# SITUATIONAL CONSTRAINTS ON THE PROSODIC RESOLUTION OF SYNTACTIC AMBIGUITY

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**ABSTRACT**

Speakers' prosodic marking of syntactic constituency is often measured in sentence reading tasks that lack realistic situational constraints on speaking. Results from such studies can be criticized because the pragmatic goals of a reader differ dramatically from those of speakers in typical conversation. On the other hand, recordings of unscripted speech do not readily yield the carefully controlled contrasts required for many research purposes. Our research employs a cooperative game task, in which two speakers use utterances from a predetermined set to negotiate moves around gameboards. Results from a set of prepositional phrase ambiguities suggest that speakers signal the syntactic structural difference between two attachment possibilities, even when the utterance context disambiguates the attachment. However, our results also show that prosodic marking is greater when the utterance is a directive one, rather than a confirmatory one, suggesting that there are some pragmatic situational constraints on prosodic resolution of ambiguity.

## 1. INTRODUCTION

A wide range of sentence comprehension studies have now shown that prosody can disambiguate syntactic structure. These studies have relied largely on materials pronounced by trained speakers who intend to provide a disambiguating contour. However, the relevance of such materials has been questioned in the comprehension literature [14], and also in recent production studies. These suggest that the utterances used are atypical [1], since speakers are far more likely to use prosody to disambiguate syntax when explicitly instructed to do so, or when the sentence is not disambiguated by the preceding context [10], findings that reflect earlier work on the relationship between syntactic structure and speech features [3]. However, these production studies also rely on oral reading tasks, which lack realistic situational constraints on speaking. Because the pragmatic goals of a reader differ dramatically from those of speakers in typical conversation, production results from reading tasks may not accurately reflect the prosody of natural conversation.

On the other hand, recordings of unscripted speech do not readily yield a sufficiently rich sample of the carefully controlled contrasts required for many research purposes. In between these two types of study — sentence lists and unscripted speech — sits research that attempts to constrain the range of likely utterance types by involving speakers in some kind of role play. For instance, map tasks [2], in which speakers have to give directions from one point on a map to another, have proved useful in eliciting such contrasts as that between given and new information; and descriptions of networks of coloured nodes have supplied a wealth of data on aspects on the planning, sequencing and repair of utterances [5]. Yet these tasks are not designed for the study of syntactic ambiguities, and cannot provide a large enough set of contrasting structures. In order to produce such contrasts, our research employs a cooperative game task, in which two speakers use utterances from a predetermined set to negotiate moves around gameboards. This set of utterances is designed to include a number of syntactic ambiguities commonly studied in comprehension studies. Our expectation is that sufficient practice with this set will ensure that speakers use these utterances fluently and without the need to read them from a list, thus providing a rich source of data for the study of syntactic ambiguity resolution in speech.

In addition, the layout of the gameboards, which — like the maps used in map tasks — differ slightly for each participant, is carefully designed to elicit key utterances in more or less constraining contexts. We are thus able to use the collected utterance data to explore the relationship of situational constraints to the necessity for and extent of prosodic resolution of syntactic ambiguity. Ultimately, the use of such utterances in comprehension studies will allow us also to investigate in greater depth the relationship between syntactic and prosodic structure in comprehension, including issues such as whether prosody directs or constrains syntactic analysis [11].

## 2. THE PRODUCTION TASK

### 2.1. Method

The language production task used in this study is a cooperative game task in which two players use scripted utterances to negotiate moves of gamepieces from starting positions to goals. The game is non-competitive, and the players are encouraged to work together to accumulate points for the successful movement of objects to their goals, while avoiding the deduction of points for false moves or incorrect usage of expressions. There are two versions of each board. One is used by the "driver", who knows the goal locations for the gamepieces, but does not know the locations of bonuses and hazards. The driver's role is to tell the other player which piece to move, to inform the other player when s/he moves incorrectly, and to confirm that a gamepiece has reached its goal position. The other board is used by the "slider", who does not know the goal locations, but does know the whereabouts of bonuses and hazards. The slider has to choose directions to move in and to report moves back to the driver, but is also required to ask the driver for more information when necessary. Neither player can see the board being used by the other, and the design of the boards and of the rules of the game encourages negotiation and the strategic use of moves. In addition, board layouts are designed to allow varying levels of situational constraints on the moves that are possible, i.e. at certain points in the game only a subset of the gamepieces can be or need to be moved. These constraints affect the likelihood of

syntactic ambiguity. Four pairs of gameboards, with differing layouts, have been used, plus a pair of practice boards and a demonstration board.

Each pair of subjects plays multiple rounds of the game, switching roles and gameboards between rounds. They wear head-mounted microphones, and their utterances are recorded simultaneously to both computer disk and cassette tape. Subjects are also required to use a placemarker, which they place in the position of the gamepiece that they wish to move, and which provides the experimenter with extra information concerning the players' intentions.

### 2.2 Materials

The gameboard utterances of interest to our investigations of syntactic ambiguity resolution include temporary syntactic ambiguities, such as the contrast between direct object and sentence complement attachment in (1) and (2),

(1) I am able to confirm the move of the cylinder.
(2) I am able to confirm the move was the final one.

as well as the global syntactic ambiguities reported in this paper, involving prepositional phrase (PP) attachment, as shown in the driver's line in (3) and in the slider's response in (4).

(3) I want to change the position of the square with the triangle.
(4) I am able to confirm the move of the square with the triangle.

Here, following the rules of the game, the move involves either a combined square-and-triangle piece (which we will refer to here as the 'house'), or the use of a triangle to move a square to another position. Syntactically, this corresponds in (3) to a contrast between low attachment of the PP 'with the triangle' as part of a noun phrase with 'the square' and the high attachment of the same PP under the verb phrase node. In (4), low attachment involves modification of 'the square' and high attachment is to an NP that is higher in the syntactic tree, namely 'the move'.

Contrasts of low and high attachments of PPs have been studied in sentence reading studies, which have revealed small but consistent differences, with greater pausing and pre-pausal lengthening prior to the PP in the high attachment case [3, 12]. In paragraph contexts, i.e. with no explicit disambiguation necessary for the reader, such differences are not found [3, 10].

Two sets of data will be discussed below. The first was collected in Wellington as a pilot study under the supervision of the second author, and the second more comprehensive data-set was collected in Kansas under the direction of the first author. Further New Zealand English data, matching the design of the Kansas data, have also been collected, and are currently undergoing analysis.

### 2.3. Pilot study

**2.3.1. Data-set.** Four pairs of subjects were used in this study. Each pair completed a practice game, with one participant as driver and the other as slider. In addition, each pair played two games more, using two further boards. Since one purpose of this pilot was to trial the range of gameboards, there was little consistency in which boards were used for each pair. The utterance set available to the subjects was, however, the same across all experiments.

Subjects' use of the placemarker was especially important in analysing the PP data, as it helped the experimenters to determine whether a speaker wanted to move the 'house' or the square, i.e. whether they intended a low or high attachment of the PP. The experimenters also kept a log of the situation of the game at the point where a PP ambiguity was uttered, and this log facilitated the subsequent analysis of the situational constraints on the PPs.

In total, we recorded 64 exemplars of the utterance illustrated in (3), 22 of which were low attachment forms, and 42 of which were high attachment forms. There were 55 cases of the slider line in (4), 19 as low and 36 as high attachments.

Durational measurements were taken of the pause (if any) before the PP, and of what we shall refer to as the 'rhyme' of the preceding word. This started at the /k/-release, this being a point that is reasonably easy to identify reliably. The 'rhyme' finished at the end of the vowel, except that in cases where the vowel was not followed by silence the end of the vowel was taken as the point at which lowering of F2 for the following /w/ commenced, as read from spectrograms for the utterances.

**2.3.2. Hypotheses.** Our first, general hypothesis was that speakers would distinguish between low and high attachment cases of the PP ambiguities by different timing patterns just prior to the PP, i.e. in the duration of the word before the PP ('square') and of any pause following that word, both of which will be greater in the high attachment case. This would provide a replication of earlier studies using sentence reading tasks [3, 12], but note that in this case the structure of the sentence is determined by the communicative needs of the speaker, rather than by any explicit disambiguation such as used in some of the earlier studies [1].

A second hypothesis is that the communicative needs of the driver will be greater than that of the slider, since the latter uses utterances that merely confirm the moves requested by the former. This difference will be reflected in a greater effect of the height of PP attachment in the driver's utterances than in the slider's utterances.

**2.3.3. Results.** Figure 1 shows the mean durations of the rhyme of 'square' and of the following pause in low and high attachment ambiguities for driver and slider utterances. Note first that there were no measurable pauses for any of the low attachment cases. The mean rhyme durations from each speaker were subjected to Analyses of Variance (ANOVAs) with speaker role (driver and slider) and PP attachment (low and high) as independent variables. Both main effects and the interaction were significant. The significant interaction ($F[1,28] = 4.56$, $p<0.05$) reflects the greater difference between attachment types for drivers (see (3) above) than for sliders (4). Post hoc analyses confirmed that the overall main effect of low versus high attachment was stronger for driver lines than for slider lines.

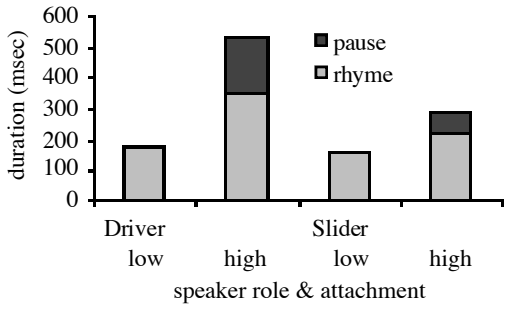


Figure 1. Rhyme and pause durations prior to PP attachment sites.

**2.3.4. Discussion.** These pilot data show that speakers distinguish PP attachment ambiguities in a situation that is quite different from sentence reading tasks, and in a situation in which explicit disambiguation is not given by the experimenter. Significantly, the data also show that when speakers are performing as drivers, and issuing instructions for subsequent moves, they are more consistent in marking the disambiguation than when they are in the role of slider, where the utterances simply confirm a move that has already been requested by the other participant. This suggests that speakers may be sensitive to the situational constraints of the gameboard and to the relative need to disambiguate more clearly. However, we noted earlier that the syntactic analyses of the driver and slider lines differ, and so it is possible that the greater difference between attachment types for drivers is a consequence of structural differences.

To investigate further the role of situational constraints on the resolution of ambiguities in production, the analysis of the more extensive data-set reported below partitions driver lines into three separate categories, according to the level of ambiguity in the game situation in which each line was uttered.

**2.4. Main study**

**2.4.1. Data-set.** The data for the main study come from 9 pairs of subjects recorded at the University of Kansas. Of these, 4 speakers were excluded because they failed to complete enough games to make the analysis of their data valid, and one because he seemed unable to relax into the game and become fluent. Apart from minor variations, the gameboards were the same as in the preceding study, and the essential aspects of the methodology did not differ, though the experimenters were not the same. All pairs completed a practice game, with one participant as driver and one participant as slider. In addition, each pair played at least two games more, using a separate board. Players played for 2 hours, and completed as many games as they could within that time, playing each board twice, once in the role of the slider, and once in the role of the driver. The maximum number of games played, not including the practice game, was 5 games, involving 3 different boards. A small number of utterances (17) were eliminated from analysis because they were disfluent in the sense of having a wrong word or mispronounced word, leaving a total of 180 PP attachment ambiguities produced by drivers (101 low and 79 high attachments) and 196 produced by sliders (120 low, 76 high). The analysis to date has focussed on the driver lines, since it is anticipated that these will be more sensitive to situational constraints than the slider lines. The digitised speech files for the driver lines have been analysed for durational properties. Here we will present data for the durations of 'square' and the following pause.

In addition, the recordings of each session and the log-sheets kept by the experimenters during the recordings were analysed to determine the level of situational ambiguity of the PP sentence in each case. Each instance was assigned to one of three categories: clearly unambiguous (e.g. it is impossible to move the 'house' and a triangle is adjacent to a square), ambiguous (it is possible, under the current game situation, to move either a square using a triangle or a 'house'), or biased. In the latter case, the game situation is such that one attachment is much more likely than another (e.g. when a triangle has just been moved adjacent to a square), but the other attachment is still possible (e.g. in the same example, the 'house' can still be moved).

**2.4.2. Hypotheses.** First, we predict that the speakers in this set, like those in the smaller preceding study, will consistently distinguish between low and high attachments of the PP, and that this will be reflected in greater durations of 'square' and the following pause in the high attachment cases. Second, we hypothesise that speakers in the driver role will be more likely to produce prosodic marking of disambiguation in ambiguous than in unambiguous cases, and that the biased situations will produce patterns more similar to the unambiguous cases.

**2.4.3. Results.** Figure 2 shows mean durations for 'square' and any following pause for low and high attachment cases in the driver utterances. Planned comparisons were performed on the subjects' mean durations, and showed that both the duration of 'square' and that of the following pause were significantly greater in the high attachment case ($F = 9.11$, $p<0.02$ and $F = 27.22$, $p<0.01$, respectively), confirming the finding of an attachment height effect for the preceding data-set.


Figure 2. Mean durations of 'square' and following pauses in driver utterances.

The low attachment data were distributed very unevenly across the speakers and the categories for level of ambiguity. There were only four utterances from three speakers in the ambiguous category, and twelve utterances from a separate set of three speakers in the biased category, as compared to eighty five utterances from thirteen speakers in the unambiguous category. Therefore, the second hypothesis, relating to the effect of

situational constraint on ambiguity resolution, was examined only for the high attachment cases, where the distribution was more even (26, 26, and 27 instances respectively). We analysed the duration of the word 'square' and the following silence for the high attachment cases at three levels of ambiguity. We used the criterion that to be included a speaker must have at least two utterances in each level of ambiguity. We included a total of eight speakers and sixty-one utterances in this analysis. In this case, the mean durations for 'square' and for the following pause did not differ significantly according to ambiguity level (Figure 3) in either ANOVAs or planned comparisons.

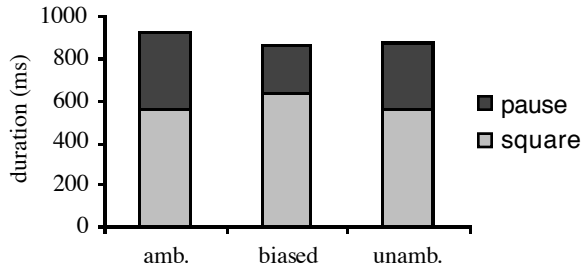


Figure 3. Mean durations of 'square' and following pauses by ambiguity level, in high attachment driver utterances.

At the time of writing, work is in progress on the phonetic and phonological analysis of the tonal properties of our PP attachment ambiguities. One issue that will be addressed is whether the situational constraints resulting in different ambiguity levels are reflected in tonal differences, despite the lack of durational differences. If so, the data will reflect earlier research showing reduction of tonal but not durational contrasts in NN/NV category ambiguity sequences such as 'the park acts' when these follow biasing sentence contexts [12].

**2.4.4. Discussion.** The PP attachment data from this second study replicate the finding in the pilot of a difference in the marking of high and low attachments, at least in terms of the durational patterns reported here. However, they fail to support our second hypothesis that speakers in the role of drivers are less likely to give prosodic disambiguation to contextually disambiguated or biased instances of these global syntactic ambiguities. It would appear then that the marking of the higher attachment is determined chiefly by the syntactic structure of the utterances.

## 3. DISCUSSION

The results from the two studies reported above consistently show prosodic disambiguation of syntax, unlike other production studies, but are consistent with what would be expected on the basis of our comprehension work, which shows that listeners are very sensitive to prosodic disambiguation of syntax [4, 6, 7, 12, 13], and also consistent with previous results from this experimental paradigm for an Early/Late closure ambiguity [8, 9].

Our results suggest also that the pragmatic goals of the speaker may be very important to the level of prosodic phrasing assigned at syntactic boundaries, as shown by the driver/slider differences in the pilot study. These differences could also be due to the level of syntactic 'closeness' indicated by the prosodic phrasing. If it does turn out that speakers reliably mark the syntactic 'closeness' of PP relations prosodically, this indicates that the detail of what is indicated about syntax in the prosodic representation is informative indeed.

Two factors distinguish our study from previous research that has not shown such a consistent relationship between syntax and prosody [1]. First, our materials contain argument structures rather than ambiguously-attached adjuncts. We would argue that the interpretation of the former is more likely to require clear disambiguation, as reflected in our data. Second, our task more closely simulates meaningful conversation, and to the extent that our results are different from those found in reading tasks, we can argue that our results are the more representative of the degree to which prosodic disambiguation of syntax is likely to be found in 'everyday' speech.

In general, the reliability of prosodic disambiguation across the two dialects of English, and across the driver and slider constraints on communication, and across the levels of ambiguity in the moves of the game, suggests that prosody is an important source of information for sentence processing in a wide range of discourse situations.

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