Functions of Intonation Boundaries during Spoken Language Comprehension in English

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Abstract

Two experiments investigated the interaction of intonation boundaries and verb bias during spoken language comprehension in English. An online cross-modal naming task proved to be sensitive to the interaction of prosodic, syntactic, and semantic representations during resolution of a temporary syntactic closure ambiguity (e.g., *Whenever the lady checks the room…*). The results supported previous claims that intonation boundaries trigger semantic wrap-up [1] and provided new evidence that they trigger syntactic wrap-up as well. When an intonation boundary occurred at a transitive-bias verb, wrap-up resulted in a transitive interpretation and an intransitive structure. Resolution of the conflict depended on the prosodic representation associated with the structurally ambiguous noun phrase and its predictability as a direct object. While intonation boundary location can determine the initial syntactic structure for this closure ambiguity regardless of verb bias, disambiguation for transitive-bias verbs seems to depend in part on other prosodic and lexical factors.

1. Introduction

Recent experiments have documented that prosodic phrasing interacts with syntactic processing at the earliest possible moment [2]. More specifically, the location of a prosodic boundary seemed to determine the initial structure for the temporary syntactic ambiguity in (1).

(1) Whenever the lady checks the room

When the prosodic boundary occurred late, at the end of the fragment, the initial syntactic structure incorporated the ambiguous noun phrase (NP; *the room*) as the direct object of the preceding verb. When the prosodic boundary occurred early, immediately before the NP, the initial structure incorporated the NP as the subject of the following main clause. The effect held for intonation phrase boundaries and for intermediate phrase boundaries as well.

While this previous study of closure ambiguity resolution specified the prosody explicitly and used an online measure of processing, the effects might have hinged on the type of verb used in the materials (i.e., equi-bias). All the verbs could be used with or without a direct object, but few, if any, were strongly biased toward a transitive or intransitive use.

The transitivity bias of the verb is potentially quite important. The finding that prosodic phrasing immediately influenced which of two syntactic structures was built—when the verbs as a group occurred equally frequently with the two syntactic alternatives—resembles another finding; namely, that plausibility immediately influenced the resolution of a temporary syntactic ambiguity during reading, but only when the verbs were equi-biased [3]. Thus, it could be the case that when verbs are strongly biased toward a transitive or intransitive use, the location of a prosodic boundary no longer determines the initial syntactic structure.

2. Experiments

Two cross-modal naming experiments investigated the interaction of intonation boundaries and verb bias during resolution of the temporary syntactic closure ambiguity in (1). Methodology was identical in the two experiments.

2.1. Cross-Modal Naming Task

Participants listened to spoken versions of ambiguous sentence fragments. At the end of each fragment, they named a visual target as quickly as they could and then used that target to complete the sentence. Completions ensured that participants integrated the auditory fragment and visual target, and indicated the final structure and interpretation.

Targets were generally congruent with only one of the possible syntactic structures. The targets *it's* and *is* (Experiment 1), as well as plausible and implausible NP targets (Experiment 2), were expected to elicit transitive and intransitive completions, respectively. Naming times that were produced prior to some other completion type—or that required data replacement for some other reason (e.g., voice key error, participant named wrong word)—were replaced with the average of the experiment-wise individual subject and items means, just as in [2].

Naming times for each participant were also corrected to adjust for any baseline differences in responses to the visual targets. Baselines were calculated as follows: At the end of an experiment, each participant named the critical targets three times in random order following a spoken carrier phrase (i.e., *The next word will be*). Mean naming times to these control sentences were then subtracted from mean naming times in the main experiment.

2.2. Verb Bias Variable

Each experiment compared three frequency-matched sets of verbs: transitive-bias, equi-bias, and intransitive-bias. The equi-bias set contained the same verbs as [2] in an attempt to replicate their effects. Some verbs were transitive-bias and some were intransitive-bias, but few were strongly biased. The transitive-bias set contained only transitive-bias verbs; the intransitive-bias set contained only intransitive-bias verbs. Bias was determined from sentence completion data reported in [4].

2.3. Experiment 1: Verb Bias and Intonation Boundaries

Auditory fragments in Experiment 1 ended with the structurally ambiguous NP, and participants named the

visual targets *it's* and *is* at the offset of each critical sound file. Figure 1 illustrates the fundamental frequency contour for the late intonation boundary condition. Figure 2 illustrates the contour for the early intonation boundary condition. Auditory fragments always included any silence following an intonation boundary in the original recording.

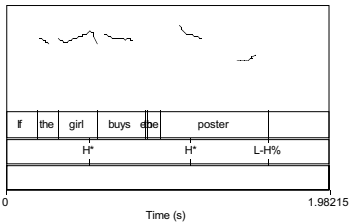

Figure 1: Fundamental frequency contour for late intonation boundary condition.

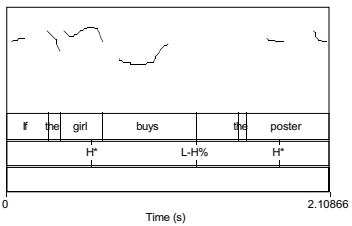

Figure 2: Fundamental frequency contour for early intonation boundary condition.

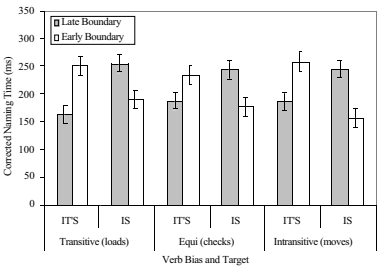

Figure 3: Corrected cross-modal naming times for transitive (*it's*) and intransitive (*is*) completions in two prosodic and three verb-bias conditions.

As shown in Figure 3, naming times were faster to *it's* than *is* in the late boundary conditions and slower to *it's* than *is* in the early boundary conditions. The boundary by target interaction was significant by subjects ($F1[1,52]=51.333$, $p < .01$) and by items ($F2[1,24]=51.811$, $p < .01$) in two 2 (boundary: late, early) X 3 (verb bias: transitive, equi, intransitive) X 2 (target: *it's*, *is*) repeated measures ANOVAs.

The results suggest that the location of the intonation boundary determined the initial syntactic analysis regardless of verb bias. With a late boundary, the structurally ambiguous NP was incorporated as a direct object. With an early boundary, the NP was incorporated as the subject of the main clause. The results replicate [2] and further demonstrate that their original finding did not hinge on their use of equi-bias verbs.

Regression analyses were also conducted to investigate possible effects of verb bias and boundary location on reanalysis. For all regression analyses, verbs were categorized into one of two groups: intransitive-bias or transitive-bias. Naming times to *is* in the late boundary condition were expected to show reanalysis to an intransitive structure, while naming to *it's* in the early boundary condition were expected to show reanalysis to a transitive structure.

As expected, naming times to *is* in the late boundary condition grew longer as transitive-bias verbs became more transitive ($R^2 = .37$, $p = .01$). Reanalysis to an intransitive structure took longer as verbs occurred more frequently with direct objects. Surprisingly, no comparable correlation was observed for intransitive-bias verbs. Even though transitive-bias and intransitive-bias verbs both demonstrated "garden path" effects on naming times (Figure 3), and resulted in intransitive sentence completions, only transitive-bias verbs showed evidence of reanalysis at the visual target. Thus, reanalysis processes for intransitive-bias verbs occurred post-naming.

This finding is consistent with the claim that intonation boundaries trigger wrap-up of any outstanding semantic or pragmatic processing [1]. When late intonation boundaries trigger wrap-up to a transitive interpretation, they trigger wrap-up to the *dominant* meaning of transitive-bias verbs and the *subordinate* meaning of intransitive-bias verbs. In turn, the results suggest that reanalysis is harder when it involves reanalyzing a commitment to a subordinate meaning.

Unexpectedly, there was no evidence of reanalysis to a transitive structure in the early boundary condition when the visual target was *it's*. Rather, correlations between transitive-bias verbs in this early boundary condition and an acceptability measure obtained during pre-testing suggested that transitive-bias verbs underwent semantic reanalysis to an intransitive interpretation in all early boundary conditions.

Specifically, naming times to transitive-bias verbs became *longer* as late boundary fragments were rated as better reflections of the speaker's intention. Regardless of whether the target was *it's* ($R^2 = .28$, $p = .03$) or *is* ($R^2 = .21$, $p = .06$), processing time for transitive-bias verbs in the early boundary condition increased as their late boundary pronunciations became more acceptable.

The transitive-bias verb correlations suggest that early intonation boundaries trigger semantic wrap-up to the dominant meaning of the verb and syntactic wrap-up to an intransitive structure.

Under this account, the target *is* was easily incorporated with the structurally ambiguous NP into the main clause. For intransitive-bias verbs, no reanalysis was required.

Transitive-bias verbs, however, required semantic reanalysis to an intransitive interpretation.

In the case of the visual target *it's*, it too was incorporated with the structurally ambiguous NP into the main clause. But this incorporation led to a topicalized NP structure (e.g., *Whenever the kid cleans, the track—it's...*). Once again, only semantic reanalysis for the transitive-bias verbs ensued.

Why would participants choose the structurally more complex and less frequent topicalized NP structure over a direct object structure with the same linear word order? Two factors probably contributed.

The effect is consistent with the patterns of reanalysis in the late boundary conditions. In both cases, reanalysis of a dominant representation was faster than reanalysis of a subordinate representation.

The global prosodic representation probably also played a role. In the early boundary conditions, the structurally ambiguous NP was spoken mid-phrase. As a result, only the topicalized NP structure matched the early intonation boundary *and* the lack of a boundary after the structurally ambiguous NP. In contrast, a direct object structure would have suffered a mismatch between the given prosodic representation and the syntactic structure. Without a second intonation boundary after the structurally ambiguous NP, the direct object structure would have been infelicitous.

This is the first experiment to demonstrate that intonation boundaries trigger syntactic wrap-up in addition to semantic or pragmatic wrap-up. It is also the only demonstration that wrap-up at a transitive-bias verb results in a transitive semantic representation and intransitive syntactic representation. Experiment 2 explores these findings further by tapping processing one word position earlier, at the structurally ambiguous NP itself.

2.4. Experiment 2: Verb Bias, Boundaries, and Plausibility

Auditory fragments in Experiment 2 ended with the verb in one of three boundary conditions: no boundary, intermediate phrase boundary, or intonation phrase boundary. Participants named noun phrases that were either plausible or implausible as direct objects of the verb. Figures 4 – 6 illustrate the fundamental frequency contours for the three boundary conditions. Auditory fragments always included any silence following a prosodic boundary.

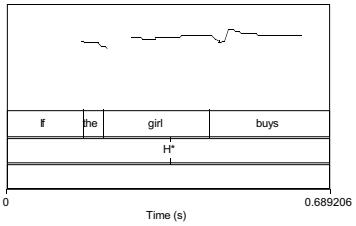

Figure 4: Fundamental frequency contour for condition with no boundary at the verb.

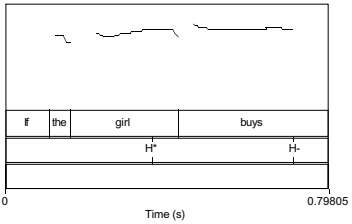

Figure 5: Fundamental frequency contour for condition with early intermediate boundary at the verb.

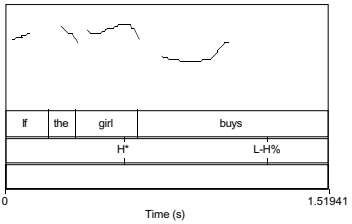

Figure 6: Fundamental frequency contour for condition with early intonation boundary at the verb.

As expected, verb bias, boundary, and plausibility all contributed to the final structure and interpretation. As shown in Table 1, the proportion of direct object sentence completions decreased from plausible (Pl) to implausible (Im) conditions, from transitive-bias to intransitive-bias conditions, and from the no boundary to intonation boundary conditions. The three-way interaction of verb bias, boundary, and plausibility was reliable by subjects ($F1[4,216]=4.113$, $p < .01$) and by items ($F2[4,36]=4.658$, $p < .01$) in two 3 (verb bias) X 3 (boundary) X 2 (plausibility) repeated measures ANOVAs.

Table 1: Proportion of direct object sentence completions in three verb bias, three prosodic boundary, and two direct object plausibility conditions.

	Transitive		Equi		Intransitive	
Boundary	Pl	Im	Pl	Im	Pl	Im
None	.87	.32	.81	.27	.82	.10
Intermediate	.75	.22	.66	.11	.48	.03
Intonation	.53	.12	.42	.04	.22	.03

Consistent with the findings of Experiment 1, intonation boundaries following transitive-bias verbs elicited both *transitive and intransitive* sentence completions when the target was plausible. This is to be expected if intonation boundaries at the verb trigger

semantic wrap-up to the dominant meaning but syntactic wrap-up to an intransitive structure.

The 12 verbs in the transitive-bias intonation boundary condition seemed to fall into two groups: those that elicited transitive completions and those that elicited intransitive completions. Neither the transitivity-bias of the verb nor any of the pre-tests of acceptability predicted the likelihood of a transitive completion. Rather, stimuli that elicited fewer direct object completions seemed, at least subjectively, to have less predictable direct objects. For example, *imitates the buzzer*, *kills the ducks*, and *visits the teacher* are all plausible, but they seem less likely than *kicks the chair*, *loads the van*, or *pulls the rope*.

Independent of these possible semantic predictability effects, these results can be interpreted as support for the claim that intonation boundaries trigger wrap-up of outstanding semantic, pragmatic, *and syntactic* comprehension processes. When wrap-up occurs at a transitive-bias verb, it involves commitment to the dominant (transitive) meaning and subordinate (intransitive) structure.

The results of Experiment 1 suggested that resolution of this conflict tended to favor preserving the subordinate representation. However, that conclusion was not supported in Experiment 2. Rather, a separate factor, predictability, seemed to be at work. While this does not eliminate the possibility that reanalysis is affected by the status of the underlying representations, it does suggest that disambiguation in the early boundary transitive-bias verb condition depends on more than just the early intonation boundary. Other factors, such as predictability and the global prosodic representation, seem to play a role. Indeed, transitive completions are felicitous in the early intonation boundary condition in Experiment 2 because the plausible NP target does not come with its own prosodic representation. Participants are free to assign a second intonation boundary immediately after the NP.

In terms of reaction time data, it was only possible to analyze naming times to implausible targets. Because these targets tended to elicit intransitive sentence completions, they minimized the number of cells that required data replacement for being a different completion type.

Overall, naming times to implausible targets were especially long in the intransitive-bias no boundary condition. Although the effect was not significant, it was not surprising that these times were long. Verb bias and target failed to support a transitive analysis, while the prosodic representation failed to support an intransitive analysis.

Regression analyses of these implausible conditions were conducted to investigate effects of verb bias and boundary. This time, however, the effects were not limited to reanalysis. Rather, they seemed to reflect initial representations.

Naming times in the transitive-bias no boundary condition were correlated with acceptability measures from pre-testing. Naming times grew *shorter* as visual targets became more acceptable as direct objects ($R^2 = .28$, $p = .05$). Naming times also grew *longer* as visual targets became more acceptable as subjects of the main clause ($R^2 = .21$, $p = .07$). Because the implausible targets were ultimately reanalyzed as subjects of the main clause, these patterns suggest that cross-modal naming is sensitive to the initial semantic or syntactic transitive representation.

When intermediate boundaries followed transitive-bias verbs, naming times grew *shorter* as verbs became more likely to occur with a direct object ($R^2 = .28$, $p = .05$), even though these implausible targets were ultimately reanalyzed as subjects of the main clause. Although the current experiments do not focus on intermediate phrases, the results are consistent with claims in [1] that intermediate phrases delay syntactic integration. In fact, this experiment potentially provides the first online evidence of prosodic visibility. Regardless, the results again suggest that cross-modal naming is sensitive to the initial syntactic (i.e., transitive) representation.

Finally, when an intonation boundary followed an intransitive-bias verb, naming times grew *shorter* as verbs became more likely to occur without a direct object ($R^2 = .21$, $p = .07$). Note that this condition is unlikely to involve reanalysis; there should be wrap-up to an intransitive structure and meaning at the verb. Thus, the intermediate phrase accompanying the intonation boundary may delay syntactic integration. At the very least, cross-modal naming appears to be sensitive to the initial syntactic (i.e., intransitive) representation.

3. Conclusions

Experiment 1 replicated previous findings [2] that the location of an intonation boundary can determine the initial structure for the temporary closure ambiguity in (1). While the results also demonstrated that the effect did not depend on the use of equi-bias verbs, the effect did depend on more than intonation boundary location. Intonation boundaries were found to trigger wrap-up of semantic *and syntactic* processing. In turn, they sometimes resulted in representations that conflicted in their transitivity. Resolution of that ambiguity fell to other prosodic and semantic factors. Finally, the results demonstrated that cross-modal naming is highly sensitive to initial syntactic, semantic, and prosodic representations.

4. Acknowledgements

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5. References

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