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Interplay of Syntactic Parsing Strategies and Prosodic Phrase Lengths in Processing Turkish Sentences

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1 Introduction

One of the most influential theories in sentence processing research, the Garden Path Model, maintains that the human language parsing mechanism (henceforth *the parser*) is guided by universal syntactic parsing strategies such as Late Closure and Minimal Attachment (Frazier 1978). Consider the ease of reading (1) and (2) below (without any commas indicating the syntactic structure).

- (1) When Roger leaves the house it's dark.
- (2) When Roger leaves the house is dark.

(Kjelgaard and Speer 1999:153)

According to the Late Closure (LC) principle, whose predictions are tested in this study, incoming words are preferentially attached to the phrase currently being processed. This is the case in (1), where the incoming words, *the house*, attach locally into the verb phrase currently being processed. However, the parser would face difficulty in processing (2) because the LC strategy would favor the analysis *Roger leaves the house*, whereas the correct analysis of (2) has *the house is dark*, with Early Closure (EC) of the first clause *Roger leaves*.

Studies contributing to the original development of the Garden Path Model and other models at the time were based mostly on data from reading studies, but over the years it became more practical to study spoken language, and its prosody, as suitable software tools became available. Research investigating the processing of spoken language indicates that prosodic cues¹ can have a facilitatory effect when located at syntactically appropriate positions in utterances (Lehiste 1973, Kjelgaard and Speer 1999 among others). For instance, a pause after *leaves* or an increased pitch accent on *leaves* could prevent the parser being tempted by the incorrect LC analysis in (2). Some studies found prosodic cues to be so influential that they would mislead the parser towards an incorrect interpretation when presented at syntactically inappropriate positions (i.e., a prosodic boundary after *leaves* in (1) or after *the house* in (2)). Speer, Kjelgaard and Dobroth (1996) and Kjelgaard and Speer (henceforth abbreviated as SKS) reported an interesting asymmetry for such conditions. It was found that incorrect clause boundary prosody disrupted the parsing of EC sentences like (2) more than it disrupted the parsing of LC sentences like (1).

This study investigates two possible explanations for this asymmetry. (i) Does the LC strategy apply not only when prosody is absent but also when it is not supportive? (ii) And/or do phrase lengths affect the perceived informativeness of prosodic cues? The answers to these questions will have consequences for our understanding of the nature of the interplay between prosodic and syntactic information in human language processing. Experiments were conducted in Turkish, a language whose morpho-syntax is well-suited to this study (see Section 2) but which has not been previously investigated in relation to the role of prosody in syntactic parsing and comprehension.

1.1 Previous Findings and Their Interpretation

SKS investigated LC/EC ambiguities such as (1) and (2) above. They employed acceptability judgment, end-of-sentence comprehension, and cross-modal naming tasks. Experimental items had three prosodies: cooperating, conflicting and neutral (baseline) as in (3) (|| marks prosodic boundaries, / marks syntactic boundaries and boldface indicates contrastive focus to elicit neutral prosody elsewhere in the sentence).

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¹Prosody is the stress, rhythm, and intonation in spoken utterances, which have measurable acoustic-phonetic correlates, such as variation in fundamental frequency, amplitude and duration.

- (3) a. Cooperating prosody, LC syntax: When Roger leaves the house || / it's dark.
 b. Cooperating prosody, EC syntax: When Roger leaves || / the house is dark.
 c. Conflicting prosody, LC syntax: When Roger leaves || the house / it's dark.
 d. Conflicting prosody, EC syntax: When Roger leaves / the house || is dark.
 e. Neutral prosody, LC syntax: When **Roger** leaves the house / it's dark.
 f. Neutral prosody, EC syntax: When **Roger** leaves / the house is dark.
 (Kjelgaard and Speer 1999:156)

Within the cooperating prosody conditions, LC and EC structures were processed equally efficiently. In the neutral prosody conditions, there was an advantage for the LC structure, which can be attributed to the parser following the syntactic processing strategy of LC, as it does in reading where there is also an absence of prosodic information. For purposes of the present study, the observation of main interest is the finding of an advantage for the LC structure in the conflicting prosody conditions.

SKS list some possible explanations, specific to their study, for this asymmetry (e.g., a possible topicalized noun phrase reading of the ambiguously attached NP in the LC–syntax conflicting conditions, such as ...*the house, it's dark*). However, a proposal of a general default LC parsing strategy not just when prosody is absent but also when prosody is perceived as uninformative is especially worthy of further investigation because of a similar LC syntax advantage observed in a subsequent study by Augurzky (2006) in a different syntactic construction (relative clause attachment ambiguity) in a different language (German). The following section discusses the LC advantage in the SKS and Augurzky studies from a different perspective.

1.2 A Novel Explanation for the Conflicting Prosody Results

The similar outcomes of the SKS and Augurzky studies are intriguing in view of how different the constructions tested were. However, there is another overlap between these experiments which could also possibly explain the data. The alternative explanation is related to the lengths of the prosodic phrases, and it derives from research demonstrating the effects of phrase lengths on the perceived informativeness of prosodic cues. Neither SKS nor Augurzky systematically manipulated the length of the phrases in their sentence materials. However, the Rational Speaker Hypothesis (RSH) formulated by Clifton, Carlson and Frazier (2006) proposes that prosodic breaks flanking short constituents are treated by perceivers as more informative about the syntactic structure of an utterance than prosodic breaks flanking long constituents. The rationale is that if a prosodic break might have been produced by the speaker in order to divide up an over-long constituent, then it may not be taken seriously by listeners as an indicator of syntactic structure; however, a prosodic break that has no length motivation is more likely to be attributed by listeners to the needs of the syntactic structure, and thus could have a greater impact on what structure the parser assigns to the sentence. Support for this hypothesis was provided by data from NP coordination and adverb phrase attachment in English.²

Furthermore, it has been reported that in some languages speakers tend to divide their utterances into equal size units, following a eurythmic ‘uniformity principle’ (Italian: Ghini 1993, Brazilian Portuguese: Sandalo and Truckenbrodt 2002, French (‘balance’): Pynte 2006). The Uniformity principle states that “A string is ideally parsed into same length units” (Sandalo and Truckenbrodt 2002:298, cf. Ghini 1993). Pynte (2006) reported such uniformity effects in listeners’ attachment of prepositional phrases in French. He observed that listeners relied on the lengths of previous prosodic units to predict the length of the next one, generating syntactic expectations. When a long phrase followed a sequence of short ones, its length was treated as more informative of the syntactic structure: there was more low PP–attachment than when all phrases were long. Pynte’s findings encourage extension of the Rational Speaker Hypothesis (RSH) to all rhythmic phenomena. Thus we propose the *Extended Rational Speaker Hypothesis (ERSH)*:

²Clifton et al. (2006) counted number of syllables in their metric of phrase length. Here, we assess length in terms of the number of prosodic words.

Extended Rational Speaker Hypothesis (ERSH): Listeners are sensitive to the speaker's reasons for producing a prosodic phenomenon. If it could be due either to syntactic alignment or to eurythmic pressures, the possibility of the latter reduces the probability that the listener will treat it as a consequence of the syntax.

For Kjelgaard and Speer's conflicting prosody conditions (3c) and (3d) above, it can be observed that the length of phrases before and after the prosodic boundary might have affected the results. In the EC syntax condition with conflicting LC prosody, (3d), the prosodic break is placed before a short phrase (*is dark*) consisting of 1 prosodic word (PWd), 2 syllables. According to the ERSH, it would be taken as a strong cue to syntactic disambiguation since phrase length cannot justify the break. However, in the LC syntax condition with conflicting EC prosody, (3c), the prosodic break occurs between two longer units (*when Roger leaves*, and *the house it's dark*) consisting of 3 PWds, 4 syllables and 2 PWds, 4 syllables respectively, which is more balanced. The ERSH therefore implies that the EC prosodic break in (3c) is not as strong a cue to syntactic disambiguation for perceivers as the LC prosodic break in (3d) is. Thus, the SKS finding of greater resilience of LC syntax to conflicting prosody might be due to a tendency for listeners to disregard the EC prosodic break that conflicts with the LC syntax. If so, this would not reflect any effect of LC/EC syntax per se, but would be a fact about the particular sentences used in the SKS experiments, given their specific distributions of phrase length.³ Similar length distributions are observed for the conflicting prosody conditions for Augurzky's German materials, which also favored LC syntax. Moreover, an EC advantage found by Schafer, Speer, Warren and White (2000) is also explained, since in their materials the length distribution favored the EC structure.

In the present study, the lengths of the prosodic phrases in the LC and EC prosodic contours are systematically manipulated, in order to determine whether phrase lengths affect how easily the parser copes with conflicting prosody, as could be expected on the basis of the ERSH. This could be investigated in English by adding phrase length variation into the SKS materials. However, the Turkish language also has LC/EC temporary ambiguities and has other properties that are especially helpful in designing such a study, as will be clear below.

2 The Present Study

Two auditory experiments were conducted to investigate whether or not the outcomes of previous studies, particularly the SKS experiments on English, would replicate in Turkish with comparable methodology and a different LC/EC ambiguity, illustrated in (4) below. The specific aim was to find out whether or not phrase lengths would have an effect on the parser's evaluation of prosodic breaks, in addition to or instead of the effects of a syntactic Late Closure strategy.

The experimental sentences all contained 6 PWds grouped into two prosodic phrases, but the groupings differed between 2+4 PWds, 3+3 PWds, and 4+2 PWds. In Turkish every lexical word is realized as a PWd (Inkelas and Orgun 2003). The prosodic phrases in the target materials for the experiments consisted of 3+3 PWds (balanced), or 4+2 PWds (unbalanced) or 2+4 PWds (unbalanced). In deciding on the appropriate length of material before/after the prosodic break, an analysis of pause frequencies provided in Nash (1973) was used. Nash's pause frequency data revealed that readers paused every 4.2 words on average (with a range from 2.9 to 7.8 words). Therefore, prosodic phrases of 2 PWds would be perceived as short, while those with 3 or 4 PWds would fall within normal range.⁴ To explore phrase length effects, an additional word was included in either the subject or the VP of a basic five-prosodic-word pattern. The lengthening words (in parentheses in (4)), such as adverbs, were words that would not introduce an additional prosodic boundary or add significantly to the meaning of the sentence.

³In what follows, we will discuss prosodic phrasing in terms of length balance only. Whether absolute phrase length or length balance is the more important factor cannot be determined on the basis of the present study. It can be investigated in further work using longer sentences with multiple prosodic phrases (cf. Pynte 2006).

⁴It should be noted that the results of the experiments reported here might reflect the fact that the two-prosodic-word phrases were perceived as unduly short, rather than prosodic imbalance. The current experiments do not address this (see footnote 3).

- (4) a. LC: Ø (Yaklaşık) **yedi** öğrenci-nin psikoloğ-u || /
 (Pro) Approximately seven student-GEN psychologist-3SG.POSS-
 (oldukça) sev-il-di san-ıyor-uz.
 (NOM) much like-PASS-PAST think-PROG-1PL.
 ‘We think that the psychologist of (approximately) seven students was (much) liked.’
- b. EC: Ø (Yaklaşık) **yedi** öğrenci-nin || / psikoloğ-u
 Pro Approximately seven student-GEN psychologist-ACC
 (oldukça) sev-diğ-i-ni san-ıyor-uz.
 (much) like-FN-3SG.POSS-ACC think-PROG-1PL
 ‘We think that (approximately) seven students liked the psychologist (much).’

All target sentences consisted of a main clause verb, whose subject was phonologically null, following a complement clause containing an overt subject and a verb phrase. (Turkish is a head-final pro-drop language.) The temporary syntactic ambiguity of these sentences has two contributing causes. One is homophony of the morpheme on the second noun (psychologist, in (4)), which is phonologically identical within each target sentence item set but which must be interpreted as a third person singular possessive suffix in the LC versions, and as an accusative case marker in the EC versions. The second cause is that subjects are marked differently in finite complement clauses, as in the LC versions, than in nominal complement clauses, as in the EC versions. In finite complements the subject is nominative; in nonfinite (nominal) complement clauses the subject is in genitive case and hence is temporarily confusable with a genuine possessive construction. This case-marking difference between LC and EC conspires with the fact that nominative case marking in Turkish is phonologically null (thus is indicated in parentheses in the above examples) in a finite complement clause (Göksel and Kerslake 2005). In the LC version (4a), the two nouns (student and psychologist) form a complex NP, which has no overt nominative marking but functions as the subject, i.e., late closure of the subject: student-GEN psychologist-3SG.POSS-(NOM). In the EC version (4b), only the first noun constitutes the subject; the subject must be closed early, ending at student-GEN, because the subordinate verb is transitive and it is preceded by its accusative object: psychologist-ACC. Thus the subordinate verb is the crucial disambiguator between late closure and early closure of the subject.

An intonational phrase (IPh) prosodic boundary would normally fall between the subject and the verb phrase of the complement clause.⁵ The location of that IPh boundary in utterances of sentences like (4a,b) provides a clear prosodic cue to their respective syntactic structures, eliminating the ambiguity before the morphosyntactic disambiguation at the embedded verb becomes available. In Experiment 1, target items were similar to the SKS materials with respect to the relation between LC/EC syntax and phrase lengths. In the LC condition, the subject had 4 PWds, yielding a natural prosodic phrasing of 4+2 PWds (unbalanced); in the EC condition, the subject had 3 PWds, yielding a natural prosodic phrasing of 3+3 PWds (balanced). In Experiment 2, the length distribution was reversed; in the LC condition, the subject had 3 PWds, yielding a natural prosodic phrasing of 3+3 PWds (balanced); in the EC condition, the subject had 2 PWds, yielding a natural prosodic phrasing of 2+4 PWds (unbalanced). Table 1 below illustrates phrase length distribution in Experiments 1 and 2.

If differences in processing difficulty between LC and EC structures were due entirely to the Late Closure parsing strategy, outcomes of these two experiments should be similar. However, if prosodic balance also plays a role in sentence processing, different outcomes for the two experiments are predicted, as detailed below.

⁵ In both (4a) and (4b), the constituent before the prosodic boundary is the subject of the subordinate clause. The default topic position in Turkish is sentence-initial. Subjects typically occur at the beginning of sentences, and are the default topic in the canonical SOV word order (Erguvanlı 1984). Topics are followed by an IPh boundary, associated with an exaggerated high pitch accent, a rising tone with a following optional pause (Kamali 2008, Kan 2009, Vallduví and Engdahl 1996).

	Cooperating Prosody	Conflicting Prosody	Neutral Prosody ⁶
Experiment 1	LC (4+2 PWds)	LC (3+3PWds)	LC (4+2 PWds)
(Lengths similar to SKS)	EC (3+3 PWds)	EC (4+2 PWds)	EC (3+3 PWds)
Experiment 2	LC (3+3 PWds)	LC (2+4 PWds)	LC (3+3 PWds)
(Lengths reversed)	EC (2+4 PWds)	EC (3+3 PWds)	EC (2+4 PWds)

Table 1. Phrase length distribution in three prosody conditions in Experiments 1 and 2.

2.1 Experiment 1

2.1.1 Materials

The target sentences in Experiment 1 had longer subjects (e.g., including the modifier “approximately” in (4a,b)) but shorter VPs (the modifier “much” in (4a,b) was not present). The LC and EC target sentences were each recorded by the first author, with three different prosodies: cooperating, conflicting and neutral.⁷ Cooperating prosody had an IPh boundary following the subject, cuing the correct syntactic structure; conflicting prosody had an IPh boundary in the position appropriate to the incorrect interpretation of the temporary ambiguity; neutral prosody had no prosodic boundary (made natural by a contrastive accent on a word inside the subject, marked in bold in (4a,b), which ‘flattened out’ the intonation of the remainder of the sentence).

There were a total of 144 experimental sentences: 48 cooperating prosody (24 LC, 24 EC), 48 conflicting prosody (24 LC, 24 EC), and 48 neutral prosody (24 LC, 24 EC). The items were distributed across six lists counterbalancing for prosody (cooperating, conflicting, and neutral) and syntactic structure (LC vs. EC). Thus, each list included 24 target sentences. In each list, there were an additional 24 sentences of a different ambiguity with cooperating, conflicting and neutral prosody and also 48 unambiguous fillers of various syntactic construction types, of which 24 had neutral prosody and 24 had congruent prosody. In addition, there were 10 items used in a practice session prior to the beginning of the experiment and 10 implicit ‘warm-up’ items, 5 at the beginning of each list and 5 half way through, where participants were encouraged to take a rest break. Thus, each list following the practice session consisted of 106 sentences.

2.1.2 Participants and Procedure

Fifty-four native speakers of Turkish took part in the experiment (mean age = 25.2, 17 male). The procedure was designed to closely match that of SKS’s end-of-sentence comprehension experiments. Following informed consent procedures, a participant was seated comfortably in front of a computer in a quiet room. The sentences were presented auditorily via noise-cancelling headphones. Participants were given instructions by the researcher at the beginning of the experiment. They were told to listen to the sentences carefully and at the end of each sentence to indicate as quickly as possible whether or not they had comprehended the sentence (the ‘got it’ task, Frazier, Clifton and Randall 1983), by pressing either the ‘yes’ button or the ‘no’ button (written on a green and red background respectively) on the keyboard. They were also instructed that they would be presented with comprehension questions at the end of some sentences. Thus, they needed to listen to the sentences carefully. There were 24 comprehension questions following either experimental or filler items; these were presented on the screen, after the participant’s ‘got it’ response. The practice session and implicit warm-up sentences were also followed by intermittent comprehension questions. Participants received 15 Turkish Liras (~\$8.5 at the time of the experiments) for their participation.

⁶ Neutral prosody had no overt prosodic boundary (see below); the phrase length distribution shown here reflects syntactic phrasing for this condition.

⁷ All target items were pre-tested via normative semantic ratings, and by pronunciation acceptability ratings, by trained judges. They were also subject to phonetic analyses to ensure the relevant prosodies (see details in Dinçtopal-Deniz 2014).

2.1.3 Data Analysis and Results

One participant's data were excluded due to failure to meet the criterion of > 85% accuracy on the comprehension questions. Some additional data points were excluded from the analyses due to either failure to press a key before the time-out limit (20 seconds) or too quick key presses (before the sound file ended); together, these amounted to 1% of the data.

The data were analyzed via mixed effects modeling (Baayen, Davidson and Bates 2008) using the R statistical computing software, version 2.15.2 (R Core Team 2012). The main analyses were run on log-transformed RTs and the independent variables were Prosody and Syntax. The model for Prosody showed that sentences with conflicting prosody were processed slower than the ones with neutral prosody ($\beta = 102$, $SE = 31.35$, $t = 3.59$, $p < .001$). Although sentences with cooperating prosody were processed faster than the ones with neutral prosody, the difference did not reach statistical significance ($\beta = -15.31$, $SE = 25.71$, $t = -0.6$, $p = .95$). The model with Syntax as a predictor variable showed that the LC structures were processed faster than EC structures ($\beta = -56.32$, $SE = 21.82$, $t = -2.51$, $p < .05$).

After analyses for main effects of each predictor variable, a more complex model including an interaction of the two predictors was built. A likelihood ratio test comparing the simple models to the complex one with interaction suggested that the model including the interaction explained the data better than the simpler ones ($X^2(3) = 8.03$, $p < .05$). This interaction model also allowed for random slopes for subjects by Prosody ($X^2(7) = 19.56$, $p < .01$). (See Dinçtopal-Deniz 2014 for further details on model building and data analysis.) RTs can be observed in Figure 1.

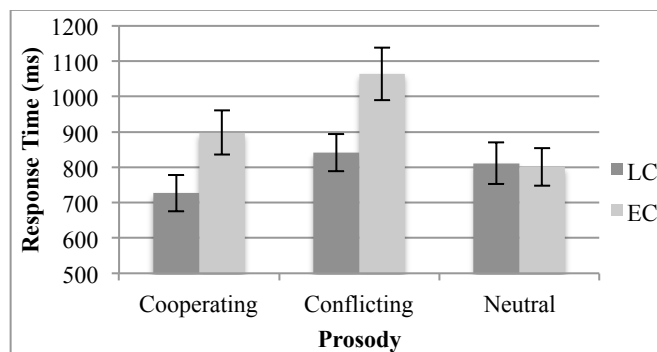


Figure 1: Experiment 1: Mean response times with standard errors for 'understood' responses.

Planned pairwise comparisons using the *glt* function showed that in cooperating and conflicting prosody conditions, structures with LC syntax were processed faster than those with EC syntax ($\beta = -.125$, $SE = .059$, $z = -2.10$, $p < .05$ for cooperating prosody, and $\beta = .251$, $SE = 0.062$, $z = -4.03$, $p < 0.001$ for conflicting prosody). There was no significant difference between LC and EC syntax in the neutral prosody condition ($\beta = .00007$, $SE = .062$, $z = .001$, $p = .992$).

Some tentative conclusions can be drawn from these response time data. As anticipated, positive responses were faster for cooperating prosody than for conflicting prosody, with neutral prosody in between. There was a clear LC syntax advantage in cooperating and conflicting prosody conditions. This advantage could be due to the syntactic LC strategy but it could also be attributed to the ERSH for the reasons discussed in Section 1.2 above. Results of Experiment 2 will allow us to disentangle these two possible explanations. In the neutral prosody condition, there was no advantage for either structure (unlike for SKS who observed an LC advantage in the neutral prosody condition). This absence of an LC advantage may indicate that the LC strategy did not apply. However, it is possible that an LC bias was present but was offset by an EC bias, due to a preference for balanced phrasing, as the Uniformity Hypothesis would suggest; in Experiment 1 a balanced 3+3 PWds would be associated with the EC syntax. This conclusion would rest on the assumption that listeners mentally project missing prosodic boundaries, as readers do (Pauker, Itzhak, Baum and Steinhauer 2011). However, a more conclusive statement can only be made after examining the results of Experiment 2.

So far we have considered RT's to 'understood' responses, but the percentage of 'understood'

responses in each condition is also of interest.

	Cooperating Prosody	Conflicting Prosody	Neutral Prosody
LC	96	97	94
EC	98	85	92

Table 2: Experiment 1: Percent ‘understood’ responses.

As can be seen from Table 1, the percent ‘understood’ responses (i.e., ‘yes’ button press to the ‘got it?’ query) was quite high (above 80%) for all the conditions. When compared with the neutral prosody condition, participants’ overall tendency to respond ‘yes’ increased for the cooperating prosody (odds ratio: $\beta = 2.6$, $SE = 1.47$, $z = 2.47$, $p < .05$) and it decreased overall for the conflicting prosody though this difference was not statistically significant ($\beta = .67$, $SE = 1.35$, $z = -1.3$, $p = .18$). Participants’ responses to the two syntactic constructions (LC/EC) show a similar pattern to their processing times in the conflicting prosody and the neutral prosody conditions. That is, in the conflicting prosody condition, participants were more likely to respond ‘yes’ for LC syntax than EC syntax ($\beta = 11.1$, $SE = 1.7$, $z = 4.51$, $p < .001$), while in the neutral prosody condition there was no significant difference in the probability of ‘yes’ responses for LC and EC syntax (z 's < 1.61). However, in the cooperating prosody condition also, the ‘yes’ responses did not differ significantly between LC and EC syntax, which does not mirror the RT data, where the LC structure showed a significant advantage. This could be due to the ease of comprehending both syntactic structures since prosody and syntax match in both.

These results for response times and ‘yes’ responses in Experiment 1 will be compared to those in Experiment 2 in order to understand whether or to what extent phrase lengths may have influenced processing rather than or in addition to a syntactic Late Closure strategy.

2.2 Experiment 2

2.2.1 Materials

In Experiment 2, the subject was shorter than in the Experiment 1 materials, since the modifier (approximately, in (4a,b)) was not present, while the subordinate VP was longer, with the addition of a modifier (much, in (4a,b)). As a result the natural prosodic pattern, with a break after the subject, is 3+3 for the LC version and 2+4 for the EC version. In all other respects the materials were identical to those of Experiment 1, including the number of experimental items, the fillers and practice items, and the proportion and distribution of comprehension questions.

2.2.2 Participants and Procedure

Fifty-two native speakers of Turkish drawn from the same subject pool as Experiment 1 took part in Experiment 2 (mean age = 26.2, 14 male). The procedures were the same as for Experiment 1.

2.2.3 Data Analysis and Results

All participants met the criterion of >85% accuracy on the comprehension questions. Some data were excluded from the analyses due either to no response before the time-out limit or to responding before the sound file ended; together these comprised 1.8% of the data.

Statistical software and procedures were the same as for Experiment 1. The log-transformed RTs were entered into a mixed effects model. The main analyses were run on the logRT with Prosody and Syntax as the independent variables. While building a model, each predictor variable was first entered into the model separately. The model for Prosody indicated that sentences with cooperating prosody were processed faster than those with neutral prosody ($\beta = -.52.41$, $SE = 25.87$, $t = -2$, $p < .05$) and sentences with conflicting prosody were processed slower than those with neutral prosody ($\beta = 138.96$, $SE = 33.88$, $t = 4.58$, $p < .001$). The model with Syntax as a predictor variable showed that there was not a significant difference between the LC and EC structures overall ($\beta = -17.96$, $SE = 23.84$, $t = -.76$, $p = .45$).

As for Experiment 1, a more complex model including the two predictors was then built. A log likelihood analysis comparing the simple models to the complex one with interaction indicated that the model including both predictors accounted for the data better than the simpler ones ($X^2(1) = .51, p = .47$ for the comparison of the simple model for Prosody vs. the complex model with Prosody and Syntax; $X^2(2) = 44.64, p < .001$ for the comparison of the simple model for Syntax vs. the complex model with Prosody and Syntax). This complex model also allowed for random slopes for subjects by Prosody ($X^2(7) = 16.03, p < .05$). RTs are shown in Figure 2.

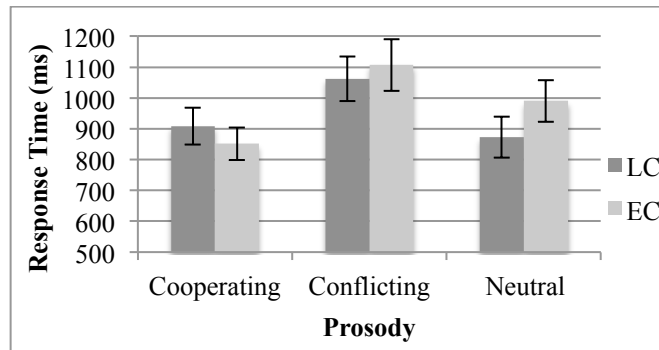


Figure 2: Experiment 2: Mean response time with standard errors for ‘understood’ responses.

Planned pairwise comparisons showed that in cooperating and conflicting prosody conditions, there was no reliable difference between the LC syntax and the EC syntax structures ($\beta = 6.97, SE = 44.77, z = -.161, p = .87$ for cooperating prosody, and $\beta = -2.19, SE = 45.08, z = -.05, p = .96$ for conflicting prosody). But for the neutral prosody condition, the LC structures were processed faster than the EC structures ($\beta = -86.12, SE = 39.63, z = 2.1, p < .05$).

Turning now to the ‘understood’ responses in Experiment 2, Table 3 shows the percentages for each condition. When compared to neutral prosody, it was more likely for participants to respond positively for the cooperating prosody (odds ratio: $\beta = 6.24, SE = 1.67, z = 3.54, p < .001$), but the conflicting prosody showed no reliable difference from the neutral prosody (odds ratio: $\beta = 1.04, SE = 1.38, z = .13, p = .89$). The specific results for each closure ambiguity condition are in accord with the response time data. Participants were more likely to indicate that they had understood the LC syntax than the EC syntax in the neutral prosody condition (odds ratio: $\beta = 4.3, SE = 1.68, z = 2.82, p < .05$), whereas there was no reliable response difference between LC and EC syntax in the cooperating and conflicting prosody conditions (z 's < 1.4).

	Cooperating Prosody	Conflicting Prosody	Neutral Prosody
LC	99	94	96
EC	98	92	90

Table 3: Experiment 2: Percent ‘understood’ responses.

The important finding here is that there was no LC advantage except in the neutral prosody condition, unlike Experiment 1. For the cooperating and conflicting prosody, the LC advantage of Experiment 1 disappeared; LC and EC syntax were processed equally easily. This implies that the LC advantage observed in Experiment 1 was not solely due to a syntactic LC strategy; phrase lengths evidently also influenced the ease of processing, presumably indirectly through their effect on how prosodic boundaries are evaluated by listeners as indicators of syntactic structure, as proposed by the ERSH. In Experiment 2, unlike Experiment 1, the LC analysis was not boosted by unbalanced prosody. On the other hand, since the EC analysis had unbalanced prosody in Experiment 2, the ERSH does not explain why Experiment 2 did not show an EC advantage instead. These two observations together suggest that there was a trade-off in Experiment 2 between the ERSH, which would favor EC, and a syntactic LC bias, which would disfavor EC.

This explanation for the overt prosody conditions is entirely compatible with the finding of an LC advantage for the neutral prosody condition, where ERSH is inapplicable, allowing the LC strategy to dominate the parse. However, an alternative explanation is also viable: the LC advantage might instead reflect a preference for 3+3 balanced prosody in the absence of overt prosodic phrasing, on the assumption, discussed above, that listeners mentally project a prosodic boundary when it is missing from the stimulus, as per Pauker et al.’s Boundary Deletion Hypothesis (2011) and Fodor’s (2002) Implicit Prosody Hypothesis for silent reading. With a bias toward balanced phrase lengths, boundary projection would suffice to predict an LC preference in Experiment 2’s neutral prosody condition. However, a syntactic Late Closure influence would still have to be assumed in general, in order to explain why no net EC advantage was observed in Experiment 1 for neutral prosody, length-balanced for EC.

3 Conclusion

We conclude by considering the crucial comparison between the two experiments, which can allow us to disentangle the various potential influences on ambiguity resolution in these constructions. Table 3 presents the summary findings from Experiments 1 and 2 together.

Experiment	Cooperating Prosody	Conflicting Prosody	Neutral Prosody
Expt. 2A	LC < EC	LC < EC	LC = EC
Expt. 2B	LC = EC	LC = EC	LC < EC

Table 3: Experiment 1 and 2, response time data pattern.

A mixed effects model was run to compare the RT data of Experiments 1 and 2. In this model, there was one more condition, namely Length which represented the subject vs VP length manipulation of the materials across the two experiments. As for the individual Experiments 1 and 2, analyses started with simpler models and were built up to where Length (Experiments 1 and 2), Prosody (cooperating, conflicting and neutral) and Syntax (LC and EC) interacted. A model including Length as well as Prosody and Syntax was compared via a likelihood ratio test to a simpler model including the Prosody and Syntax interaction. This indicated that the interaction model with Length, Prosody and Syntax explained the data better than the simpler one ($\chi^2(6) = 13.4, p < .05$). (See Dıngtopal–Deniz 2014 for details on intermediate model building steps.)

By comparing Figures 1 and 2, it can be seen that RT differences between the two experiments emerged in the LC structure in the overt prosody conditions, and in the EC structure for neutral prosody, supporting different mechanisms for processing overt prosody and absence of prosody as has been suggested above. Let us consider the two cases separately. For the overt prosody, the between–experiments difference for LC structure for both cooperating and conflicting prosody was in the expected direction, though only the latter was significant ($\beta = 162, SE = 119.47, z = 1.57, p = .11, \beta = 251.98, SE = 131.1, z = 2.33, p < .05$, respectively). This supports the hypothesis that when prosodic boundaries are overtly marked in the acoustic signal, a syntactic LC strategy and the interface processing principle ERSH are both at work. In Experiment 1, where they reinforced each other, there was a significant LC syntax advantage in both prosody conditions. In Experiment 2, where they opposed each other, it appears that they cancelled each other out: there was neither an LC syntax advantage, as would follow from Late Closure, nor an EC syntax advantage as would follow from the ERSH.

Turning to the neutral prosody condition, it is striking that it is the EC condition that shows the greatest RT difference across the experiments, with longer RTs in Experiment 2 than Experiment 1, though the difference does not quite reach conventional levels of significance ($\beta = 193.1, SE = 124.64, z = 1.83, p = .07$). This direction of RT differences was also predicted, on the basis that the ERSH does not apply when there is no overt boundary. The only relevant factors could be syntactic Late Closure and length balance in projected prosody. The observed LC advantage in Experiment 2 can be explained under the assumption that either or both factors were at work: LC syntax would be favored by the Late Closure strategy and also by the fact that LC structure was associated with balanced lengths. In Experiment 1, by contrast, there was neither an LC advantage,

as would follow from syntactic Late Closure, nor an EC advantage as would follow from balanced lengths in that experiment; apparently these two factors cancelled each other out. Thus, Experiment 1 and 2 neutral prosody results together indicate that both factors were at work.

All together, all three factors that we have considered here have been shown to have a role to play in LC/EC ambiguity resolution.

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