

Prosodic Disambiguation of Low versus High Syntactic Attachment across Lexical Biases in English

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ABSTRACT

In this study, the prosodic disambiguation of the syntactic attachment differences was investigated in relation to the effect of lexical bias. Speech materials were composed of N1-conj-N2-PP phrases such as “walkers and runners with dogs.” The results show that the use of durational pattern is dominant over the pitch pattern to differentiate the attachment differences. The characteristic pitch contour was the rise and fall over N1 and N2 in the high attachment. The pitch contour in the low attachment was the rise and fall over N2 and N3 although the frequency of such patterns was lower for the low attachment case. For the durational pattern, the lengthening in the N2 region plays a significant role in the disambiguation of the syntactic attachments. The interaction between the lexical bias and the syntactic attachment was not statistically significant in the duration data.

Keywords: prosody, syntactic structure, attachment, lexical bias, pitch pattern, durational pattern

1. Introduction

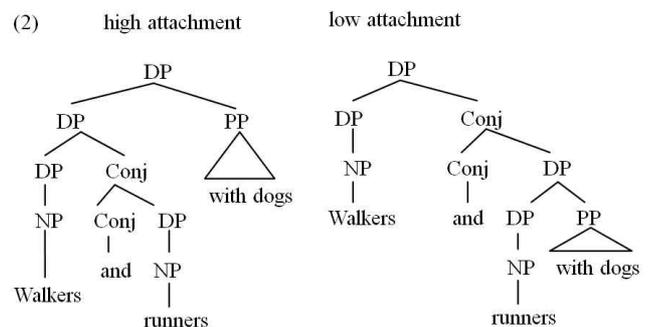
In spoken sentence production, speakers use prosody to make grouping of words and put emphasis on certain words so that they convey intended sentence meaning. Prosodic grouping and prosodic prominence of a spoken sentence is acoustically implemented in fundamental frequency, duration, and amplitude. In this paper, we focus on the prosodic grouping and its relatedness with syntactic structure and lexical bias.

1.1 Syntactic attachment and lexical bias

When a sentence has two attachment structures, it makes the sentence meaning ambiguous. The following phrase has two underlying syntactic structures that make the phrase meaning ambiguous.

(1) Walkers and runners with dogs

The ambiguity of the phrase (1) is due to the high attachment and low attachment of the prepositional phrase (PP) “with dogs”. In the high attachment, the PP modifies the conjoined noun phrase, “walkers and runners”. In the low attachment, the PP modifies only the preceding noun “runners”. The two syntactic structures of the phrase (1) are as below.



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In a syntactically ambiguous sentence, the comprising lexical items make the interpretation of the sentence bias toward one of the two possible syntactic structures. For example, the phrases in (3) are both syntactically ambiguous, but the semantic

relation between lexical items leads the sentence to bias toward one of the two meanings.

- (3) a. Sailors and airmen with families
(lexical bias toward high attachment)
b. Athletes and painters with sketchbooks
(lexical bias toward low attachment)

In the phrase (3a), the prepositional phrase “with families” tends to modify “sailors and airmen” (high attachment). On the other hand, in the phrase (3b), the prepositional phrase “with sketchbooks” tends to modify only “painters” (low attachment). This bias toward one of the two syntactic attachments is due to the semantic relation between the lexical items in the phrase.

The purpose of the production experiment in the study is to investigate whether prosodic disambiguation of syntax (low attachment and high attachment) is influenced by lexical bias (high lexical bias and low lexical bias) in sentences like (4a) and (4b).

- (4) a. Sailors and airmen with families...
(high lexical bias)
Low attachment:
[Sailors] and [airmen with families]
High attachment:
[[Sailors and airmen] [with families]]
b. Athletes and painters with sketchbooks...
(low lexical bias)
Low attachment:
[Athletes] and [painters with sketchbooks]
High attachment:
[[Athletes and painters] [with sketchbooks]]

In the sentence (4a) the prepositional phrase “with families” modifies “sailors and airmen” or only “airmen”. These two structural options of the sentence will be realized in their prosodic differences, which might be affected by the lexical bias factors.

In this paper, we pose two research questions. The one is “Where and how are prosodic cues realized in disambiguation of this structure?” The other is “Is prosodic disambiguation weaker for sentences that are lexically (or pragmatically) biased for the intended interpretation?” The predictions of the study are as follows.

- The structural difference will tend to induce different prosodic phrasing for the two interpretations of N1-conj-N2-PP phrases.
- Low attachment interpretations will tend to phrase N2 with the PP, and N1 separately, while high attachment interpretations will tend to phrase N1 and N2 together.
- If speakers adjust their prosody for the bias of the materials, they will tend to produce stronger indications of syntactic structure when it goes against the lexical bias, and in cases where there is no strong lexical bias.

Concerning the prosodic realization, we investigate the pitch patterns and durational patterns of the target phrases to determine what are the characteristic pitch contours for attachment conditions and which regions are lengthened in relation to the other regions of the phrases.

1.2 Related works

Previous studies have shown that the prosodic features such as duration and pitch can be used to convey boundaries that disambiguate syntactically ambiguous utterances.

The durational pattern is explained by segmental lengthening and pausing before prosodic boundary. In the perception experiment of Lehiste et al. (1976), duration of words containing ambiguous phrase boundaries were contracted and expanded. The results indicate that listeners tend to interpret longer sequence as the phrase with phrase boundary. O'Malley et al. (1973) found that speakers consistently place pauses at parenthesis in spoken algebraic expressions. In a related work, Streeter (1978) showed a lengthening of the operand in the algebraic expression of the form “(A plus E) times O” and “A plus (E times O)” led listeners to recover the location of the right parenthesis. Price et al. (1991) reports that the location of a relatively large break index before sentence final prepositional phrase appears to block the low attachment of the phrase, and the relatively small index appears to enhance it. Wightman et al. (1992) found that there are at least four statistically significant levels of boundary, using duration alone, and possibly more when pauses and boundary tones are considered. According to Wightman et al. (1992), pauses are associated with major prosodic boundaries.

Another important acoustic cue for prosodic boundary is fundamental frequency. Cooper and Sorensen (1977) conducted experiments to determine the extent to which speakers' syntactic coding influences fundamental frequency contours in the region

of syntactic boundaries. Measurements were obtained for key word segments at syntactic boundaries in sentences. The result was that significant fall-rise patterns of F0 were at the boundaries between main conjoined clauses and at the boundaries between main and embedded clauses. Warren (1985) shows the attachment differences are implemented by a continuing declination of fundamental frequency or a sharp fall on the critical region in the minimal and non-minimal attachment sentences.

It has been well known that not only the syntactic structure but also other linguistic structures influence the prosodic organization of a spoken sentence (Cutler, et al., 1997; Wagner and Watson, 2010). In this paper, based on the previous studies concerning the prosodic disambiguation of syntactic attachment differences, we investigate how lexical bias and syntactic attachment structure interact and influence on the pattern of prosodic grouping. Prosodic phrasing by durational cues and pith pattern will be examined in relation with those syntactic and lexical factors

2. Method

2.1 Participants

For the lexical bias pretest, 18 native speakers of American English participated in a written questionnaire. In the production experiment, the participants were 10 native speakers of American English who didn't participate in the lexical bias pretest. Most were students of University of Hawaii at Manoa, and they were naïve with respect to the purpose of the experiments. Two production sessions for each participant were separated by at least a week.

2.2 Materials

The target phrase was a conjoined noun phrases followed by a modifying prepositional phrase like (5).

(5) Walkers and runners with dogs

Two different meanings of the above phrase can be suggested due to its syntactic ambiguity. The meaning and the syntactic difference are as below.

- (6) a. Walkers don't have dogs and runners have dogs.
(Low attachment: [Walkers] and [runners with dogs])
- b. Both walkers and runners have dogs.
(High attachment: [[Walkers and runners] [with dogs]])

Besides the phrase has a syntactic ambiguity, it also can be lexically biased concerning the attachment preferences. For example, the PP can be lexically biased toward the high attachment or low attachment, and it can be neutral in the preferences.

(7) High attachment bias:

Buses and cars with diesel engines...

Equi-bias:

Smiles and phrases with hidden meanings...

Low attachment bias:

Spoons and knives with dulled edges...

Lexical bias was determined by a written questionnaire pretest. We set up test sentences using the phrases from the BNC corpus search and conducted a written questionnaire. The 91 test items were mixed with 20 control sentences that used number agreement to force high attachment (e.g., The house and the barn that have white walls...) or low attachment (e.g., The boy and the girl who is holding a book...). The order of disambiguating choices was counterbalanced between lists, and 4 different randomizations of items were tested. 18 participants (different from those in the main experiment) read 91 complete sentences containing the test structure. After reading each sentence, they answered a forced choice disambiguating question about the PP attachment. Then, they rated their confidence in their answer. In the written questionnaire there were five scales between the lowest 1 for the low attachment and highest 5 for the high attachment. The 16 high bias sentences (the sentences 1 to 16 in Appendix) have the average 4.19 score. The 16 equi bias sentences (the sentences 17 to 32 in Appendix) have the average 3.07 score. The 16 low bias sentences (the sentences 33 to 48 in Appendix) have the average 2.09 score. The final set was matched as closely as possible for the lengths of the N1, N2 and PP region across the three lexical sets as shown in the Table 1.

Table 1. Lexical bias groups with average bias score and syllable number of target regions

Bias	5 = high, 1 = low	Sylls in N1	Sylls in N2	N1 & N2	Sylls in PP
High	4.19	1.88	2.13	5.00	4.69
Equi	3.07	2.06	1.94	5.00	4.50
Low	2.09	2.19	2.44	5.63	4.00

2.3 Design of recording materials

The experimental items were divided into 2 lists. In each list, half of the experimental items (8 items for each bias group and 24 items in total) were presented so as to induce low attachment, and the other half to induce high attachment. The attachments were reversed for the second list. In each list, the 48 test items were randomized with 40 filler items, with a different randomization for each test session. All filler items contained two conjuncts. The fillers used a mix of short subjects and long subjects, as well as prenominal and postnominal modification, to prevent the participants from repeating a single prosodic form. Each participant was tested on both lists, with at least one week interval between production sessions for each list. The order of the lists was divided across the participants.

2.4 Production experiment

Phrase-combination task was used for the production experiment. The participants saw two consecutive frames of the stimuli on a computer screen. The first frame presented two noun phrases on two separate lines. Participants were instructed to remember these and press the space bar to see the second frame when they are ready. The second frame contained two verb phrases. Upon seeing the second frame, the participants produced a sentence that combined the two noun phrases from frame 1 into the subject and employed the most appropriate verb phrase from frame 2 as the predicate. This second frame stayed on the screen until the participants finish the production of the sentence. Low attachment was indicated by presenting an unmodified N1 and a modified N2, and high attachment was indicated by a modified N1 and N2 as in Figure 1.

Low attachment condition	
First frame	Second frame
walkers runners with dogs	use the outer portion of the park. serve what is known as bright beer.
High attachment condition	
First frame	Second frame
walkers with dogs runners with dogs	use the outer portion of the park. serve what is known as bright beer.

Figure 1. Stimuli examples for low and high attachment conditions

In both cases, participants were instructed to produce a natural phrase like “walkers and runners with dogs”. Participants were not instructed to provide a disambiguating prosody. They were told simply to say the sentences “naturally, as if talking to a friend or classmate, and so that they’d be easy for your friend to understand”.

Audio recordings were made to a laptop computer at a 44.1 kHz sampling rate using sound recording and editing software Audacity. Each sentence region of the sound files was saved into separate sound files for measurement of critical regions. The sound files were screened to eliminate the inappropriate items that are incorrect combinations or that include speech errors such as stuttering, long pause, and mispronunciation. Then, the items were labeled with the sentence transcript and segmented word by word, and the pause in between. The fundamental frequency contours over the target regions were extracted and the durations of the target regions, N1, pause following N1, conjunction ‘and’, N2, and pause following N2 were measured.

2.5 Acoustic measurements

The data were measured using speech analysis program, Praat. The waveforms and the spectrograms were used to identify the boundaries of each target region of the materials. The durations for the first noun(N1), the following pause, conjunction ‘and’, the second noun(N2) and the following pause before the preposition ‘with’ were measured. The first noun region was measured from the onset of visible spectrographic display like stop burst, the onset of the frication, or the start of the glottal pulse, to the offset of the frication energy for N1 final /s/ and /z/. For the three items in which the first noun ends with nasal /n/, the offset of the nasal low amplitude region was measured as the right boundary of the first noun. The criteria for the onset and the offset of the second noun region were the same as those for the first noun region. For this N2 region, the final consonants were /s/ or /z/ except one item which ends with /n/. The pause durations after N1 and N2 regions were measured for the interval between the offset of the frication or the nasal stop and the following glottal pulse for the words ‘and’ and ‘with’.

3. Results

3.1 Qualitative assessment of overall pitch patterns

General pitch patterns that differentiate the attachment conditions are illustrated in Figure 2. The first panel shows the pitch pattern of the high attachment condition, where the f_0 maximum is located on the N1 final or the following conjunction ‘and’, and the pitch is falling over the N2 region. The second panel shows the pitch pattern of the low attachment condition, in which the f_0 maximum is located on the N1 final

or the following conjunction ‘and’, and this part is the same as the case of high attachment. But there is the second pitch peak on the N2 final or preposition ‘with’, and the characteristic pitch pattern that shows the difference from high attachment is that the pitch contour is rising over the N2 region.

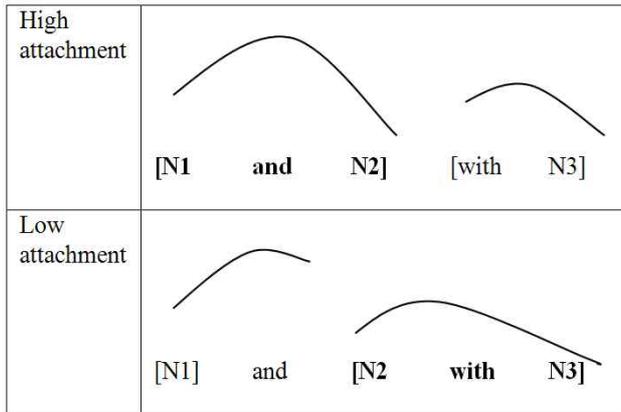


Figure 2. Schematic pitch contours for low attachment and high attachment

In sum, the high attachment tokens have one pitch peak in the region of N1 through preposition ‘with’, and the low attachment tokens have two pitch peaks, higher first one on N1 final or ‘and’ and the lower second one on N2 final or ‘with’. Therefore, the pitch contour groups the N1 together with N2 in high attachment, and N2 together with N3 in low attachment, which is the expected prosodic phrasing for the syntactic differences.

In the following we present sample productions showing high and low attachment prosodic disambiguation. The Figure 3 is a typical high attachment sample. It shows that one f0 peak is placed on ‘and’. The contour is characterized to have rise and fall pitch pattern that groups N1 and N2. The pitch is rising over the N1 region and it is falling over the N2 region. The durational pattern is that N2 undergoes lengthening and often has a following pause.

The Figure 4 is a low attachment sample which has two f0 peaks

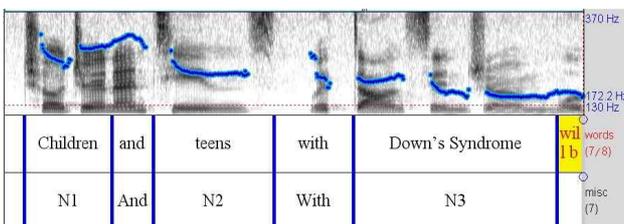


Figure 3. Typical high attachment pitch pattern with one f0 peak over N1 and N2

peaks, one on N1 final or ‘and’ and the other on N2 final or ‘with’. It has rising f0 over N1 region and rise and fall f0 over N2 and N3 region. The pitch contour of the N1 region is the same as that of the high attachment. As for the durational pattern, N1 is lengthened. It also has optional glottalization in the initial of ‘and’. The initial glottalization of ‘and’ of the speech sample in Figure 4 is shown in Figure 5.

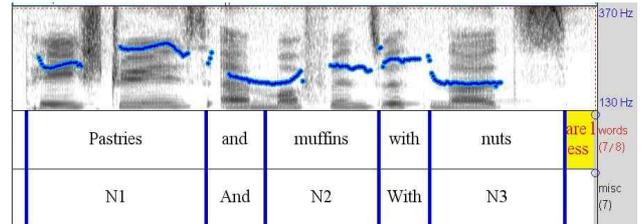


Figure 4. Low attachment sample with two f0 peaks

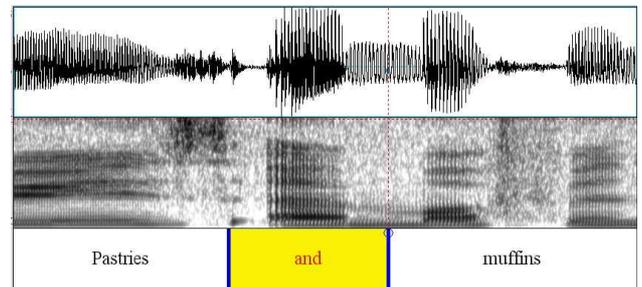


Figure 5. Glottalization of ‘and’ initial in low attachment

Another low attachment sample is shown in Figure 6. The sample shows that there is one peak on N1 final and the f0 is falling over N2. This pitch pattern is the pattern that usually occurs in the high attachment condition, but the durational pattern shows that it is a low attachment sample. The N1 is lengthened and the initial of ‘and’ is glottalized, which makes a sensation of prosodic boundary after N1.

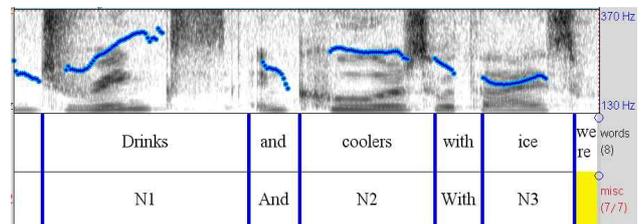


Figure 6. Low attachment sample with one f0 peak and N1 lengthening

The third sample of low attachment in Figure 7 also shows a tune for the high attachment having one f0 peak on N1, but it has a durational pattern of low attachment. N1 is lengthened,

and N2 is shortened with rapid speech rate to make a sensation of the grouping of N2 and N3 together.

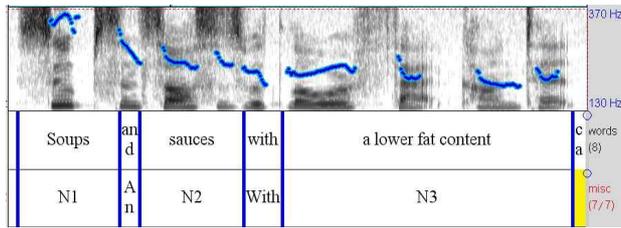


Figure 7. Low attachment sample with one f0 peak and complementary durational pattern

Among the ten speakers, four speakers employed higher percentage of correct pitch pattern for the attachment conditions compared to the rest 6 speakers. The 6 speakers showed lower percentage of correct pitch pattern for low attachment condition. They tended to rely on durational pattern to differentiate the attachment conditions. Overall, all the 10 speakers mainly manipulated the durational pattern for the disambiguation of the attachment differences. The Table 2 shows the number and percentage of tokens with correct pitch pattern for 4 speakers.

Table 2. The number and percentage of tokens with appropriate pitch pattern for 4 speakers

speaker	low attachment	high attachment	total
Eng01	34/45 (76%)	30/42 (71%)	64/87 (74%)
Eng03	18/41 (44%)	32/41 (78%)	50/82 (61%)
Eng04	19/43 (44%)	31/42 (74%)	50/82 (59%)
Eng05	25/38 (66%)	25/43 (58%)	50/81 (62%)

The other 6 speakers have the similar percentage of correct high attachment pitch pattern, but their correct pitch pattern for low attachment was around 25%. They showed the complementary strategies of using durational pattern to implement the low attachment.

Whether the first peak location is on N1 final or ‘and’ varied across speakers. For instance, the speaker Eng03 consistently put the first peak on conjunction ‘and’. The effect of the syllable number on the peak location is not clear in this experiment.

In sum, the characteristic pitch pattern for high attachment was the rise and fall pitch pattern over N1 and N2 region with f0 peak on N1 final or ‘and’, and the pitch pattern for the low attachment was the rise over N1 with f0 peak on N1 final or

‘and’ and the rise and fall f0 over N2 and N3 region with the second f0 peak on N2 final or ‘with’. Taking apart the N2 region, the f0 falls over N2 region for the high attachment and it rises over the N2 region for the low attachment. The speakers tended to employ the right duration pattern when they don’t implement the right pitch pattern for the attachment.

3.2 Durational patterns

For each subject, the duration of target region was averaged in the two attachment conditions across three lexical biases. A two-factor ANOVA was performed on these data, testing the effect of the factors: (1) lexical bias with the three levels high, equi, low, (2) attachment condition with the levels low and high, and the interaction between the two factors. In the 960 tokens(10 speakers × 48 sentences × 2 lists), the tokens with disfluency and outliers were excluded, and the number of the sentences that were analyzed was 832. The distribution of the durations of the N1, N2, N1 plus Pause, and N2 plus Pause didn’t show the normal distribution which is required for ANOVA. After the logarithmic transformation and the exclusion of the 10 outliers, the duration distribution approached to the shape of the normal distribution. As the number of tokens was large enough, ANOVA could be properly used for the analysis of the data.

There was a small but significant effect of syntax for N2. N2 duration was greater for high attachment than for low attachment productions. A very small numerical difference for N1 was in the predicted direction, but did not approach significance. Durations of the first noun(N1), the first noun and the following pause(N1+P), the second noun(N2), and the second noun and the following pause(N2+P), and the conjunction ‘and’ averaged for all participants. The descriptive statistics for 832 tokens of each critical region appear in Table 3.

Table 3. Mean durations and standard deviations in millisecond of critical regions for attachment difference

	Low attachment		High attachment	
	Mean	SD	Mean	SD
N1	510	164	503	157
N1+P	516	167	508	161
N2	494	163	510	160
N2+P	514	170	536	170
and	148	56	149	52

Durations of the first noun averaged 510 and 503 ms for the low attachment and high attachment across three levels of lexical bias. The first noun durations of low attachment were slightly longer than those of high attachment. But the difference was not statistically significant ($F(1, 830)=0.24, p<0.5$). The second noun durations of high attachment were longer than those of low attachment for all lexical biases. The second noun durations averaged 494 and 510 ms for the low attachment and the high attachment. The attachment condition had a significant impact on the duration of the second noun region ($F(1, 830)=2.77, p<0.1$).

Previous researches have shown that prosodic phrasing correlated with syntactic disambiguation is realized by durational cues such as segmental lengthening and pause insertion. In this study we examined the effects of the combination of lengthening and pause.

The durations of the noun and the following pause was also averaged for the comparison with the durations of the noun region itself. Durations of the first noun and the following pause averaged 516 and 508 for the low attachment and the high attachment. But the difference was not statistically significant ($F(1, 830)=0.36, p<0.5$). Durations of the second noun and the following pause averaged 514 and 536 ms for the low attachment and the high attachment. The duration of the second noun and the following pause was significantly longer in high attachment condition ($F(1, 830)=4.25, p<0.05$). The durations of the conjunction ‘and’ averaged 148 and 149 ms for the low and the high attachment. The difference was not statistically significant ($F(1, 830)=0.23, p<0.5$).

There was a significant correlation between the first noun and the following pause (Pearson coefficient 0.210, $p<0.01$). The correlation between the second noun and the following pause was also significant (Pearson coefficient 0.133, $p<0.01$). The

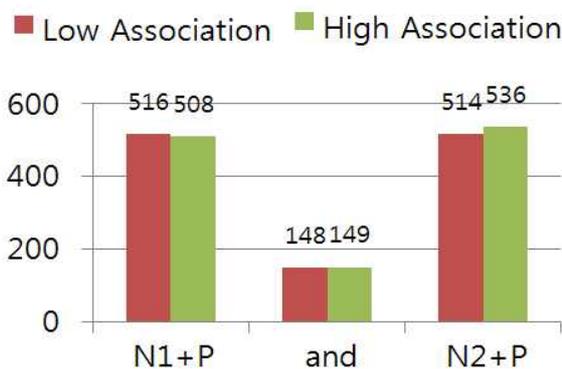


Figure 8. Duration differences in low and high attachment of N1+P, and, N2+P region

significant positive correlation between the noun regions and the following pauses indicates that the pause duration increases accordingly as the duration of the preceding noun increases. Figure 8 shows the duration differences between two attachments in N1+P, ‘and’, and N2+P. The difference in N2+P durations is largest among three pairs.

There were highly significant effects of lexical bias for both N1 and N2. This was expected since syllable length showed some variation across sets. There was no interaction of syntax with lexical bias. Table 4 is the mean durations across the lexical bias groups for the attachment conditions for all tokens in the experiment.

Table 4. Durations of N1 and N2 regions in millisecond for lexical bias and attachment condition

	High bias		Equi bias		Low bias	
	Low att.	High att.	Low att.	High att.	Low att.	High att.
N1	445	439	500	501	586	574
N2	490	516	442	459	553	570

Table 4 shows the duration pattern consistent for each attachment condition. The duration of N1 region is longer in low attachment condition relative to high attachment condition across 3 lexical bias groups. The duration of N2 region is longer in high attachment condition across 3 lexical bias groups.

To see the lexical bias effect on the durational pattern with controlling the syllable number effect, we chose the speech samples of which N1 and N2 are one syllable words. The samples of 6 treatments, that is, the samples for high bias and low attachment, high bias and high attachment, equi-bias and low attachment, equi-bias and high attachment, low bias and low attachment, and low bias and high attachment were chosen to compare the duration pattern differences among the 6 groups. The 6 speech samples were chosen from the speech samples of one speaker(Eng01), and the two tokens for each lexical bias

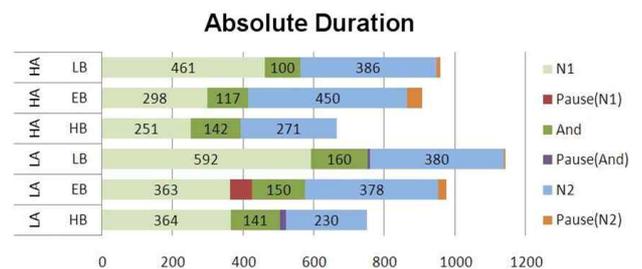


Figure 9. Duration pattern in millisecond of N1 through N2 region in speech samples for 6 treatments

were the same item. The duration pattern for the speech samples of the 6 treatments appears in Figure 9.

As it is seen in Figure 9, the N1 durations for low attachment are longer than those for high attachment (592ms vs. 462 ms for low bias pair, 363ms vs. 298ms for equi-bias pair, and 364ms vs. 251ms for high bias pair). For the N2 region, the N2 durations for high attachment are longer than those for low attachment (386ms vs. 380ms for low bias pair, 450ms vs. 378ms for equi-bias pair, and 271ms vs. 230ms for high bias)

Figure 10 and Table 5 show the relative duration of each region for 6 treatments in percentage.

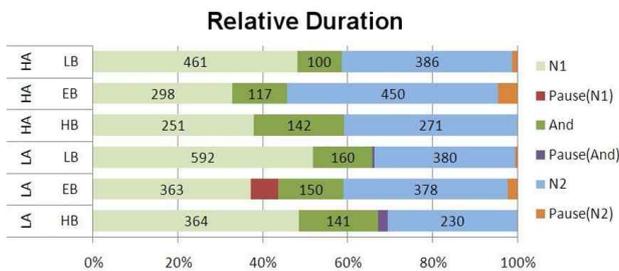


Figure 10. Relative duration in percentage scale of N1 through N2 region for 6 treatments

Table 5. The percentage of the duration of N1 through N2 region for the speech samples of 6 treatments

	N1	N1_P	And	And_P	N2	N2_P
HA_LB	48%	0%	10%	0%	40%	1%
HA_EB	33%	0%	13%	0%	50%	5%
HA_HB	38%	0%	21%	0%	41%	0%
LA_LB	52%	0%	14%	1%	33%	0%
LA_EB	37%	6%	15%	0%	39%	2%
LA_HB	48%	0%	19%	2%	31%	0%

For N1, the relative duration in percentage is higher for low attachment than for high attachment (52% vs. 48% for low bias pair, 37% vs. 33% for equi-bias pair, 48% vs. 38% for high bias pair). For N2, the relative duration in percentage is higher for high attachment than for low attachment (40% vs. 33% for low bias pair, 50% vs. 39% for equi-bias pair, and 41% vs. 31% for high bias pair).

Figure 11 indicates that there is some lexical bias effect on the durational pattern of N1 and N2 regions for attachment condition in these 6 speech samples. The N1 and N2 lengthening patterns are different among three lexical bias groups even though these samples have the same number of syllables in N1 and N2. The left panel of the Figure 11 shows that for low attachment, the N1 duration of low bias sample is

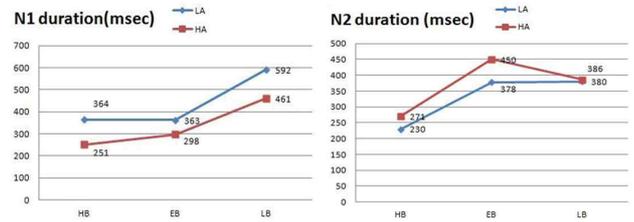
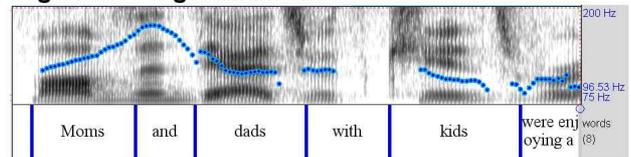


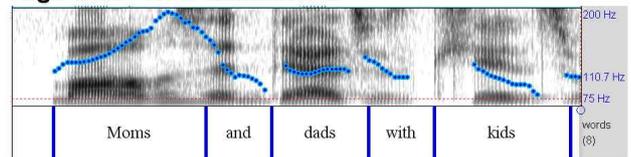
Figure 11. N1 and N2 durations for attachment conditions across lexical biases

longest and the N1 duration of high bias sample is shortest. The right panel of the Figure 11 shows that for high attachment, the N2 duration of low bias is longer than that of the high bias even though the N2 duration of equi-bias sample is longest

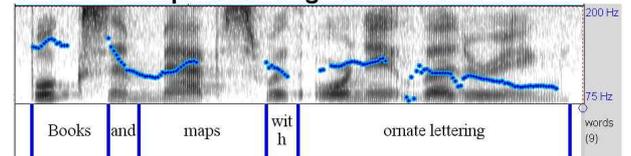
High bias - High attachment



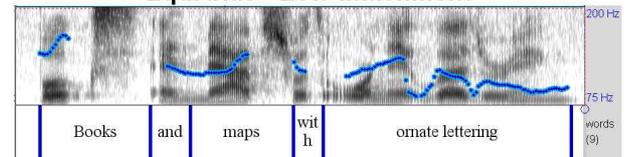
High bias - Low attachment



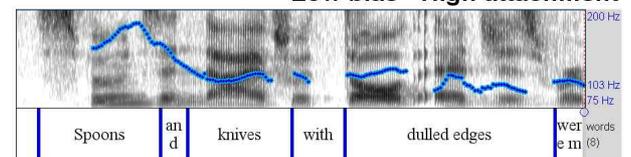
Equi bias - High attachment



Equi bias - Low attachment



Low bias - High attachment



Low bias - Low attachment

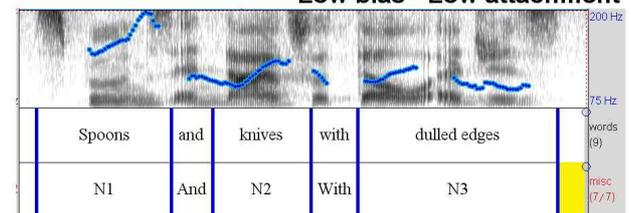


Figure 12. Speech samples with pitch contour and duration pattern for 6 treatments

among the three lexical bias groups.

The speech samples with pitch contour for 6 treatment groups appear in Figure 12. For all the lexical bias groups there exist pitch pattern differences between high attachment and low attachment. The high attachment samples have N2 final prosodic boundary with f0 peak on N1 final or 'and'. The low attachment samples have an N1 final prosodic boundary with the first f0 peak on N1 final or 'and', and the second f0 peak on N2 final or 'with'. After the first f0 peak, the tune for low attachment starts to rise at the beginning of the N2 and phrase N2 and N3 apart from N1.

The degree of the lengthening of N1 in low attachment and the lengthening of N2 in high attachment was strongest in low lexical bias group and weakest in high lexical bias group overall. One exception of the overall tendency was that the N2 lengthening for high attachment was the strongest in equi-bias group.

4. Discussion

The characteristic pitch contour in the high attachment was the rise and fall over N1 and N2, and this contour has the effect of grouping this region as one prosodic phrase. The pitch pattern for the low attachment was the rise and fall contour over N2 and N3. The speakers tended to have difficulty in realizing the right pitch contour in low attachment. That might be due to the fact that the first word of the target phrase, 'N1' is not long enough to make one prosodic group by itself. The speakers might have difficulty in separating the N1 as one prosodic group and starting another prosodic group on the N2. When they don't realize the right pitch pattern in low attachment, the speakers usually employed the durational cues such as N1 lengthening and/or N2 shortening. Overall, the durational pattern was more consistent to differentiate the syntactic attachment conditions across lexical biases than the pitch pattern. The dominant use of durational pattern over pitch pattern for syntactic disambiguation in this study might be due to the relatively short length of the target phrase.

Watson and Gibson (2004) showed that the size of syntactic constituent and the syntactic argument relationships contribute to the place of the prosodic boundary. The length of the noun phrase and the short length of the first and second noun probably influence on the prosodic phrasing and the location of f0 peak, and especially the function words connecting the nouns such as 'and' and 'with' might play a role in the characteristic

pitch contour for the attachment differences in the materials of this study.

5. Conclusion

The research questions of this study were how the prosody disambiguates the syntactic attachment differences and whether this prosodic disambiguation is affected by lexical information such as lexical bias. We examined the pitch pattern and durational pattern for the prosodic phrasing. The production experiment in this paper supports previous studies in that both pitch pattern and durational pattern are the prosodic cue correlated with syntactic boundary.

The characteristic pitch pattern in the high attachment condition was the rise and fall f0 contour over the N1 and N2 region to make prosodic grouping of N1 and N2 apart from N3. The pitch pattern for the low attachment condition was the rise and fall f0 contour over the N2 and N3 region that groups N2 and N3 apart from N1. The percentage of the correct pitch pattern was high for high attachment and low for low attachment. It might be partly because the N1 region is too short to be separated from the rest of the phrase and make it as one group to convey the meaning of low attachment employing f0 contour.

As for the durational pattern, in the high attachment condition the second noun region was significantly longer than the same region in the low attachment condition. This is consistent with a stronger prosodic boundary at the end of the second conjunct for high attachment productions than low attachment ones. The duration data suggest that the local lengthening in the second noun region rather than the first noun region might be the dominant cue to disambiguate between the syntactic low and high attachment structures.

The interaction of lexical bias and attachment was not statistically significant in duration data, suggesting that speakers' tendency to disambiguate through durational differences was not significantly affected by lexical bias. But the duration data don't show much about the effect of lexical bias as the composition of the phonemes and the number of phonemes and syllables vary between items and lexical bias groups.

Further research is needed to determine whether and how the lexical information such as lexical bias affects the prosodic disambiguation of syntactically ambiguous sentences. Prosody interacts with other linguistic factors in speech production and identifying the related factors will help define the role of prosody in speech communication.

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Appendix

SENTENCES IN THE PRODUCTION EXPERIMENT

1. Restaurants and cafes with views of the ocean have attracted tourists to the city.
2. Players and families with excited faces greeted each other in the aisle.
3. Brothers and sisters with large brown eyes were waiting for their turn in the registration line.
4. Buses and cars with diesel engines had turned the snow to a gray mess.
5. Evenings and weekends with gallery openings are the hardest times to find parking.
6. Charts and drawings with bright colors can capture a reader's attention.
7. Tubs and showers with safety handrails are increasingly popular as the baby boomers age.
8. Sailors and airmen with families prefer to be stationed in the U.S.
9. Sheets and pillowcases with high thread counts cost more but feel nicer.
10. Companies and manufacturers with poor security can hide behind the law.

11. Children and teens with Down's Syndrome will be the models for the Spring catalog.
12. Pants and skirts with low waistlines are comfortable and stylish.
13. Magazines and newspapers with upbeat stories were put on the shelves of the hospital.
14. Moms and dads with kids were enjoying a real family holiday in the sun.
15. Bottles and vases with narrow openings can be cleaned with a long-handled brush.
16. Boxes and bags with torn sides were loaded with books of every size and color.
17. Children and adults with disabilities were first in line for an urgent improvement in benefits.
18. Bookcases and cabinets with sliding glass panels lined the walls of the study.
19. Technicians and paramedics with advanced training oppose the legislation.
20. Producers and directors with big budgets keep close track of how movies do on opening weekend.
21. Walkers and runners with dogs use the outer portion of the park.
22. Computers and phones with good screens are better for games than TV sets.
23. Soups and sauces with a lower fat content can be easy to make.
24. Books and maps with ornate lettering covered the large desk.
25. Investors and buyers with good credit will have no trouble finding mortgages.
26. Pastries and muffins with nuts are less popular than the bakery's other items.
27. Smiles and phrases with hidden meanings let some feel special while others get left out.
28. Overcoats and jackets with heavy linings are hard to find in Hawaii.
29. Hot-tubs and bathrooms with luxurious tiling are featured in this month's catalog.
30. Beaches and parks with lots of shade are good places for a party.
31. Benches and chairs with cushions filled the entranceway.
32. Bats and gloves with some wear are necessary for the demonstration.
33. Cakes and cookies with big chunks of chocolate beckoned shoppers from down the street.
34. Passengers and stewardesses with big smiles passed through the aisles.
35. CDs and DVDs with good soundtracks were strewn across the floor.
36. Footrests and keyboards with ergonomic designs have reduced the division's work-related injuries by 17%.
37. Schools and homes with young children are located near the airport in question.
38. Students and professors with recent degrees are most likely to use electronic resources.
39. Teachers and retirees with low incomes responded the weakest to the tax proposal.
40. Cleansers and moisturizers with sunscreen are the most important products for healthy skin.
41. Swimming pools and gardens with curving walkways add to the appeal of these properties.
42. Drinks and coolers with ice were delivered to the banquet hall.
43. Detectives and soldiers with rifles searched the area.
44. Dancers and musicians with large cases bustled around the backstage area.
45. Air-conditioners and computers with great colors are among the hot items.
46. Spoons and knives with dulled edges were mixed together in the drawer.
47. Athletes and painters with sketchbooks gathered in the park.
48. Schoolchildren and vendors with bright carts filled the street for the festival.