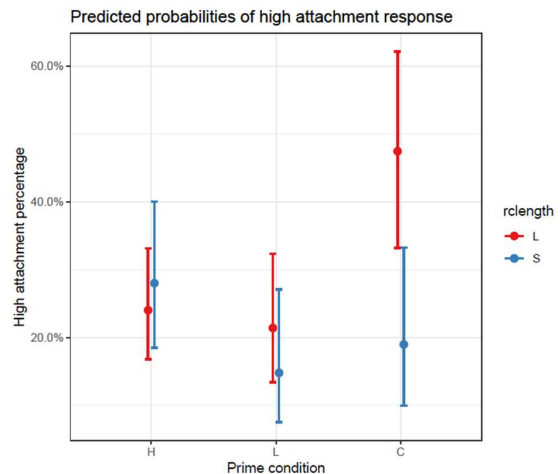

Figure 4: *Two-way interaction between prime condition (H = high/late boundary, L= low/early boundary, C= control) and relative clause length (rclength, L= long and S= short) are plotted against the percentage of high attachment results predicted in the mixed effects regression model. Note that only the high/late prime boundary resulted in a significantly greater high attachment preference relative to the mean.*

The responses were submitted to a mixed-effects logistic regression predicting high attachment judgment from the prime boundary location (early, late, control), the RC weight (short, long), their interaction, and random intercepts for participant and item. All categorical variables (prime height, RC length and gender) were sum coded using the R function contr.sum. Sum coding was used as there was no clear baseline, and instead each variable was compared with the overall mean. However, this resulted in the model comparing the prime heights (high or low) but the control was incorporated into the overall mean for these statistical analyses.

	Estimate β	SE (β)	z	p
(Intercept)	-1.11748			
Prime (high or late boundary)	0.06904	0.18187	0.380	0.7042
Prime (low or early boundary)	-0.40940	0.18861	-2.171	**0.0300 ***
RC length (short)	-0.26561	0.15830	-1.678	0.0934 .
Prime (high):RC Length (short)	0.36944	0.18210	2.029	**0.0425 ***
Prime (low):RC Length (short)	0.04034	0.18810	0.214	0.8302

Table 1: *Estimates, standard errors, z and p values. Positive estimates indicate the amount of increase in log-odds relative to the Intercept.*

The resulting model (Table 1) showed primes with an early boundary corresponded to a significantly weaker preference for high attachment as we expected (β prime.low = -4.09, p < 0.05). An unexpected significant interaction was observed between the late prime boundary location and short RC (β prime.low = 3.69, p < 0.05). This interaction can be seen in Figure 4. The control condition is a good illustration of what we expect to see based on the "antigravity effect" of RC attachment.

4. Discussion

Our initial hypothesis of a priming effect from delexicalised auditory stimuli on RC ambiguity resolution was confirmed, suggesting that prosody alone can influence attachment preference. Participants were significantly more likely to attach low after hearing primes in the early boundary condition. This is consistent with most auditory RC attachment studies which have shown an asymmetric pattern in prosodic influence in disambiguation, which could be in part because the early boundary condition is less common in general [12], [13] and therefore is a more salient signal. Cross-linguistically, early boundary conditions have been shown to have strong effects on RC disambiguation, while a late boundary condition "results in a weaker or even absent effect" [14, p. 244] so our significant results are not surprising and support the wider literature.

However, we also found an unexpected interaction: when late boundary primes were combined with short RCs, subjects were significantly more likely to choose high attachment. While this seems to contradict the antigravity effect, the significance may be driven by the responses to the control condition. Additional research is required to determine if the presence of either prosodic break has a similar effect.

The difference between the long and short RC conditions seems to have been minimized by the presence of a break (either in the early or late boundary condition), which is not anticipated by the IPH. The pattern in both the control and early boundary conditions follow the "antigravity" prediction, that heavy RCs are more likely to attach high. However, the late boundary condition has the opposite pattern.

There are three possible explanations for the pattern reversal, and all of them are rooted in the fact that the short RCs after the late prosodic break had little variation. This could have resulted in their being perceived as essentially identical and creating a stronger priming effect. Alternatively, they may simply be more memorable. Lastly, the third

possibility is that the three very similar prime patterns created metric expectations. A recent ERP study by Breen, Fitzroy and Ali [15] had participants silently read rhyming couplets that ended in weak-strong (WS) or strong-weak (SW) lexical stress pattern. When the final word was inconsistent with the expectation, they found negativities similar to those found in metric violations in music (SW expectation) and a positivity found in explicit listening metric violations (WS condition). These suggest that metric expectations are being constructed during silent reading. In our case, the similarity of the final rhythms in the condition with a late boundary and short RC may have created a strong rhythmic expectation that participants matched when they silently read the target sentence.

It is worth noting that no similar interaction was reported by Luo, Yan and Zhou [16] who conducted an eyetracking study with prosodic disambiguation using speech that was delexicalised using a lowpass filter. It is therefore possible that the "fafafa" speech delexicalisation method emphasised rhythmic elements which might be rendered less noticeable with a lowpass filter, or which may not be relevant in the Chinese construction they were investigating. As this is, to our knowledge, the only RC attachment priming study to use the "sasasa" or "fafafa" delexicalised speech method, further research is required into whether the anti-antigravity effect of the late boundary and short RC prime interaction and whether the minimized differences between long and short RC conditions in the presence of any break can be replicated with lexical or lowpass-filtered speech,

5. Conclusion

The study found that delexicalized auditory primes affected the RC ambiguity resolution in silent reading, specifically in that participants were significantly more likely to choose low attachment after hearing an early boundary prime as predicted by the IPH. Additionally, more research with a larger sample size is required to determine whether the statistical significance of an interaction between late prosodic breaks and short RCs is driven by the responses to the control condition and therefore not meaningful, or if it actually indicates an interesting effect which could be caused by the rhythmic similarity of the prime or metric expectations. Importantly, the results of this study do support the hypothesis that prosody alone can influence RC attachment in silent reading.

6. Acknowledgements

7. References

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