

Phrase Length and Prosody in On-Line Ambiguity Resolution

Ronit Webman-Shafran · Janet Dean Fodor

Published online: 10 March 2015
© Springer Science+Business Media New York 2015

Abstract We investigated the processing of ambiguous double-PP constructions in Hebrew. Selection restrictions forced the first prepositional phrase (PP1) to attach low, but PP2 could attach maximally high to VP or maximally low to the NP inside PP1. A length contrast in PP2 was also examined. This construction affords more potential locations for prosodic boundaries, and has a sharper structural contrast between the two attachment sites, than the single-PP construction which has yielded mixed results in previous work. A combined production–comprehension task showed more productions of pre-PP2 prosodic boundaries for long-PP2 than short-PP2. In comprehension, high PP2-attachment was favored by a prosodic boundary before PP2, regardless of PP2 length. This study provides performance data supporting the interplay of phrase lengths with structure-sensitivity as posited in the linguistics literature on the syntax–prosody interface, and supports the claim that readers are sensitive to the structural implications of the prosody they project onto sentences.

Keywords PP-attachment · Reading aloud · Sentence comprehension · Syntax–prosody interface · Phrase lengths

Introduction

Research on the syntax–prosody interface has provided clear evidence that speakers reliably produce prosodic cues to *clause* boundaries and listeners use these cues in parsing sentences

R. Webman-Shafran (✉)
49B Golomb Street, 4435749 Kefar Sava, Israel
e-mail: Ronit.shafran@gmail.com

R. Webman-Shafran
The English Department, Faculty of Education, Beit Berl College,
4490500 Beit Berl, Israel

J. D. Fodor
Graduate Center, City University of New York, 365 Fifth Avenue, New York, NY 10016, USA
e-mail: Jfodor@gc.cuny.edu

(Price et al. 1991; Schafer et al. 2000, among others). However, some doubt remains regarding whether the same applies to syntactic *phrase* boundaries.¹ This uncertain situation is summarized by Millotte et al. (2007), who note a variety of conflicting experimental results reported in the literature. (See Millotte et al.'s discussion for details.) They note two possible causes for the contrary findings: experimental protocols that do or do not emphasize cooperative communication; and phrase lengths which are or are not felicitous for the prosodic phrasing at issue. Regarding the latter, Millotte et al. note: "The actual realization of a prosodic boundary in a sentence depends on several factors, such as the syntactic structure, but also the length of the resulting prosodic constituents, with overly long and overly short constituents being disfavoured" (p. 900). As a result, prosodic groupings that match syntactic phrase structure may be avoided if they yield intermediate phrases that are non-optimal in length. Some frequently cited English examples fail to conform to standard length expectations, including *Tap || the frog with the flower* (Snedeker and Trueswell 2003) and *They rose early || in May* (Allbritton et al. 1996). (In this paper we mark intermediate phrase boundaries with the double-bar notation ||.)

We endorse the emphasis on phrase length as an important contributor to prosodic phrasing. Its role has been codified in the theoretical literature on the syntax–prosody interface in the form of optimal length constraints (such as BinMin and BinMax which jointly favor two prosodic words per intermediate phrase; Selkirk 2000, and elsewhere). Optimal length constraints may in some cases out-rank structure-based constraints; see further discussion below. In sentence processing studies, phrase length has emerged as a factor influencing height of attachment of a relative clause (RC) which could modify either a lower or a higher noun head. Short RCs are more likely to attach to the lower noun than long RCs, apparently universally (Kamide et al. 1998, for Japanese; Pynte and Colonna 2000, for French; Fernández 2000/2003, for English and Spanish; Wijnen 2001, for Jabberwocky; Lovrić 2003, for Croatian; Maia et al. 2004, for Brazilian Portuguese; Abdelghany 2010, for Egyptian Arabic; among others). This has been attributed (Fodor 2000) to the need for a short RC to be grouped prosodically into a larger phrase with adjacent words, which amounts to grouping it with the lower of the two nouns.

There are also constraints which promote uniformity ('balance') of prosodic phrase lengths within the same utterance, whether they are all long or all short. Sandalo and Truckenbrodt (2002) report that in Brazilian Portuguese, phrase length uniformity is a high-ranked constraint, such that a subject and following verb must be phrased in equal-sized units, regardless of their absolute lengths or their alignment with syntax. Examples (1) and (2) from Sandalo and Truckenbrodt illustrate this. The obligatory phrasing is evidenced by stress retraction to avoid stress clash within an intermediate phrase; it occurs between V and the following N in (1), but not in (2) where uniformity with the subject calls for single-word phrasing in the verb phrase. (The stressed syllable in the verb 'dançou' is underlined. As above, || marks an intermediate phrase boundary.)

(1) O cangurú australiano dançou samba. N A || V N
 the kangaroo Australian danced samba
 'The Australian kangaroo danced samba.'

(2) O cangurú dançou samba. N || V || N * N || V N
 the kangaroo danced samba
 'The kangaroo danced samba.'

¹ The prosodic phrases typically associated with sub-clausal syntactic phrases are referred to in the literature in various terms: *intermediate phrases*, *major phrases*, *phonological phrases* or *p-phrases*. We will follow Millotte et al. (2007) and use the term *intermediate phrase*.

Pynte (2006) reports performance data which reveal a preference for phrase length uniformity in French. In three different methodological protocols he found evidence that the processing of an NP PP sequence (e.g., ‘cette chaîne de/du vélo’) was influenced by whether it was preceded or surrounded in a sentence by short phrasing (one prosodic word per syntactic constituent) or by longer phrasing (two prosodic words per syntactic constituent). In the former case, uniformity would favor the version ‘Ce matin || il enlève || cette chaîne || du vélo’ (This morning he removes this chain from the bicycle) with the PP attached at the VP level; in the latter case it would favor the version ‘Le lendemain matin || il avait enlevé || cette chaîne de vélo’ (The next morning he had removed this chain of the bicycle, i.e., had removed this bicycle chain) in which the PP attaches inside the object NP. Performance in an auditory word monitoring task confirmed a well-established preference for VP-attachment, but also showed a significant benefit for NP-attachment when the context phrases were short but the target NP PP sequence was pronounced as long (i.e., without an internal prosodic break: ‘Ce matin || il enlève || cette chaîne de/du vélo’). Pynte attributes this to the fact that the ‘de’ (NP-attachment) version provides a syntactic motive for the violation of the prosodic uniformity constraint.

Here we report results from an elicited production study of a PP attachment ambiguity in Hebrew, designed to explore further the interplay of structural and length-based constraints on prosodic phrasing and their impact on syntactic processing. This construction is outlined in (3); an example sentence is in (5) below.

(3) Subject-pronoun + Verb Object-NP PP1(low-attached) PP2(ambiguous attachment)

This double-PP construction contains a sequence of two PPs, making it longer than the single-PP construction which has more often been studied, with conflicting outcomes. The inclusion of two PPs affords more potential locations for prosodic boundaries, and satisfies the advice of Millotte et al. to employ sentences that are long enough to permit insertion of prosodic phrase breaks without violating optimal length requirements. PP1 is unambiguously attached low to the object NP, due to selection restrictions; thus there is no potential for a garden path analysis of the material prior to PP2. PP2 is ambiguously attached, either low to the NP inside PP1 or higher at the VP level, modifying the verb. Whether and how these two different interpretations are reflected in prosodic phrasing is the topic of interest. Also, systematic manipulation of the length of PP2 provides a direct test of hypotheses concerning the extent to which syntactic alignment of prosodic phrasing may be tempered by phrase lengths. Specific predictions are presented below, in the section *Predictions*, for the prosodic phrasing of this syntactic construction in its two PP2-length conditions, reflecting potential interactions among a number of syntax–prosody interface constraints familiar in the phonological literature.

For guidance on this construction there are few precedents to refer to. In a series of experiments, Schafer, Speer and Warren explored the preferred prosody and attachment of an ambiguous PP2 (e.g., ‘with the triangle’) following an unambiguously attached PP1 (‘of the square’ in ‘I want to change the position of the square with the triangle’). Two such sentences were included in a semi-scripted two-person cooperative board game task (Warren et al. 2000). It was found that a break before PP2 was more strongly associated with high PP2 attachment than with low PP2 attachment. However, there was no manipulation of phrase lengths in this study. Also, the high-attachment prosodic phrasing is unbalanced with respect to phrase lengths: ‘I want to change the position of the square || with the triangle’. This contrasts with our materials, which include also a long PP2, offering the possibility of high PP2 attachment with more balanced phrase lengths so that the respective contributions of attachment height and phrase length can be assessed.

signal (in this case, prosodic grouping) reflect the syntactic and semantic interpretation of an utterance”. Thus meaning does not contrast here with syntax, and the actual predictions made are very similar to those of a pure syntax-alignment constraint as proposed by Selkirk and others.

Thus there is room for additional investigation of potential interactions between phrase lengths and syntactic structure in determining the placement of intermediate phrase boundaries in PP constructions. We now provide full details of the experimental stimuli employed in the present study.

Materials Design

Each target stimulus consisted of two sentences: a target double-PP construction as defined above, preceded by a preamble sentence that provided a referent for the subject of the double-PP construction, which was always a one syllable 3rd person pronoun, unstressed and cliticized to the verb. An example is shown in (5) in transliteration with English translation.

(5) Preamble: Rafi lo ‘ohav laxsof ‘et rigšot-av.
 Rafi not like to expose ACC feelings-his.
 ‘Rafi doesn’t like to expose his feelings.’

Target:	Subject	Verb	Object-NP	PP1	PP2
	hu	histir	‘et ha-ka’as šelo	‘al ha-gerušin	mi-tami.
	he	hid	ACC the-anger his	about the- divorce	from-Tami
	‘He hid his anger about the divorce from Tami.’				

The verb (including the cliticized subject pronoun), the object NP and the PP1 were each one prosodic word. (A prosodic word in Hebrew is a phonological unit which carries a single primary stress; [Ussishkin 2000](#); [Ben-David 2001](#); [Adi-Bensaid and Bat-El 2004](#); [Izre’el 2012](#)). The short version of PP2 contained one prosodic word; the long version contained either two or three prosodic words, sufficient in Hebrew to stand alone as an intermediate phrase. A long PP2 was created by adding one or two prosodic words to the short PP2, such as the family name ‘Toledano’ for example (5) above. The words that were added were proper names or other words that did not greatly alter the meaning of the PP and were therefore unlikely to affect the plausibility of one or other choice of PP2-attachment (see [Hirose 2003](#)). Thus, any observed effects of PP2 length could reasonably be attributed to phrase length rather than to semantics or pragmatics.

As noted, the target sentences were constructed in such a way that PP1 could only attach low to the object NP, not high to the VP, due to lexical selection restrictions. In (5), ‘his anger about the divorce’ is acceptable, but ‘hid about the divorce’ is not. The PP2 in final position (‘from Tami’), on the other hand, was such that it could felicitously attach either high to the VP or low to the NP inside PP1. In (5), ‘hid from Tami’ is acceptable and so is ‘the divorce from Tami’. Care was taken to ensure that the target sentences were evenly balanced with respect to the acceptability of these two possible interpretations; see the materials pre-test below. It was of primary interest in this study to discover whether there were differences in the preferred prosody and interpretation of the target structure when the only determining factor was phrase length. To achieve balanced ambiguity, two criteria were applied. The noun inside PP1 had to be able to stand on its own without a required complement, in order to prevent pressure for a low-attaching PP2 to fulfill that role. Likewise, the verb should

not require an additional complement following the direct object (NP including PP1), or be strongly associated with the preposition of PP2, in order to avoid a high attachment bias.

The preamble sentence which preceded the double-PP construction and provided a referent for its pronominal subject was identical for the short-PP2 and long-PP2 versions of the target sentence. The pronoun in the target sentence consisted always of one unstressed syllable, eliminating between-item prosodic length differences at that position. A length difference there might have affected prosodic phrasing later in the sentence, including at the critical PP2 region (Bradley et al. 2003). In addition, a pronominal subject minimized the overall complexity of the target sentences. (A phonologically null subject would have been more minimal but is not licensed in Hebrew in the third person.)

The preamble sentences varied between 3 and 8 words long. They were included in the pre-test of the materials, and the outcomes confirmed that for the items selected for use in the main experiment, the preambles did not bias toward either interpretation of the target construction; see below.

Materials Pretest

Forty ambiguous items (preambles plus target sentences), each in a short-PP2 and a long-PP2 version, were constructed to meet the criteria described above. A pre-test was used to identify the 24 out of these 40 items which were most evenly balanced with respect to the two possible interpretations and which had the least difference in plausibility between the short and long versions of PP2. These 24 items were employed in the main experiment. In the pretest and in the main experiment, all materials were presented in Hebrew script (see Fig. 1 below).

In the pre-test the 40 items in their short and long versions were distributed between two lists, each presented to two native speakers of Hebrew who had some linguistics background. The four judges read each preamble plus target sentence and indicated by marking on a seven point scale (see (6) below) the extent to which that sentence sequence was compatible with the two phrases presented beneath it. Selecting the central mark indicated that the sentence was equally compatible with the two interpretations.

(6)	_ _ _ _ _ _				
	<table style="width: 100%; border: none;"> <tr> <td style="text-align: center; width: 50%;">histir mi-tami</td> <td style="text-align: center; width: 50%;">ha-gerušin mi-tami</td> </tr> <tr> <td style="text-align: center;">hid from-Tami</td> <td style="text-align: center;">the-divorce from-Tami</td> </tr> </table>	histir mi-tami	ha-gerušin mi-tami	hid from-Tami	the-divorce from-Tami
histir mi-tami	ha-gerušin mi-tami				
hid from-Tami	the-divorce from-Tami				

Selected items satisfied two criteria. Of the four judgments, no two differed by more than two points on the scale; and none fell at one of the extremes of the scale (i.e., marked as fully unambiguous). The mean score for all the selected sentences was 4.1, the short receiving a mean score of 4.0, and the long, a mean score of 4.2. A *t*-test revealed that the difference between the mean score of the selected sentences and the center scale point 4 was not reliable, $t(23) = 1.51$, $p > 0.01$, and nor was the difference between the mean scores of the short and long items $t_2(23) = 1.19$, $p > .20$. Thus, all of the selected sentences (in both their short and long versions) exhibited a well-balanced ambiguity.

Filler Items

The 24 items selected for the main experiment were interspersed among 48 unambiguous filler items, creating a 1:2 ratio of experimental to filler items. All filler items contained two sentences, to resemble the preamble + target format of the experimental items. They represented varied syntactic constructions. Half contained no preposition, and half contained

prepositions at varying positions (preamble, target and/or answers). For these sentences there was only one correct answer, unlike for the experimental items. The aim was to encourage participants to assume that there was always a single correct answer, so that they would not become too aware of the ambiguity of the target items. Minimizing awareness of the ambiguity reinforced the aim of our study to exclude factors related to communicative intent, such as ‘audience design’ (Bell 1984; see also discussion in Kraljic and Brennan 2005) in order to focus the investigation on interactions between phrase lengths and syntactic alignment. In addition, poor performance on the fillers could be used to exclude data from participants not sufficiently attentive to the task.

Presentation

In the main experiment, materials were presented visually in the format described below. Each experimental item (preamble sentence + target sentence) was followed by presentation of the two potential ‘answers’, as in the pre-test, which could reveal how the target sentence had been interpreted. The 24 target items and the fillers were distributed across four lists, in a 2x2 design that crossed PP2 Length (short/long) and Order of Presentation of Answers (high attachment right/high attachment left). The Order of Presentation of Answers factor was designed to detect any bias toward the answer read first (which might sway the interpretation) or toward the answer that was read last (possibly more salient). The fillers were constant across the lists, with order of presentation of correct/incorrect answers counterbalanced. There were three overt practice items, and four covert practice items at the beginning of the list.

Participants and Procedure

Fifty three native speakers of Hebrew participated in the experiment (15 male). All were B.A. students of psychology in the Open University in Israel, and were naïve with respect to the purpose of the experiment. Subsequently 13 participants were disqualified for failing to meet pre-set performance criteria: no more than 15 % comprehension errors on fillers; no more than 15 speech errors (false starts, word omissions, etc.) in reading aloud, or more than two missing or cut-off recordings.

The experiment was conducted with the use of DMDX software (Forster and Forster 2003). Participants were tested individually. Following informed consent procedures and written instructions, there was a practice session with opportunity for further explanation if needed. The experimenter made no mention of ambiguity in the sentences. However, of the three sentences in the practice session, one was ambiguous, to implicitly prepare the participants for the types of items they would encounter during the experiment.

Each item was presented in three frames, illustrated in Fig. 1 below. The first frame displayed a centered plus sign. Pressing the space bar triggered simultaneous presentation of a pair of sentences: a preamble sentence and its associated target sentence, one beneath the other. The participant read the two sentences aloud for recording as soon as the sentences appeared on screen, i.e. without preview.⁴ Participants had been instructed to read naturally at a normal pace. After reading aloud, the participant pressed a marked keyboard key which triggered addition of the two potential answer phrases to the screen beneath the sentences,

⁴ The merits of ‘cold reading’ versus reading with preview are debated in the literature. To maximize naturalness we excluded preview, since its two-stage reading process does not seem typical of most daily reading. Preview is more appropriate in investigations of whether naïve speakers know how sentences can be disambiguated prosodically, which is of linguistic interest but has its own potential pitfalls. For instance, in the Breen et al. (2011) study (see above), the experimental procedure emphasized the importance of prior sentence

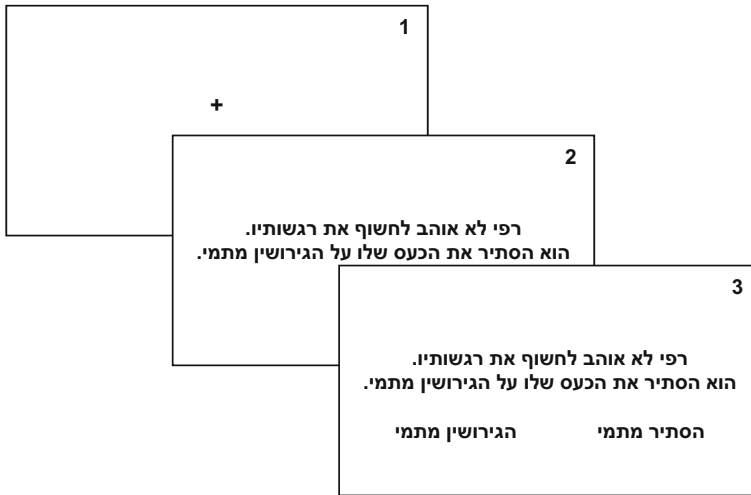


Fig. 1 Display frames in the main experiment

aligned to right and left with substantial space between. (Since Hebrew is read from right to left, the answer that appeared on the right would be read first.) After reading the two answers silently, the participant read aloud the one that he or she considered more compatible with the previous two-sentence sequence. The prosodic properties of the recorded productions of target sentence were subsequently assessed by ear judgments and acoustic analysis, described below.

Predictions

Predictions for Prosodic Phrasing

In predicting the likely prosodic contours for this double-PP construction, we adhere to familiar syntax–prosody interface constraints that have been proposed in the linguistics literature, as listed in (7). Our primary references are [Selkirk \(2000\)](#) and [Truckenbrodt \(1999\)](#);⁵ see note 1 above for terminological equivalents.

- (7) a. Align_R XP: “The right edge of any XP in syntactic structure must be aligned with the right edge of a MaP in prosodic structure” ([Selkirk 2000](#): 232)
 b. Wrap: “Each syntactic XP must be contained in a phonological phrase” ([Truckenbrodt 1995](#): 10)

Footnote 4 continued

comprehension, and pronouncing the sentences so as to maximize interpretability (pp. 1545–1546), which could have encouraged exaggerated phrasing that deliberately gave priority to sentence structure over typical phrase lengths. This is hard to assess, since specific data are provided for only one sentence set (pp. 1548–1549), the eight sentences derived from example (4) above. But in those items, prior to any ambiguity, a prosodic boundary was produced with probability .44 after the initial determiner and noun (‘the professor’), which seems high for normal reading.

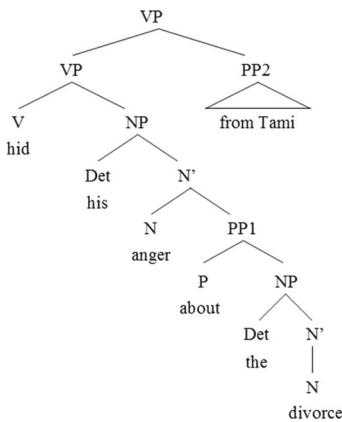
⁵ We believe our analysis here is fully compatible with Selkirk’s more recent Match theory ([Selkirk 2011](#)), but the traditional Selkirk/Truckenbrodt model is likely to be more familiar to readers and it suffices for exposition in the present case.

- c. BinMin: “A major phrase must consist of at least two minor/accentual phrases.” (Selkirk 2000: 244)
- d. BinMax: “A major phrase must consist of no more than two minor/accentual phrases.” (Selkirk 2000: 244)
- e. Uniformity: “A string is ideally parsed into same length units.” (Ghini 1993: 56)

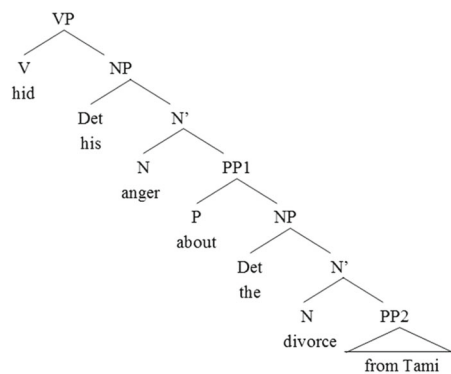
These are to be understood as ‘soft’ constraints within an Optimality Theory (OT) framework, in which some constraints are ranked higher than others and take precedence in case of conflict. While OT constraints are claimed to be universal, their ranking can vary across languages, creating different observable surface patterns.

Applying these constraints to the double-PP construction under study here, there are three possible positions at which—in principle—a prosodic break might occur: between the verb and its object NP; between the object NP and PP1; and between PP1 and PP2. (A break between the pronominal subject and the verb in these materials would be extremely unnatural and can be excluded from consideration.) The long and short versions of each sentence are identical up to and including PP1, and the syntactic structure of both versions up to that point is right-branching, as displayed (for the short PP2 version) in (8).⁶

(8) a. High PP2 attachment



b. Low PP2 attachment



Since Hebrew is a right-alignment language (i.e., like English, it aligns only the ends of syntactic constituents with prosodic phrase edges; Shaked 2007), the right-branching sequence as far as the word ‘divorce’ in both (8a) and (8b) affords no structurally motivated prosodic break positions. Thus prosodic phrasing of that sequence would be guided only by the length constraints, and by Wrap which would favor no breaks in that sequence at all.⁷ For both sentence versions, therefore, the following would be anticipated. A break between V and its object NP, or between the NP and the PP1 that unambiguously modifies it, would be

⁶ These tree diagrams are simplified for present purposes. A variety of different structures, some much more elaborate, have been proposed by syntacticians for PP-attachment constructions. Of relevance to the prosodic phrasing is whether there are syntactic XP right-edges between PP1 and PP2, as there are in (8a) but not (8b). The same would be true in a syntactic theory framework that does not insist on binary branching: e.g., in (7a) the verb, its object NP (including PP1) and the PP2 might be three daughters of the same VP.

⁷ Wrap does not apply at the clausal level (Truckenbrodt 1995) but it does at the VP level which encompasses all the syntactic phrases in this construction. However, Truckenbrodt’s constraint drew a distinction between arguments and adjuncts which we disregard here. Therefore what we are calling Wrap, for convenience, should be regarded as some more general cohesional grouping tendency which disfavors prosodic breaks within syntactic constituents.

disfavored by Wrap. However, as a ‘soft’ constraint within OT, Wrap could be outweighed by other considerations, such as length constraints, inducing a break in one or other of those locations. What those length pressures might be differs between the long and short versions of PP2. If PP2 is long, a break between PP1 and PP2 would satisfy Uniformity, creating a fair balance between the length of V+NP+PP1 (3 prosodic words) and the length of PP2 (2 or 3 prosodic words). Since the long-PP2 version exerts considerable pressure towards there being a break *somewhere* in the word string, we predicted that a break was probable and that it would be located most likely at the left edge of PP2 in accord with Uniformity (and BinMin). If this option were taken, there would be little or no pressure for breaks to occur at earlier locations in the sentence. Thus this pattern, with a break at [PP2 only], would be predicted to be common for long PP2.

If PP2 is short, a break at [PP2 would yield an unduly short final phrase that offends BinMin, and a length imbalance (3 + 1 prosodic words) that offends Uniformity. For short PP2, this implies that a break at [PP2 would be avoided if viable alternatives exist. A prosody with no phrase breaks at all would be optimal with respect to Wrap, but the overall sentence length of 4 prosodic words could make that difficult to maintain under pressure from BinMax. As an alternative, a length-induced break might occur earlier in the sequence. In principle this could be either at the [NP position (1 + 3 prosodic words) or at the [PP1 position (2 + 2 prosodic words). The latter would be favored by all of BinMin, BinMax and Uniformity, since a break at [PP1 balances two phrases each with 2 prosodic words. Thus, for short PP2 items there is predicted to be a tussle between a cohesive structural constraint and two kinds of length constraints (optimal length and balanced length).

To summarize: Setting aside any independent (e.g., semantic/pragmatic) preference for high versus low attachment (shown to be negligible by the materials pre-test), the interplay of well-attested constraints on prosodic phrasing point to expectation of a high proportion of [PP2 breaks for the long PP2 sentence version, and a mix of phrasing patterns for the short PP2 version: either no break at all, or an earlier break most likely at [PP1.

Predictions for Preferred Interpretation

In the literature on RC-attachment preferences, it has been proposed (Fodor 1998; Lovrić 2003; Shaked 2009, among others) that a prosodic boundary induced by purely prosodic (eurhythmic) considerations such as phrase lengths may instead be interpreted by a perceiver as motivated by syntactic configuration, and could thereby influence the perceiver’s semantic interpretation of the sentence. This amounts to applying the interface constraints in reverse, from the phonological form to its possible causes.⁸ Specifically: for a language in which XP alignment is to the right (the Align_R constraint), a prosodic break before a RC might be attributed to a high attachment structure in which one or more syntactic right edges separate the RC from the preceding nouns. Translating this hypothesis to the case of PP-attachment,

⁸ This is complementary to the Rational Speaker Hypothesis of Clifton et al. (2006), which claims that a listener may discount the syntactic significance of a prosodic boundary if the boundary could have been motivated by phrase length considerations. The two phenomena are not incompatible. If a prosodic break could be due *either* to syntactic alignment *or* to non-syntactic influences such as phrase lengths or information structure (e.g., focus), a rational processor could assume with some probability that it is a cue to syntactic alignment and with a reciprocal probability that it is due to such other factors. If the source-ambiguous prosody was in fact due to non-syntactic factors, this uncertainty will sometimes yield a structural interpretation of a non-structurally induced break. If the source-ambiguous prosody was in fact due to syntactic alignment, the uncertainty will sometimes yield an RSH effect, i.e., disregarding a break as a cue to syntactic structure. In short: the multiple causal factors that feed into prosodic structuring can create ambiguity with regard to prosody’s import for syntactic structure, and errors of interpretation can occur in either direction.

it would predict that in reading aloud, a prosodic break at [PP2, even if in fact motivated in production by length considerations, might sometimes be construed (by a listener, or by the reader himself or herself) as indicative of high syntactic attachment of PP2. Likewise, a length-motivated break at [PP1, which has the effect of grouping PP1 with a following short PP2, might on occasion be construed as an instance of Wrap reflecting syntactic attachment of PP2 to the NP inside PP1, i.e., a low PP2 attachment interpretation.

To summarize: It is possible that the prosodic phrasing that participants produce in conformity to phonological and interface constraints will influence their assignment of syntactic structure, and hence semantic interpretation. Items with long PP2, when read with a [PP2 break, might favor high PP2-attachment, while otherwise comparable items with a short PP2 and read with a [PP1 break could favor low PP2-attachment.

Results: Ear Judgments

Data Treatment

The locations of prosodic boundaries in the recordings were assessed using a variant of the ToBI (Tones and Breaks Indices) system originally developed for English (Beckman and Hirschberg 1994) and adapted for Hebrew by Shaked (2007; 2009). It provides a transcription method for the phonological characteristics which are associated with intermediate (ip) phrase breaks in Hebrew (comparable to Break Index 3 in the ToBI system): a pitch rise from the last stressed syllable (nucleus) in a phrase to the phrase-final boundary; syllable lengthening at the end of a phrase; and a physical pause (optional in Hebrew; Laufer 1987, 1996).⁹

Of the 960 anticipated target recordings (24 target sentences produced by 40 participants), four were missing due to technical failures and five were discarded because there were missing judgments in the post-sentence ambiguity resolution task. These missing items constituted <1 % of the total dataset.

The ear judgments were made independently by two trained judges: the first author of this article and a Ph.D. student in psychology at the Tel Aviv University in Israel, both native speakers of Hebrew. The second judge was naïve with respect to the purpose of the study and was trained (on other recordings) by the first judge to employ the coding system. Details of the exact procedures for judging and for reconciling discrepant judgments (<2 % for presence/absence of an intermediate phrase boundary at any particular sentence location) are presented in full in Webman-Shafan (2011).

Results and Discussion

The ear judgments of participants' recordings revealed 4 main prosodic phrasing patterns for the target sentences: no breaks anywhere in the utterance, a break before PP1 only, a break before PP2 only, and breaks before both PP1 and PP2 and nowhere else. These categories will be referred to here as No Breaks, [PP1 Break, [PP2 Break and Both Breaks respectively. A total of 16 utterances (<2 % of the dataset) were judged as having prosodic patterns different from these four (e.g., a break before NP only) and were excluded from the

⁹ All produced boundaries were ip boundaries (break index 3). No sentence-internal IPh boundaries (break index 4) were detected in the production data. According to Shaked's (2009) adaptation of the ToBI coding system for Hebrew, an IPh boundary is marked by a falling boundary tone in contrast to the rising phrase accent at an ip boundary; no falling boundary tones were detected at the loci in question.

analysis, leaving 935 utterances in the data analysis (470 with short PP2 and 465 with long PP2).

As anticipated, there were more breaks overall in long PP2 sentences than in short PP2 sentences (373 vs. 306 respectively). A one tail paired t-test revealed that this difference was significant: $t(39) = 3.866$, $p < 0.001$. To test the relationship between PP2 length and prosodic phrasing, we first examined the distribution of the four prosodic phrasing patterns in short and long PP2 items separately; see Fig. 2 below. As predicted, long-PP2 targets were more often produced with a [PP2 Break pattern than with any of the other three phrasing patterns: No Breaks was a much less frequent runner up, and the incidence of [PP1 Breaks and Both Breaks was negligible. For short-PP2 targets, as predicted, prosody was more varied. Short-PP2 sentences were most often produced with No Breaks, followed numerically by [PP1 Breaks; there were few [PP2 Breaks and fewer Both Breaks.

The statistical analyses were conducted using Multilevel Multinomial Cross-Classified Logistic Regression Models (Baayen et al. 2008; Baayen 2008). This type of model was chosen because it considers the categorical nature of the dependent variable (No Breaks, [PP1 Breaks, [PP2 Breaks and Both Breaks) and because it takes into account the cross-classification structure of data in this study, i.e., the fact that the data is clustered in both sentences and subjects. A series of paired comparisons examined the difference in the probability of production between each two prosodic phrasing patterns, in two separate models, one for long-PP2 sentences and one for short-PP2 sentences. The Both Breaks category was excluded from the dataset for these comparisons due to the fact that many subjects as well as sentences did not show this prosodic pattern and it comprised only 7% of the total number of utterances.

For long-PP2 items, the comparisons revealed (see Table 1 below) that the probability of producing a [PP1 Break was 0.11 smaller than the probability of producing a [PP2 Break ($Z = -13.9$, $p < 0.001$), and 0.26 smaller than the probability of producing No Breaks ($Z = -7.45$, $p < 0.001$). The probability of producing No Breaks was 0.43 smaller than the probability of producing [PP2 Breaks ($Z = -7.83$, $p < 0.001$). For short-PP2 targets, there was no significant difference in the probability of producing No Breaks and [PP1 Breaks ($Z = 2.63$, $p = 0.242$). However, No Breaks showed a 2.66 greater probability of being

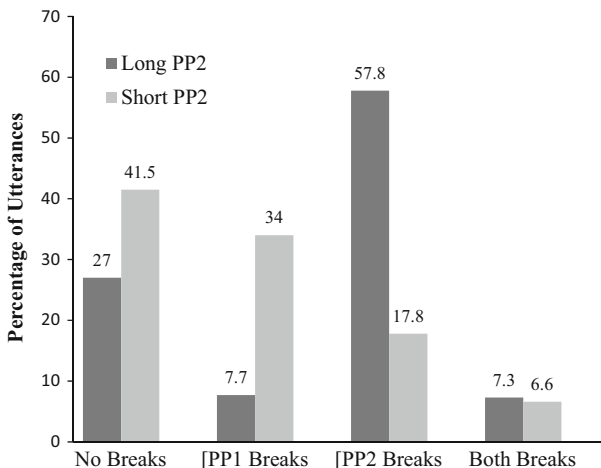


Fig. 2 Percentage of occurrences of the four major prosodic phrasing patterns in the long-PP2 and short-PP2 utterances, based on ear judgments

Table 1 Comparison of the difference in the probability of production between each two prosodic phrasing patterns, in two models, for long-PP2 and short-PP2 sentences separately

PP2 Length	Comparison type	<i>b</i>	SE	Sig.	Odds
Long	No breaks versus PP2 breaks	−0.83	0.23	<0.001	0.43
Long	PP1 breaks versus PP2 breaks	−2.17	0.32	<0.001	0.11
Long	PP1 breaks versus No breaks	−1.34	0.27	<0.001	0.26
Short	No breaks versus PP2 breaks	0.98	0.22	<0.001	2.66
Short	PP1 breaks versus PP2 breaks	0.70	0.33	0.033	2.01
Short	PP1 breaks versus No breaks	−0.28	0.24	0.242	0.76

b stands for estimated coefficients

produced than [PP2 Breaks; ($Z = 7.58$, $p < 0.001$) and [PP1 Breaks showed a 2.01 greater probability of being produced than [PP2 Breaks ($Z = 5.25$, $p = 0.03$).

In general, the ear judgments bear out the theoretical predictions regarding PP2 length and prosodic patterns. For the long PP2 items there is a highly significant preference for a prosodic break immediately preceding PP2, which is favored by length-based considerations. In productions with a [PP2 break, there is little pressure for a merely length-induced break elsewhere, and indeed the number of Both Breaks is very low. For short PP2 items, where it was predicted that the Wrap constraint and the length constraints would compete with each other, the range of phrasings is indeed more varied than for the long-PP2 sentences. No Breaks (Wrap-motivated) and [PP1 Breaks (Uniformity-motivated) occurred with comparable frequency, with a lower incidence of [PP2 breaks.

A Multilevel Cross-Classified Multinomial Logistic Regression Model was conducted to investigate the effect of PP2 length on prosodic breaks. Table 2 presents the probabilities of producing No Breaks vs. [PP2 Breaks and of producing [PP1 Breaks vs. [PP2 Breaks, in short PP2 sentences compared with long PP2 sentences as fixed effects (Level 1). Subjects and sentences were defined as random effects (Level 2). The dependent variable was the pattern of prosodic breaks produced (No Breaks, PP1 Breaks, PP2 Breaks). The Intra-Class-Correlation (ICC) suggested there was a cross-classification effect on the results by the cluster structure of the data. Both cluster types showed ICC levels that satisfy the minimum threshold (5%; Heck et al. 2012): the subject ICC was 17% and the sentence ICC was 19%. These ICC levels justify our cross classification modeling strategy. Model 1 in Table 2 presents the null model, a model with intercept only. Model 2 tests the effect of PP2 length (short PP2 vs. long PP2) on the probability of a break's presence and location. It shows that a long PP2 reduces the probability of a No Break pattern compared with that of a [PP2 Break ($b = -1.80$, $p < 0.001$); the probability of a [PP2 Break is six times greater than the probability of No Break when the sentence is in its long version compared with its short version ($1/[EXP(-1.80)]$). This difference in probability is even greater when comparing [PP1 Breaks to [PP2 Breaks ($b = -3.02$, $p < 0.001$);¹⁰ the probability of a [PP2 Break is 21 times higher than the probability of a [PP1 Break in long PP2 sentences compared with short PP2 sentences ($1/[EXP(-3.02)]$). These results indicate that PP2 length significantly affected prosodic phrasing patterns.

¹⁰ The comparisons of the probabilities of producing one prosodic break pattern with respect to the other in long versus short PP2 items involve PP2 Breaks as a reference category: PP2 Breaks is compared separately to No Breaks and to PP1 Breaks.

Table 2 Results of multilevel multinomial logistic regression for produced break patterns

		Model 1	Model 2	Odds
<i>Fixed effects</i>				
Category 1: NB versus PP2				
Level 1: measurement	Intercept	−0.14 (0.17)	0.93*** (0.22)	
	Length (long)		−1.80*** (0.18)	0.17
Category 2: PP1 versus PP2				
Level 1: measurement	Intercept	−0.66** (0.21)	0.71* (0.29)	
	Length (long)		−3.02*** (0.25)	0.05
<i>Variance components</i>				
Category 1: NB versus PP2				
Level 2—subjects	Subject intercept $\sigma_{\text{subject}}^2$	0.72*** (0.85)	0.82*** (0.90)	
Level 2—sentences	Sentence intercept $\sigma_{\text{sentence}}^2$	0.09 (0.30)	0.20** (0.45)	
	ICC subjects	.17	–	
	ICC sentences	0.04	–	
Category 2: PP1 versus PP2				
Level 2—subjects	Subject intercept $\sigma_{\text{subject}}^2$	0.16* (0.40)	0.37** (0.61)	
Level 2—sentences	Sentences intercept $\sigma_{\text{sentence}}^2$	0.77*** (0.88)	1.27*** (1.13)	
	ICC subjects	0.02	–	
	ICC sentences	.19	–	

Standard errors are in parentheses for fixed effects and standard deviations are in parentheses for random parameters

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

The striking difference in preferred prosodies between the long and short versions of the materials adds on-line behavioral evidence for the length-sensitive constraints on prosodic phrasing that have been proposed in the phonological literature. It also underscores the warning by Millotte et al. (2007) that in prosody production, phrase lengths may be as powerful a factor as syntactic alignment. The only unexpected finding in these ear judgment data is the substantial proportion of No Breaks prosody for the long PP2 sentences, despite the fact that the overall sentence length is five or six prosodic words and would be expected by BinMax to have to be divided somewhere. Several explanations should be considered in future work. One possibility which has some independent support is that in addition to prosodic influences there is an effect of the purely syntax-based Late Closure strategy in syntactic parsing, which favors low attachment (Frazier 1978; aka Recency: Gibson et al. 1996). A growing number of studies (including De Vincenzi and Job 1993; Fernández 2000/2003; Augurzyk 2006, and Dinçtopal and Fodor 2013) suggest that a syntactic Late Closure preference exists

alongside prosodic interface preferences. Syntactic Late Closure would be more consonant with absence of a break between PP1 and PP2. Thus it is possible that the incidence of No Breaks prosody for long PP2 sentences was due to Late Closure fighting against the predicted length-motivated [PP2 break.

Alternatively, the unexpectedly high proportion of No Breaks for long PP2 might simply be due to the conservative approach adopted in making the ear-judgments, which took into consideration the word-level characteristics of Hebrew prosody. An intermediate phrase boundary was not registered by the judges if an observed high tone plus lengthening could reasonably be attributed instead to lexical stress falling on the final syllable of the word (Becker 2003). Possibly this caution resulted across the board in identification of fewer phrasal breaks than were actually produced, inflating the No Breaks category at the expense of the other patterns.

Acoustic Analysis

Data Treatment and Results

An acoustic analysis of segment durations was performed as a check on the validity of the ear judgments. For the durational analysis we arbitrarily selected from the total database a subset of 200 utterances, consisting of ten target sentences produced by 20 participants, each reading only the long or the short PP2 version. (see Webman-Shafran 2011 for further details of the item selection process.) One missing recording among these 200 utterances resulted in a body of 99 short-PP2 utterances and 100 long-PP2 items.

The segments that were measured are shown in (8a) and (8b). Note: PP2(start) is the string in the long PP2 which is identical to the string in the short PP2; PP2(continuation) is the remaining material in the long PP2 which is not part of the short PP2.

(8) (a) pronoun+verb / object NP / pause / PP1 / pause / PP2(start) / extra material in long PP2

SV / NP / pause-0 / PP1 / pause-1 / PP2(start) / PP2(continuation)

(b) pronoun+verb / object NP / pause / PP1 / pause / short PP2

SV / NP / pause-0 / PP1 / pause-1 / PP2(short)

The duration of the object NP plus any following pause (pause-0), and of PP1 plus any following pause (pause-1) were measured in order to assess the incidence of prosodic phrase boundaries at [PP1 and [PP2 respectively. The SV and PP2 segments served for comparison. The SV region was expected to involve no change in duration between long-PP2 and short-PP2 items (since a break there would follow just one prosodic word, and in any case should be unaffected by the length of PP2 in this reading-without-preview protocol). The PP2(start/short) region (i.e., PP2(start) in the long-PP2 items and PP2(short) in the short-PP2 items) was predicted to exhibit greater durations when PP2 was short than when it was long, due to sentence final lengthening for the short version.

The acoustic analysis was performed with the aid of Speech Analyzer acoustic analysis software (SIL International, version 3.0). Full details of the procedure and data analysis are presented in Webman-Shafran (2011). For reasons of space they are not included in this report. The mean segment durations, now summing the length of a constituent and the

Table 3 Mean durations in milliseconds of the segments and standard deviations of segment durations in the four measured regions in long-PP2 and short-PP2 sentences

	Long-PP2		Short-PP2	
	Duration	SD	Duration	SD
SV	425	94	432	94
NP + Pause	619	185	695	246
PP1 + Pause	744	263	652	209
PP2 (start/short)	492	144	565	128

pause that follows it, are shown in Table 3. (Ear judgments showed a negligible incidence of boundaries following the verb and following PP2(start), so no measurements were made of pauses following those items.) The findings can be briefly summarized as follows. Object NP durations were greater when PP2 was short than when it was long (significant by participants, approaching significance by items), in line with the ear-judgments showing that when PP2 was short, there were more [PP1 breaks than when it was long. PP1 durations were significantly greater (by participants and by items) when PP2 was long than when it was short, consonant with the ear-judgment finding of a greater tendency for a prosodic boundary immediately preceding PP2 in long-PP2 sentences than in short-PP2 sentences. Thus, the acoustic analysis yielded results in accord with the ear judgments; PP2 length was a significant predictor of prosodic phrasing patterns.

Effects of Length and Prosodic Phrasing Patterns on Attachment

Answer choices for the target sentences were coded as indicating either high attachment or low attachment of PP2. As anticipated above (section *Predictions for preferred interpretation*), the observed effect of PP2 length on prosodic phrasing could have consequences for the preferred attachment interpretation, with more high attachment of PP2 when a prosodic boundary immediately preceded PP2. In the absence of any evident rationale for a *direct* causal association between phrase lengths and interpretation, it seems reasonable to assume that any such relation between them would be mediated by the prosodic phrasing, i.e., that phrase lengths affect prosodic phrasing which affects interpretation. This assumption receives empirical support from the following analyses.

The relationship between PP2 length and attachment, on the one hand, and between prosodic phrasing and attachment, on the other, were tested with Multilevel Cross-Classification Binary Logistic Regression Models. As above, we used the cross-classification modeling strategy here as it considers the nested structure of the data. Logit models were run because the dependent variable was binary (high vs. low attachment).

Order of presentation of answers (high attachment response on the left/high attachment response on the right), PP2 length (long/short) and prosodic phrasing patterns (No Breaks/PP1 Breaks/PP2 Breaks) were included as fixed effects (Level 1). Subjects and sentences were included as random effects (Level 2). The dependent variable was attachment. Table 4 below portrays how the random effects and fixed effects influence attachment. Both cluster types show ICC levels that satisfy the minimum threshold. The subject ICC is 5 % and the sentence ICC is 21 %. Model 2 shows that the order of presentation of answers has no effect on attachment height ($b = 0.003$, $b > 0.05$); thus, the presentation order of answers did not bias attachment choices. The roles of PP2 length and of produced prosody, as shown respectively in Models 2 and 3 in Table 4, are discussed individually below.

Table 4 Results of multilevel binary logistic regression for attachments (high vs. low)

		Model 1	Model 2	Odds	Model 3	Odds
Fixed effects	Intercept	0.09 (0.03)	−0.18 (0.24)		0.46 (0.27)	
Level 1: measurement	Order		0.003 (.22)	1.03	−0.03 (0.22)	0.97
	Length		0.56*** (0.15)	1.75		
	NB versus PP2				−0.55** (0.18)	0.58
	PP1 versus PP2				−0.65** (0.21)	0.52
Variance components						
Level 2—subjects	Subject intercept $\sigma_{\text{subject}}^2$	0.23*** (0.48)	0.24*** (0.49)		0.25*** (0.50)	
Level 2—sentences	Sentences intercept $\sigma_{\text{sentence}}^2$	0.95*** (0.97)	0.99*** (0.99)		0.92*** (0.96)	
ICC subjects		0.05				
ICC sentences		.21				

Standard errors are in parentheses for fixed effects and standard deviations are in parenthesis for random parameters

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Length and Attachment: Results and Discussion

A comparison of high attachment rates for short-PP2 and long-PP2 sentences revealed a greater tendency to attach high in long-PP2 targets (55.9%) than in short-PP2 targets (46.2%). Model 2 in Table 4 above confirms that PP2 length was significantly related to sentence comprehension: it estimates an increase in the probability for high attachment when PP2 is long compared with short ($b = 0.56, p < 0.001$).

These findings for attachment preference are broadly compatible with the hypothesis that prosodic phrasing assigned on purely phonological grounds may be construed (even by the individual who produced that prosodic phrasing) as a cue to attachment height. The comprehension data showed more cases of high PP2 attachment when PP2 was long than when it was short, in line with the finding (above) that there were more breaks before PP2 when PP2 was long than when it was short. Of greater theoretical import, however, is the relationship between the produced prosody and the preferred interpretation, which we turn to next.

Prosody and Attachment: Results and Discussion

The preferred interpretations for the different prosodic phrasing patterns were tallied for short and long items separately, with outcomes shown in Fig. 3. (The Both Breaks category is represented here, but was excluded from the statistical analyses because of the paucity of data points.)

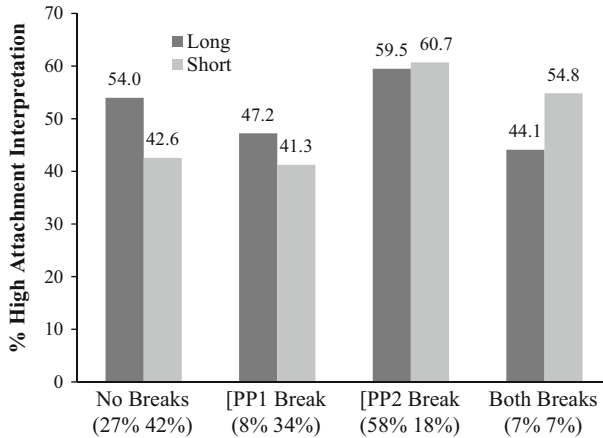


Fig. 3 Percentage of high PP2 attachment for the four major prosodic phrasing patterns for long-PP2 and short-PP2 targets. The numbers in parentheses indicate the incidence of each prosodic phrasing pattern as a percentage of the complete ear judgment database, for the long-PP2 and short-PP2 utterances respectively

The relation between produced prosodic phrasing and attachment preference was examined by collapsing over the length manipulation. Overall, utterances produced with a break before PP2 had a greater rate of high attachment (59.77 %) than utterances produced with a break before PP1 (42.35 %). Model 3 in Table 4 above confirms that a [PP1 Break] significantly reduces the probability of high attachment in comparison to a [PP2 Break] ($b = -0.65$, $p < 0.01$). In addition, utterances produced with a break before PP2 had a greater rate of high attachment (59.77 %) than utterances produced with no breaks (47.04 %), and Model 3 confirms that the No Break prosody significantly reduces the probability of high attachment compared with a [PP2 Break] ($b = -0.55$, $p < 0.01$). These differences in attachment preference across the prosodic patterns are as had been predicted.

Extrapolating these results onto the effect of No Breaks versus PP1 Breaks reveals no reliable interpretive contrast between these two categories, contrary to our prediction that the PP1 Break category would be associated with a lower attachment rate than the No Break (neutral) category: a [PP1 Break] reduces the probability of high attachment slightly more than the No Break pattern, but this difference is statistically insignificant ($b = -0.02$, $p = .65$). What these categories have in common is the absence of a break before PP2.

Models 2 and 3 revealed a significant effect of phrase length on interpretation when prosody was controlled for, and a significant effect of [PP2] prosodic breaks on interpretation regardless of phrase lengths. The latter is in accord with the hypothesis that the effect of PP2 length on PP2 attachment was indirect, mediated by the effect of PP2 length on prosodic phrasing.

Direct and Indirect Effects on Attachment

To examine statistically the hypothesis that the effect of PP2 length on PP2 attachment was mediated by the effect of PP2 length on prosodic phrasing, we analyzed potential indirect effects between PP2 length, break location and attachment height. For this, we used Mplus v. 7.1, a statistical tool that can run multi-level structural equation models. In this model we defined the sentence as a level-two cluster since it had an ICC level above the required threshold. Figure 4 presents the full path diagram which includes direct, mediating (indirect),

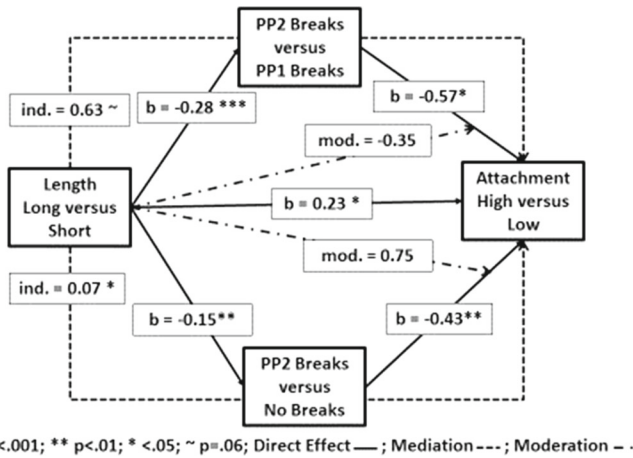


Fig. 4 Estimates of direct and indirect effects on attachment level

and moderating effects.¹¹ This analysis shows a direct effect of PP2 length on prosodic breaks (revealed in a PP2-length-based difference in the probability of producing [PP2 Breaks versus [PP1 Breaks, and [PP2 Breaks versus No Breaks), ($b = -0.28, p < 0.001$; $b = -0.15, p < 0.01$ respectively). It also shows a direct effect on attachment of the differences in break production probabilities among the three break locations (for [PP2 versus [PP1, $b = -0.57, p < 0.05$; for [PP2 versus No Breaks, $b = -0.43, p < 0.01$). But more importantly for explanatory purposes, this model reveals that break location effects (both [PP2 Breaks versus [PP1 Breaks, and PP2 Breaks versus No Breaks) mediated the effect of PP2 length on attachment. In other words, PP2 length led to a difference in the probability of producing [PP2 Breaks versus [PP1 Breaks and to a difference in the probability of producing [PP2 Breaks versus No Breaks, and those differences in break productions in turn brought about a difference in attachment (indirect = 0.63, $p = 0.06$; indirect = 0.07, $p < 0.05$ respectively). The latter result is significant while the former falls just short of conventional levels of significance. Although there was also found to be a direct effect of length on attachment ($b = 0.23, p < 0.05$), high or low attachments were mainly a function of prosodic break decisions: a comparison of the total break location effect with the length effect revealed that the break location effect was significantly stronger than the length effect (Wald’s Chi-Squared, one-tailed = 3.26, $p = 0.035$).¹²

In sum: the results of this analysis support a relationship of interest between prosody and preferred attachment. There was a significant direct association between prosodic break patterns and PP2 attachment, and there was also a mediating effect of prosodic patterns on the relation between PP2 length and PP2 attachment, for [PP2 break prosody versus both [PP1 break and No Breaks, the latter comparison being slightly more robust. This is in line with the prediction that the prosodic contour that a reader projects onto a written sentence may influence how the sentence is interpreted, in much the same way (though perhaps less strongly) as if the prosody had been part of the physical stimulus. While this

¹¹ Mediation would mean that the Length effect on Attachment was expressed indirectly through the Break location, while moderation would mean that the Break location effect on Attachment is different for different Lengths, so that the mediating effect of Breaks is moderated by the main effect of Length on Attachment.

¹² Possible moderation effects were also examined, that is: interactions between length and break locations, but they revealed no significant moderating effect ($mod. = 0.75, p > 0.05$; $mod. = -0.35, p > 0.05$).

has been proposed previously, in the implicit prosody literature, as a plausible explanation for interpretive consequences of phrase lengths in silent reading, it has not previously been documented as rigorously as in the present analysis.

On the other hand, the findings do not clearly support a privileged relationship between a prosodic break at [PP1 and low attachment of PP2, even though a [PP1 break (with no other break) would group PP2 with the NP inside PP1. A [PP1 break was not associated more strongly with low attachment of PP2 than was the No Breaks prosody, despite a numerical trend in that direction. It appears that the definitive factor was the absence of a break at PP2, which is shared by the [PP1 break condition and the No Break condition. There are several possible explanations for this. One is simply the sparsity of data points in the [PP1 break condition with long PP2, in this read-aloud paradigm. This possibility could be followed up in a listening study with balanced numbers of spoken stimuli, to establish whether an overt [PP1 break in the input would still be only a weak cue to the syntactic attachment of PP2. However, there are other interesting and plausible explanations for the ‘no-difference’ result obtained here, taken just as it stands.

One explanation is that the syntactically-based Late Closure principle, which encourages low attachment, prevails when prosodic cues are unavailable or uninformative, as is the case in the No Break category in this study. This has been documented in a variety of constructions in several languages: see [Kjelgaard and Speer \(1999\)](#) for English; [Augurzky \(2006\)](#) for German; [Fernández \(2007\)](#) for Spanish; [Dinçtopal and Fodor \(2013\)](#) for Turkish.

An alternative explanation is that a [PP1 break in this double-PP construction is only an *indirect* cue for low attachment of PP2. A break at the left edge of PP1 could be motivated only by length considerations, because the syntactic structure is unambiguously right-branching at that point (see (8a,b) above); it offers no syntactic right-edges for a prosodic break to align with. To state this more strongly: it would not be possible for a perceiver to associate a structural break with that [PP1 prosodic break, given that the syntax in these materials requires PP1 to attach low, inside the preceding object NP. The [PP1 break *can* influence syntactic ambiguity resolution but only indirectly, by suppressing any tendency to break at [PP2, since the two loci are only one prosodic word apart. This is how the [PP1 break groups PP1 and PP2 together—inadvertently, in a strictly linguistic sense, but possibly suggesting to a perceiver that the two PPs form a syntactic unit. This indirectness, then, may be why a [PP1 break was a weaker cue to syntax and interpretation than the [PP2 break which straightforwardly signals a discontinuity in the syntactic structure as in (8a).

This investigation of the three-way potential relationship between phrase length, prosodic break location, and preferred interpretation (high/low PP2 attachment) revealed an effect on interpretation both of phrase length and of [PP2 prosodic breaks, but the effect of the prosodic breaks was stronger. The multi-level structural equation model analysis further established that much of the effect of PP2 length on PP2 attachment was indirect, mediated by the effect of PP2 length on prosodic phrasing.

General Discussion

In this study of on-line preferences for PP-attachment, we have explored the conjecture of [Mil-lotte et al. \(2007\)](#) that previously uncertain results concerning the effectiveness of prosodic disambiguation of PP-attachment constructions can be attributed at least in part to variation in the degree of compatibility between the syntactically/semantically relevant prosodic phrasings and the lengths of the syntactic phrases. The theoretical linguistics literature on the syntax–prosody interface has long emphasized the relevance of both phrase lengths and

syntactic alignment in determining prosodic phrasing, and our study has demonstrated one instance of this at work in on-line sentence processing.

Our study departed from most previous experiments on the processing of PP-attachment ambiguities by varying the length of the ambiguously attaching PP, in order to ascertain whether its length would affect PP-attachment preferences in reading, as has been documented for relative clause attachment in a number of previous studies (Lovrić 2003; Fernández 2000/2003; Vasishth et al. 2004, among others).¹³ More generally, our aim was to examine the on-line interaction of purely phonological (eurhythmic) phrasing biases with syntax–prosody alignment preferences. For this purpose we worked with a double-PP construction which is richer in prosodic opportunities than the single-PP construction that has more commonly been studied. The results of our study show a clear effect of *attachee* length on prosodic phrasing, as has been found in other attachment ambiguities. Most interestingly, our data analysis supports a causal influence of the produced prosodic phrasing on the preferred syntactic height of attachment. We have argued that this is most plausibly regarded as due to readers responding to their own (length-influenced) produced prosody as they would if it had been part of an auditory stimulus.

Two significant insights have emerged, one practical and one of relevance to the theory of the prosody–syntax interface. The first is a confirmation that future experimental studies of syntax–prosody alignment will not be fully informative unless phrase lengths are controlled, to ensure observance of the optimal length constraints which interact with and may outrank alignment constraints. The second insight concerns the linguistic status of intermediate phrase boundaries, as studied here, compared with the more stalwart properties of Intonational Phrase (IPh) boundaries, noted by Nespor and Vogel (1983), Price et al. (1991) and Selkirk (2005) among many others.

IPh boundaries are typically described as precisely located and acoustically robust, well marked by F0 movement and temporal variables. In contrast, intermediate phrase boundaries are often described not only as less strongly marked acoustically, but also as optional, and positionally not tightly regulated by the grammar, only probabilistically related to syntactic structure. However, the influence of syntactic phrase lengths on the incidence of intermediate prosodic boundaries suggests a different perspective. While it is no doubt true that IPh boundaries are more prominent acoustically than ip boundaries, more strongly marked by producers and more detectable for perceivers, it is possible that the difference in their *reliability* as cues to syntactic structure may follow simply from the fact that ip boundaries, which mark phrasal rather than clausal units, are subject to length constraints in addition to structural constraints, while IPh boundaries are not. IPh breaks are remarkably immune to influences of phrase lengths.¹⁴ Long IPhs are abundant, including parenthetical clauses, non-restrictive relative clauses, interjections of various kinds (termed ‘Comma Phrases’ in

¹³ Hemforth et al. (2006) compared attachment of long and short PPs in German, with effects that they attribute to richness of information structure rather than phrase length per se, but full details are not available. Hirose (2003) showed syntactically relevant shifts in prosodic phrasing of multi-clausal sentences in Japanese, determined by whether an initial subject NP was long or short.

¹⁴ Selkirk (2005, p. 31) cites four major influences on Intonational Phrases, one of which is “markedness constraints on minimum and maximum size of Intonational Phrase (and Major Phrase)”. However, examples are hard to come by. The only instance involving Intonational Phrases that Selkirk presents (her example (72)) actually reveals instead a tendency to promote syntactic XPs in a list construction from Major Phrase (our intermediate phrase) to Intonational Phrase if they are too long to satisfy the maximum *length constraint on Major Phrases*. Watson and Gibson (2004) present production data showing that the probability of an intonational phrase break increases with the length of the intonational phrases on either side of it, but they note that what they classified as intonational phrase boundaries included break index 3 (ip) as well as break index 4 (IPh).

Selkirk 2005 and elsewhere, from Potts 2005). But short IPhs also exist, as in (9)–(11), and are completely acceptable and easily processed.

- (9) After all, she is your mother.
 (10) The older boy, Jim, was reluctant to brush his teeth.
 (11) The upper branches, which sagged, were entirely removed.
 (12) I left, despite not having received answers to any of the questions I had arrived with.

There is also no pressure toward balance/uniformity for IPh phrasing. A long IPh can follow a short one without need to equate its length, as in (12). In other words, IPh boundary locations are apparently governed almost exclusively by syntax/semantics/pragmatics (information structure), in contrast with ip boundary locations which are governed by the complex interplay of syntax/semantics and eurhythmic/phonological constraints that we have discussed here. (Both may be susceptible to yet other factors such as speech rate and formality, as noted by Nespor and Vogel 1986; Ferreira 1993; Selkirk 2005, and many others.) Within this theoretical context, it may prove unnecessary to classify intermediate phrase boundaries as being optional and not well-controlled grammatically. Rather, they are controlled by a more heterogeneous range of factors than IPh boundaries are.

Appendix

Experimental items in their long and short versions, with and without the words in parentheses, respectively. The first sentence in each item is the preamble and the second is the target sentence. Where the two interpretations translate differently into English, the translation shows the high-attachment version before the low-attachment version.

Participants saw the sentences in Hebrew script, as illustrated in Fig. 1 above. For reasons of space this is not shown here. Anyone wishing to see the original Hebrew materials may email the corresponding author.

- (1) gadi nisa ledaber be-šeket. hu laxaš ‘et ha-bdixa al ha-matana
 Gadi tried to speak in-quiet. he whispered ACC the-joke about the-present
 le-dafna (‘avramovski)
 to-Dafna (Avramovski)
 ‘Gadi tried to talk quietly. He whispered the joke about the present to/for Dafna
 (to/for Dafna Avramovsky)’
- (2) rafi lo ‘ohev laxsof ‘et rigšot-av. hu histir ‘et ha-ka’as šelo ‘al ha-
 Rafi not like to expose ACC feelings-his. he hid ACC the-anger his about the-
 gerušin mi-tami (toledano)
 divorce from-Tami (Toledano)
 ‘Rafi doesn’t like to expose his feelings. He hid his anger about the divorce from
 Tami (from Tami Toledano).’
- (3) ha-profesor le-limudim mizraxiyim melumad beyoter. hu katav bikorot
 the-profesor for-studies eastern learned extremely. he wrote reviews
 ‘al širim be-‘aravit (palestina’it)
 about poems in-Arabic (Palestinian)
 ‘The Professor of Eastern Studies is extremely learned. He wrote reviews about poems
 in Arabic (in Palestinian Arabic).’

- (4) Ha-kcinim hitkansu le-diyun xašuv. hem 'arxu 'et ha-the-officers convened for-discussion important. they conducted ACC the-taxkir 'al ha-lexima ba-layla (ha-'axaron) debriefing about the-fight in the-night (the-last)
'The officers convened for an important discussion. They conducted the debriefing about the fighting at night (last night).'
- (5) ha-metargemet 'avda kaše letargem 'et ha-proyect. hi tircema 'et ha-the-translator worked hard to finish ACC the-project. she translated ACC the-mismaxim šel ha-mumxe le-sinit (cantonezit) documents of the-expert to/for-Chinese (Cantonese)
'The translator worked hard to finish the project. She translated the documents of the expert on/into Chinese (on/into Cantonese Chinese).'
- (6) menahel ha-xevra ne'elac lehagiv 'al divrey ha-'anašim manager the-company was compelled to respond on talks the-people sviv-o. hu hikxiš 'et ha-šmuot 'al hitpatrut-o ba-yešiva around-him. he denied ACC the-rumors about resignation-his in the-meeting (ha-du švuit). (the-bi weekly)
'The manager of the company was compelled to respond to what people were talking about around him. He denied the rumors about his resignation in the meeting (in the bi-weekly meeting).'
- (7) ha-rav šel ha-'ir matif le-nedivut. hu hidgim 'et ha-the-rabbi of the-city preaches for-generosity. he demonstrated ACC the-xašivut šel ha-netina la-kehila (ha-yisra'elit) importance of the-giving to the-community (the-Isra'eli)
'The city rabbi preaches for generosity. He demonstrated the importance of contributions to the community (to the Israeli community).'
- (8) sar ha-tikšoret dogel be-liberaliyut. hu hibi'a 'et minister the-communication advocates in-liberalism. he expressed ACC hitnagdut-o le-cenzura ba-radyo (ha-'ezori) objection-his for-censorship in the-radio (the-regional)
'The minister of communication is liberal. He expressed his objection to censorship on the radio (on the regional radio).'
- (9) ha-hanhala ko'eset 'al menahel ha-proyect. hu hidlif 'et ha-yedi'a the-management angry 'on manager the-project. he leaked ACC the-news 'al ha-bonus la-'ovdim (le-ovdey ha-xevra) about the-bonus to/for the-workers (to/for-workers the-company)
'The management is angry at the project manager. He leaked the news about the bonus to/for the workers (to/for the company workers).'
- (10) ha-patolog ha-xadaš mecuyan. hu pi'ane'ax 'et ha-gorem la-mavet The-pathologist the-new superb. He deciphered ACC the-cause to the-death ba-nitu'ax (ha-xadšani) in the-surgery (the-innovative)
'The new pathologist is superb. He deciphered the cause of the death in the surgery (in the innovative surgery).'

- (11) yo'av soxe'ax 'arukot ba-telefon ha-'erev. hu hivhir 'et ha-siba
Yoav talked a long time on the-phone this-evening. he clarified ACC the-reason
la-nesia'a le-savat-o (ha-kšiša)
to the-trip to-grandmother-his (the-old)
'Yoav talked a long time on the phone this evening. He clarified the reason for the
trip to his grandmother (to his old grandmother).'
- (12) ha-kalkelan 'ose 'avoda yocet min haklal. hu xaza 'et ha-hekef šel
the-'economist is doing job exceptional. he predicted ACC the- extent of
ha-'inflaci'a be-yuni (ha-'axaron)
the-inflation in-June (the-last)
'The economist is doing an excellent job. He predicted the extent of inflation
in June (last June).'
- (13) sigal racta še-yaxševu še-yeš la harbe xaverim. hi talta
sigal wanted that-(people) will think that-there is to her many friends. she hung
cilum šel ha-'ovdim be-misrad-a (ha-xadaš)
picture of the-workers in-office-her (the new)
'Sigal wanted people to think she has many friends. She hung a picture of the
workers in her office (in her new office).'
- (14) 'alon hivti'ax le-xaver-to še-hu yetapel ba-kol. hu
alon promised to-girlfriend-his that-he will take care in the-everything. he
yaxin 'et ha-'uga la-mesiba be-šabat (ha-krova)
will make ACC the-cake for the-party on-Shabat (the-close)
'Alon promised his girlfriend he'll arrange everything. He will make the cake for the
party on Saturday (next Saturday).'
- (15) ha-mefaked šaha ba-basis. hu ra'a 'et ha-kvuca šel ha-nimlatim
the-commander was in the-base. he saw ACC the-group of the-escapees
me-ha-xalon (ha-cfoni-ma'aravi)
from-the-window (the-north-western)
'The commander was in the base. He saw the group of escapees from the window (from
the north-western window).'
- (16) dana hirgiša corex ledaber 'al be'ayot-eha. hi te'ara 'et ha-
dana felt need to talk about problems-her. she described ACC the-
kšayim be-nisu'e-ha la-šadran (ha-mefursam)
difficulties in-marriage-her to the-broadcaster (the-famous)
'Dana felt the need to talk about her problems. She described the difficulties in her
marriage to the broadcaster (to the famous broadcaster).'
- (17) hitmana xoker xadaš la-mikre. hu 'asaf 'eduyot la-peša
assigned investigator new for the-case. he gathered testimonies for the-crime
ba-kele (bekele ma'asiyahu)
in the-prison (in prison Maasiyahu)
'A new investigator was assigned for the case. He gathered testimonies for the
crime inside prison (inside Ma'asiyahu prison).'

- (18) ha-komikay hitra'ayen le-toxnit televizya. hu te'er 'et ha-the-comedian was interviewed to-program TV hi described ACC the-koši šel ha-ktiva be-humor (yehudi tipusi) difficulty of the-writing in-humor (Jewish typical) 'The Comedian was interviewed to a TV show. He described the difficulty of writing in humor (in typical Jewish humor).'
- (19) 'etmol dani sixek trivi'a. hu gila pitaron le-xida ba-'iton yesterday Dani played trivia. he found solution for a-riddle in the newspaper (ha-mada'i) (the-scientific) 'Dani played Trivia yesterday. He found a solution for a riddle in the newspaper (in the scientific newspaper).'
- (20) ha-zamar ha-mevukaš 'avad gam ba-xag. hu hišmi'a kta'im me-the-singer the-demanded worked also in the-holiday. he played parts from-hofa'a-to ba-park (be-park hayarkon) show-his in the-park (in-Park Hayarkon) 'The popular singer worked in the holiday too. He played parts of his show in the park (in Hayarkon Park).'
- (21) la-mištara hayta haclaxa bilti cfuya. he tafsa 'et ha-xašudim ba-to the-police there was success not expected. she caught ACC the-suspects in the-prica be-xacor (haglilit). break-in in-Hatzor (Haglilit). 'The police had an unexpected success. They caught the suspects in the break-in in Hatzor (in Hatzor Haglilit).'
- (22) ha-pelefon šel ha-'av ha-tari cilcel. hu kibel 'et ha-bsora 'al ha-the-cellphone of the-father the-fresh rang. he got ACC the-news about the-leda ba-monit (be-monit ha-šerut) delivery in the-taxi (in-taxi the-service) 'The cellphone of the new father rang. He received the news about the delivery in the taxi (in the taxi service).'
- (23) ha-xotfim hištaltu 'al ha-matos. hem hesitu 'et ha-maslul šel ha-tisa the-hijackers took over on the plane. they diverted ACC the-course of the-flight le-gine'a (ha-xadaša) to-Guinea (the-new) 'The hijackers took over the plane. They diverted the course of the flight to Guinea (to New Guinea).'
- (24) ha-more le-tzuna hu 'iš mikco'a recini. hu takaf 'et ha-the-teacher to-nutrition is person profession serious. he attacked ACC the-tofa'a šel ha-nišnuš ba-ši'ur (ba-ši'urim šelo) phenomenon of the-snacking in the-class (in the-classes his) 'The nutrition teacher is a professional. He criticized the phenomenon of snacking in class (in his classes).'

References

- Abdelghany, H. (2010). *Prosodic phrasing and modifier attachment in standard Arabic sentence processing*. Unpublished doctoral dissertation, CUNY Graduate Center, New York, NY.
- Adi-Bensaid, L., & Bat-El, O. (2004). The development of the prosodic word in the speech of a hearing impaired child with a cochlear implant device. *Journal of Multilingual Communication Disorders*, 2, 187–206.
- Allbritton, D. W., McKoon, G., & Ratcliff, R. (1996). The reliability of prosodic cues for resolving syntactic ambiguity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 22, 714–735.
- Augurzky, P. (2006). *Attaching relative clauses in German: The role of implicit and explicit prosody in sentence processing*. MPI series in human cognitive and brain sciences, 77. Leipzig.
- Baayen, R. H. (2008). *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge: Cambridge University Press.
- Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, 59, 390–412.
- Becker, M. (2003). Hebrew stress: Can't you hear those trochees? *University of Pennsylvania Working Papers in Linguistics*, 9(1), 45–57.
- Beckman, M. E., & Hirschberg, J. (1994). *The ToBI annotation conventions*. Unpublished manuscript. Columbus, OH: Ohio state University.
- Bell, A. (1984) Language style as audience design. In N. Coupland, & A. Jaworski (Eds.), *Sociolinguistics: A reader and coursebook* (pp. 240–50). New York: St Martin's Press Inc.
- Ben-David, A. (2001). *Language acquisition and phonological theory: Universal and variable processes across children and across languages*. Doctoral dissertation, Tel-Aviv University. [in Hebrew].
- Bradley, D., Fernández, E. M., & Taylor, D. (2003). Prosodic weight versus information load in the relative clause attachment ambiguity. *Paper presented at the 16th annual CUNY conference on human sentence processing*, Cambridge, MA.
- Breen, M., Watson, D., & Gibson, E. (2011). Intonational phrasing is constrained by meaning not balance. *Language and Cognitive Processes*, 26(10), 1532–1562.
- Clifton, C, Jr, Carlson, K., & Frazier, L. (2006). Tracking the what and why of speakers' choices: Prosodic boundaries and the length of constituents. *Psychonomic Bulletin and Review*, 13(5), 854–861.
- De Vincenzi, M., & Job, R. (1993). Some observations on the universality of the late—Closure strategy. *Journal of Psycholinguistic Research*, 22(2), 189–206.
- Dinçtopal & Fodor (2013). Syntactic late closure and rational speaker effects: Evidence from Turkish. *Poster presented at the 19th annual conference on architectures and mechanisms for language processing (AMLAP)*, Aix-Marseille Université, Marseille, France.
- Fernández, E. M. (2000/2003). *Bilingual sentence processing: Relative clause attachment in English and Spanish*. Doctoral dissertation, CUNY Graduate Center, New York, NY, 2000. Also in H. Clahsen & L. White (Eds.), *Language acquisition and language disorders*, vol. 29. John Benjamins Publishers, Amsterdam (2003).
- Fernández, E. M. (2007). How might a rapid serial visual presentation of text affect the prosody projected implicitly during silent reading? *Conferências do V Congresso Internacional da Associação Brasileira de Linguística*, 5, 117–154.
- Ferreira, F. (1993). Creation of prosody during sentence production. *Psychological Review*, 100(2), 233–253.
- Fodor, J. D. (1998). Learning to parse? *Journal of Psycholinguistic Research*, 27(2), 285–318.
- Fodor, J. D. (2002). Prosodic disambiguation in silent reading. In M. Hirotani (Ed.), *Proceedings of NELS 32*, University of Massachusetts, GLSA, Amherst, MA.
- Forster, K. I., & Forster, J. C. (2003). DMDX: A windows display program with millisecond accuracy. *Behavior Research Methods, Instruments & Computers*, 35(1), 116–124.
- Frazier, L. (1978) *On comprehending sentences: Syntactic parsing strategies*. Doctoral Dissertation, University of Connecticut.
- Ghini, M. (1993). ϕ -formation in Italian: A new proposal. *Toronto Working Papers in Linguistics*, 12, 41–79.
- Gibson, E., Pearlmutter, N., Canseco-González, E., & Hickock, G. (1996). Recency preference in the human sentence processing mechanism. *Cognition*, 59, 23–59.
- Heck, R. H., Thomas, S. L., & Tabata, L. N. (2012). *Multilevel modeling of categorical outcomes using IBM SPSS*. New York: Routledge.
- Hemforth, B., Petrone, C., d'Imperio, M., Pynte, J., Colonna, S., & Konieczny, L. (2006) *Length effects in PP-attachment: Prosody or pragmatics? Poster presented at the 19th meeting of the CUNY conference on human sentence processing*, New York.
- Hirose, Y. (2003). Recycling prosodic boundaries. *Journal of Psycholinguistic Research*, 32(2), 167–195.

- Hirsch, A. & Wagner, M. (2011). Syntactic differences in the reliability of prosodic disambiguation. *Paper presented at Experimental and Theoretical Advances in Prosody 2 (ETAP 2)*, McGill University.
- Izre'el, S. (2012). What has Babylonian mythology to do with the way my son Oren speaks Hebrew? Syntax and prosody in ancient and spoken texts. *Journal of Advanced Linguistics Studies*, 1(1), 1–36.
- Kamide, Y., Mitchell, D. C., Fodor, J. D., & Inoue, A. (1998). Relative clause attachment ambiguity: Further evidence from Japanese. Paper presented at the 11th annual CUNY conference on human sentence processing. New Brunswick, NJ: Rutgers University.
- Kjelgaard, D., & Speer, S. (1999). Prosodic facilitation and interference in the resolution of temporary syntactic closure ambiguity. *Journal of Memory and Language*, 40(2), 153–194.
- Kraljic, T., & Brennan, S. E. (2005). Prosodic disambiguation of syntactic structure: For the speaker or for the addressee? *Cognitive Psychology*, 50(2), 194–231.
- Laufer, A. (1987). *Hangana ('Intonation')*. Jerusalem: Institute for Judaic studies, Hebrew University of Jerusalem. [in Hebrew].
- Laufer, A. (1996). Pauses in fluent speech and punctuation. In M. Bar-Asher (Ed.), *Studies in Hebrew and Jewish languages presented to Shelomo Morag* (pp. 277–294). Jerusalem: The Center for Jewish Languages and Literatures, The Hebrew University of Jerusalem and The Bialik Institute. [in Hebrew].
- Lovrić, N. (2003). *Implicit prosody in silent reading: Relative clause attachment in Croatian*. Unpublished doctoral dissertation. New York, NY: CUNY Graduate Center.
- Maia, M., Lourenço-Gomes, M. C., & Moraes, J. (2004). Prosodic effects on the reading comprehension and the oral production of ambiguous relative clauses and prepositional phrases in Brazilian Portuguese. *Poster presented at the 17th annual CUNY conference on human sentence processing*. College Park, Maryland.
- Millotte, S., Wales, R., & Christophe, A. (2007). Phrasal prosody disambiguates syntax. *Language and Cognitive Processes*, 22, 898–909.
- Nespor, M., & Vogel, I. (1983). Prosodic structure above the word. In A. Cutler & D. R. Ladd (Eds.), *Prosody: Models and measurements* (pp. 123–140). Berlin: Springer.
- Nespor, M., & Vogel, I. (1986). Prosodic phonology. Dordrecht: Foris.
- Potts, C. (2005). Lexicalized intonational meaning. In Shigetō Kawahara (Ed.), *University of Massachusetts Occasional Papers 30 (UMOP 30)* (pp. 129–146). Amherst, MA: GLSA.
- Price, P. J., Ostendorf, M., Shattuck-Hufnagel, S., & Fong, C. (1991). The use of prosody in syntactic disambiguation. *Journal of the Acoustical Society of America*, 90(6), 2956–2970.
- Pynte, J. (2006). Phrasing effects in comprehending PP constructions. *Journal of Psycholinguistic Research*, 35(3), 245–265.
- Pynte, J., & Colonna, S. (2000). Decoupling syntactic parsing from visual inspection: The case of relative clause attachment in French. In A. Kennedy, R. Radach, D. Heller, & J. Pynte (Eds.), *Reading as a perceptual process* (pp. 529–547). Oxford: Elsevier.
- Sandalo, F., & Truckenbrodt, H. (2002). Some notes on phonological phrasing in Brazilian Portuguese. *MIT Working Papers in Linguistics*, 42, 285–310.
- Schafer, A. J., Speer, S. R., Warren, P., & White, S. D. (2000). Intonational disambiguation in sentence production and comprehension. *Journal of Psycholinguistic Research*, 29, 169–182.
- Selkirk, E. (2000). The interaction of constraints on prosodic phrasing. In M. Horne (Ed.), *Prosody: Theory and Experiment* (pp. 231–262). Dordrecht: Kluwer.
- Selkirk, E. (2005). Comments on intonational phrasing in English. In S. Frota, M. Vigário, & M. J. Freitas (Eds.), 11–58, *Prosodies*. Berlin: Mouton de Gruyter.
- Selkirk, E. (2011). The syntax-phonology interface. In J. Goldsmith, J. Riggle, & A. Yu (Eds.), *The handbook of phonological theory* (2nd ed.). Oxford: Blackwell.
- Shaked, A. (2007). Competing syntactic and phonological constraints in Hebrew prosodic phrasing. *The Linguistic Review*, 24(2–3), 169–199.
- Shaked, A. (2009). *Attachment ambiguities in Hebrew complex nominals: Prosody and parsing*. Unpublished doctoral dissertation. New York, NY: CUNY Graduate Center.
- Snedeker, J., & Trueswell, J. (2003). Using prosody to avoid ambiguity: Effects of speaker awareness and referential context. *Journal of Memory and Language*, 48, 103–130.
- Truckenbrodt, H. (1995). *Phonological phrases: Their relation to syntax, focus and prominence*. Unpublished Doctoral Dissertation. Cambridge, MA: MIT.
- Truckenbrodt, H. (1999). On the relation between syntactic phrases and phonological phrases. *Linguistic Inquiry*, 30(2), 219–255.
- Ussishkin, A. (2000). *The emergence of prosody*. Unpublished doctoral dissertation. Santa Cruz: University of California.

- Vasishth, S., Agnihotri, R. K., Fernández, E. M., & Bhatt, R. (2004). Relative clause attachment in Hindi: Effects of RC length and RC placement. *Poster presented at the Architectures and Mechanism for Language Processing (AMLaP) conference*, Aix-en-Provence, France.
- Warren, P., Schafer, A. J., Speer, S. R., & White, S. D. (2000). Prosodic resolution of prepositional phrase ambiguity in ambiguous and unambiguous situations. *UCLA Working Papers in Phonetics*, 99, 5–33.
- Watson, D., & Gibson, E. (2004). The relationship between intonational phrasing and syntactic structure in language production. *Language and Cognitive Processes*, 19, 713–755.
- Webman-Shafran, R. (2011). *Prosody and parsing in a Double PP construction in Hebrew*. Unpublished doctoral dissertation, CUNY Graduate Center, New York, NY.
- Wijnen, F. (2001). Prosody in visual sentence processing. *Paper presented at the Prosody in Processing workshop*. Utrecht, NL: Utrecht Institute of Linguistics OTS.