INTRODUCTION

Previous research on syntactic processing indicates that syntactically ambiguous sentences are frequently strongly biased towards one meaning over another (for a review, see Gibson, 1991). These interpretation biases are influenced by several factors, including the principle of the late closure (Frazier & Fodor, 1978; Frazier, 1979), semantic features (Trueswell, Tanenhaus, & Garnsey, 1994), and context (Altmann, van Nice, Garnham, & Henstra, 1998). Consider, for example, the syntactically ambiguous sentence, *Bill thought John died yesterday*. Wanner (1980) notes that the interpretation of *John died yesterday* is preferred based on the principle of late closure in that the parser prefers to attach the critical word *yesterday* to the recently processed phrase *John died* rather than to the (earlier processed) matrix clause *Bill thought*.

In spite of the strong interpretation biases of ambiguous sentences, most research on prosodic disambiguation assumes that the two possible meanings of a syntactically ambiguous sentence are equally plausible (Lehiste, 1973; Price, Ostendorf, Shattuck-Hufnagel, & Fong, 1991; Fox Tree & Meijer, 2000; Kraljic & Brennan, 2005; Millotte, Wales, & Christophe, 2007). We know of only one prior study to investigate the influence of interpretation biases on disambiguating prosody. The study, conducted by Wales and Toner (1979) assessed interpretation biases for 30 ambiguous sentences based on the majority interpretation of these sentences when read by 96 participants. The size of the majority was used to establish bias strength. The sentences were then embedded in paragraphs that disambiguated meaning through context, and 4 speakers read these paragraphs. The sentences were then excised and presented to listeners, who were asked to identify the intended meaning of the sentence. The results showed that listeners were more successful at disambiguating weakly biased sentence than strongly biased ones. The authors concluded that this meant that listeners had used prosodic cues to disambiguate meaning in one case, but in the other. However, since no acoustic measures of the sentences were provided, we do not know whether listeners' performance was in fact due to the effect of bias strength on perception, or whether sentences with different bias strengths were produced with more or less salient prosodic cues to intended meaning.

The current study aimed to investigate the effect of interpretation bias strength on the speakers' production of disambiguating prosody. Following Wales and Toner (1979), the prediction was that speakers would prosodically disambiguate weakly biased sentences better than strongly biased ones. In order to encourage the use of disambiguating prosody, speakers were asked to contrast the alternate interpretation of an ambiguous sentence using prosody. Acoustic measures were used to assess the consistency with which temporal and intonational cues marked relevant syntactic phrase boundaries as a function of interpretation bias strength.

METHODS

Participants

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

Stimuli

Interpretation bias strength was established for a heterogeneous set of 18 sentences in Choe and Redford (submitted). We selected a subset of 10 sentences for this study: half of the sentences had a strong interpretation bias; the other half had a weak interpretation bias. The sentences in each group were matched for ambiguity type. Each ambiguous sentence and its two possible meanings are presented in TABLE 1. We have labeled the alternate meaning of the sentence based on the principle of late closure. A late closure interpretation is referred to as Meaning A; otherwise the interpretation is referred to as Meaning B.

TABLE 1. Stimulus sentences are shown as a function of bias strength and alternate meanings. The relevant grouping of words/phrases is indicated in brackets. Words or phrases that were the focus of acoustic measurement are underlined.

Bias Strength	Sentence	Meaning A (Late closure)	Meaning B (Earlier attachment)
Strong	They like more active children than Alex. (1) (2)	[more active] children	more [active children]
	She saw a man eating fish. (1) (2)	[man eating] fish	man [eating fish]
	The coach knows you realize your goals. (1) (2)	[you realize your goals]	[you realize] your goals
	The teacher greeted the girl with a smile. (1) (2)	greeted [the girl with a smile]	[greeted the girl] with a smile
	Boiling water makes me nervous. (1) (2)	[boiling water]	[boiling] [water]
Weak	Carrie doesn't know how good meat tastes. (1) (2)	[how good] meat	how [good meat]
	Flying planes can be dangerous. (1) (2)	[flying planes]	[flying] [planes]
	Max speaks several languages you know. (1) (2)	[languages you know]	languages [you know]
	I know more talented soccer players than Jo. (1) (2)	[more talented] soccer players	more [talented soccer players]
	I saw an elephant in my pajamas. (1) (2)	saw [an elephant in my pajamas]	[saw an elephant] in my pajamas

Procedure

The experimenter informed each speaker that the sentences they were to read were ambiguous. The experimenter then taught the alternate interpretations of the sentences to the speakers. To do this, the experimenter provided a context for the specific interpretation of the sentence, but not a spoken model of the sentence itself. The experimenter then taught speakers about prosody. Specifically, speakers listened to different prosodic renditions of a single unambiguous sentence that was pre-recorded for the purposes of training prosody to naïve participants.

Once the experimenter was satisfied that each speaker understood all the alternate meaning of the ambiguous sentences and the parameters of prosody, each stimulus sentence was presented in a random order to the speaker with its different meanings indicated. The speaker was asked to contrast the two meanings of the sentence using prosody in a read-aloud task. Each speaker was asked to produce each sentence twice with the same meaning.

The experiment was performed in a quiet laboratory room. Participants' speech was digitally recorded for later analyses to a Marantz PMD 660 using a Shure ULXS4 wireless receiver and lavaliere microphone.

Acoustic Measurement

Acoustic measurements were made to characterize the disambiguating prosodic patterns that speakers used when reading the sentences. Four hundred sentences (10 ambiguous sentences X 2 intended meanings X 2 repetitions X 10 speakers) were acoustically analyzed.

Acoustic measurements focused on the words or phrases that straddled the site of the boundary critical to late vs. early attachment. These words/phrases are underlined in TABLE 1. The word/phrase to be attached is labeled with a (2), and the immediately preceding word/phrases to which item (2) can be attached is labeled with a (1) in TABLE 1.

Total word/phrase durations and the average F0 of the main stressed vowels were measured for both item (1) and (2). When pauses occurred in between item (1) and (2), their durations were added to the overall duration of the preceding word/phrase. Individual differences in speaking rate and pitch were normalized across speakers by expressing the temporal and F0 measures as ratios. Ratios were calculated by dividing the value of the item (1) by the value of the item (2). Word duration ratios and with-pause duration ratios were calculated separately.

RESULTS

First, we examined whether each speaker completed the task as request by using different prosodic patterns to disambiguate syntactically ambiguous sentences. Absolute differences of the three acoustic measurements of prosodic patterns (word duration ratios, with-pause duration ratios, and F0 ratios) were calculated by subtracting the value associated with Meaning A from that associated with Meaning B of the same stimulus sentence produced by the same speaker. The average unsigned differences are presented in TABLE 2.

TABLE 2. Mean unsigned differences between productions associated with Meaning A and Meaning B are shown for word duration ratios, with-duration ratios, and F0 ratios as a function of bias strength. Standard deviations are presented in parentheses.

Bias Strength	Word Duration Ratios	With-pause Duration Ratios	F0 Ratios
Strong	0.31 (0.27)	0.54 (0.55)	0.46 (0.47)
Weak	0.38 (0.38)	0.47 (0.47)	0.42 (0.48)
Average	0.35 (0.33)	0.51 (0.51)	0.44 (0.47)

The absolute differences shown in TABLE 2 indicate that speakers successfully produced the alternate meaning of syntactically ambiguous sentences with different prosody. TABLE 2 also shows that absolute differences of with-pause duration ratios were larger than those of word duration ratios, which indicates that speakers frequently inserted pauses between item (1) and (2) to disambiguate one meaning from another. In order to test whether bias strength affected speakers' ability to produce different prosodic renditions of the sentence, paired *t*-tests were conducted for each measure. The results showed that the absolute differences between Meaning A and Meaning B renditions did not differ as a function of interpretation bias strength. That is, speakers were distinguished equally between alternate meanings of sentences with weak and strong interpretation biases.

Although the absolute differences indicated that each speaker used prosody to disambiguate between alternate meanings of a sentence, these differences do not indicate the nature of the patterns employed. Previous work led us to expect that speakers would insert a prosodic phrase boundary at the juncture between the item (1) and (2) only when Meaning B was intended. This expectation was tested in a two-way repeated measures ANOVA with bias strength and intended meaning as the within-subjects factors. The dependent variable was the mean value of three acoustic measures that were calculated for each speaker across sentences and repetitions within the two categories of interest (bias strength and intended meaning). An alpha level of .05 was used as the criterion for significance.

The results indicated significant main effects of bias strength on word duration ratios, $F(1, 9) = 22.47$, $MSE = 0.23$, $p = .001$, and on F0 ratios, $F(1, 9) = 5.45$, $MSE = 0.07$, $p = .044$. The main effect of intended meaning on word duration ratios was also significant, $F(1, 9) = 7.27$, $MSE = 0.09$, $p = .025$. The results also indicated a significant interaction between bias strength and intended meaning on both word duration ratios, $F(1, 9) = 15.49$, $MSE = 0.11$, $p = .003$, and with-pause duration ratios, $F(1, 9) = 17.16$, $MSE = 0.17$, $p = .003$. There were no significant interaction between bias strength and intended meaning on F0 ratios. The significant interactions are shown in FIGURE 1.

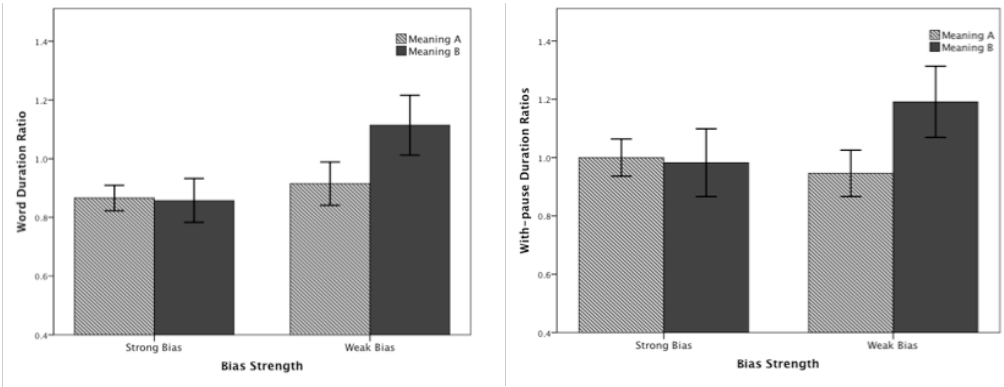

FIGURE 1. Word duration ratios (left) and with-pause duration ratios (right) are presented as a function of bias strength and intended meaning. Error bars indicate the 95% confidence interval.

FIGURE 1 shows that both the word duration ratios and with-pause duration ratios were larger for Meaning B than for Meaning A only when sentences had a weak interpretation bias. This result indicates that speakers reliably lengthened item (1) and frequently inserted a pause at the juncture between item (1) and item (2) to indicate Meaning B only when the sentences had a weak interpretation bias.

DISCUSSION

The results from the current study indicate that speakers produce different prosodic renditions of syntactically ambiguous sentences when asked to convey the alternate meanings of the sentences using only prosody. More importantly, though, the results show that interpretation bias strength affects speakers' ability to prosodically disambiguate the sentences. That is, bias strength influenced the consistency with which speakers prosodically marked a disambiguating syntactic phrase boundary. When an ambiguous sentence had a weak interpretation bias, speakers reliably indicated the phrase boundary. When an ambiguous sentence had a strong interpretation bias, alternate meanings were coded with prosody, but the ensuing patterns did not reliably mark the relevant syntactic boundary.

One reason that speakers may fail to consistently mark disambiguating syntactic boundaries under conditions of strong interpretation bias is that they may choose to highlight semantic-pragmatic features of the sentence rather than structure. The preferred and less preferred meanings of a sentence with a strong interpretation bias may stand in starker contrast to one another compared to the preferred and less preferred meanings of a sentence with a weak interpretation bias. Thus, less preferred interpretations of a strongly biased sentences may be produced "against" the preferred (presupposed) interpretation. This is precisely the context in which contrastive focus marking would be used: a context in which the supposition and presupposition do not match. Of course, focus marking will often result in a misalignment between prosodic and syntactic boundaries (Schafer & Jun, 2001). A focus-marking strategy would explain our result that speakers produced equally different prosodic renditions of the ambiguous sentences, but failed to prosodically disambiguate (via boundary marking) those sentences with strong interpretation biases.

In conclusion, speakers reliably mark disambiguating syntactic boundaries only when the alternate meanings of an ambiguous sentence are equally accessible to the speaker. It is likely, that when alternate meanings stand in stark contrast to one another because one interpretation is strongly favored over another, syntactically appropriate boundary marking may be obscured by contrastive focus marking. This will result in inconsistent or syntactically inappropriate boundary marking.

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