The Effect of Interpretation Bias on the Production of Disambiguating Prosody

Choe, Wook Kyung[1] • Redford, Melissa A.[2]

ABSTRACT

Previous research on syntactic processing shows that the interpretation of a syntactically ambiguous sentence is frequently strongly biased towards one meaning over another. The current study investigated the effect of bias strength on the production of disambiguating prosody for English ambiguous sentences. In Experiment 1, 40 speakers gave default readings of 18 syntactically ambiguous sentences. Questioning was used to prove intended meanings behind default readings. Intended meanings were treated as interpretation biases when a majority of speakers read a sentence with the same intended meaning. The size of the majority was used to establish bias strength. In Experiment 2, 10 speakers were instructed to use prosody to disambiguate given alternate meanings of the sentences from Experiment 1. The results indicated an effect of bias strength on disambiguating prosody: speakers used temporal juncture cues to reliably disambiguate alternate meanings for sentences with a weak interpretation bias, but not for those with a strong bias. Overall, the results indicated that interpretation biases strongly affect the production of prosody.

Keywords: prosody, disambiguation, interpretation bias, interpretation bias strength, syntactic ambiguity

1. Introduction

Although prosodic and syntactic boundaries do not always align (Gee & Grosjean, 1983; Shattuck-Hufnagel & Turk, 1996; Jun, 1998), they do so frequently enough to support the hypothesis that prosodic structure is derived partly from syntactic structure (Cooper & Paccia-Cooper, 1980; Nespor & Vogel, 1986; Selkirk, 1986). One consequence of this frequent alignment is that listeners can use prosodic cues to disambiguate syntactically ambiguous sentences (Lehiste, 1973; Lehiste et al., 1976; Price et al., 1991; Allbritton et al., 1996; Carlson et al., 2001). For example, Lehiste et al. (1976) showed that listeners were able to resolve structural ambiguities when the duration of interval between the critical words was manipulated. Other work confirmed these early findings and further indicated that intonational patterns (e.g., boundary tones) provide an additional cue for the disambiguation of ambiguous sentences (Price et al., 1991).

In spite of the clear evidence that listeners use prosodic information to decode and process syntactic structures, syntax and prosody are functionally independent (for an overview, see Shattuck-Hufnagel & Turk, 1996). One consequence of this independence is that speakers may insert prosodic boundaries even in the absence of a syntactic boundary. For example, the implementation of prosodic focus, which is driven by semantic-pragmatic factors, is known to trigger discordances between syntactic and prosodic boundaries (Schafer & Jun, 2001). With respect to syntactically ambiguous sentences, it is possible that speakers sometimes respond more strongly to semantic-pragmatic factors than to structural factors. In such cases, prosody may be used to highlight elements in a focus-marking way rather than to cue syntactic boundary locations.

The current study investigated the question of whether speakers'use of disambiguating prosody is influenced by their attention to semantic pragmatic factors. We assumed that attention to semantic-pragmatic factors varies with how readily a

sentence can be interpreted in one way versus another. Accordingly, the study tested the effect of interpretation bias on speaker's production of disambiguating prosody.

Biases in the interpretation of syntactically ambiguous sentences

Research on disambiguating prosody typically treats the possible meanings of an ambiguous sentences as equally plausible (e.g., Price et al., 1991; Allbritton et al., 1996; Snedeker & Trueswell, 2003; Kraljic & Brennan, 2005; Millotte et al., 2007; Jeon, 2011). However, research on syntactic processing shows that the interpretation of a syntactically ambiguous sentence is frequently strongly biased towards one meaning over another (for a review, see Gibson, 1991; Tanenhaus & Trueswell, 1995). Consider, for example, the phenomenon of garden-path sentences brought on by the strong preference to attach current items to the most recently processed item. This preference has been attributed to the principle of late closure (Frazier & Fodor, 1978; Frazier, 1979), and it applies equally to sentences with more than one sensible interpretation (Wanner, 1980).

In spite of the strong preference for late closure, it can be overridden by other conditioning factors such as semantic features (Trueswell et al., 1994), context (Altmann et al.,1998), and lexical/construction frequency (Spivey & Tanenhaus, 1998). For example, Trueswell et al. (1994) argued that the animacy of a noun phrase affects listeners' processing of sentences. Eye-movement data indicated that readers preferably identify an ambiguous verb form as past tense when it follows an animate noun, but prefer a past participle interpretation when it follows an inanimate noun.

In sum, syntactic processing research indicates that factors such as the principle of late closure, semantic features, context, and lexical frequency all influence the interpretation of ambiguous sentences. These influences result in interpretation biases that may or may not affect a speaker's ability to disambiguate their meaning using prosody.

Interpretation biases and disambiguating prosody

The hypothesis that interpretation biases may influence disambiguating prosody has rarely been investigated. In fact, we know of only one prior study that specifically addressed this question. Wales and Toner (1979) examined the effect of interpretation biases on listeners' ability to identify intended meanings of syntactically ambiguous sentences based on prosodic

information. A reading task was used to seek participants' interpretation of 30 ambiguous sentences. When the majority of participants interpreted a sentence in just one way, it was categorized as strongly biased towards a single meaning. When participants were more evenly divided in their interpretation of a sentence, it was categorized as weakly biased towards a particular meaning. Once bias strength was established, four speakers were trained in the two possible meanings of each sentence. These speakers were then asked to produce the two meanings of the sentence using disambiguating prosody. Next, the spoken sentences were presented to listeners who were asked to identify the intended meaning for each sentence. The results showed that listeners were more apt to use prosody to disambiguate meanings of weakly biased sentences than those of strongly biased ones. When ambiguous sentences had strong interpretation biases, listeners mainly defaulted to the preferred interpretation of the sentence.

Wales & Toner's (1979) study focused on listener behavior rather than on speaker behavior. Listeners defaulted to a preferred meaning for the strongly biased sentences and used prosody to identify the intended meaning of weakly biased sentences, but we do not know the extent to which this may have been due to how speakers produced alternative sentence meanings. There is the possibility that speakers provide better cues to alternative meanings for sentences with weak interpretation biases compared to those with strong interpretation biases. Specifically, speakers may less consistently mark boundaries in sentences with strong interpretation biases because the alternative meaning stands in especially stark contrast to the preferred meaning. Attention may therefore be drawn to semantic-pragmatic features, which encourages the use of focus marking to highlight alternatives rather than syntactic boundary marking.

The current study

The goal of the current study was to test the hypothesis that interpretation biases affect the production of disambiguating prosody. The prediction was that a strong interpretation bias would encourage semantic-pragmatic processing of sentence meanings. Semantic-pragmatic processing was expected to result in the use of focus marking. A focus marking strategy would likely result in weaker or even contradictory cues to the structures that coincide with the different intended meanings. The results would provide evidence that interpretation biases should be considered as an important factor when investigating prosodic

disambiguation.

The study consisted of two parts. In Experiment 1, we established the preferred interpretation of a heterogeneous set of syntactically ambiguous sentences, and the consistency with which the preferred interpretation was chosen across speakers (bias strength). In Experiment 2, we taught a subset of speakers from Experiment 1 the alternate meanings of the ambiguous sentences and then asked them to disambiguate the meanings using prosody. Acoustic measures were made to test for the effect of interpretation bias (strong vs. weak) on the consistency with which temporal and intonational cues were used for boundary marking.

2. Experiment 1: Default interpretations of ambiguous sentences

2.1 Methods

2.1.1 Participants

Forty native speakers of English participated in the current experiment. All were undergraduate students at the University of Oregon. All participants received course credit for their participation.

2.1.2 Stimuli

Eighteen syntactically ambiguous sentences, adapted from those used in Lehiste et al. (1976) and Price et al. (1991), were used in the current study. Each stimulus sentence had two possible meanings. One of the two meanings followed from the principle of late closure in that the critical word or phrase was directly attached to the preceding word or phrase. For example, the different meanings of the ambiguous sentence *the teacher greeted the girl with a smile* turn on whether the critical phrase *with a smile* was attached to the preceding phrase, *the girl,* or to the earlier processed phrase, *the teacher.* When the critical phrase has a late closure attachment, the sentence means that *the girl was smiling.* When the critical phrase has an earlier attachment, the sentence means that *the teacher was smiling.* Sentence interpretation that followed from the principle of late closure are referred to as Meaning A, otherwise the interpretation is referred to as Meaning B. Each ambiguous sentence with the two meanings is in Table 1.

Table 1. Stimulus sentences with two possible meanings (Late vs. early attachment is indicated by the relevant grouping of word/phrases in brackets.)

Sentence	
Meaning A (Late closure)	Meaning B (Earlier attachment)
We need more creative teachers.	
[more creative] teachers	more [creative teachers]
I know more talented soccer players than Jo.	
[more talented] soccer players	more [talented soccer players]
They like more active children than Alex.	
[more active] children	more [active children]
I like visiting relatives.	
[visiting relatives]	[visiting] [relatives]
Flying planes can be dangerous.	
[flying planes]	[flying] [planes]
Boiling water makes me nervous.	
[boiling water]	[boiling] [water]
She saw a man eating fish.	
[man eating] fish	man [eating fish]
Carrie doesn't know how good meat tastes.	
[how good] meat	how [good meat]
The children rolled up the rug.	
[rolled up] the rug	rolled [up the rug]
Taylor raises tiny dogs and cats.	
tiny [dogs and cats]	[tiny dogs] and cats
The old men and women stayed home.	
old [men and women]	[old men] and women
There are excited students and teachers in the room.	
excited [students and teachers]	[excited students] and teachers
The teacher greeted the girl with a smile.	
greeted [the girl with a smile]	[greeted the girl] with a smile
I saw an elephant in my pajamas.	
saw [an elephant in my pajamas]	[saw an elephant] in my pajamas
Put the dog food in the bowl on the floor.	
the dog food [in the bowl on the floor]	[the dog food in the bowl] on the floor
Pat knew by the way he was driving.	
[by the way he was driving]	[by the way] he was driving
The coach knows you realize your goals.	
[you realize your goals]	[you realize] your goals
Max speaks several languages you know.	
[languages you know]	languages [you know]

2.1.3 Procedure

Ambiguous sentences were presented to speakers in random order on individual index cards. Each speaker read each sentence aloud once. After the speaker read a sentence, the experimenters posed one or more predetermined disambiguating question(s) to establish which of the two possible meanings that speaker had intended during the reading. The disambiguating questions used with each stimulus sentence are presented in Appendix I.

Since experimenters were required to discover a speaker's intended meaning without cuing the speaker of the ambiguity, only those predetermined questions were used. If the scripted

question and answer interaction did not provide enough information to determine the intended meaning for a sentence, the sentence was noted, and after the speaker completed the default reading of all sentences, the experimenter provided the possible meanings of the noted sentences and asked the speaker to clarify which meaning they had intended. Note that this procedure was used in only a minority of cases. Only 8 out of 40 speakers did not provide sufficient information during the question and answer interaction to disambiguate the intended meaning of some sentences. Only 2 speakers noticed that some sentences were in fact ambiguous. That is, the vast majority of speakers likely never even considered an alternate meaning during their default production.

Speakers performed the task in a quiet laboratory room. Their speech was digitally recorded to a Marantz PMD 660 using a Shure ULXS4 wireless receiver and lavaliere microphone that was attached to a hat worn by the speakers.

2.2 Results

The results were that most speakers preferred Meaning A interpretations over Meaning B interpretations for most of the sentences (see Table 2). We will refer to an interpretation that the majority of speakers intended as the "interpretation bias" for a particular sentence. The size of the majority was taken to indicate the strength of the interpretation bias (bias strength). This strength varied by sentence, but a majority of the sentences had over 90% agreement among speakers in their default interpretation. When 90% or more of the participants agreed on a particular interpretation for a particular sentence, the sentence was considered to have a strong interpretation bias. Otherwise, the sentence was considered to have a weak interpretation bias. Table 2 indicates that 11 sentences had a strong interpretation bias, and 7 sentences had a weak interpretation bias. The table also indicates whether that bias was for Meaning A or Meaning B.

The data in Table 2 suggest that interpretation biases are not affiliated with particular structures. That is, the set of sentences with strong interpretation biases is as heterogeneous as the set of sentences with weak interpretation biases. The exception to this statement is sentences with an ambiguity in adjectival scope (5 through 7). These sentences were interpreted by 95% of the participants according to Meaning A, which is to say the adjective was interpreted to apply over a wide rather than narrow scope. While we acknowledge that punctuation could have been used to bias speakers towards a particular meaning for some

sentences, punctuation would not have affected the preferred interpretation for a majority of the sentences[3]. In any case, the issue here is not so much which interpretation was preferred, but rather how strongly biased speakers were towards a single interpretation given the written presentation of the stimulus.

Table 2. Interpretation biases for each sentence
(The percentage of speakers who interpreted the sentence according to the preferred meaning is provided in parentheses.)

Bias strength	No.	Sentence	Majority Responses
Strong	1	The children rolled up the rug.	A (100.0%)
	2	I like visiting relatives.	B (100.0%)
	3	They like more active children than Alex.	A (97.5%)
	4	She saw a man eating fish.	B (97.5%)
	5	Taylor raises tiny dogs and cats.	A (95.0%)
	6	The old men and women stayed home.	A (95.0%)
	7	There are excited students and teachers in the room.	A (95.0%)
	8	The coach knows you realize your goals.	A (92.5%)
	9	We need more creative teachers.	A (92.5%)
	10	The teacher greeted the girl with a smile.	B (92.5%)
	11	Boiling water makes me nervous.	A (90.0%)
Weak	12	Pat knew by the way he was driving.	A (80.0%)
	13	Put the dog food in the bowl on the floor.	A (80.0%)
	14	Carrie doesn't know how good meat tastes.	A (75.0%)
	15	Flying planes can be dangerous.	A (65.0%)
	16	Max speaks several languages you know.	A (62.5%)
	17	I know more talented soccer players than Jo.	A (57.5%)
	18	I saw an elephant in my pajamas.	B (55.0%)

2.3 Discussion

The results from Experiment 1 indicate that interpretation

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3) An independent mini-experiment was conducted to find whether punctuation would be used consistently by college-aged students to disambiguate the meanings of ambiguous sentences. Six participants were asked to punctuate each sentence according to its two different meanings in such a way as to clarify the alternate meanings of the sentence. The results showed inconsistent use of punctuation across sentences with the exception of one sentence, *Max speaks several languages you know*. Five out of six participants inserted a comma between *languages* and *you know* to indicate the tag question interpretation.

biases are the norm, rather than the exception, when syntactically ambiguous sentences are produced absent a meaningful context. The results further show that interpretation biases are often quite strong, and that this bias usually favors a Meaning A interpretation (14 out of 18 sentences). The preference towards a Meaning A interpretation can be explained by the principle of late closure (Frazier & Fodor, 1978; Frazier, 1979), which describes a preference whereby new lexical items are preferentially attached to the most recently processed phrase. Take, for example, the sentence as *put the dog food in the bowl on the floor.* According to the principle of late closure, speakers will prefer to attach the critical phrase *in the bowl* to the adjacent noun phrase *the dog food* rather than to the verb *put,* and this is what 80% of our participant did.

Note, though, that the results also provide some evidence for the view that semantic or pragmatic information can override the processing preference described by the principle of late closure (Rayner et al., 1983; McRae et al., 1998). For example, the sentence *I saw an elephant in my pajamas* was biased towards a Meaning B interpretation rather than a Meaning A interpretation. This bias was likely induced by the pragmatic knowledge that an elephant would not wear the speaker's pajamas. The grammatical function of the critical word/phrase could also have affected the interpretation (i.e., subject vs. object). Insofar as a noun phrase that immediately precedes the verb is considered to be the subject of a sentence in English (Payne, 2006), sentence such as *flying planes can be dangerous* were more likely to be interpreted with the meaning that *planes are dangerous* rather than with the meaning that *the action of flying is dangerous.* That said, the finding that relatively few sentences were biased towards a Meaning B interpretation underscores the importance of the principle of late closure.

3. Experiment 2: Production of disambiguating prosody

The purpose of Experiment 2 was to investigate the effect of interpretation bias on the realization of disambiguating prosody in a task where speakers were required to convey alternate meanings of ambiguous sentences using only prosody. The acoustic characteristics of the speaker's production were analyzed to examine (a) whether individual speakers used reliably different temporal and intonational patterns to disambiguate meanings, and (b) whether interpretation bias strength affected the consistency with which disambiguating prosodic cues were used for boundary marking.

3.1 Methods

3.1.1 Participants

A subset of ten participants from Experiment 1 participated in Experiment 2. All received course credit for their participation.

3.1.2 Stimuli and procedures

Each of the speakers was taught about prosody. The experimenter explained that prosody involved speech rhythm, phrasing and intonation. The experimenter explained the parameters of prosody with reference to a pre-recorded sentence: *So here we have a yellow dog with a long tail and a brown dog with a short tail.* Five productions of this sentence were provided, each with a different timing and intonational pattern. The different patterns conditioned different phrasing, which were highly salient to the participants even though they did not convey different sentence meanings.

After the experimenter was satisfied that the speakers understood that prosody can be manipulated independently of lexical content, they were asked to read aloud the 18 ambiguous sentences from Experiment 1 using only different prosodic patterns to disambiguate the sentences. Before they began, the experimenter ran through all the sentences to make sure that they correctly understood the two possible meanings of each. If a speaker had difficulty seizing the ambiguity and the different possible meanings, the experimenter would provide a context for each meaning. The experimenter was careful, though, not to provide a spoken model of the sentence itself. Once a speaker clearly understood the different meanings of each sentence, they were presented with flash cards, each of which listed a sentence and one of the associated meanings. Speakers read aloud the ambiguous sentence written on the card with the intended meaning in mind. Speakers produced each sentence twice in row with the same intended meaning. The flash cards were randomized according to one of the 3 pre-determined random orders. A total of 720 sentences were elicited in this way (18 sentences × 2 meanings (Meaning A and B) × 2 repetitions of each meaning × 10 speakers), and the sentences were recorded in the same environment as Experiment 1.

3.1.3 Acoustic measurement

Acoustic measurements were made to characterize the prosodic patterns that speakers produced. Measurement focused on the words/phrases on either side of the boundary critical to the differentiation between a late closure reading and an earlier attachment[4]. These word/phrases are underlined in Table 3.

Table 3. Words/phrases on either side of a boundary
critical for disambiguation

Bias strength	No.	Sentence
Strong	1	The children <u>rolled</u> <u>up</u> the rug. (1) (2)
	2	I like <u>visiting</u> <u>relatives</u>. (1) (2)
	3	They like <u>more</u> <u>active</u> children than Alex. (1) (2)
	4	She saw a <u>man</u> <u>eating</u> fish. (1) (2)
	5	Taylor raises tiny <u>dogs</u> <u>and cats</u>. (1) (2)
	6	The old <u>men</u> <u>and women</u> stayed home. (1) (2)
	7	There are excited <u>students</u> <u>and teachers</u> in the room. (1) (2)
	8	The coach knows <u>you realize</u> <u>your goals</u>. (1) (2)
	9	We need <u>more</u> <u>creative</u> teachers. (1) (2)
	10	The teacher greeted <u>the girl</u> <u>with a smile</u>. (1) (2)
	11	<u>Boiling</u> <u>water</u> makes me nervous. (1) (2)
Weak	12	Pat knew <u>by the way</u> <u>he was driving</u>. (1) (2)
	13	Put the dog good <u>in the bowl</u> <u>on the floor</u>. (1) (2)
	14	Carrie doesn't know <u>how</u> <u>good</u> meat tastes. (1) (2)
	15	<u>Flying</u> <u>planes</u> can be dangerous. (1) (2)
	16	Max speaks <u>several languages</u> <u>you know</u>. (1) (2)
	17	I know <u>more</u> <u>talented</u> soccer players than Jo. (1) (2)
	18	I saw <u>an elephant</u> <u>in my pajamas</u>. (1) (2)

The word/phrase to be attached is indicated with a (2) in Table 3. The immediately preceding word or phrase which (2) can be attached is labeled with a (1) in the table. The current study measured the prosodic characteristics (both temporal and intonational) of just these words/phrases in the 18 ambiguous sentences. The prediction was that prosodic boundary marking would be used to identify the critical boundary between (1) and

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4) In the three sentences with adjective scope ambiguity (5 through 7 in Table 3), we selected just the noun that preceded "and" rather than the noun + the adjective. This was done because previous work indicates that the alternate readings of these types of sentences are reliably distinguished in production and perception by the total duration of noun + and + noun (Lehiste, 1973; Lehiste et al., 1976)

(2) in cases where Meaning B is intended.

Whole word/phrase durations and the average F0 of the main stressed vowels were measured. When pauses occurred at the juncture, their duration was added to the total duration of item (1). Individual differences in speaking rate and pitch were normalized across speakers by dividing the duration or F0 of item (1) by item (2). Word/phrase duration ratios (hereafter, "word duration ratios") and word/phrase ratios with intervening pause durations (hereafter, "with-pause duration ratios") were calculated separately.

3.2 Results

Before testing for an effect of bias on production, we first investigated whether speakers managed different prosodic renditions of the same sentence to convey different intended meanings. Absolute differences were calculated for each of the three acoustic measures (word duration ratios, with-pause duration ratios, and F0 ratios) by subtracting measurement values associated with Meaning B renditions from those associated with Meaning A renditions of the same sentence produced by the same speaker. The average unsigned difference values are presented in Table 4.

Table 4. Mean unsigned differences between productions
associated with Meaning A and B for word duration ratios,
with-pause duration ratios, and F0 ratios
(Standard deviations are provided in parentheses.)

Bias Strength	No.	Word Duration Ratio	With-pause Duration Ratio	F0 Ratio
Strong	1	0.85 (0.94)	0.97 (1.02)	0.59 (0.62)
	2	0.19 (0.19)	0.32 (0.39)	0.64 (0.57)
	3	0.36 (0.22)	0.37 (0.26)	0.28 (0.31)
	4	0.46 (0.35)	1.05 (0.83)	0.29 (0.25)
	5	0.24 (0.13)	0.52 (0.38)	0.54 (0.47)
	6	0.41 (0.18)	1.01 (0.46)	0.21 (0.27)
	7	0.32 (0.25)	0.72 (0.39)	0.33 (0.33)
	8	0.27 (0.18)	0.43 (0.38)	0.82 (0.70)
	9	0.56 (0.39)	0.87 (0.91)	0.36 (0.50)
	10	0.15 (0.18)	0.38 (0.40)	0.47 (0.36)
	11	0.32 (0.30)	0.46 (0.42)	0.47 (0.41)
Weak	12	0.26 (0.17)	0.48 (0.30)	0.43 (0.60)
	13	0.27 (0.14)	0.71 (0.51)	0.24 (0.25)
	14	0.63 (0.53)	0.72 (0.65)	0.20 (0.14)
	15	0.30 (0.29)	0.40 (0.39)	0.26 (0.25)
	16	0.44 (0.32)	0.59 (0.39)	0.56 (0.48)
	17	0.40 (0.37)	0.42 (0.42)	0.36 (0.41)
	18	0.13 (0.12)	0.24 (0.30)	0.75 (0.71)

The absolute differences shown in Table 4 indicate that speakers used different prosody to disambiguate the syntactically ambiguous sentences: there were no zero values. A Mann-Whitney U test showed that the mean unsigned differences of sentences with strong interpretation biases were not significantly different from those of sentences with weak interpretation biases. This result indicated that speakers were equally able to produce different rendition of the sentences to convey different meanings regardless of bias strength. It is also evident from Table 4 that the absolute differences of with-pause duration ratios were larger than the absolute differences of word duration ratios (with-pause, $M = 0.59$, $SD = 0.57$; word duration, $M = 0.36$, $SD = 0.38$). This result was due to the frequent use of pausing to disambiguate one meaning from another.

Note that the unsigned values given in Table 4 do not indicate what patterns were used with what meanings. Prior work led us to expect that speakers would use prosodic boundary marking to identify the critical boundary between item (1) and item (2) when Meaning B was intended. That is, if speakers prosodically mark the critical boundary when Meaning B was intended, word duration ratios and with-pause duration ratios would be larger due to final lengthening on item (1) and/or pausing between item (1) and (2), while F0 ratios would be smaller due to F0 dropping on item (1). This expectation and the effect of bias strength on disambiguating prosody were examined in a two-way repeated measures ANOVA. The dependent variable was the mean value of a measure calculated for each speaker across sentences and repetitions within the factors of interest (bias strength and intended meaning (A vs. B)). The results of this analysis are presented in Table 5.

Table 5. Results from Repeated Measures of ANOVAs to test for the effect of bias strength and intended meaning on prosodic patterns.

Dependent Variable	Effect	df	MSE	F	p	pη²
Word duration ratios	Strength (S)	1	0.08	5.73	.040	.39
	Meaning (M)	1	0.06	5.49	.044	.38
	S X M	1	0.18	20.97	.001	.70
	Error (S X M)	9	0.01			
With-pause duration ratios	Strength (S)	1	0.05	1.74	.219	.16
	Meaning (M)	1	0.15	4.45	.064	.33
	S X M	1	0.42	20.29	.001	.69
	Error (S X M)	9	0.02			
F0 ratios	Strength (S)	1	0.01	0.41	.538	.04
	Meaning (M)	1	0.00	0.00	.955	.00
	S X M	1	0.03	0.20	.668	.02
	Error (S X M)	9	0.02			

The results indicated significant main effects of bias strength and intended meaning on word duration ratios, and a significant interaction between bias strength and intended meaning on both word duration ratios and with-pause duration ratios. There were no significant effects of either bias strength or intended meaning on F0 ratios. The significant interactions are shown in Figure 1.
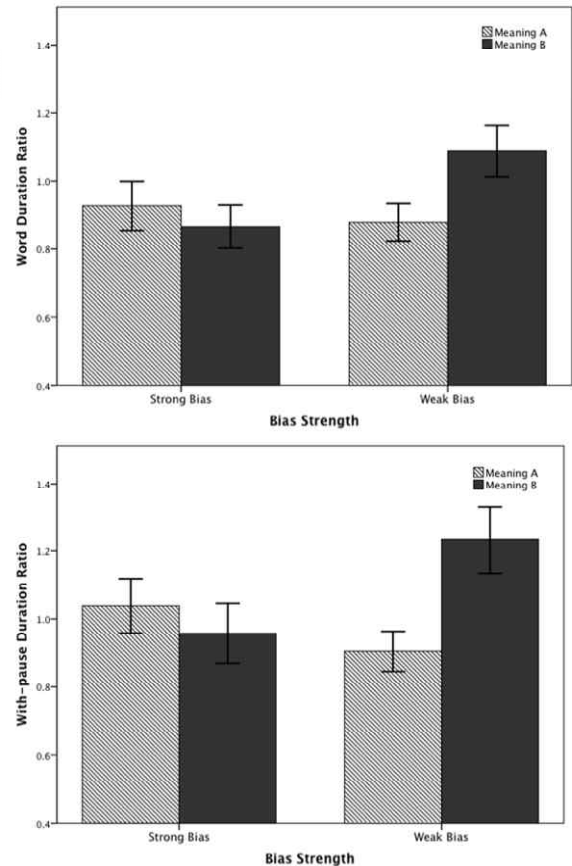

Figure 1. Word duration ratios (top) and with-pause duration ratios (bottom) as a function of bias strength and intended meaning with the 95% confidence interval error bars

Figure 1 indicates that the significant main effect of intended meaning was in the same direction for both word duration ratios and with-pause duration ratios: speakers consistently lengthened the first word/phrase (item 1) and often inserted a pause between the first word/phrase (item 1) and the second word/phrase (item 2) to indicate a Meaning B interpretation. However, speakers used this boundary marking strategy only when ambiguous sentence had weak interpretation biases.

4. General Discussion

The principal finding emerging from the present study is that the extent to which an ambiguous sentence is likely to be

interpreted in one way rather than in another affects the consistency with which speakers produce disambiguating prosody. Speakers reliably and consistently marked syntactic boundaries that differentiated alternate meanings of ambiguous sentences when an ambiguous sentence had a weak interpretation bias. When ambiguous sentences were strongly biased towards one meaning over another, speakers differentiated between the two meanings using prosody, but the temporal and intonational patterns were inconsistently applied at the relevant boundary. The effect of bias on production supports the hypothesis that the variable use of disambiguating prosody emerges from differences in the extent to which the speaker's attention is influenced by semantic-pragmatic considerations.

The hypothesis that speaker's use of disambiguating prosody is influenced by semantic-pragmatic considerations was proposed in the context of two linguistic functions that prosody serves: syntactic boundary marking versus focus marking. The idea was that syntactic boundary marking is a default behavior that may be overridden or obscured by prosodic focus marking. Although the results support this idea in the main a few caveats are also in order.

First, English speaking speakers do not appear to prosodically mark sentence internal boundaries by default. Experiment 2 showed that speakers mark the boundary only when they are aware of alternate interpretations of sentences. Even then, the boundary is only marked if the interpretation bias for the sentence is weak. When speakers are asked to prosodically disambiguate sentences with strong interpretation biases, they fail to consistently mark the relevant boundary even while producing the sentences with distinct prosodic patterns. We have suggested that the inconsistent use of prosody in this context may be due to a focus marking strategy. The preferred and less preferred meanings of sentences with strong interpretation biases stand in starker contrast to one another compared to the preferred and less preferred meanings of sentences with weak interpretation biases. Speakers are implicitly aware of the strong contrast between meanings and indicate this via prosody. The less preferred interpretations of a given sentence are uttered "against" the preferred (presupposed) interpretation. This is precisely the context in which contrastive focus marking should be used: a context in which the supposition and the presupposition do not match.

Whereas boundary marking is mainly encoded by pre-boundary lengthening and pausing, contrastive focus is realized through a combination of pitch accenting, lengthening of

the focused item, the deaccentuation of a post-focus item, and occasionally the introduction of a prosodic boundary either before or after the focused item (Turk & White, 1999; Selkirk, 2002; Strangert, 2003). The extent to which any and or all of these cues are employed is up to the speaker (see, e.g., Jun, 2003). Thus, unlike boundary marking, focus marking in English is more dependent on a speaker's particular style than on language norms and so is more idiosyncratic than boundary marking. The suggestion is that the null effect of meaning on prosodic patterns for strongly biased sentences was due to this idiosyncracy: prosodic patterns differed by meaning, but these patterns were not consistently associated with the same meanings across speakers.

In sum, sentence internal boundary marking may not occur by default, but is used when alternate meanings are equally accessible to a speaker. However, when alternate meanings stand in stark contrast to one another because one interpretation is strongly favored over another, syntactically appropriated boundary marking may be obscured by focus marking, which can result in inconsistent or syntactically inappropriate boundary marking.

Of course, it may also be that a majority of speakers were never able to grasp the less preferred meaning of sentences with strong interpretation biases. If they were unable to fully grasp the meaning, they would be unable to indicate its structure. This possibility seems unlikely to us, though, given the care we took in training speakers about the different intended meanings and given that speakers did modify prosodic patterns when producing sentences with alternate meanings, regardless of bias strength.

A final possibility is that speakers in the current study were less effective at conveying intended meaning via prosody than would be expected in a more natural context. For instance, several previous studies stress the importance of situational ambiguity and social interaction in promoting the use of disambiguating prosody (Allbritton et al., 1996; Snedeker & Trueswell, 2003). However, many results from other studies indicate that speakers are capable of producing disambiguating prosody when asked to do so or when the situation requires it (Price et al., 1991; Schafer et al., 2005; Kraljic & Brennan, 2005). In the context of the current results, the contradictory findings from previous studies might be taken to suggest that the prosodic disambiguation of weakly biased sentences can be produced on demand, but that the disambiguation of strongly biased sentences requires additional environmental support (i.e., greater ecological validity).

In conclusion, the present results indicate that prosodic

disambiguation is strongly influenced by interpretation biases and it is used consistently only when alternate interpretations of the sentence are (more) equally plausible. When alternate interpretations are equally plausible, speakers mark the relevant syntactic boundary using pre-boundary lengthening and pausing. When an alternate interpretation is highly unlikely, speakers do not effectively disambiguate meaning via prosody even though prosody is manipulated as a function of intended meaning. The effect of bias in production is interpreted in the context of the differing functions of linguistic prosody.

References

Allbritton, D. W., McKoon, G., & Ratcliff, R. (1996). Reliability of prosodic cues for resolving syntactic ambiguity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 714-735.

Altmann, G. T. M., van Nice, K., Garnham, A., & Henstra, J. A. (1998). Late closure in context. *Journal of Memory and Language, 38,* 459–484.

Carlson, K., Clifton, Jr., C, & Frazier, L. (2001). Prosodic boundaries in adjunct attachment. *Journal of Memory and Language, 45,* 58–81.

Cooper, W., & Paccia-Cooper, J. (1980). *Syntax and speech.* Cambridge, MA: Harvard University Press.

Frazier, L. (1979). *On comprehending sentences: Syntactic parsing strategies,* Ph.D. dissertation, University of Massachusetts, Amherst, MA.

Frazier, L., & Fodor, J. D., (1978). The sausage machine: a new two-stage parsing model. *Cognition, 6,* 291-325.

Gee, J. P., & Grosjean, F. (1983). Performance structures: A psycholinguistic and linguistic appraisal. *Cognitive Psychology, 15,* 411-458.

Gibson, E. A. F. (1991). *A computational theory of human linguistic processing: Memory limitations and processing breakdown.* Unpublished doctoral dissertation, Carnegie Mellon University, Pittsburgh, PA.

Jeon, Y.-S. (2011). Durational Pattern and Syntactic Structure in Non-native English. *The Linguistic Association of Korea Journal, 19,* 191-207.

Jun, S.-A. (1998). The Accentual Phrase in the Korean prosodic hierarchy. *Phonology, 15,* 189-226.

Jun, S.-A. (2003). Prosodic phrasing and attachment preferences. *Journal of Psycholinguistic Research, 32,* 219-249.

Kraljic, T., & Brennan, S. E. (2005). Prosodic disambiguation of syntactic structure: For the speaker or for the addressee? *Cognitive Psychology, 50,* 194-231.

Lehiste, I. (1973). Phonetic disambiguation of syntactic ambiguity. *Glossa, 7,* 197-222.

Lehiste, I., Olive, J. P., & Streeter, L. (1976). Role of duration in disambiguating syntactically ambiguous sentences. *Journal of the Acoustical Society of America, 60,* 1199-1202.

McRae, K., Spivey-Knowlton, M. J., & Tanenhaus, M. K. (1998). Modeling the influence of thematic fit (and other constraints) in on-line sentence comprehension, *Journal of Memory and Language, 38,* 283-312.

Millotte, S., Wales, R., & Christophe, A. (2007). Phrasal prosody disambiguates syntax. *Language and Cognitive Processes, 22,* 898-909.

Nespor, M., & Vogel, I. (1986). *Prosodic phonology.* Dordrecht: Foris Publications.

Payne, T. (2006). *Exploring language structure: A student's guide.* Cambridge University Press.

Price, P., Ostendorf, M., Shattuck-Hufnagel, S., & Fong, C. (1991). The use of prosody in syntactic disambiguation. *Journal of the Acoustical Society of America, 90,* 2956-2970.

Rayner, K., Carlson, M., & Frazier, L. (1983). The interaction of syntax and semantics during sentence processing: eye movements in the analysis of semantically biased sentences, *Journal of Verbal Learning and Verbal Behavior, 22,* 358-374.

Schafer, A. J., & Jun, S.-A. (2001). Effects of focus on prosodic reflections of phrase structure in American English. Paper presented at the Prosody in Processing Workshop, Utrecht University, Utrecht, Netherlands.

Schafer, A. J., Speer, S. R., & Warren, P. (2005). Prosodic influences on the production and comprehension of syntactic ambiguity in a game-based conversation task. In M. K. Tanenhaus & J. C. Trueswell (Eds.), *Approaches to studying world situated language use* (pp. 209-225). Cambridge, MA: MIT Press.

Selkirk, E. O. (1986). On derived domains in sentence phonology. *Phonology Yearbook,* 3, 371-405.

Selkirk, E. O. (2002). Contrastive FOCUS vs. presentational focus: Prosodic evidence from right node raising in English. In *Proceedings of the 1st international conference on speech prosody* (pp. 643-646). Aix-en-Provence, France.

Shattuck-Hufnagel, S., & Turk, A. E. (1996). A prosody tutorial for investigators of auditory sentence processing. *Journal of Psycholinguistic Research, 25,* 193-247.

Snedeker, J., & Trueswell, J. C. (2003). Using prosody to avoid

ambiguity: Effects of speaker awareness and referential context. *Journal of Memory and Language, 48,* 103-130.

Spivey, M. J., & Tanenhaus, M. K.(1998). Syntactic ambiguity resolution in discourse: Modeling the effects of referential context and lexical frequency. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 1521–1543.

Strangert, E. (2003). Emphasis by pausing. In *Proceedings of the 15th international congress of phonetic sciences* (pp. 2477-2480). Barcelona, Spain.

Tanenhaus, M., & Trueswell, J. C. (1995). Sentence comprehension. In J. Miller & P. Eimas (Eds.), *Speech language and communication. Volume 11 of the handbook of perception and cognition* (pp. 217-262). San Diego, CA: Academic Press.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language, 33,* 285-318.

Turk, A. E., & White, L. S. (1999). Structural influences on accentual lengthening in English. *Journal of Phonetics, 27,* 171-206.

Wales, R., & Toner, H. (1979). Intonation and ambiguity. In W. E. Cooper & E. C. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett* (pp. 135-158). Hillsdale, NJ: Erlbaum.

Wanner, E. (1980). The ATN and the sausage machine: Which one is baloney? *Cognition, 8,* 209-225.

• **Choe, Wook Kyung**
Center of Liberal Education, Dong-A University
37 Nakdong-Daero 550 beon-gil, Saha-gu, Busan, Korea
Tel: (82) 51-200-1022
Email: regina1004@dau.ac.kr

• **Redford, Melissa A.**
Dept. of Linguistics, University of Oregon
1290 University of Oregon, Eugene, OR, 97403-1290, USA
Tel: (1) 541-346-3818
Email: redford@uoregon.edu

Appendix I.

Disambiguating question(s) for each ambiguous sentence used for Experiment 1 and 2 (ordered as Table 2)

Sentence Number	Sentence Question(s)
1	The children rolled up the rug. What were the children doing?
2	I like visiting relatives. What do you like? Why do you like visiting relatives?
3	They like more active children than Alex. Do you think that Alex is an active child? Why do you think that Alex is/isn't an active child?
4	She saw a man eating fish. What did she see?
5	Taylor raises tiny dogs and cats. What tiny animals does Taylor raise?
6	The old men and women stayed home. What old people stayed home?
7	There are excited students and teachers in the room. What excited people are in the room?
8	The coach knows you realize your goals. What does the coach know?
9	We need more creative teachers. What does the speaker think we need? Why does the speaker think we need more creative teachers?
10	The teacher greeted the girl with a smile. Who was smiling?
11	Boiling water makes me nervous. What makes you nervous? Why does boiling water make you nervous?
12	Pat knew by the way he was driving. What did Pat know?
13	Put the dog food in the bowl on the floor. Where was the bowl?
14	Carrie doesn't know how good meat tastes. What doesn't Carrie know? Why do you think that Carrie doesn't know how good meat tastes?
15	Flying planes can be dangerous. What can be dangerous? Why do you think flying planes can be dangerous?
16	Max speaks several languages you know. What languages does Max speak?
17	I know more talented soccer players than Jo. Do you think that Jo is a good soccer player? Why do you think that Jo is/isn't a good soccer player?
18	I saw an elephant in my pajamas. Who was wearing pajamas?