

Intonational Phrasing in Language Production and Comprehension

By

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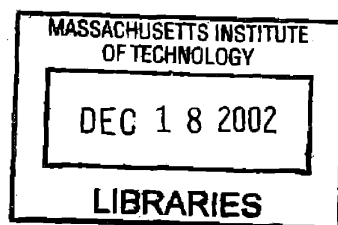
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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

The work presented in this thesis was conducted with two aims in mind. The first was to understand where speakers prefer to place intonational boundaries in language production. The second was to understand where listeners prefer to hear boundaries in language comprehension.

Achieving this first goal is far from straightforward. For example, consider the sentence below in

(1a).

- (1a) The talk that the professor at the conference disliked was about phonology.
- (1b) The talk // that the professor // at the conference // disliked // was // about phonology.
- (1c) The talk that the professor at the // conference disliked was about phonology.
- (1d) The talk that the professor at the conference disliked // was about phonology.

This sentence is very difficult to produce without any intonational boundaries. One gets the overwhelming intuition that one needs to place a pause somewhere in this sentence, and that this need is independent of breath requirements. However, it clearly cannot be the case that just adding intonational boundaries to a sentence makes the sentence easier to understand. Sentence (1b), for example, contains five intonational boundaries, but it is not clear that this sentence is any easier to understand than (1a), suggesting that having too many intonational boundaries can make a sentence almost as difficult to produce as having no boundaries at all. As is evidenced by the boundary in (1c), the location of the intonational boundary seems to be equally important in determining complexity. The boundary in this example seems to make the sentence difficult to understand, whereas the boundary in (1d) intuitively feels like the most natural place to produce a boundary in this sentence.

Much of the work in linguistics has tackled this problem under the assumption that speaker preferences are a result of linguistic competence or grammatical knowledge. These approaches have enjoyed limited success in explaining intonational phrasing preferences, partly because of the wide degree of variation in boundary placement. I will argue that intonational boundary placement is partly a function

of processes related to language production and performance factors rather than linguistic knowledge. Other researchers have made similar proposals (Cooper & Paccia-Cooper, 1980; Gee & Grosjean, 1983; Ferreira, 1988), however their proposed models have a large number of parameters and do not provide clear explanations for speaker preferences. Generalizing from these past models, I will present a simpler theory of speakers' preferences for intonational boundaries, arguing that they reflect planning and recovery processes in sentence production. Specifically, I will argue that the phonological weight of syntactic constituents, along with semantic constraints, plays a major role in intonational phrasing.

The second goal of this thesis is to understand where listeners prefer to hear intonational boundaries. I will argue that in language production, one of the factors influencing intonational boundary placement is syntactic structure. If this turns out to be correct, it means that listeners can theoretically use intonational boundary information to make inferences about dependency relationships between lexical heads as a sentence is processed. Evidence from the ambiguity resolution literature suggests that something like this seems to be true:

- (2a) The cop saw the spy // with the binoculars.
- (2b) The cop saw // the spy with the binoculars.

The boundary in (2a) tends to bias a listener towards an interpretation where the cop has the binoculars. In (2b), one gets the intuition that the spy has the binoculars. Thus, listeners appear to use intonational boundary information to choose between different possible syntactic interpretations of a sentence.

The work presented below will focus on a relatively unexplored area of language comprehension and intonational boundaries, namely, the role intonational boundaries play in unambiguous sentences. I will propose that listeners use intonational boundaries as cues that signal where not to attach incoming heads in the syntactic representation constructed thus far, and that this principle applies in the processing of both ambiguous and unambiguous structures.

I should point out that the work here is only an initial step in understanding intonational phrasing in production and comprehension. Below, a wide range of factors will be examined all of which seem to affect intonational boundaries including phonological factors, semantic relationships, syntactic structure,

and discourse structure. In this chapter, I will review work from linguistics and psychology that have attempted to explain the distribution of intonational boundaries and will present some production models that predict likely locations for intonational boundaries. In Chapter 2, I will present the LRB, a new model that predicts likely locations for intonational boundaries based on an utterance's syntactic, semantic, and phonological structure, and explore the predictions of the model in a series of production experiments. In Chapter 3, the role of intonational phrase boundaries in language comprehension will be discussed and differing theories will be tested, including the cue-based hypothesis discussed briefly above. Finally in Chapter 4, some general conclusions concerning the work presented in this thesis will be discussed as well as some implications this work has for such topical issues in sentence processing as prosodic bootstrapping and implicit prosody.

1.2 INTONATIONAL PHRASE BOUNDARIES

In general, there is a great deal of controversy concerning how various prosodic constituents are defined (and whether they even exist). However, there is generally very little controversy surrounding the definition of intonational phrases and intonational phrase boundaries. An intonational phrase is a segment of speech composed of words over which a tune, a perceptually coherent intonational contour, is realized.

The tune of an intonational phrase has been formalized in a number of different ways. ToBI, which stands for tones and break indices, is currently the most popular system among American prosodic phonologists. This system, which is based on ideas first presented by Beckman & Pierrehumbert (1986), describes pitch relationally using only two tones: High (H) and Low (L). Tones that coincide with sentence level stress are labelled pitch accents and are labeled with an "*", as in H*. Tones that describe the direction of pitch movement that follows a pitch accent are called phrase accents and are labeled with a "-", as in L-. These phrase accents coincide with intermediate phrase boundaries, a prosodic unit below the level of the intonational phrase (Pierrehumbert & Hirschberg, 1990). The tone that an intonational phrase boundary ends on is called a boundary tone, and is labeled with a "%", as in H%. Words that coincide with a boundary tone are often lengthened and followed by a pause.

Pierrehumbert & Hirschberg (1990) define an intonational phrase as a prosodic unit that contains at least one pitch accent, followed by a phrase accent, and ending with a boundary tone. Intonational phrases are often (but not always) separated by pauses, and the final word of the phrase tends to be longer than the same word in a phrase-medial position. Below are possible intonational phrasings for the given sentences ("//" delineate intonational phrase boundaries).

- (3a) The professor who the students liked // taught the class.
- (3b) Homer // as you know // can't take care of himself
- (3c) Take out the trash // Bart.
- (3d) It was possible to parse the example sentence // in several different ways
- (3e) It was possible // to parse the example sentence in several different ways

Intonational phrase boundaries can separate clauses (3a); surround asides (3b); precede vocatives (3c); and occur in more than one position in an utterance, (3d) and (3e).

A variety of factors seem to determine where intonational boundaries can occur. Some are semantic and pragmatic in nature. Focused words and new words tend to have sentence level stress, and stressed words tend to mark the end of intonational boundaries. Asides, non-restrictives, sentential adverbs, vocatives, and parentheticals also seem to require their own intonational phrase (Nespor & Vogel, 1987).

Other factors appear related to processes in production and memory. Longer sentences are more likely to be broken into intonational phrases than shorter sentences, and sentences that are spoken slowly are more likely to be divided by intonational boundaries than sentences that are spoken more quickly (Cooper & Paccia-Cooper, 1980; Nespor & Vogel, 1986).

The interesting question for the linguist and psycholinguist is understanding how these factors interact to determine intonational phrasing. In the remainder of this thesis, I will attempt to provide some initial answers to this question.

1.3. COMPETENCE, PERFORMANCE, AND PROSODIC STRUCTURE

One of the goals of this thesis is to demonstrate that intonational phrasing is partly a product of processes in language production. I will argue that these processes include planning and recovery by sentence production mechanisms.

One of the assumptions behind this hypothesis is that the location of intonational phrase boundaries is partly a product of performance factors in language production rather than a result of a speaker's linguistic competence. Roughly, linguistic competence is the knowledge that a speaker has about their language, while linguistic performance relates to the processes involved in language production and comprehension. Understanding how we should characterize the distinction between linguistic performance and competence has proved to be a difficult problem. In most cases, researchers must simply make a priori assumptions about whether the acceptability of an utterance is due to performance or competence. To illustrate, both structures in (4) are unacceptable to most native speakers of English.

(4a) The student infect the teacher

(4b) The teacher who the student who the nurse cured infected went to the hospital.

In (4a), the difficulty occurs because the verb *infect* does not agree in number with the subject *student*. Most researchers would assume that the difficulty associated with this sentence is related to linguistic competence. Part of what a native speaker knows about their language is that verbs and subjects have to agree in number. Crucially, the problem with sentence (4a) is that it violates the speaker's knowledge about their language. Sentence (4b), on the other hand, is difficult because of its large number of embedded clauses. Presumably, there is no grammatical rule that restricts the number of embedded clauses in a sentence (although see Joshi et al., 2000 for another view). This is evidenced by the fact that replacing the subject of the most embedded clause with a personal pronoun reduces the complexity of the sentence (Gibson, 2000). Thus, most researchers argue that difficulty associated with (4b) is related to performance factors. Speakers and listeners do not have the attentional or memory resources to compute the syntactic structure of (4b) even though the structure is grammatical. In contrast to sentence (4a), the

difficulty associated with (4b) stems from processing limitations in producing and/or comprehending the sentence.

Of course, attributing the unacceptability of (4a) to competence and the unacceptability of (4b) to performance is only an assumption, since there is no a priori way to make such a distinction. Many researchers have argued that the distinction is not even a coherent one (Rohde, 2002).

Although it is difficult to determine whether a linguistic phenomena is attributable to linguistic performance or competence, it will be argued that a performance based account provides the best account of the relationship between syntactic structure and intonational phrasing. As will be discussed below, much of the work on prosodic phonology in linguistics has tackled the problem of prosodic phrasing under the assumption that prosodic boundaries are a product of a speaker's linguistic competence. It is assumed that there exists a specific set of rules or parameters for deriving a prosodic structure from a given syntactic structure of an utterance, and that this knowledge system rules out sets of prosodic structures. Below it will be argued that competence based theories fail to give an adequate account of the variation found in intonational phrasing. In addition, the fact that intonational boundaries can occur anywhere in an utterance defeats any attempt at describing intonational phrasing within a grammatical framework.

1.4 COMPETENCE AND THE PROSODY-SYNTAX INTERFACE

For the most part, linguists have assumed that prosodic phenomena are part of a speaker's knowledge about their language, or their linguistic competence (Nespor & Vogel, 1986; Selkirk, 1984, 1986; Truckenbrodt, 2000, and others). Thus, most linguistic work in prosodic phrasing has focused on how prosodic units relate to syntactic structure. Researchers differ in how they believe this knowledge is represented, but there is little debate as to whether the representations that mediate these phenomena are part of a speaker's grammatical knowledge or whether they are the result of processes involved in

sentence production. Rather, the fact that a prosodic grammar exists is taken for granted. These assumptions most likely find their roots in early attempts at characterizing a phonological representation within a generative framework. In *The Sound Pattern of English* (Chomsky & Halle, 1968), a sentence's phonological representation was a continuation of the syntactic derivation, occurring after the derivation of surface structure. A series of re-adjustment rules applied to surface structure and inserted prosodic boundaries that roughly reflected an utterance's syntactic bracketing. More recently, phonologists have abandoned the view that prosodic structure is a late stage syntactic representation, arguing that prosodic structure requires a representation independent from that of syntax (Selkirk, 1984; 1986; Nespor & Vogel, 1986; Truckenbrodt, 1999, and many others). However, in the tradition of Chomsky and Halle (1968), the configuration of the prosodic representation is almost always described in terms of syntax. The claims of independence from syntactic structure stem mainly from arguments that only a restricted set of syntactic factors play a role in prosodic phrasing. Thus, there is not a one to one correspondence between prosodic structure and syntactic structure, even though many aspects of prosodic structure are derived from syntactic structure. It is also assumed that this prosodic representation is part of a native speaker's knowledge about their language. There is a grammatical system that describes the set of possible prosodic representations for a set of utterances.

Much of the more recent work in prosodic phonology has focused on understanding how syntax interacts with prosodic phrasing at the level of the phonological phrase. For a brief review of some of this research, see Appendix A. In the next section, I will present work by researchers who have attempted to extend grammatical theories of prosodic phrasing to the level of the intonational phrase.

1.4.1 THE PROBLEM OF INTONATIONAL PHRASING

Intonational phrases hold a unique position in this area of research, because very few researchers have proposed grammatical accounts of where intonational boundaries are licensed. A problem with this approach is the optionality of intonational boundaries for an utterance. If a given sentence can be segmented into any number of different intonational phrase patterns, it is unclear how a syntactic rule or

constraint can deterministically specify prosodic structure (see Shattuck-Hufnagel & Turk, 1996, for a thorough review of the evidence).

Nespor & Vogel (1986) (NV) attempt to solve this problem by formulating a general rule for IP construction that produces IPs that are subject to restructuring.

(5) Intonational Phrase Formation

An I domain may consist of 1) all the phonological phrases in a string that are not structurally attached to the sentence tree at the level of s-structure, or 2) any remaining sequence of adjacent phonological phrases in a root sentence.

The definition in (5) correctly predicts that non-restrictives, asides, parentheticals, and vocatives will occur in separate intonational phrases.

- (6a) [They have] [as you know] [been living together for years]
 (6b) [He will never] [as I said] [accept your proposal]
 (6c) [Charles wouldn't] [I imagine] [have done such a thing]
 (From Nespor & Vogel, 1986)

Clauses or phrases that are not part of the matrix clause are parsed into intonational phrases, so “as you know”, “as I said”, and “I imagine” are grouped together into intonational phrases in (6). Then the surrounding portions of the root clause are segmented into intonational phrases. NV recognize the shortcomings of this approach. They point out that a large number of factors play a role in restructuring the default intonational phrasing into smaller intonational phrases, including IP length, rate of speech, style, and contrastive prominence. They concede that longer intonational phrases are more likely to be broken up into shorter intonational phrases and these factors make it impossible to predict where intonational boundaries will occur; however, they offer some syntactic constraints on how these utterances can be restructured. They claim that speakers tend to restructure boundaries so that they only occur after noun phrases. In addition, speakers tend not to separate an obligatory argument from its verb, even if it does not violate the NP constraints. Speakers may also place intonational boundaries before a new clause, but only if this clause does not interrupt an NP as in the boundary between a head NP and a relative clause.

Nespor & Vogel's (1986) account of intonational phrasing is unsatisfying for a few reasons. First of all, in its specific constraints, it makes incorrect predictions. For example, Nespor & Vogel predict that sentence (7) should be ungrammatical.

(7) Sesame Street is brought to you by // the children's television workshop (Shattuck-Hufnagel & Turk, 1996)

Nespor & Vogel (1986) claim that speakers place intonational boundaries only after noun phrases. In (7), the intonational boundary violates this condition by occurring after a preposition. As children all over the United States can confirm, this sentence is perfectly acceptable.

Nespor & Vogel also argue that speakers tend not to place intonational boundaries between verbs and their obligatory arguments. Thus, they claim that (8b) is ungrammatical for native speakers because a boundary occurs between *give* and its obligatory argument *to the stray cats*. (8a), on the other hand, is acceptable because *for the stray cats* is not an obligatory argument of *give*, so the presence of an intervening intonational boundary should not cause difficulty.

(8a) That kind old lady always buys fresh meat // for the stray cats that live in the park.

(8b) That kind old lady always gives fresh meat // to the stray cats that live in the park. (Nespor & Vogel, 1986)

In reality, most native English speakers would find (8a) and (8b) equally acceptable. In fact, in Chapter 3, experimental results will be presented that suggest that listeners actually prefer the intonational phrasing in (8b) over an identical structure that lacks intonational boundaries, suggesting that Nespor & Vogel's predictions fail when faced with empirical data.

A second grammatical account of intonational phrasing has been proposed by Selkirk (1984). Selkirk (1984) argues that intonational phrases are subject to a semantic well-formedness constraint called the Sense Unit Condition. The Sense Unit Condition states that an intonational phrase must form a sense

unit. A sense unit is defined as a constituent formed by a head and, optionally, the head of any number of its modifiers and/or arguments. For example, the Sense Unit Condition is violated in (9), resulting in an unacceptable sentence.

(9) * [Three mathematicians] [in ten derive a lemma].

Here the offending structure is "in ten derive a lemma." "In ten" and "derive a lemma" do not participate in a head-argument relationship, so the utterance violates the Sense Unit Condition.

(10), on the other hand, is a perfectly acceptable sentence.

(10) [Mary gave the book] [to John].

In (10), the verb "gave" is the head of the sense unit of the first intonational phrase, and it takes "Mary" and "the book" as its arguments. Since this intonational phrase contains a head and its dependents, it forms a sense unit. The second intonational phrase "to John" also forms a sense unit since it includes no semantically unrelated words. The alternative intonational phrasing of the same sentence in (11) is unacceptable.

(11) * [Mary gave] [the book to John].

The first intonational phrase in (11) consists of a head and its dependent, "Mary" and "gave" forming a proper sense unit. The second intonational phrase, however, consists of "the book" and "to John". These two noun phrases are not dependents, and thus, do not form a Sense Unit.

Of course, this is a theory of the types of distributions of intonational phrasing that do not occur. Selkirk points out that a wide array of discourse and pragmatic factors play a role in determining how a speaker actually segments a given utterance into intonational phrases.

There are some problems with Selkirk's proposal. For example, all of the sentences in (12) violate the Sense Unit Condition:

- (12a) ?The bank gave // the money to John
 (12b) The bank gave the money // to John on Wednesday
 (12c) The bank gave the money to John // and a calendar to Susan

In each case, the constituents within the intonational phrase do not participate in a mutual dependency relationship. Although intuitions suggest that the intonational phrasing of (12a) is unacceptable, the phrasing in (12b) sounds more acceptable and the phrasing in (12c) sounds perfectly good. The variability in these structures' acceptability suggests that the Sense Unit Condition must be revised in some way. In fact, it is not even clear that the unacceptability of sentences such as (12a) is robust.

Manipulating the context in which (12a) appears seems to increase its acceptability:

- (13a) Did the bank lend the money to John?
 (13b) No. The bank GAVE // the money to John

Focusing and placing stress on the verb *gave* seems to increase the overall acceptability of the sentence. These cases suggest that semantic cohesion probably plays some role in intonational phrasing, but the sense unit condition does not accurately characterize this relationship.

Theoretical claims aside, the acceptability of sentences such as (7) and (12a) suggest that intonational boundaries can be placed almost anywhere in a sentence. If this is true, any attempt at devising a grammar of intonational phrasing is seriously misguided. Not only must a grammar specify a set of possible utterances, it must also rule out possible structures in a language. If an intonational boundary can be placed anywhere in a sentence, attempts at devising grammars for intonational phrasing must be abandoned.

The free variation in intonational boundary placement suggests that the appropriate question in this domain is not whether various intonational phrase patterns are grammatical or ungrammatical. The

interesting question is why are certain intonational phrasings more frequent than others? For instance, although (7) demonstrates that an intonational boundary between a preposition and a noun phrase is possible, such an occurrence probably occurs relatively infrequently, and it would be interesting to understand why.

Another way of thinking about this problem is understanding the optionality of intonational phrasing and understanding what factors control this optionality. As was discussed in the introduction, intuitions suggest that intonational boundaries are much more likely to occur in certain positions than in others. For example, in (1d) repeated in (14) below, one would probably place a boundary between the subject and the verb if one were to produce this sentence:

(14) The talk that the professor at the conference disliked // was about phonology.

Given the enormous variability in intonational phrasing, one would like to know why an intonational boundary is more likely to occur at one location over another. Unfortunately, this question is ignored in accounts that focus only on the acceptability of different intonational phrase structures. In the next section, I will argue that this question is most readily answered in performance-based accounts and will present a brief review of some existing performance based theories.

1.5. PERFORMANCE

1.5.1. MOTIVATION FOR A PERFORMANCE BASED APPROACH

In this section I will discuss a set of performance-based models proposed by researchers such as Cooper & Paccia-Cooper (1980); Gee & Grosjean (1983), and Ferreira (1988). These researchers argue that intonational boundaries or pause size is partly a function of processes in production. The claim is that the processes associated with constructing linguistic structure directly influence the likely location of intonational phrase boundaries or the intensity of a pause.

There are several reasons for thinking that intonational phrase boundary information may be a function of processes in production. First of all, the variation in intonational boundary placement is easily incorporated into a production-based framework. For instance, if boundaries reflect time points at which production mechanisms are planning upcoming constituents, the variance we see in intonational boundary placement could result from the variance in resources available to a speaker in different contexts. Fatigue, concentration, speech rate, as well as other factors could influence the amount of resources a speaker has to plan an utterance, thereby influencing the likelihood of an intonational boundary at a given location. Although the probabilistic nature of intonational phrasing can be incorporated into a performance-based account, it is not clear how a rule based competence model can deal with this variation.

Secondly, the fact that factors from multiple domains affect intonational phrasing poses a problem for a competence-based model. A grammar for intonational phrasing would have to represent discourse structure, information structure, phonological structure, syntactic structure and semantic structure all at one level of representation. Steedman's (2000) categorial grammar comes close to this sort of monostratal representation, but his theory cannot account for the effects of sentence phonology on intonational phrasing (Ferreira, 1991; Gee & Grosjean, 1983), and segment level phonology is not included in his grammar. Alternatively, the grammar could be represented by a system of ranked constraints that represent factors across the afore-mentioned domains in an optimality theoretic framework. However, the standard assumption in optimality theory is that components of the language system such as semantics, syntax, phonology, and discourse structure are modular. A representation that uses constraints that are derived from different domains of linguistic knowledge would undermine this assumption.

In contrast, a performance-based model can potentially allow for affects of factors that span domains. Since generation and maintenance of discourse structure, information structure, syntax, semantics, and phonology must occur in language production, it is possible that these factors all affect intonational phrasing at each stage of production. How this might be implemented depends on the

specific properties of the hypothetical production model, but a model *could* be constructed that could account for these facts. It is not clear that this is the case with a competence-based account.

Below I will present three models that attempt to describe the distribution of pauses and intonational boundaries while positing performance based theories of these prosodic patterns. In addition, I will present the subset of data that these models succeed in describing as well as the models' shortcomings.

1.5.2. COOPER & PACCIA-COOPER

The first model to be discussed was proposed by Cooper & Paccia-Cooper (CPC) (1980). They argue that syntactic structure directly affects the pause structure of an utterance and examined the distribution of segmental lengthening and pausing at word boundaries in a variety of constructions. They found that the number of right brackets at a word boundary correlates with the size of the pause and pre-boundary segmental lengthening. CPC argued that this correlation is evidence for the hierarchical tree structure proposed in standard transformational theories of the early 1980s. Based on their data, CPC argued that there has to be some psychological reality to tree structure since pause size and segmental lengthening correlate with major phrase boundaries. Furthermore, they argue that this correlation exists because syntactic constituents serve as units of processing. Larger pausing and segmental lengthening occur at points where a large number of syntactic constituents are completed because the production mechanism requires a rest period after expending a large number of resources. To test their claim, speakers read a variety of different globally ambiguous structures that varied in the number of right brackets at a word boundary of interest. For example, they tested sentences like the one in (15a) and (15b):

(15a) [[Jeffrey]_N [hit [the cop]_{NP} [with [the stick]_{NP}]_{PP}]_{VP}]_S
(Jeffrey had the stick.)

(15b) [[Jeffrey]_N [hit [the cop [with [the stick]_{NP}]_{PP}]_{NP}]_{VP}]_S
(The cop has the stick.)

At the boundary between “cop” and “with” in (15a), one constituent is completed: the NP “the cop”. In (15b), the PP “with the stick” modifies the noun “cop”, so no constituent is completed between “cop” and “with”. Therefore, CPC argue that the pause after cop in (15a) will be larger than the pause after “cop” in (15b), because the former has one more completed constituent boundary than the latter. This is what they found: speakers placed a larger pause after “cop” in (15a) than (15b), and the word “cop” was lengthened more in (15a) than in (15b).

Using pause and lengthening data from experiments similar to the one described above, CPC developed an algorithm that generates pause length predictions. The theory has two components. In the first component, the utterances’ syntactic tree is used to calculate the relative size of a pause and the amount of the lengthening of the pre-boundary word. The steps from the first component are as follows (quoted directly from CPC):

Step 1. Define the structural representation of the utterance, using rewrite rules of phrase structure grammar.

Step 2. Locate the key boundary

Step 3. Locate the dominating phrase structure nodes by finding the highest nodes which dominate the word to the immediate left or right of the key boundary but which do not dominate both of these words.

Step 4. Determine the number of flanking nodes between the dominating phrase structure nodes and the nodes immediately dominating the words to the immediate left and right of the key boundary, assigning a value of 0 to (a) any nodes referring to minor category terms (including conjunctions, determiners, and nonlexical prepositions)¹ and (b), when considering the left side of the boundary, any nonterminal nodes that do not branch into at least two nodes, each of which dominates a major category item².

Step 5. Add one unit of strength to any branching S node.

Step 6. Multiply by two the number of nodes listed for the left side of the boundary.

Step 7. Combine the number of nodes for both left and right sides of the boundary,

¹ It is unclear how CPC define “nonlexical” preposition.

² In CPC’s text, they say that 0 is assigned to non-terminal nodes only when they occur on the left side of the boundary. However, in their example and in their figure, they apply this rule to both sides of the boundary. Here, I will assume that a 0 value is assigned to both sides of the boundary.

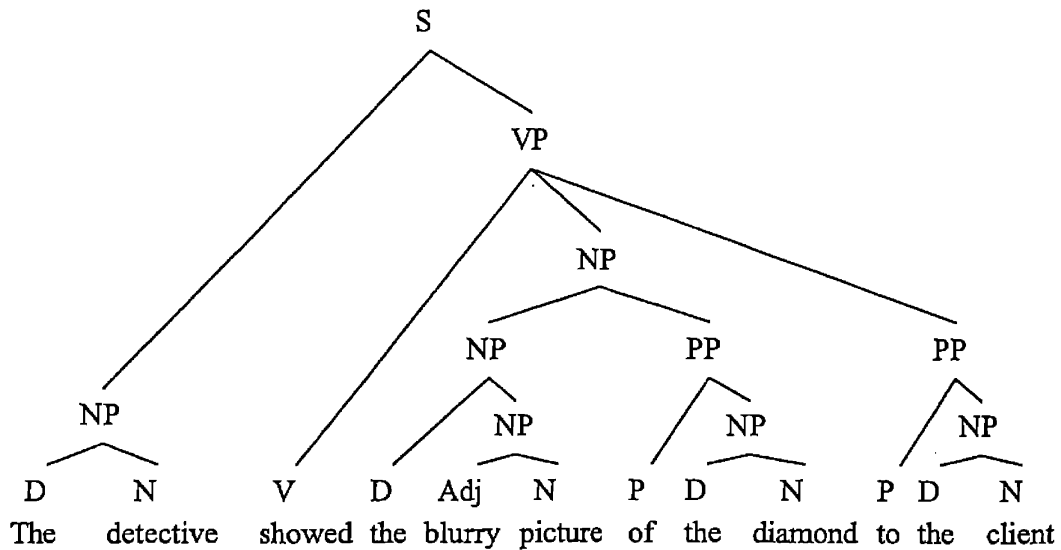


Figure 1.1 The syntactic representation to which the CPC algorithm applies.

(16b) The 1 detective 4 showed 4 the 1 blurry 3 picture 4 of 1 the 1 diamond 5 to 1 the 1 client.

The values generated after applying the algorithm to the tree structure in (16a) are presented in sentence (16b). To illustrate, the syntactic boundary strength for the boundary between “detective” and “showed” is calculated as follows. First, we find the dominating phrase structure nodes (Step 3), which in this case are the subject NP and the matrix VP. Next, we determine the flanking nodes (Step 4). For the left side of the boundary, this includes only an N. The NP is not included because it does not immediately dominate two major category items (Step 4b). On the right hand side of the boundary, the flanking nodes are VP and V. The total boundary strength is calculated by multiplying the number of left hand flanking nodes by two, and then adding the number of right hand nodes to the product $(1*2)+2=4$.

The second component of the algorithm, which includes eight more steps, weights the output of the first component to account for non-syntactic factors. The first of these factors attempts to account for that fact that people prefer to bisect sentences into relatively equal parts. The algorithm weights pauses towards the center of the sentence more heavily than those on the periphery. There are also mechanisms

in the algorithm that compensate for the fact that longer utterances are more likely to have pauses and that utterances that are pronounced quickly are less likely to have pauses.

CPC proposed this theory as a possible model of pause and lengthening structure, but did not empirically test the theory's predictions. Gee and Grosjean (1983) tested these predictions in a study that will be discussed in the next section. In Gee & Grosjean's experiment, the CPC model actually made better predictions when only the first component of the algorithm is applied. Therefore, only the first component will be considered in this discussion.

The CPC has a few drawbacks. First of all, Ferreira (1993) points out some empirical problems with the model. Essentially, CPC's model predicts that the number of right hand brackets at a word boundary should correlate with the size of the pause and the amount of lengthening of the pre-boundary word. Ferreira (1993) tested this claim by having speakers produce utterances that contained subject NP's like the ones below:

- (17a) [The [friendliest]_{AdjP} cop]_{NP}
 (17b) [The friend [of [the cop]_{NP}]_{PP}]_{NP}
 (17c) [The man [who's [[[a cop]_{NP}]_{VP}]_S]_{S'}]_{NP}

The number of right brackets after the word "cop" increases from (17a) to (17c). Thus, CPC predict that (17c) will have a larger pause after the word "cop" than (17b) because there are five right brackets in (17c) while there are only three right brackets in (17b). (17c) should have a smaller pause than both (17a) and (17b) because only one brackets follows the word "cop".

Ferreira found that there was no significant difference in the length of the pre-boundary word "cop" or in the size of the pause following it in (17a), (17b), or (17c) as compared to the word cop. This is a problem for CPC's model because it suggests that pause size is not merely a function of the type or number of constituents that have recently been completed. Ferreira argues that the overall prosodic tree of a sentence is the important factor in determining pause size in these sentences. Although these subjects are very different syntactically, they have the same number of syllables and are similar prosodically.

Ferreira also found that the size of a pause at a given word boundary was not a function of syntactic structure, but rather a function of the phonological properties of the word preceding the pause. In a production experiment, she found that the size of a pause was inversely correlated with the vowel length of the preceding word. Words with long vowels were followed by shorter pauses than words with short vowels. In addition, bigger pauses occurred at intonational phrase boundaries than in intonational phrase medial positions.

From this data, Ferreira (1988, 1993) argues that syntax plays a role in determining the relative *likelihood* of an intonational boundary while prosodic structure and segmental phonology determine the relative *size* of a pause. CPC's earlier results may have been an artifact of their data analysis. Because they took the averages of pause lengths across subjects, it is unclear whether the variance they found in pause size and word length across sentence positions was mirrored in individual utterances or whether the variance simply reflected differences in the frequency of intonational boundaries of roughly the same size. Ferreira's data suggests that the latter is probably correct.

Thus, another problem with CPC's model is that it provides no explanation for the variance in intonational phrase boundary placement that was discussed above. The model was designed to predict relative pause size and segmental lengthening, assuming that the pause duration for word boundaries is a continuous variable that is dependent on syntactic structure. As Ferreira (1988) point out, the reality seems to be that pauses are dependent on intonational phrasing and prosodic structure. Intonational boundary placement is binary in that boundaries either occur or do not occur. Whether a boundary occurs or not is dependent on a number of factors, some of which are syntactic and some of which are not. The intensity of pausing and lengthening at a given boundary is dependent on the phonological properties of the word preceding the boundary and not syntactic structure. Thus, a more sensible use of CPC's algorithm is to predict the relative likelihood of intonational boundaries at word boundaries.

Ferreira's results suggest that a simple one to one mapping between syntactic structure and intonational phrasing does not exist, and that perhaps additional factors need to be integrated with a syntactic account to correctly predict pause size and boundary placement. In the next section, I will

review Gee & Grosjean's (1983) algorithm, which integrates syntactic structure and prosodic structure to predict pause size.

1.5.3 GEE & GROSJEAN

Gee & Grosjean (1983) (GG) propose an algorithm that integrates aspects of both syntactic and prosodic structure to predict pause size. The motivation for designing such an algorithm was to capture some of the phonological factors that appear to constrain intonational phrasing. Intonational boundaries tend not to occur between phonologically light function words and content words, even if this word boundary coincides with a major syntactic boundary.

Like CPC's model, GG's algorithm generates values that predict the relative size of a pause at each word boundary. Given the drawbacks of predicting pause size using only syntactic information, I will present GG's theory as theory of the likelihood of intonational boundary placement at word boundaries.

The likelihood values generated by the algorithm are produced by a series of steps which ultimately result in the construction of a hierarchical tree. The values themselves are generated by counting nodes in the tree at each word boundary. The details of the algorithm are discussed below.

In the first step of GG's algorithm, a sentence is divided into phonological phrases as defined by Nespor & Vogel (1986). Then, each of the words within a phonological phrases are adjoined in a right-branching tree:

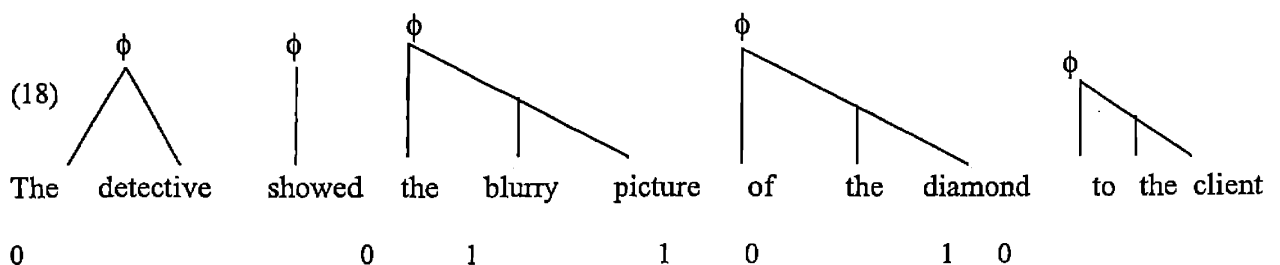


Figure 1.2 GG Phonological phrasing rule. Segmentation into phonological phrases

To compute the boundary strength values for the word boundaries within the phonological phrases, the number of nodes that the constituent at each boundary dominates is computed. In the case of "blurry" and "picture," for example, there is one node that dominates each of these words so the value at this position is one. Junctions between function words and content words are counted as zero unless the node dominates another function/content word boundary in which case, it is counted as one. Thus, the junction between "The" and "detective" is counted as zero, but the junction between "to" and "the" in "to the client" is counted as one.

The next step is to adjoin these phonological phrases in accordance with three grouping principles. The first principle is the Syntactic Constituent Rule. This rule adjoins all phonological phrases that form a syntactic constituent, excluding VPs, into a right branching tree.

(19)

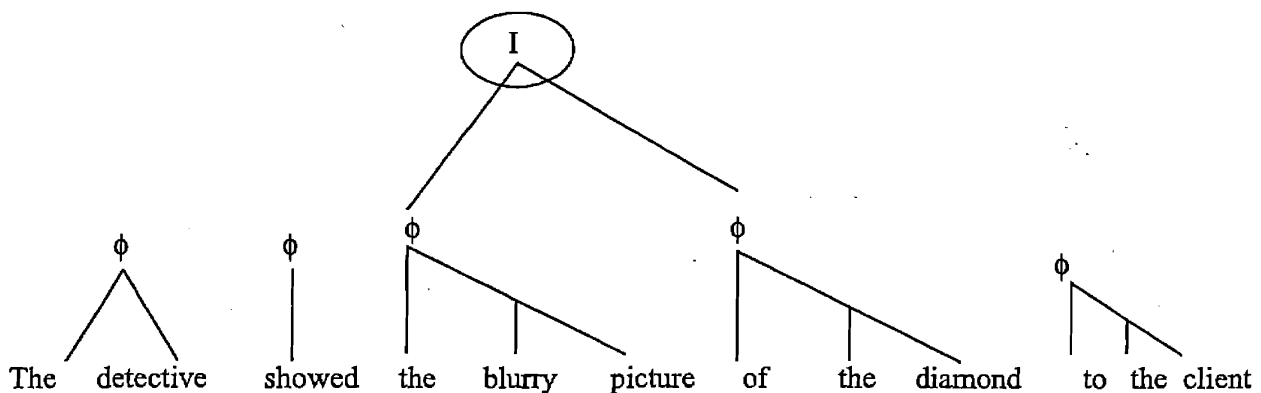


Figure 1.3 GG Syntactic constituent rule. "the blurry picture" and "of the diamond" are joined because the two phonological phrases form a syntactic constituent. Note the verb phrase is not included in this rule.

In the figure above, the phonological phrases "the blurry picture" and "of the diamond" are grouped together because they form a noun phrase.

The second rule is the Verb Rule. The phonological phrase headed by the main verb is grouped with the following prosodic unit unless the combination of the phonological phrases headed by the verb and the subject have fewer nodes than the following material. In such a case, the verb is grouped with the subject. GG claim that this rule reflects a general tendency for utterances to divide into intonational phrases of roughly equal length. When the subject is long and the object is short, the verb will group with the object. When the subject is short and the object is long, the verb will group with the subject.

(20)

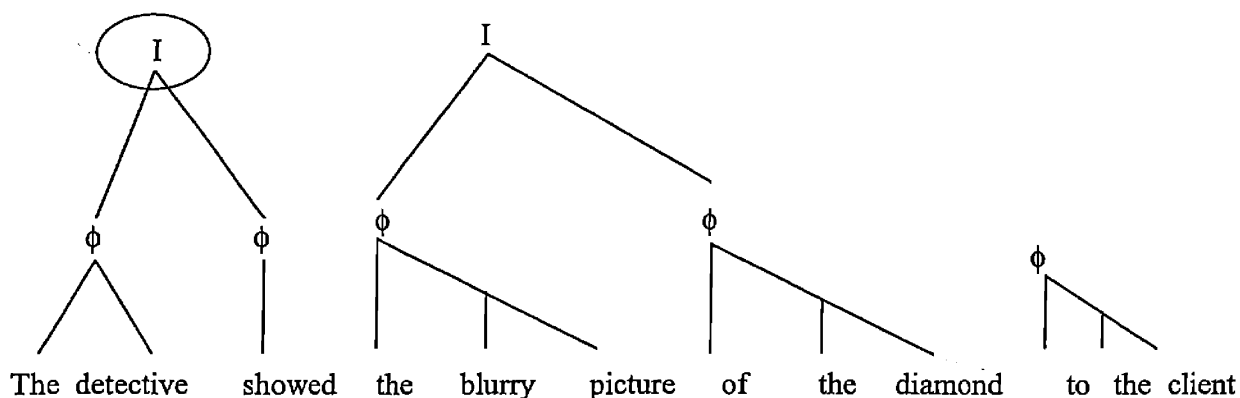


Figure 1.4 GG Verb rule. "The detective" and "showed" are grouped together because the verb joined with the subject is simpler than the verb grouped with the object

The final rule is the General Bundling Principle. All remaining strings of phonological and intonational phrases are grouped together in a left branching structure. GG point out that new and focused information tends to occur towards the end of a sentence and that intonational boundaries are more likely to precede new information.

(21)

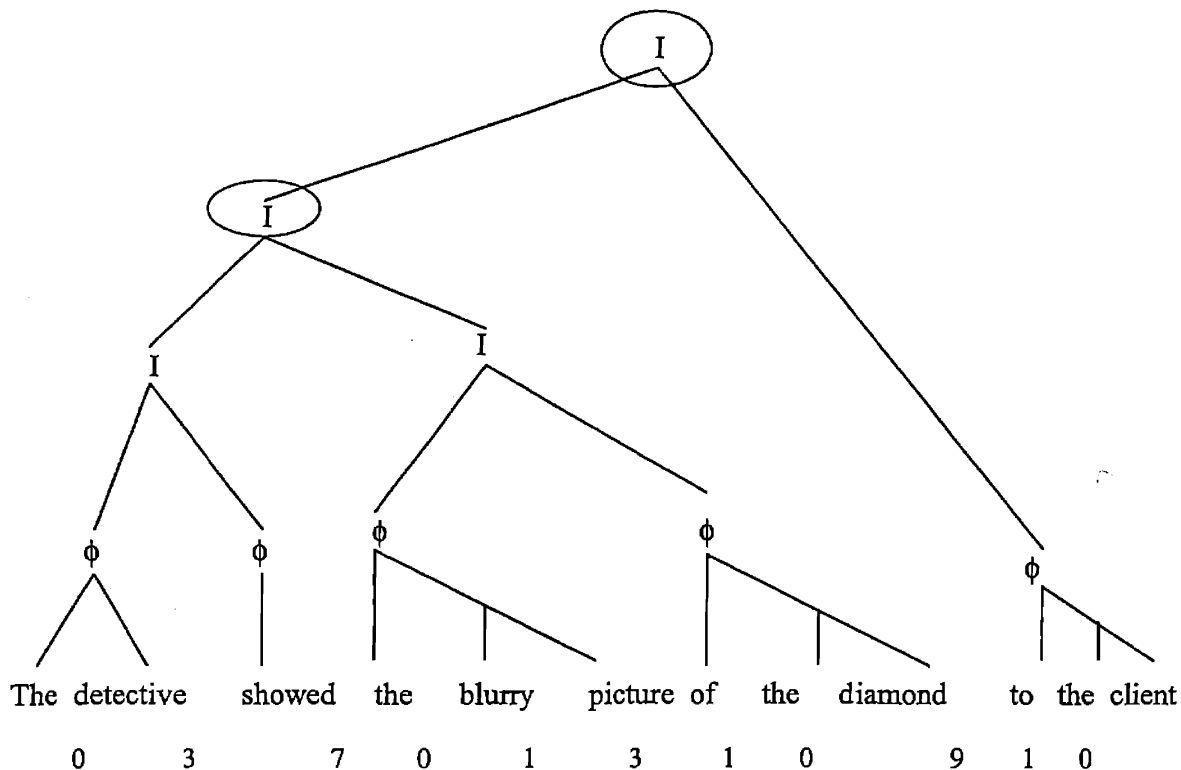


Figure 1.5. GG general bundling principle. The remaining I and ϕ -phrases are joined in a left branching tree

Once the tree has been constructed, predictive values are calculated by adding up the number nodes that are dominated by the boundary node. The boundary node is the lowest node in the tree that dominates both of the words at the boundary in question. A value of one is added to any boundary before or after a complex-word and to the boundary before the sentence final word. For example, the boundary between "picture" and "of" receives a value of 3, because summing the boundary node (i.e. the I-node dominating "the blurry picture of the diamond") and the two nodes that it dominates yields a value of 3. The values at each word boundary represent the relative likelihood of an intonational phrase boundary

occurring. The preceding steps apply to a single clause at a time, and there are additional rules for multi-clause sentences.

GG derived this model post-hoc based on data from a set of 14 different sentences produced by subjects in the lab. Overall, the model accounts for 92% of the variance in pause size³, outperforming CPC's model, which only accounts for 66% of the variance in pause size, as well as a model proposed by Grosjean, Grosjean, & Lane (1978), which accounts for only 68% of the variance.

Despite the impressive performance of this model, it has a few shortcomings. First of all, the theory has a large number of steps and parameters considering the small set of sentences from which it was developed. The data set consists of 14 sentences, yet there are 10 steps in the algorithm which suggests that data-fitting may have played to large a role in the model's success with these sentences. The robustness of the results are also somewhat suspect since only 6 subjects participated in the experiment, and there was only one token for each of the 14 sentences. Subjects were also simply asked to read the sentences into a tape recorder, so it is unclear whether these results generalize to non-read speech or speech to another person.

It is also unclear how cognitively grounded the explanations for the parameter settings are. For example, why should phonological phrases that form a constituent adjoin in a right branching tree while phonological phrases that do not form constituents adjoin in a left branching tree? Because the parameters of the model are difficult to isolate, it is unclear which aspects of the model have predictive power and whether the particular parameter settings are crucial to the model's success.

1.5.4 FERREIRA'S X-BAR ALGORITHM

Ferreira's model differs from earlier model in that she argues that two different processes are responsible for the distribution of pauses: processes in planning and processes in timing.

³ As in the CPC studies, the dependent measure in this experiment was the size of pauses at word boundaries averaged over subjects.

Pauses that are associated with timing are derived from a metrical grid structure. The metrical grid as proposed by Liberman & Prince (1977), Hayes (1983) and Selkirk (1984), is based on the notion that speakers attempt to maintain a balanced rhythm, alternating between stressed and unstressed syllables. This is accomplished by aligning words in a grid, where syllables receive extra beats if they are the position of main word stress, secondary word stress, or sentence level stress. Additional rules manipulate the grid to ensure that the speech is in fact rhythmic, and stressed syllables do not appear too close or too far apart. In addition, silent positions called “demibeats” are inserted at word boundaries. Demi-beats predict the relative size of pauses at word boundaries as well as the amount of lengthening of the pre-pausal word. The size of a demibeat is a function of the syntactic properties of the preceding word as well as the syntax at the word boundary. For example, a demibeat is added to a word boundary if that boundary occurs after a lexical head, aligns with a phrase, or follows a daughter phrase of the S.

Pauses associated with planning reflect processes that convert a syntactic structure into a phonological structure, which, in turn, serves as a high level motor program for speech. If the syntactic structure is too long, it will overload working memory capacity, and a break will be inserted somewhere in the utterance. Ferreira argues that the break will occur at a point in the sentence such that the resulting units are as semantically coherent as possible, defining coherency as having a minimal number of dependencies across units. Ferreira points out that this type of semantic/prosodic organization is advantageous to both the speaker and the listener because semantically coherent objects are easier to maintain in working memory, and preserving the semantic coherence within an intonational phrase facilitates comprehension for the listener.

Ferreira implements this theory by using a version of X-bar theory (Jackendoff, 1977) to predict the most likely position for an intonational phrase boundary. X-bar theory is useful in this case because arguments and modifier relationships are explicitly represented in X-bar structure, allowing Ferreira to approximate semantic coherence by making generalizations about the configuration of the tree. She argues that the higher two units attach within the tree, the greater their semantic independence, and the less likely they are to be separated by an intonational phrase. For example, Ferreira would argue that an

intonational boundary is less likely to occur between a head and its argument, which are syntactic sisters, than between a head and a modifier since the modifier is a sister of the head's projection, and not sisters with the head itself.

The algorithm works by scanning the tree to locate the node in the X-bar tree that dominates each word boundary. Once this node is identified, its immediate daughters are matched to a syntactic category template. There are nine syntactic pair templates, each associated with a numerical ranking. The word boundary receives the ranking associated with its matched template. The higher the ranking is, the greater the likelihood of an intonational boundary at the word boundary.

(22)

- | | | | |
|---------------|--------------|---------------|--------------|
| (1) $X^0 X^0$ | (2) $X^0 X'$ | (3) $X^0 X''$ | (4) $X^0 XP$ |
| (5) $X' X'$ | (6) $X' X''$ | (7) $X' XP$ | (8) $X'' XP$ |
| (9) $XP XP$ | | | |

Although she does not explicitly state this, her theory implicitly encodes the idea that the probability of an intonational boundary at a given word position is a function of the distance between the head of the right hand constituent and the head with which it has a dependency relationship. Distance in this case is measured in the number of nodes that must be transversed to move from one head to the other. Thus, two neighboring XPs, nodes that are maximally distant from their projecting heads, are more likely to be separated by an intonational phrase boundary than two X^0 , which are minimally distant from their projecting heads.

(23a)

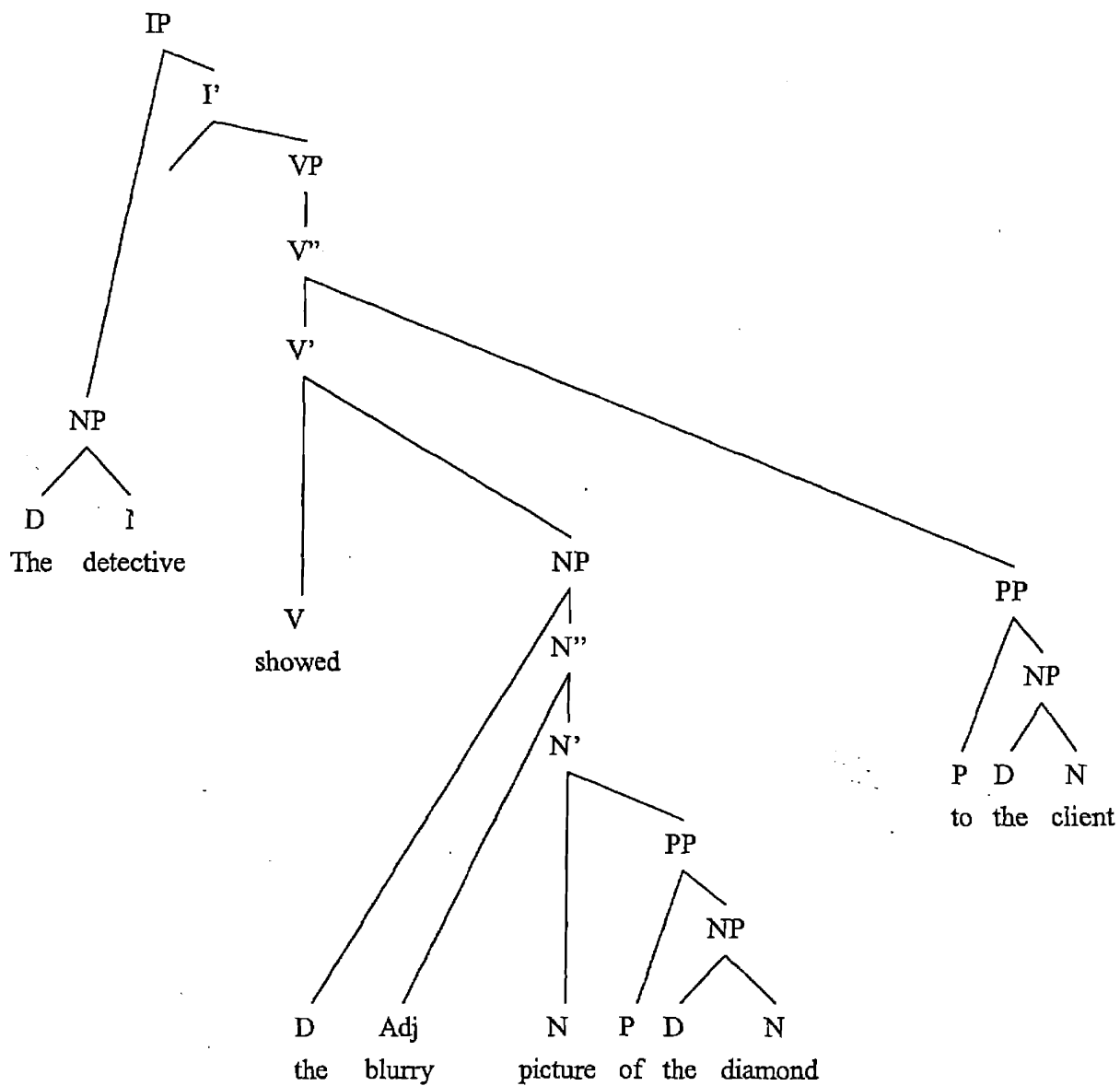


Figure 1.6. Ferreira X-bar tree. The X-bar tree to which Ferreira's X-bar algorithm applies.

(23b) The 1 detective 7 showed 4 the 3 blurry 2 picture 4 of 4 the 1 diamond 7 to 4 the 1 client

In order to calculate the value for the word boundary between “detective” and “showed”, for example, one first finds the dominating node, which is an IP. The IP’s daughters are NP and I’. The template for this pair is X’ XP, which has a rank of 7. Thus, the value for this point in the sentence is 7, marking this point as a relatively likely place for an intonational phrase boundary.

One of the interesting properties of this model is that it instantiates Selkirk’s notion of semantic coherence while actually making predictions about likely locations for intonational boundaries. As I discussed above, Selkirk’s Sense Unit condition simply places constraints on intonational boundary placement, defining where boundaries can and cannot occur according to semantic restrictions. She claims that constituents cannot occur within the same intonational phrase if there is no dependency relationship between them. Ferreira implements this idea of semantic coherence, but argues that the occurrence of semantically related material within the same intonational phrase is an artifact of processes in production, and contrary to Selkirk’s claim, not a grammatical constraint on the phonology of a sentence. Semantically related material tends to occur together in the same intonational phrase because it is constructed together in the process of sentence production.

In the model that I will present below, I will argue that this idea of semantic coherence is important, but the X-bar representation that Ferreira proposes is incapable of accounting for some of the factors that govern intonational boundary placement. I will show that a major determiner of intonational boundary placement is the phonological size of syntactic constituents, which is a notion that is difficult to instantiate in a syntactic representation such as X-bar. In Ferreira’s theory, phonology only plays a role in determining the timing properties of pauses between words. I will argue that it also influences the distribution of intonational boundaries.

1.6 CONCLUSIONS

In this section, I have presented theories that have made a variety of different claims about the type of representations and mental processes that play a role in intonational boundary placement.

Linguistic theory has mainly taken a competence-based approach to understanding intonational boundaries. This approach will most likely not be successful in accounting for intonational phrasing because of the variance in boundary placement and because of the numerous factors that appear to affect boundary placement.

I have also discussed a class of theories that argue that intonational boundaries reflect (among other things) processes in production. Although these theories are highly successful in predicting intonational boundary placement, they have a large number of parameters and steps, and it is unclear how they map onto current cognitive architectures of production.

Below I will present a new theory of intonational phrasing that operates under the assumption that intonational phrasing is partly a product of processes in production. Unlike previous models, the model has fewer parameters and steps, and may provide insight into the language production mechanism.

CHAPTER 2: THE LRB

2.1. THE LRB

The LHS/RHS boundary weight (LRB) hypothesis is a theory of the likelihood of prosodic boundary placement based on the dependency relationships between words. Two observations from Experiment 1 (presented below) underlie the proposed model: 1) Speakers tend to produce intonational boundaries immediately after completing large syntactic constituents and 2) speakers tend to produce intonational boundaries before large syntactic constituents if they are not an argument of the most recent head.

2.1.1 THE LHS HYPOTHESIS

The first component of the LRB is the Left Hand Side Constituent hypothesis or LHS hypothesis as defined in (1)

(1) LHS Hypothesis: Intonational boundaries tend to occur after the completion of a large syntactic constituent. A syntactic constituent is defined as *completed* if it has no rightward dependents.

The hypothesis in (1) may reflect a refractory period for the sentence production mechanism, or the need for more time in producing the upcoming constituent after expending resources on the most recent constituent.

Recent work by Schafer et al. (2001; see also Cooper & Paccia-Cooper, 1980, for similar results) suggests that speakers tend to place boundaries after large syntactic constituents. In a two person game-playing task, speakers gave listeners instructions to move pieces with a set of sentences supplied by the experimenters. Sentences like the ones in (2) were used with interpretations that involved either an attachment of the prepositional phrase to the verb *change* or a local attachment to the noun *square*.

(2) I want to change the position of the square with the triangle.

Speakers tended to place an intonational boundary before the prepositional phrase *with the triangle* when they intended the verb attachment interpretation in which the triangle is the instrument for moving the square. In contrast, speakers did not tend to place a boundary at this location in the noun attachment interpretation, in which the triangle is on the square. In the verb attachment case, the boundary before *with* coincides with the end of the NP *the position of the square*, leading to a greater likelihood of an intonational boundary. On the other hand, in the noun attachment, there are no completed constituents immediately to the left of *with* (the NP *the square* has a rightward dependent initiated by *with*), leading to a small likelihood of a boundary being produced.

I believe that CPC, GG, and Ferreira's are successful partly because this generalization was instantiated in their respective models. For example, in CPC's algorithm, the number of both the right and left brackets at a word boundary are used to predict boundary strength with the caveats discussed above. CPC weight right brackets more heavily than left, arguing that they are more important in determining pause size. This is consistent with the LHS hypothesis because right brackets correspond with the ends of syntactic constituents and a higher number of right brackets will generally correspond with a longer syntactic constituent.

(3a) [[Jeffrey]_N [hit [the cop]_{NP} [with [the stick]_{NP}]_{PP}]_{VP}]_S

(3b) [[Jeffrey]_N [hit [the cop [with [the stick]_{NP}]_{PP}]_{NP}]_{VP}]_S

For example, in (3) above, CPC found that there was a larger pause after the word *cop* in (a) than in (b). They account for this by arguing that one more syntactic boundary is completed at the word boundary after *cop* in (a) than (b).

This prediction is consistent with the predictions of the LHS hypothesis. However, unlike CPC, the LHS hypothesis posits that it is the size of the most recently completed constituent, and not the number of completed constituents that determines the likelihood of an intonational boundary, although

these are likely to be correlated. The more constituents there are that have been completed at a word boundary, the longer the most dominating constituent is going to be. However, Ferreira's (1993) criticism of CPC's theory discussed above suggests that syntactic length is not the most relevant factor.

- (4a) [The [friendliest]_{AdjP} cop]_{NP}
 (4b) [The friend [of [the cop]_{NP}]_{PP}]_{NP}
 (4c) [The man [who's [[a cop]_{NP}]_{VP}]_S]_{S'}]_{NP}

The subject NPs in (4) did not differ in the size of their post-subject pause, suggesting that the size of the pause is not correlated with the number of syntactic boundaries at a word boundary, contra the predictions of CPCs model. However, this finding is consistent with the LHS hypothesis. The hypothesis states that the size of the completed constituent predicts intonational boundary likelihood, and all of the sentences in (4) have the same phonological length.

This hypothesis is also implicitly instantiated in Gee & Grosjean's model. As discussed above, a prosodic tree structure is derived from an utterance's syntactic structure to determine pause size at a given word boundary (see figure X in Chapter 1). The number of nodes dominated by the boundary node predicts the size of the pause. Two aspects of this model in particular are consistent with the claim that boundaries tend to occur after long syntactic constituents. The first is the syntactic constituent rule and the second is the general bundling principle.

The syntactic constituent rule groups phonological phrases that form either a clause or a noun phrase together under a single right branching I-node. An important consequence of this adjunction is that intonational boundaries before and, more importantly, after the resulting constituent are more likely than intonational boundaries between phonological phrases within the resulting constituent. This follows directly from the structure of the tree. Nodes that dominate the borders of the constituent must necessarily include the nodes that the I-node dominates, resulting in larger pause predictions. In addition, because longer constituents will have more phonological phrases and, thus, more nodes, it follows that the longer the phonological constituent is, the greater the predicted likelihood of an intonational boundary

before and after the constituent. This parameter is consistent with the idea that boundaries are more likely to occur after large syntactic constituents and the relevant measure of size is phonological length.

The other relevant aspect of GG's theory is the general bundling principle, which applies after the syntactic rule and the verb rule have applied. It essentially adjoins all remaining phonological phrases into a single left branching tree where nodes at the end of the sentence dominate nodes towards the beginning of the sentence. A consequence of adjoining these phonological phrases into a left branching structure is that boundary nodes at the end of a sentence will dominate more nodes than boundary nodes at the beginning of the sentence. This translates into a greater likelihood of intonational phrase boundaries at the end of a sentence than at the beginning. Again, since the ends of large syntactic constituents are more likely to occur at the end of the sentence than at the beginning, the success of this rule in prediction may reflect a preference for boundaries at the end of long syntactic constituents.

2.1.2 THE RHS HYPOTHESIS

The second component is the Right Hand Side Constituent hypothesis or RHS defined in (5).

(5) RHS Hypothesis: Speakers tend to place boundaries before long syntactic constituents.

A possible motivation for (5) is that speakers need extra processing time to plan a longer syntactic constituent. Some evidence for this comes from work by Sternberg et al. (1978), who found that speakers' initiation times for a list of words was a function of the number of stressed syllables they were about to produce. Sternberg and colleagues (1978) argued that these stress groups serve as a unit of planning in production. The more of these units there are in the production program, the longer the initiation time. However, Sternberg's work was only on lists of words, not full sentences. Ferreira (1991) followed up this work by studying initiation times for utterances of full sentences. She found that the length and the syntactic complexity of a sentence's subject were correlated with the sentence initiation times, although the length and complexity of the object did not seem to affect initiation times. However,

she did find that the probability of pausing before the verb phrase was positively correlated with the complexity of the sentence's direct object. She argues that this pause and initiation time data may reflect processes in planning an upcoming constituent.

CPC and GG's algorithms, as discussed above, are consistent with the RHS. CPC's predicts that the likelihood of an intonational boundary is partly a function of the number of left brackets at a word boundary. Constituents that begin with a large number of left brackets are probably longer than constituents that begin with a lower number of brackets. Similarly, in GG's algorithm the likelihood of an intonational boundary before a syntactic constituent is partly a function of the number of phonological phrases in the upcoming constituent. Under GG's theory, a node that dominates a syntactic constituent with a large number of phonological phrases will dominate more nodes than a shorter syntactic constituent, resulting in a higher predicted likelihood of an intonational phrase boundary at the word boundary preceding the constituent.

This body of evidence suggests that either the size or the complexity of upcoming constituents affect intonational boundary placement. In section 2.1.4. it will be argued that it is the length of the constituent that is the crucial factor.

2.1.3. SEMANTIC RELATEDNESS

An additional factor that seems to play a role in determining intonational phrasing is the semantic relationship between dependencies. As discussed above, Selkirk (1984) argues that intonational phrase boundaries in an utterance are subject to a semantic well-formedness constraint called the Sense Unit Condition (SUC). The SUC states that heads that do not have a dependency relationship cannot occur together in an intonational phrase. Formally, Selkirk defines the SUC as follows:

- (6) The Sense Unit Condition of Intonational Phrasing: The immediate constituents of an intonational phrase must together form a sense unit. Two constituents C_i, C_j form a sense unit if (a) and (b) are true of the semantic interpretation of the sentence:
- a. C_i modifies C_j (a head)
 - b. C_i is an argument of C_j (a head)

The SUC therefore predicts that sentence (7b) should sound worse than sentence (7a).⁴ In (7a), both intonational phrases form sense units. Each constituent within the intonational phrases has a dependency relationship with another constituent within that intonational phrase. However, in (7a), the second intonational phrase does not form a sense unit (though the first one does). This is because *the book* and *to Mary* do not participate in a head-argument or head-modifier relationship.

- (7a) [John gave the book] [to Mary]
 (7b) [John gave] [the book to Mary]

One important implication of the Sense Unit Condition is that semantically related words (in Selkirk's sense) tend to be grouped together in the same intonational phrase, while semantically unrelated words are not. Because the semantics of a sentence seems to constrain intonational phrasing, how a sentence is phrased must be more than a function of just the size of the syntactic constituents.

This idea also plays an important role in Ferreira's (1988) X-bar algorithm. The X-bar model instantiates head argument/modifier relationships through the geometric properties of the X-bar tree. Since the number of nodes between dependents determines intonational phrasing in Ferreira's models, arguments are more likely than restrictive modifiers (which are more likely than non-restrictive modifiers) to occur within the same intonational phrase as their heads. This follows because there are more nodes between a head and its arguments than between a head and its modifier. It may be this property of the model that allows for the success of the model on Ferreira's test sentences.

In light of this, the RHS hypothesis presented in (5) is rewritten in (8)

⁴ As was mentioned in Chapter 1, sentence (7b) sounds more acceptable if 'gave' is pronounced with contrastive stress.

(8) RHS Hypothesis: Intonational Boundaries tend to occur before large syntactic constituents if and only if they are not semantically related to the most recently processed head. As a first approximation at semantic relatedness, syntactic constituents are considered semantically related to the immediately preceding head if they are one of the head's arguments.

2.1.4 MEASURING SIZE

There are many possible units that could be used to measure constituent size, including phonemes, syllables, words, and larger syntactic or phonological phrases. In most instances, these units of measurement will be highly correlated with each other. For example, consider the increasing size of the subject NP in (9a-c):

(9a) The reporter wrote a story.

(9b) The reporter at the press conference wrote a story.

(9c) The reporter at the press conference in Washington wrote a story.

Whether one counts phonemes, syllables, words or phrases, the size of the subject increases through (9a), (9b), and (9c). Therefore, any one of these units would probably serve as a good approximation of size in most cases.

As a first approximation, phonological phrases will be used as a measure of size. In English, phonological phrases are defined as all the words within the maximal projection of a lexical head on the lexical head's left side (Gee & Grosjean, 1983; Nespors & Vogel, 1986). Phonological phrases have been proposed by a number of researchers to describe some of the timing properties of function words and content words in English (Selkirk, 1984; 1986; Nespors & Vogel, 1986; Gee & Grosjean, 1983). Function words are words that have little to no lexical content. These include categories like determiners, complementizers, and prepositions. Content words, on the other hand, have lexical meaning and include categories like nouns and verbs. In spoken utterances, function words tend to de-stress and adjoin to adjacent content words, forming phonological phrases.

There is a great deal of controversy concerning how phonological phrases should be defined. Other researchers define this term differently (see Shattuck-Hufnagel & Turk, 1996 or Appendix A for a review). The Nespors & Vogel (1986) definition that is used here has some advantages and disadvantages.

On the one hand, phonological phrases as described by Nespor & Vogel (1986) seem to accurately describe potential locations for intonational boundaries. In general, intonational boundaries tend to occur at the boundaries of phonological phrases rather than within phonological phrases as defined by Nespor & Vogel (although there can be some exceptions; see Shattuck-Hufnagel & Turk (1996)). This claim also has some empirical support. Gee & Grosjean (1983) found that in English, speakers tend not to place intonational boundaries between function words and the adjacent content word on the right. In light of this finding, the model presented here only considers phonological phrase boundaries as possible sites for intonational phrase boundaries.

However, Ferreira (1988) points out some drawbacks to Nespor & Vogel's characterization of phonological phrasing. She correctly argues that unstressed words do not always adjoin to the stressed word on the right:

(10a) John picked up movie tickets

(10b) The professor has forgotten

In (10a), the particle *up* cliticizes to the main verb *picked* on its left while in (10b), the auxiliary verb *has* adjoins to the subject NP *professor*, and is often contracted in this context.

For the purposes of measuring size, how phonological phrases are defined is not particularly crucial to the arguments presented here since, as discussed above, most units of size would most likely do just as well. Only a carefully controlled experiment that manipulates potential units of length (e.g. syllables, words, phonological phrases, etc..) can determine what the appropriate metric is. Ferreria's (1988) criticism becomes more important when we consider potential sites for intonational phrasing, since it is argued here that an intonational boundary is more likely to occur at a phonological phrase boundary than within a phonological phrase. For now, Nespor & Vogel's definition of phonological phrasing will be used with the knowledge that the definition must be extended or revised.

2.1.5 AN EXAMPLE

Given the working hypotheses described above, the LHS/RHS boundary weight is defined in (11):

(11) The LHS/RHS intonational boundary weight is defined to be the sum of 1) the number of phonological phrases over which the largest completed left-hand-side (LHS) syntactic constituent extends; and 2) the number of phonological phrases over which the largest right-hand-side (RHS) syntactic constituent extends if it is not an argument of the most recent lexical head.

In addition, in order to reflect the fact that intonational boundaries are more likely at phonological phrase boundaries than at other word boundaries, an additional value of 1 is added to the values in (13) for each phonological phrase boundary location, whereas word boundaries that are not phonological phrase boundaries receive a value of zero.

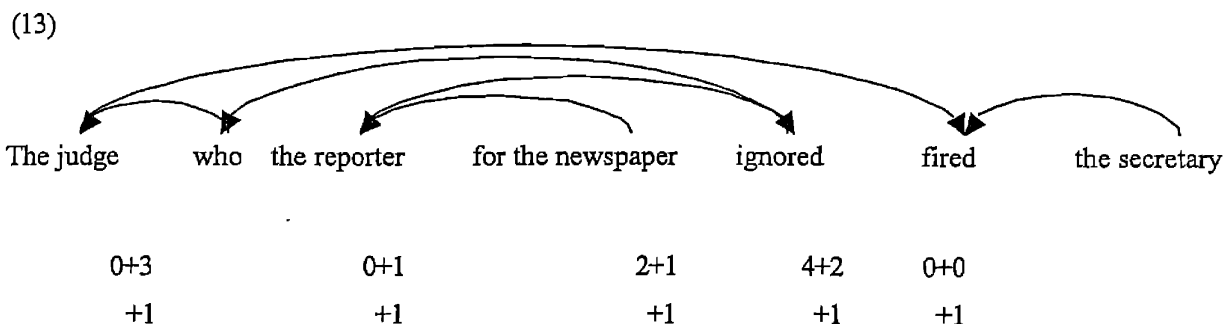
The LHS/RHS boundary weight (LRB) hypothesis is then given in (12):

(12) The LHS/RHS boundary weight (LRB) hypothesis: The LHS/RHS boundary weight is proposed to be correlated with the probability of producing a boundary at a given location.

Characterizing the relationship between syntax/semantics and intonational phrasing in this way has a few advantages. Because the LRB relies only on dependency relationships between heads, the model is consistent with any grammatical theory that posits head dependency relationships. Past models required very specific syntactic systems to generate predictions (Cooper & Paccia-Cooper, 1980; Gee & Grosjean, 1983; Ferreira, 1988).

Another useful property of the model is that it makes straightforward predictions in both ambiguous and unambiguous sentences. The LRB makes predictions based on the assumption that intonational phrasing occurs because of general memory and production processes rather than as a means of ambiguity resolution. The underlying assumption in the comprehension literature has been that intonational phrasing is used by the producer (and listener) in situations where there is more than one possible interpretation for a sentence. We hypothesize that processes that determine intonational phrasing are a ubiquitous part of language production and not simply a tool for ambiguity resolution.

An example is provided in (13) of how the LRB hypothesis applies to a sentence:



The phonological phrases – all the words up to and including a noun or verb – are shown separated by large spaces in (13). The first number at each phonological phrase boundary is the size of the LHS constituent. The second number represents the size of the largest RHS constituent being integrated at that position (as long as it is not an argument of the head to which it is integrating).

The first potential boundary site is between the phonological phrases [*The judge*] and [*who the reporter*]. The LHS value for this boundary is 0 because *the judge* is not yet complete at this point. The attaching RHS constituent at this point is the relative clause *who the reporter for the newspaper ignored*, which consists of three phonological phrases. Because this phrase is not an argument of the head to which it attaches (*judge*), the value for RHS constituent size is 3. The total here is therefore 3.

The second potential boundary occurs between [*who the reporter*] and [*for the newspaper*]. No constituents up to this point have been completed, so the LHS value is 0. The RHS constituent size value is 1 here, because the attaching prepositional phrase is not an argument of *newspaper*, and it has length 1. The total value at this boundary is therefore 1.

The third potential boundary occurs between [*for the newspaper*] and [*ignored*]. The largest constituent completed at this boundary is the NP *the reporter for the newspaper*. Because this NP is extended over two phonological phrases, the LHS value is 2. The RHS size is length 1 (*ignored*), which is counted because it is not an argument of the constituent to which it attaches. The total at this point is therefore 3.

The fourth potential boundary occurs between [*ignored*] and [*fired*]. At this point, the largest completed constituent is the matrix subject of the sentence, which extends over 4 phonological phrases, creating an LHS value of 4. The size of the RHS constituent to be integrated at this point is two, reflecting the two phonological phrases in the VP *fired the secretary*. Thus the total value at this boundary is 6.

The fifth and final potential boundary in this sentence occurs between [*fired*] and [*the secretary*]. No syntactic constituents are completed at this point, so the LHS is 0. The size of the RHS constituent in this integration is 1 phonological phrase, the NP *the secretary*, but it is not counted because this NP is an argument of the head to which it is integrating, the verb *fired*. Hence the total value at this point is 0.

Thus, the LRB hypothesis predicts that a boundary is most likely to occur before the matrix verb *fired* (total value = 6). Furthermore, the probability of boundaries at other locations is predicted to vary according to the values determined by the linear sum of the two factors.

2.2. EXPERIMENT 1

In Experiment 1, the goal was to understand the relationship between intonational phrase boundaries and linguistic structure. The results of this experiment were used to develop the parameters of the LRB, which was formulated post-hoc to account for the distribution of intonational boundaries in the structures in this experiment. It was hypothesized that a relationship existed between intonational phrase boundaries and the dependency structure of a sentence, specifically the size of syntactic constituents and the relationship between heads and their arguments. These results allowed us to model the precise nature of this relationship with a minimal number of parameters.

Most previous work in prosody in sentence production was not conducted with multiple tokens of controlled stimuli (e.g. Selkirk, 1984; Cooper & Paccia-Cooper, 1980). Generally, the paradigm has been to create a list of sentences that vary in syntactic structures, and to test the predictions of the models against participant's productions. Gee & Grosjean (1983) tested 14 sentences with different syntactic structures, and Ferreira (1988) tested 10 sentences with different structures. However, in both of these

studies, only one token of each type was tested, so it is difficult to know whether their findings generalize across multiple tokens.

To avoid these types of problem, multiple tokens for syntactic constructions like the ones below were devised:

(S1) Subject-extracted RC

The judge who ignored the reporter fired the secretary.

(S2) Object-extracted RC

The judge who the reporter ignored fired the secretary.

(S3) Object-extracted RC plus one NP

The judge who the reporter for the newspaper ignored fired the secretary.

(S4) Object-extracted RC plus two NPs

The judge who the reporter for the newspaper in the capitol ignored fired the secretary.

(S5) Subject-extracted RC within an object extracted RC

The judge who the reporter who attacked the senator ignored fired the secretary.

(S6) Object-extracted RC within another object extracted RC

The judge who the reporter who the senator attacked ignored fired the secretary.

(S7) Two right branching RCs

The reporter ignored the judge who fired the secretary.

(S8) Three right branching RCs

The senator attacked the reporter who ignored the judge who fired the secretary.

The conditions were constructed to vary sentence structure and the integration distance of the main verb. In the first two conditions, the structure of the RC was manipulated. The main subject was modified by either a subject-extracted RC (S1) or object extracted RC (S2). In conditions (S3) and (S4), the size of the object-extracted relative clause was manipulated by the addition of one or two prepositional phrases, respectively. The purpose of this manipulation was to determine whether increasing the size of the subject NP would increase the likelihood of an intonational boundary occurring before the verb. Conditions (S5) and (S6) were both doubly nested sentences. They contained RCs whose subjects were modified by another RC. These sentences are typically associated with a high level of difficulty (see Gibson, 1998 and the references there). Conditions (S7) and (S8) contained right branching structures.

The distribution of intonational boundaries in the speakers' utterances were compared to the predictions of Gee & Grosjean's (1983) Phi algorithm, Ferreira's X-bar algorithm (1988), and the LRB. It

should be noted that although the predictions of the LRB are compared with the predictions of these models, these particular syntactic constructions were not designed to test the models' differences. They were designed primarily to understand the role of syntactic constituent size in determining intonational phrasing.

One of the challenges of experimental work in sentence production is eliciting controlled syntactic constructions, while at the same time, getting the speaker to use production processes as naturally as possible. Like many researchers in sentence production (Cooper & Paccia-Cooper, 1980; Gee & Grosjean, 1983; Ferreira, 1988), we use a reading task, despite some of the obvious drawbacks. Still, some work has shown that the prosodic patterns in read and spontaneous speech are prosodically phrased in similar ways (Blaauw, 1994; Ferreira, 1991), and it is likely that the processes used in natural speech production and in reading aloud highly overlap. Therefore, although a more natural speech task would have been desirable, a reading task is used as a first approximation in order to allow for experimental control.

With these concerns in mind, a novel paradigm was used to elicit the test sentences from the speaker. Each trial was conducted with two participants: a listener and a reader. The reader was given a written list of test sentences and was instructed to read the sentences silently to her/himself so that s/he fully understood the meaning of the sentence before producing it out loud. This was to ensure that the production was made with knowledge of the upcoming material. After the reader produced the sentence, the listener was presented with a question on the computer that s/he had to answer. This task encouraged the reader to communicate the content of the sentence in as natural a manner as possible.

2.2.1 METHOD

Subjects

Sixteen pairs of native English speakers from the MIT community participated in the study for \$5.00 each. One participant was recorded while reading sentences and the other answered questions about the sentences on a computer.

Materials

Eight different syntactic constructions like the ones in (S1)–(S8) were used and 32 tokens for each of the conditions were tested. The intonational boundary predictions of each algorithm are shown in Table 2.1.

Sentence S1												
	The	judge	who	ignored	the	reporter	fired	the				
Phi	0	5	0	3	0	9	3	0				
X-bar	3	8	2	4	1	7	4	1				
LRB	0	3	0	1	0	6	1	0				

Sentence S2										
	The	judge	who	the	reporter	ignored	fired	the		
Phi	0	5	1	0	3	9	4	0		
X-bar	3	8	2	1	7	7	4	1		
LRB	0	3	0	0	3	6	1	0		

Sentence S3												
	The	judge	who	the	reporter	for	the	newspaper	ignored	fired	the	
Phi	0	7	1	0	3	1	0	5	11	4	0	
X-bar	1	8	2	2	4	4	1	7	7	4	1	
LRB	0	4	0	0	2	0	0	4	7	1	0	

Sentence S4														
	The	judge	who	the	reporter	for	the	newspaper	in	the	capitol	ignored	fired	the
Phi	0	8	1	0	5	1	0	4	1	0	7	13	4	0
X-bar	1	8	2	2	4	4	2	4	4	1	7	7	4	1
LRB	0	5	0	0	3	0	0	3	0	0	5	8	1	0

Sentence S5													
	The	judge	who	the	reporter	who	attacked	the	senator	ignored	fired	the	
Phi	0	3	1	0	7	1	0	3	9	13	4	0	
X-bar	3	8	2	3	8	2	4	1	7	7	4	1	
LRB	0	5	0	0	3	0	1	0	5	8	1	0	

Sentence S6													
	The	judge	who	the	reporter	who	the	senator	attacked	ignored	fired	the	
Phi	0	3	1	0	7	1	0	3	9	13	3	0	
X-	3	8	2	3	8	2	1	7	7	7	4	1	

bar												
LRB	0	5	0	0	3	0	0	3	5	8	1	0
Sentence S7												
	The	reporter	ignored	the	judge	who	fired	the				
Phi	0	5	3	0	9	0	3	1				
X-bar	1	7	4	3	8	3	4	1				
LRB	0	6	1	0	3	0	1	0				
Sentence S8												
	The	senator	attacked	the	reporter	who	ignored	the	judge	who	fired	the
Phi	0	5	3	0	9	0	3	0	13	0	3	1
X-bar	1	7	4	3	8	2	4	3	8	2	4	1
LRB	0	8	1	0	5	0	1	0	3	0	1	0

Table 2.1 The numeric predictions of Gee & Grosjean's Phi algorithm, Ferreira's X-bar algorithm, and the LRB. Each value is the prediction for the word boundary following the word in the corresponding column. Higher numbers indicate greater likelihood of placing an intonational boundary at that point.

The items were constructed so that their syntactic structures were as in (S1)-(S8) up to the final verb of the sentence (e.g. *fired* in the examples above). For some items, there were small variations between items beginning at this point. The final verb sometimes varied in tense and aspect, but always constituted exactly one phonological phrase. There was also some variation in the material following the verb. In twenty-five of the items, one phonological phrase followed the final verb, whereas in the other seven, the verb was followed by two phonological phrases. The syntactic structures of these continuations varied from item to item. To ensure that any correlations between the models' predictions were not due to this variation, a regression was done on seven of the items that had identical syntactic structures. The results for all the items grouped together were essentially the same as those for the seven items with identical syntactic structures.

The materials were divided into eight counterbalanced lists in a Latin Square design. Each list contained a random ordering of the 32 items. There were no filler trials in this initial experiment, partly because of the variety of different structural types. To avoid effects of item position, a second set of eight

lists was created by switching the position of the first 16 and final 16 items in each list, making a total of 16 lists.

Procedure and Analysis

Two participants were included in each trial. One participant, the reader, was presented with a list of sentences to read to the second participant, the listener. The reader was instructed to read the sentence silently to her/himself until s/he was sure that he could produce the sentence correctly. S/he then read the sentence out loud exactly once. The reader's speech was recorded, and the recordings were digitized at a 16Khz rate and then analyzed using a waveform editor.

The listener was engaged in a yes/no question-answering task on a computer. While listening to the sentence produced by the reader, the listener was presented with a blank white screen on a computer screen. After hearing the sentence, the listener pressed the space bar, and a question about the sentence was presented. No feedback was given to the listener or reader about whether the question was answered correctly.

Each production was transcribed by three coders for intonational breaks using a subset of the TobI coding system, similar to the transcription system used by Price et al. (1991). The strength of a boundary was marked by each of the coders using the following break indices: 4 – intonational phrase boundary, 3 – intermediate phrase boundary, 1 – normal word boundary, P- hesitation pause, and D - disfluency. Because of their perceptual similarity, intonational and intermediate phrase boundaries were collapsed in the analysis below.

Sentences whose comprehension questions were answered incorrectly were excluded from the analysis. Furthermore, sentences with disfluencies, such as word repetitions, mispronunciations, and hesitation pauses were excluded from the analysis, yielding a total of 340 out of 512 sentences to be analyzed.

Reliability between coders was measured by calculating the proportion of the instances two particular transcribers agreed on the label of a word boundary using the method described in Pitrelli et al.

(1994). The reliability for the entire data set was 94%. Since the level of reliability was high, the entire data set coded by the first author is used.

2.2.2. RESULTS

As can be seen in Figure 1, there is a linear relationship between the LRB predictions and proportion of intonational phrase boundaries. Overall, the LRB accounts for a significant amount of the variance, $r^2=.74$ ($N=85$, $r < .001$). The overall variance accounted for by Ferreira's (1988) X-bar algorithm and Gee & Grosjean's (1983) Phi algorithm was also highly significant, $r^2 = .71$ ($N=85$, $r < .001$) and $r^2 = .76$ ($N=85$, $r < .001$), respectively. There were no significant differences among the models. As we mentioned above, a regression was performed on seven items that had identical syntactic structures in order to discount effects of variation within particular conditions. The X-bar, Phi, and LRB algorithms still accounted for a significant amount of the variance, $r^2=.64$, ($N=85$, $p<.001$), $r^2 = .66$, ($N=85$, $p<.001$), and $r^2=.65$, ($N=85$, $p < .001$) respectively.

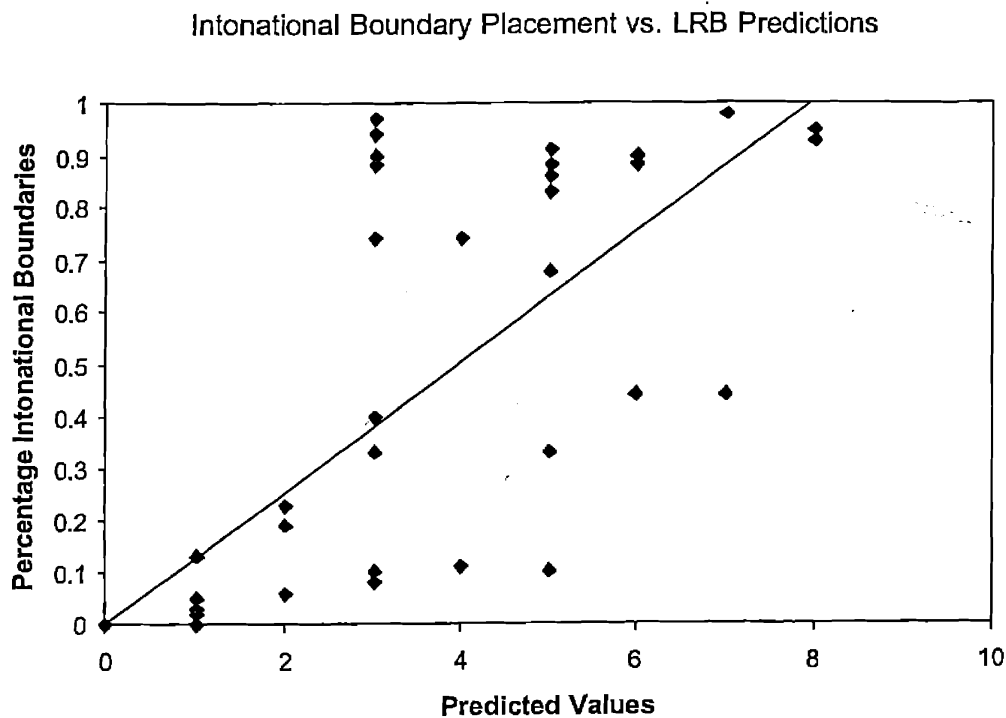


Figure 2.1. The LRB predictions plotted against the percentage of intonational phrase boundaries that were produced in Experiment 1

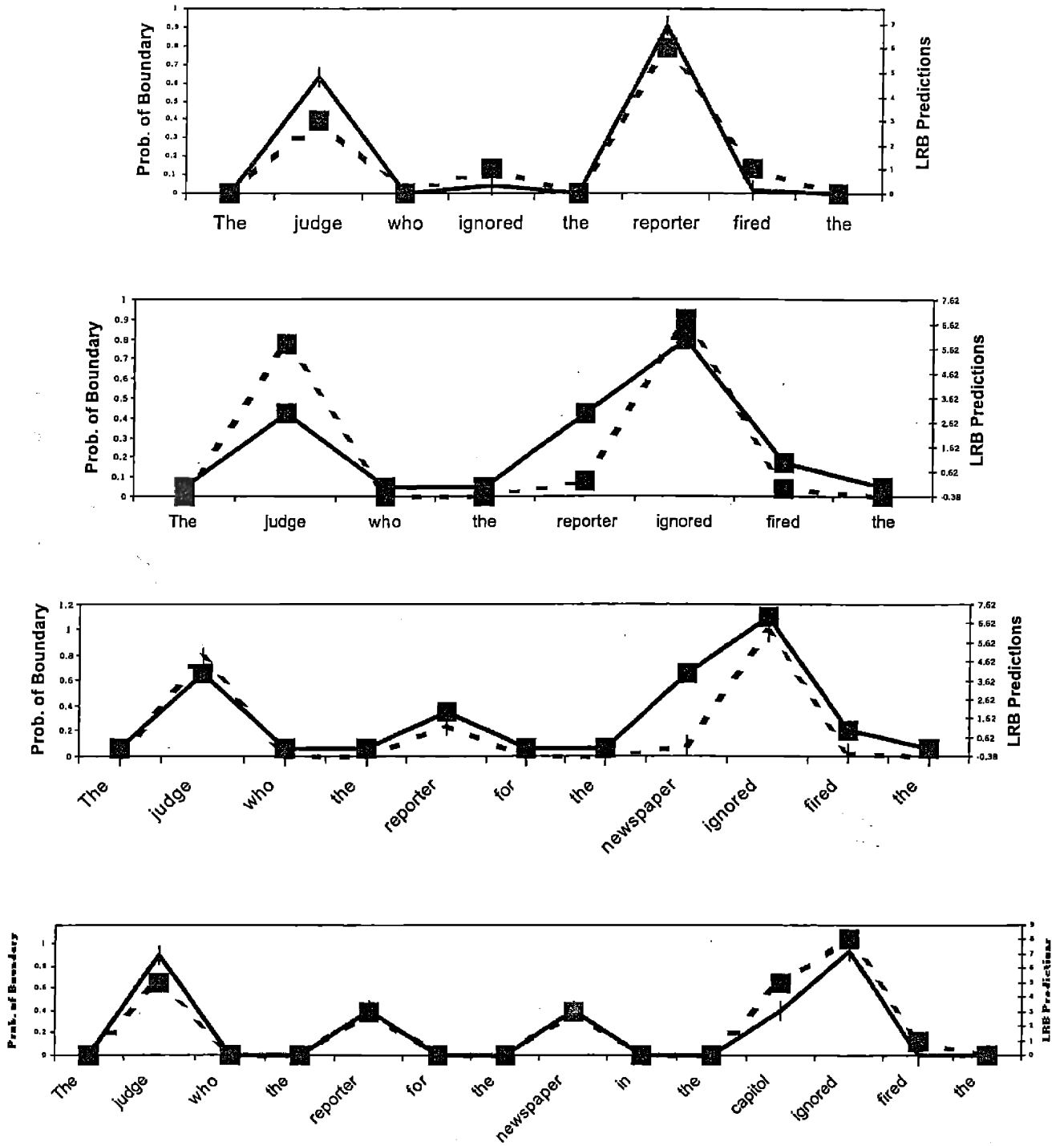


Figure 2.2. The percentage of intonational boundary placement graphed against the predictions of the LRB for sentences S1 -S4 in Experiment 1.

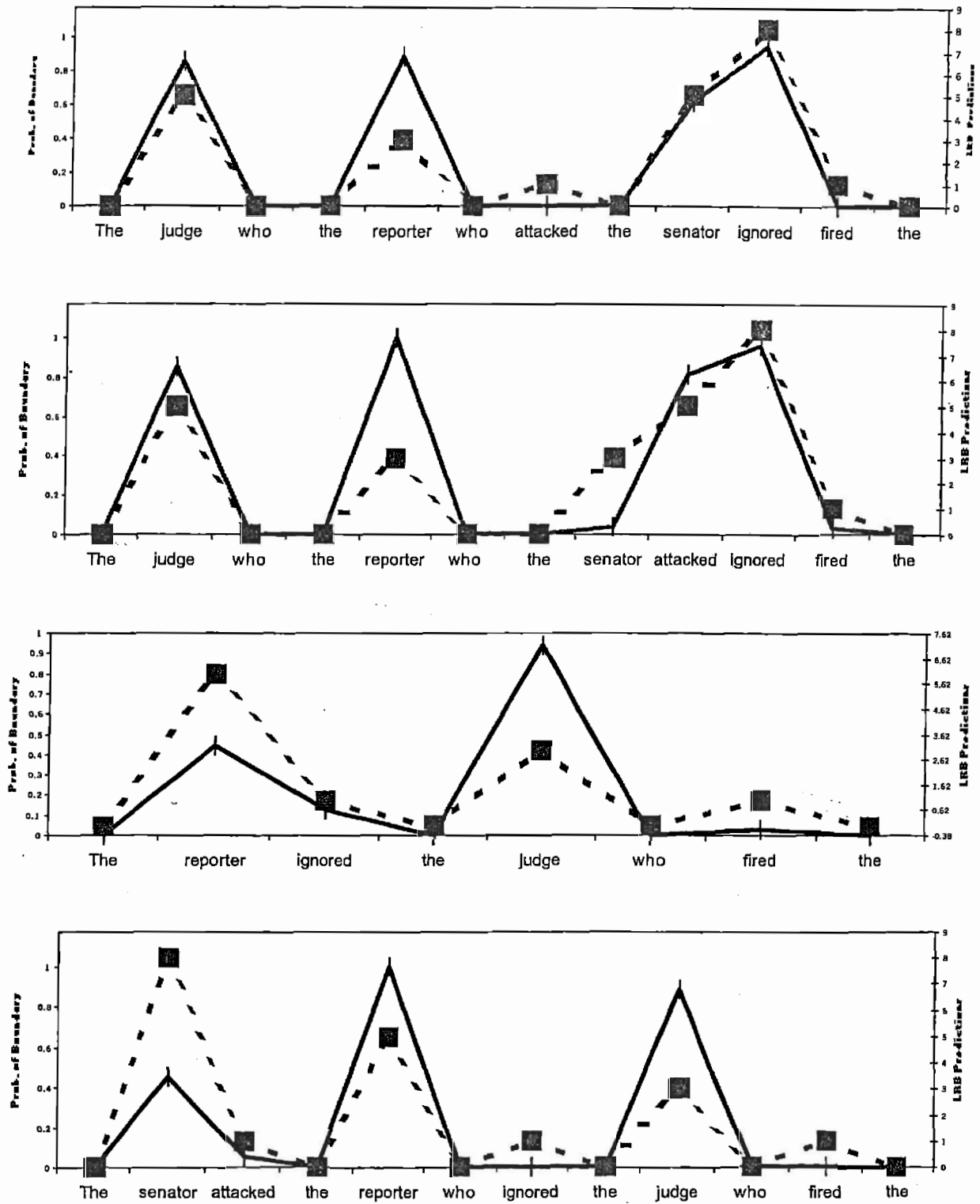


Figure 2.3. The percentage of intonational boundary placement graphed against the predictions of the LRB for sentences S5-S8 in Experiment 1.

Figures 2.2 and 2.3 show the LRB predictions versus the percentage of the time intonational boundaries were placed at a word boundary for each of the items. The variance accounted for by each theory for each sentence type is listed in Table 2.

Variance accounted for by each model in Experiment 1			
Sentence in Experiment 1	Model		
	X-Bar	Phi	LRB
S1	.65	.90	.93
S2	.58	.76	.75
S3	.57	.82	.78
S4	.68	.85	.90
S5	.85	.64	.83
S6	.73	.70	.74
S7	.78	.90	.48
S8	.52	.69	.53
Overall Variance	.71	.76	.74

Table 2.2. The variance accounted for by Ferreira's (1988) X-bar model, Gee & Grosjean's (1983) Phi algorithm, and the LRB, for each sentence type in Experiment 1.

Variance accounted for by LHS and RHS in Experiment 1		
Sentence in Experiment 1	LRB Component	
	LHS constituent r^2	RHS constituent r^2
S1	.63	.96
S2	.44 ^a	.89
S3	.42	.83
S4	.43	.84
S5	.60	.79
S6	.58 ^a	.68
S7	.08 ^a	.50 ^a
S8	0.05 ^a	.56
Overall Variance	.36	.50

^a indicates non-significance

Table 2.3. The variance accounted for by the LHS and the RHS constituent components of the LRB for the sentence types in Experiment 1.

The variance accounted for by LHS and RHS constituent component of the LRB is listed for each sentence type in Table 3. The RHS parameter accounts for more variance than the LHS parameter, but, with the exception of S7 and S8, the LHS component still accounts for a significant amount of the variance in each sentence type in which it varied.

In addition, the two components of the LRB account for different portions of the variance. Both the LHS and RHS component account for a significant amount of the variance after the other has been partialled out, $r^2=.26$, ($N=85$, $r < .0001$) and $r^2=.56$, ($N=85$, $p < .0001$) respectively.

One potential concern is that these correlations may be driven by phonological phrasing. Many of the data points, 48%, come from word boundaries that are within phonological phrases for which LRB predicts no intonational boundaries, and for which very few boundaries were produced. However, when these points were taken out of the regression, the LHS and RHS parameters still account for a highly significant portion of the variance, $r^2 = .54$, ($N=41$, $p < .001$). For these data points, the X-bar and Phi algorithm also accounted for a significant amount of the variance, $r^2 = .67$ ($N=41$, $p < .0001$) and $r^2 = .61$ ($N=41$, $p < .0001$), respectively.

2.2.3. DISCUSSION

The results from Experiment 1 provide support for the LRB. Points that occur before and after large syntactic constituents are highly correlated with intonational phrase boundaries. The results were also compatible with Gee & Grosjean's Phi algorithm and Ferreira's X-bar algorithm. There were no significant differences among the three models overall.

Although the performance of the three models was very similar, the models performed differentially well on different sentence types. In particular, the LRB performed numerically better than the other two algorithms in S1, S4, and S6. The Phi algorithm performed best on S2, S3, S7, and S8. The X-bar performed best on S5.

The LRB did particularly poorly on S7 and S8 compared to its performance in the other conditions. The LRB predictions for each word boundary in S7 are shown in (14) along with the percentages of intonational boundaries that were produced in Experiment 1 at the relevant position.

(14) The 0 reporter 6 ignored 1 the 0 judge 3 who 0 fired 1 the 0 secretary.

0 .44 .13 0 .94 0 .03 0

The LRB predicts that the largest boundary will occur after *the reporter* because this position is located immediately before the verb phrase, a relatively large syntactic constituent. The second largest boundary is predicted to occur between *judge* and *who*, because the relative clause is two phonological phrases long. The actual results show the opposite trend with respect to these two positions. That is, speakers were more likely to place a boundary between *judge* and *who*, rather than between *reporter* and *ignored*.

One possible reason for this result may have to do with discourse factors rather than structural factors. In its written form, an RC is ambiguous between a non-restrictive reading and a restrictive reading. Non-restrictive modifiers provide new information about the head that they modify. In the nonrestrictive interpretation of the RC in (14), the listener is informed that there is a judge, and that judge fired the secretary. A restrictive modifier, on the other hand, does not typically provide new information. Rather, it picks out a referent from a contrast set. In (14), if one imagines more than one judge (e.g., a judge who fired a secretary, and a judge who did something else), a restrictive reading of the RC informs the listener that the judge who fired the secretary was the judge in question. The two interpretations of the RC can be disambiguated using intonational phrasing. A non-restrictive modifier is generally preceded by an intonational phrase boundary, whereas a restrictive modifier is not preceded by such a boundary. One possible interpretation of the results from Experiment 1 is that speakers are assigning non-restrictive readings to the RCs in these items, by placing boundaries before the RCs.

Corroborating evidence for this hypothesis comes from reading studies in sentence comprehension, where it has been shown that interpretations that presuppose the simplest discourse set

are preferred (Altmann & Steedman, 1988; Grodner & Watson, 2001). In the absence of context, the non-restrictive reading presupposes a simpler discourse set than the restrictive reading because it requires fewer presuppositions. A restrictive relative clause interpretation requires the construction of a contrast set (i.e. more than one judge in (16)) for interpretation. A non-restrictive reading, on the other hand, requires no such presupposition and may have been the default interpretation for the speaker.

The large number of boundaries before the relative clause in S7 and S8 might also have been a result of the position of the relative clause in the sentence. In these sentences, the relative clauses modified the direct objects and occurred at the end of the sentence. Speakers typically place new information at the end of a sentence and old information at the beginning of the sentence (CITE). Because non-restrictive relative clauses convey new information, subjects may be more likely interpret relative clauses that appear at the end of a sentence as non-restrictives, placing a boundary before the relative clause.

In the next experiment these intuitions about intonational phrasing and relative clauses are empirically tested to see if the restrictiveness of a relative clause can affect intonational phrasing. If so, the poor performance of the LRB hypothesis in S7 and S8 may be a result of discourse factors, and the superior performance of the other algorithms may be a coincidental result of the discourse structure.

2.3. EXPERIMENT 2

This experiment had two goals. The first was to determine whether the restrictiveness of a relative clause plays a role in intonational phrasing. Intuitions suggest that speakers place intonational boundaries before and after non-restrictive relative clauses (Selkirk, 1978; Nespor & Vogel, 1984; Shattuck-Hufnagel & Turk, 1996). However there has been very little empirical work testing to see whether these intuitions describe speaker's actual behavior. Hirschberg & Avensani (1997) did some work on this problem. They looked at the degree to which English and Italian speakers use prosody to disambiguate a variety of constructions, including restrictive and non-restrictive relative clauses. Subjects read sentences containing relative clauses, and these sentences were embedded in paragraphs that

disambiguated the relative clause towards either a restrictive or non-restrictive reading. They found that only 60% of the relative clauses were disambiguated using prosody. This is a surprisingly low number that may have been an artifact of their task. They simply had speakers produce read speech to an experimenter who was recording them. It is possible that speakers did not disambiguate the sentence because the task did not involve communicating information to a listener, but rather involved speaking to a confederate in the experiment. In Experiment 2, the questions explored in Hirschberg & Avensani's work are further explored using the same speaker-listener paradigm that was used in Experiment 1. The speaker-listener paradigm is somewhat more natural because the task involves both a listener and a speaker. The presence of the listener might encourage the speaker to prosodically disambiguate the relative clause since the speaker knows that the listener has never encountered these structures before. In Hirschberg & Avensani's experiment, the speaker most likely knew that the experimenter who they were reading to was familiar with the materials. In addition, the fact the listener must answer a question about the sentence in this paradigm encourages the speaker to convey as much information about the sentence as possible.

The second goal of this experiment was to determine whether sentence position influences how a speaker interprets a relative clause. In Experiment 1, speakers were more likely to place intonational boundaries before relative clauses situated at the end of a sentence than before relative clauses situated at the beginning of the sentence. As was discussed in the Experiment 1 discussion, this may be related to speakers' tendencies to place given information at the beginning of a sentence and new information at the end of a sentence. Since restrictive relatives are typically associated with given information and non-restrictive relatives are typically associated with new information, the position in which the relative clause appears may influence how the speakers in the experiment interpret it. Speakers may be biased to interpret relatives that occur at the beginning of a sentence as restrictive and relatives that occur towards the end of a sentence as non-restrictives.

To tackle these goals, the restrictiveness and sentence position of relative clauses was manipulated to determine whether these factors affected intonational boundary placement before the

relative clause. The hypothesis is that the LRB's relatively poor performance on S7 and S8 in Experiment 1 was due to the influence of these factors on intonational phrasing, overriding potential structural factors that may have played a role in intonational phrasing. The prediction is that more boundaries will occur before non-restrictive relative clauses and before relative clauses that occur towards the end of the sentence.

Restrictiveness was manipulated by placing sentences in different contexts. In the restrictive context, two referents from the same category were introduced to establish a potential contrast set for the referent in the target sentence. Each of the referents was restricted by a prepositional phrase modifier (e.g. *a director at a banquet* and *a director at a film premiere*). Thus, the relative clause in the target sentence would probably be interpreted as restrictive since it was restricting over a set of already introduced discourse referents, providing old information as a pointer. In the non-restrictive contexts, two referents from different categories were introduced without any modification (e.g. *a director* and *a producer*). Thus, the relative clause in the target sentence was not restricting over a set of referents but rather provided new information about an unambiguous referent.

The referents mentioned in the context sentence were either the subject or the object of the target sentence. This enabled the manipulation of the presence of the relative clause at the beginning and the end of the sentence.

Items such as the ones below were used in this experiment:

(15a)

Restrictive Interpretation / Subject Modifying Relative Clause

A group of film critics praised a director at a banquet and another director at a film premiere. *The director who the critics praised at a banquet insulted an actor from an action movie during an interview.*

(15b)

Restrictive Interpretation / Object Modifying Relative Clause

A group of film critics praised a director at a banquet and another director at a film premiere. *An actor from an action movie insulted the director who the critics praised at a banquet during an interview.*

(15c)

Non-Restrictive Interpretation / Subject Modifying Relative Clause

A group of film critics praised a director and a producer. *The director who the critics praised at a banquet insulted an actor from an action movie during an interview.*

(15d)

Non-Restrictive Interpretation / Object Modifying Relative Clause

A group of film critics praised a director and a producer. *An actor from an action movie insulted the director who the critics praised at a banquet during an interview.*

Speakers produced these short paragraphs for listeners who then answered questions about the events in the sentences. The sentences that were crucial for analysis are italicized. The crucial word boundary for comparison occurs between *director* and *who*. If restrictedness plays a role in boundary placement, there will be more boundaries at this position than in the non-restrictive conditions. If position in the sentence plays a role, there will be more intonational boundaries at this point in the object modifying conditions.

In addition, the predictions of the LRB, GG, and Ferreira will be compared to the results. The relatively poor performance of the LRB on sentences S7 and S8 was hypothesized to be due to the fact that speakers interpreted relative clauses that modified direct objects as non-restrictives. The question of interest here then, is whether the LRB performs poorly compared to the other models in predicting intonational phrasing in the non restrictive – direct object condition, thereby mirroring the results of Experiment 1 and whether this difference in performance disappears in the restrictive- direct object condition. Such a result would suggest that the poor performance of the LRB in S7 and S8 is due to discourse factors rather than structural factors.

2.3.1. METHOD

The same listener-reader paradigm that was used in Experiment 1 was used in Experiment 2.

Subjects

A total of eleven pairs of participants from the MIT community (eleven readers and eleven listeners) participated for \$5 each.

Materials

All items had the same structure as (15) above. X fillers were randomly mixed with the experimental items, so that subjects would not divine the purpose of the experiment. The items were presented on four counterbalanced lists so that subjects only so one condition for each item.

Procedure

The same ToBI coding procedure that was used in Experiment 1 was used here. Two coders listened for prosodic breaks. Only data points that both coders agreed upon were included in the analysis. In addition, for this analysis, intermediate boundaries and intonational boundaries were collapsed.

2.3.2 RESULTS

Analysis revealed two main affects at the word boundary immediately before the relative clause in each condition. First, there was a main effect of restrictiveness with more intonational boundaries occurring before non-restrictive relative clauses than restrictive relative clauses, 33.8% vs. 20.9% respectively ($F_1(1,10) = 4.86, p=.05, F_2(1,19) = 4.86, p < .05$). Second, there was a main effect of the position of the relative clause. Intonational boundaries were more likely to occur before relative clauses that modified direct objects than relative clauses that modified subjects, 38.0% vs. 16.7% respectively ($F_1(1, 10)= 6.94, p < .05, F_2(1,19) = 11.95, p < .01$).

Experiment 2 Results	
Condition	Percentage Intonational Boundary
Restrictive / DO Modifier	32.7% (8.2)
Restrictive / S Modifier	9.1% (6.3)
Non-Restrictive / DO Modifier	43.1% (8.7)
Non-Restrictive / S Modifier	24.4% (6.6)

Table 2.4. The percentage of times speakers placed an intonational boundary before the relative clause in Experiment 2. The standard error is presented in parenthesis.

In order to compare these results with the findings from Experiment 1, the data was compared to the predictions of the three models. Overall, the models account for a significant amount of the variance. LRB yields in r^2 of .69, $F(1,58)=128.83$, $p < .001$. Gee & Grosjean yield in r^2 of .67, $F(1,58)=116.82$, $p < .001$. Ferreira yields an r^2 of .26 $F(1,58)=20.01$, $p < .001$. The difference between the model's predictions were not significant, but there was a marginally significant difference between the LRB predictions and Ferreira's predictions, $t=-1.37$, $p = .09$. The r^2 for each model by condition are in Table 5.

Model Performance in Experiment 2			
	LRB	Gee & Grosjean	Ferreira
Restrictive / DO Modifier	.75	.59	.27
Restrictive / S Modifier	.74	.69	.31
Non-Restrictive / DO Modifier	.59	.77	.17 ^a
Non-Restrictive / S Modifier	.82	.77	.31
Total	.69	.67	.26

^a indicates non-significance

Table 2.5. The variance accounted for by each model of the target sentences in Experiment 2.

With the exception of Ferreira's X-bar algorithm, all the models accounted for a significant amount of the variance in phrasing in each of the conditions. The variance accounted for by Ferreira's model in the Non-restrictive / DO Modifier condition did not reach significance. Ferreira's model, although yielding significant predictions, performed poorly overall compared to the predictions of the other models.

2.3.3. DISCUSSION

As predicted, discourse structure appears to play a role in determining intonational phrase placement. Relative clauses with non-restrictive readings and relative clauses that modified a direct object were more likely to be preceded by an intonational phrase boundary than relative clauses with restrictive interpretations and relative clauses that modified a subject. These data suggests that speakers use intonational boundaries to disambiguate relative clauses. They also suggest that speakers are more likely to place boundaries before relative clause that occur at the end of a sentence. One possible

explanation for this finding is that subjects were more likely to interpret relative clauses that occur at the end of a sentence as non-restrictives since new information typically occurs at the end of a sentence. This bias may have led to more pre-relative clause boundaries.

Interestingly, the LRB model does poorly relative to GG's model on sentences with non-restrictive relative clauses that modify direct objects (.59 vs .77 of the variance), though this difference is not significant. This result parallels that of Experiment 1. In that study, the LRB also accounted for less variance on right branching structures S7 and S8 than GG's model. Both are instances of sentences that contain direct objects modified by relative clauses. The fact that the data in Experiment 1 patterns with the Non-restrictive Object Modifier condition in this experiment suggests that participants interpreted relative clauses in null context as non-restrictives when they occurred towards the end of a sentence.

Although the LRB does poorly in the non-restrictive object modifier condition as compared to GG's, this advantage disappears entirely when the same structure is placed in a context where the relative clauses requires a restrictive interpretation. In fact, the LRB model seems to have an advantage (.75 vs .59) although the difference isn't significant. These data suggest that the predictions of both models must be integrated with a theory of discourse structure and intonational phrasing to successfully predict where boundaries are likely to occur.

A surprising finding was that subjects did not disambiguate non-restrictive relatives more frequently. Most of the time, speakers preferred not to place a boundary between a relative clause and its head noun, regardless of restrictiveness and sentence position of the relative. This result is rather surprising since one gets the strong intuition that the absence of a boundary before a nonrestrictive relative and the presence of a boundary before a restrictive relative make the sentence unacceptable. As mentioned above, Hirschberg & Avensani (1997) encountered the same difficulties. This could simply be an artifact of reading. It is possible that in spontaneous speech, speakers' performance may more closely match our intuitions about intonational phrasing. However, another possibility is that speakers simply do not consistently disambiguate relative clauses, and this could be due to a number of reasons. For instance, the fact that the context of the sentence disambiguates the status of the relative clause may make

disambiguation via prosody unnecessary. Some of the issues related to whether speakers intentionally disambiguate sentences for listeners will be discussed in the next section. However, these further questions of how speakers communicate restrictedness through intonational phrasing will be left to further research and advances in methodology.

2.4. EXPERIMENT 3

The performance of the LRB, Phi, and X-bar algorithms was very similar in Experiment 1, partly because the three algorithms make very similar predictions. However, they make similar predictions for different reasons. Consider S1, repeated below as (16).

(16) The judge who ignored the reporter fired the secretary.

The LRB predicts that an intonational boundary in this sentence is most likely to occur before the verb *fired* because this point follows a relatively long subject NP and because this word boundary immediately precedes a long syntactic constituent (the verb phrase). The X-bar algorithm also predicts a boundary at this point, but does so because it is the boundary between the subject NP and the VP. The boundary between two XP level categories (ie. NP and VP) is a likely place for an intonational boundary under this theory. The Phi algorithm predicts a boundary before the verb *fired* because it marks the end of the relative clause. In the Phi algorithm, the end of a clause is a likely place for an intonational boundary to occur.

Experiment 3 was designed to separate some of the predictions of these theories. Structures were tested that contained a long syntactic constituent but were not confounded with factors predicted by the X-bar and Phi algorithm to increase the likelihood of intonational boundaries, as in (17):

(17) An artist arranged a donation of the paintings of the landscape to the museum.

In (17), the head of the direct object is *donation*, which takes *of the paintings of the landscape* and *to the museum* as arguments. Immediately before the PP *to the museum*, the long PP *of the paintings of the landscape* is completed. Because this word boundary corresponds with the end of a large syntactic constituent, the LRB predicts a high probability of a boundary occurring before the word *to*. The Phi algorithm, on the other hand, predicts that this point is an unlikely place for an intonational boundary because the noun phrase *a donation of the paintings of the landscape to the museum*, is adjoined in a right branching tree by the algorithm's Syntactic Constituent Rule. Thus, intonational boundaries are more likely to occur between phonological phrases at the beginning of the noun phrase than between phonological phrases towards the end of the noun phrase since the right branching tree necessarily requires nodes at early word boundaries to dominate more nodes. The X-bar algorithm predicts that this location is an unlikely position for a boundary to occur because *to the museum* is an argument of *donation*, and the boundary between a head and its argument is an unlikely location for a boundary to occur.⁵

2.4.1. METHOD

The same listener-reader paradigm that was used in Experiment 1 was used in Experiment 3.

Subjects

A total of ten pairs of participants from the MIT community (ten readers and ten listeners) participated for \$5 each.

⁵ Although in this case, the relevant boundary for Ferreira's (1988) analysis would appear to be the boundary between *landscape* and *to*, Ferreira treats non-adjacent arguments of the verb as if they were adjacent. Thus, the relevant boundary for analysis is between *donation* and *to*.

Materials

Thirteen sentences with the structure in (17) were tested. Because only one syntactic construction was being tested, thirty-five unrelated fillers were included. Four separate randomized lists were constructed from the items and fillers.

The predictions of the three models are presented in Table 6.

		Experiment 3 Predictions												
		An	artist	arranged	a	donation	of	the	paintings	of	the	landscape	to	the
Phi	0	3	11	0	7	1	0	5	1	0	4	1	0	
X-bar	1	7	4	3	4	4	2	4	4	1	4	4	1	
LRB	0	7	1	0	1	0	0	1	0	0	5	0	0	

Table 2.6. Predictions of the Phi algorithm, X-bar algorithm, and LRB for the items in Experiment 3.

Procedure

The same method that was used in Experiment 1 was used to code speakers' productions. The total reliability between coders was 92%. Stimuli whose comprehension questions were answered incorrectly, or which contained disfluencies or hesitation pauses were discarded, yielding 109 out of 130 sentences to be analyzed.

2.4.2. RESULTS AND DISCUSSION

The predictions of the LRB were significantly correlated with participants' intonational boundary placement, $r^2 = .52$, ($N=13$, $p < .01$) as can be seen in Figure 3. More intonational boundaries occurred between *class* and *to* than even the LRB predicted. In these sentence types, the LHS component captured most of the variance, $r^2 = .62$, ($N=13$, $p < .01$). The RHS component accounted for only $r^2 = .39$ ($N=13$, $p = .13$). The Phi algorithm's predictions were marginally significant, $r^2 = .25$, ($N=13$, $p = .08$), and the X-bar algorithm's predictions were not quite significant, $r^2 = .22$, ($N=13$, $p = .11$). The overall difference

between the models was not significant, although the LRB's predictions were marginally different from those of X-bar, $t(10) = .25$, $p = .09$. Overall, the results of this experiment suggest that speakers place intonational boundaries after large syntactic constituents, as predicted by the LHS component of the LRB.

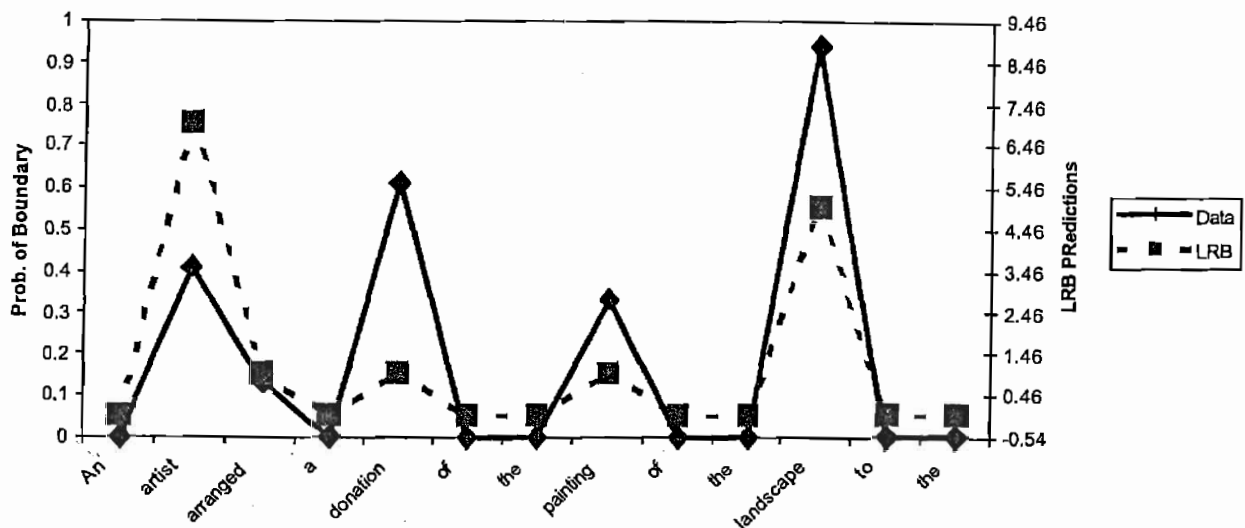


Figure 2.4. The LRB predictions vs. the percentage of intonational boundaries occurring at each word boundary for items in Experiment 2.

One striking difference between the results of this experiment and the results of Experiment 1 and Experiment 2 is the fact that the LRB, although performing significantly better than other models, does relatively poorly in comparison to its performance in the other Experiments. The LRB predicts a relatively large boundary after the subject *artist*, and a large but somewhat smaller boundary before the *to the museum*. As can be seen in Figure 1, the reverse seems to be true. Speakers tend to place more boundaries before *to the museum* than after the subject *artist*. In addition, speakers tend to place more boundaries between *donation* and *of* than is predicted by the model.

Clearly, in order to account for this data, the parameters of the LRB must be further refined. It is possible that the overall global prosodic structure of a sentence may play some role in intonational phrasing. For instance, it might be the case that the LRB semantics restrictions only apply between verbs and their arguments rather than between heads and their arguments. Thus speakers may disprefer placing

a boundary between *planned* and *the visit* because this boundary occurs between a verb and an object, but not have the same reservations about placing a boundary between *donation* and *of the painting* because donation is merely a noun.

Another possibility is that the overall prosodic structure of an utterance may be an additional factor in determining the likelihood of an intonational boundary. For instance, if a speaker has not produced a boundary for an extended amount of time, they may be more likely to produce one at a word boundary than they would otherwise. For example, it is possible that more boundaries than would have otherwise been predicted may have occurred before *to the museum* because the speakers had not recently produced the boundary.

Future work will have to investigate these questions.

2.5. EXPERIMENT 4: INTEGRATION DISTANCE VS. CONSTITUENT SIZE

In the LRB, two factors play a role in determining whether an intonational phrase occurs at a word boundary. The first factor is the size of the constituent that has just been completed and the second factor is the size of the constituent that is to be produced.

Interestingly, the first component of the LRB is confounded with another possible factor. In a right branching language such as English, the size of the constituent that has just been completed is highly correlated with the distance of integration of the upcoming constituent and its attachment site in the structure so far. For example, note (18) below:

(18) The secretary of the successful corporate executive's secretary was incompetent

The LRB predicts that an intonational boundary is relatively likely at the word boundary following the subject NP *The secretary of the successful corporate executive's secretary* because this NP is quite long.

However, an alternative hypothesis is that the relevant factor in determining intonational phrasing is the distance of integration between the verb *was* and the head of the subject NP *secretary*. In this case

was must be integrated with *secretary* because they are the heads of the matrix VP and subject NP respectively. In (18), this integration is non-local. As it turns out, in a right branching language such as English, the size of the most recently processed constituent is often correlated with the distance between the upcoming head and its dependent. Hence all the data above that was explained in terms of size could be re-interpreted as an effect of distance. Such a hypothesis is cognitively plausible. Intonational boundaries before long distance integrations may alleviate difficulty for the speaker. Reading studies have shown that the level of difficulty experienced by the reader at a given word is partly a function of the serial distance between the word and the lexical head with which it has a dependency relation (Gibson, 1998; Gibson, 2000; Grodner, Watson & Gibson, 2001). If we assume that production mechanisms are similar to comprehension mechanisms, the speaker may need the intonational phrase boundary to facilitate processes involved with the integration of a constituent that is about to be produced.

In order to differentiate these two hypotheses, structures like the one below were examined:

Right Branching

(19a) The **secretary** of the successful corporate executive **was** incompetent

Left Branching

(19b) The successful corporate executive's **secretary** **was** incompetent.

In (19a), *secretary* and *was* are integrated locally whereas in (19b), they are integrated non-locally. The integration distance based hypothesis predicts a higher likelihood of a boundary before *was* in (19a) than in (19b) because *was* because it must undergo a long distance integration to connect with its dependent *secretary*. The RHS hypothesis predicts that there should be no difference between the two conditions. In both cases, the phonological size of the subject NP is the same. Therefore, there is an equal likelihood of an intonational boundary before *was* in both conditions. Thus, in this experiment, the question of interest is the relative likelihood of an intonational boundary before the main verb across conditions.

2.5.1. METHOD

The same listener-reader paradigm that was used in Experiment 1, 2, and 3 was used in Experiment 4.

Subjects

A total of 9 pairs of participants from the MIT community (nine readers and nine listeners) participated for \$5 each.

Materials

Sixteen items with the same structure as those in (19a) and (19b) were tested. In the right branching condition, passive sentences were used. The subject of these sentences was modified by a prepositional phrase that contained a complex NP modified by two adjectives. In the left branching condition, the subject NP was modified by a noun with genitive case modified by two adjectives. The items were randomized with forty-five unrelated filler items in two counterbalanced lists.

The crucial point of analysis was the word boundary before the main verb *was*. One coder (the author) labeled the data using the ToBI transcription system. Intermediate and Intonational phrase boundaries were collapsed. Hesitation pauses and disfluencies were not counted as boundaries.

2.5.2. RESULTS AND DISCUSSION

In the left branching condition, an intonational boundary occurred before the main verb 71.0% of the time. In the right branching condition, a boundary occurred before the main verb 73.4% of the time. This difference was not significant, $F_1(1,8)=.21$, $p=.66$.

These data suggest that integration distance is not the crucial factor in determining intonational phrasing and that the size of the most recently processed constituent may be a better predictor of intonational phrasing. However, this data is only suggestive as it is difficult to interpret a null result.

For now, it will be assumed that the initial hypothesis is correct and that intonational boundaries are a function of the size of the most recently processed constituent rather than integration distance.

2.6. SUMMARY AND CONCLUSION

I have presented evidence that the intonational phrasing of a sentence is partly a function of its dependency structure. In addition to factors that have been traditionally studied, such as discourse structure, factors such as dependency relationships between syntactic heads and the size of constituents are important in determining the intonational phrasing of a sentence.

The results from Experiment 1 suggest that increasing the size of a sentence's subject increases the probability of an intonational boundary before the verb phrase. In addition, the results from Experiment 1 suggest that speakers tend to place a boundary before a long constituent such as a long verb phrase or a long relative clause. As a result, we proposed a theory, the LHS / RHS Boundary Hypothesis or LRB, which predicts the likelihood of a intonational phrase boundary at a word boundary based on two factors: the size of the most recently processed constituent and the size of the upcoming syntactic constituents.

Experiment 2 followed up the results of Experiment 1 by further exploring some of the structures that the LRB theory performed poorly on. The results from this experiment suggested that the LRB's poor performance was a result of the influence of discourse structure on intonational phrasing. Specifically, speakers tended to disambiguate the restrictiveness of a relative clause by showing a preference for placing a boundary before non-restrictive relative clauses. Speakers tended not to place a boundary before restrictive relative clauses. In addition, speakers were more likely to place an intonational boundary before relative clauses that occurred at the end of a sentence than relative clauses that occurred at the beginning of a sentence. One possible explanation for this behavior is that speakers appeared to interpret relative clauses at the end of sentences as non-restrictive relatives, possibly because new information is associated with sentence final positions. These findings suggest that the predictions of LRB must be integrated with a theory of how discourse structure determines intonational phrasing.

Finally, Experiment 4 tested an alternative explanation for the predictive power of the LHS component of the LRB: that the likelihood of an intonational boundary at a word boundary is a function of the distance between the upcoming syntactic constituent and its attachment site. The results suggest that integration distance does not play a role in predicting intonational phrasing.

This initial data suggests that the LRB is a viable theory of the relationship between syntactic structure and intonational phrasing. In this chapter, it was argued that this relationship is related to processes in sentence production, but no theory of the nature of these representations or architecture of these processes was discussed. Ultimately, if the LRB is to represent an accurate model of the relationship between syntactic/semantic structure and intonational phrasing, an account of how prosody is represented and processed in actual sentence production should be provided and eventually unified with a model of language production.

In understanding the relationship between the LRB and production, it might be useful to study different measures of size in relation to LRB. Such an approach should tell us something about which aspects of language interface with prosody. For the purposes of this paper, I have hypothesized that phonological phrases are the appropriate measure, but it is possible that one or more other factors might be appropriate measures of size. For example, everything else being equal, if increasing the number of syllables in a sentence increases the likelihood of an intonational boundary in that sentence, we can infer that intonational phrasing may reflect the planning of syllable structure or a refractory period related to processing a large number of syllables. Similarly, if adding additional words to a sentence increases the relative likelihood of an intonational boundary, we can infer that processes involved with the production of words or lexical access interface with prosodic structure. It may turn out that more than one factor interfaces with processes that generated intonational phrase boundaries.

Clearly there are a large number of questions here for future research, and the work presented in this chapter is only a first step in getting a handle on the factors that influence intonational phrasing in language production.

Chapter 3: Intonational Phrasing and Language Comprehension

3.1. INTRODUCTION

There is a vast literature demonstrating that intonational boundary information is used on-line in making parsing decisions (Pynte & Priuer, 1996; Schafer, 1997; Speer, Kjelgaard, & Dobroth, 1996; Kjelgaard and Speer, 1999; Frazier & Clifton, 1998, Marslen Wilson et al., 1992; Price et al., 1991; Beach, 1991, and many others. See Cutler, Dahan, & van Donselaar, 1997 for a review). This work has mainly shown that prosodic information can influence the interpretation of globally and locally ambiguous sentences.

However, much of this work has only demonstrated that effects of prosody exist. Only a few researchers have attempted to establish a theory of how prosody affects processing, and these theories have mainly been concerned with accounting for the role of prosody in ambiguity resolution (Schafer, 1997, Kjelgaard & Speer, 1999; Frazier & Clifton, 1998). These researchers have argued that intonational phrases act as domains of input to the syntactic parser, creating a bias towards establishing dependency relationships within intonational phrases over establishing dependency relationship between intonational phrases.

In this chapter, a new theory of how intonational phrase boundaries influence sentence processing will be presented. Contrary to proposals in the literature, I shall argue that intonational boundaries are used by listeners as cues to unlikely locations for attaching incoming words in both ambiguous and unambiguous sentences.

First, in section 2, I will review some of the findings in the literature that suggest that prosodic information plays a role in parsing. Then, in section 3, a class of theories will be presented that are based on what I call the disruption hypothesis. These theories argue that intonational phrases serve as the domain of syntactic processing and the insertion of an intonational phrase boundary between syntactic

dependents increases processing difficulty. Then, in section 4, I will propose an alternate account of the role of intonational phrasing in parsing. The differing predictions of these theories will be tested in Experiments 1 and 2. Finally, in Section 7, I will argue that listeners prefer to hear intonational boundaries before large syntactic constituents, and this claim will be tested in Experiment 3.

3.2. PROSODY AND COMPREHENSION

A great deal of evidence suggests that listeners use prosodic information to make decisions in parsing. Lieberman (1967) observed that differing syntactic surface constructions of globally ambiguous sentences can be distinguished by listeners using pauses.

- (1a) I'll move on // Saturday
- (1b) I'll move // on Saturday

In (1a), *on* is interpreted as a particle of the verb *move*, and the sentence means that the speaker will move to a new topic or idea on Saturday. In (1b), *on* is interpreted as a preposition, and the sentence means that the speaker will be moving himself or some object on Saturday. In these two interpretations, the intonational boundary coincides with a major syntactic boundary, the boundary between the verb and the direct object. The location of this syntactic boundary differs in each sentence, and the prosodic boundary clarifies which interpretation is intended. Lieberman (1967) proposed that listeners use intonational boundaries to infer the intended meaning of the sentence. Lieberman also pointed out that ambiguous sentences with interpretations that do not differ in their syntactic configurations cannot be disambiguated by prosody.

- (2) Flying airplanes can be dangerous.

In (2) *flying* can refer to the act of flying airplanes (verbal) or it can refer to the type of airplane (adjectival). Because these two interpretations have similar syntactic configurations (i.e. the dependency structure is the same but the node labels differ), they cannot be prosodically disambiguated.

Lieberman's proposals have been supported by research showing that speakers often produce disambiguating prosody, and that listeners can use this prosodic information in cases where the interpretations' surface structure differed (Wales & Toner, 1978; Lehiste, 1973; Lehiste, Olive, & Streeter, 1976; Cooper & Paccia-Cooper, 1980; Warren, 1985; Schafer, 1997). Price et al. (1991) extended these findings by showing that different ambiguity types vary in the degree to which they could be disambiguated by prosody. Price et al. (1991) also found that intonational boundaries were highly correlated with syntactic boundaries, and acoustic analyses suggested that intonational phrase boundaries are important cues in disambiguating ambiguous sentences.

Studies have also shown that prosody can be used to disambiguate sentences with temporary ambiguities, suggesting that prosodic information is used during online processing (Marslen-Wilson et al, 1992; Warren et al., 1995; Grabe, Warren, & Nolan, 1995; Speer, Kjelgaard, and Dobroth 1996). Marslen-Wilson et al. (1992) tested the effects of prosodic structure on the disambiguation of NP/S ambiguities as in (3):

- (3a) The workers considered the last offer from the management of the factory.
(3b) The workers considered the last offer from the management was a real insult.

At the point of *the last offer from the management*, the noun phrase can be interpreted as either a direct object of the verb *considered* (3a) or as the subject of a sentential complement (3b). To test whether the prosody up to the point of ambiguity can signal upcoming syntactic structure to the listener, Marslen-Wilson et al. (1992) used a cross-modal naming task. Up to the point of disambiguation, the listener heard either a sentence that had been spliced from a direct object reading, or a sentence that had been spliced from a sentential complement reading. After listening to the recording up to the word *management*, the listener was given a visually presented stimulus, *WAS*, and had to name the word as

quickly as possible. Reaction time to the probe was faster in the sentential complement prosody condition than in the direct object prosody condition, suggesting that sentential complement prosody biased the listener's interpretation. This result suggests that prosody can direct the listener's parse. Other researchers have confirmed the effect of prosody in this particular local ambiguity (Warren et al., 1995; Beach, 1991; Grabe et al., 1995). An acoustic analysis of these types of ambiguity by Nagel et al. (1996) found that listeners are biased towards the sentential complement reading when the verb is the site of pitch movement and is followed by an intonational boundary.

Listeners use intonational boundary information on-line in other types of ambiguity as well. Speer, Kjelgaard, and Dobroth (1996) found that listeners used boundaries to disambiguate NP/Z ambiguities like (4):

(4) Whenever the guard checks the door [is / it's] locked.

There is a temporary ambiguity at the point of processing the NP *the door*. This NP can be the direct object of *checks* (late closure) or the subject of the main clause yet to come (early closure). In both on-line and off-line experiments, comprehension was facilitated when an intonational boundary occurred at the corresponding clause boundary for the two interpretations: a boundary after *the door* in the late closure condition and a boundary before *the door* in the early closure condition. Understanding was facilitated compared to a baseline condition with neutral prosody. Speer, Kjelgaard, and Dobroth (1996) also found that switching the prosodic boundaries for the two interpretations interfered with comprehension relative to the baseline.

These results suggest that intonational boundary information is used on-line in language comprehension to infer the intended syntactic structure of an utterance. Given the evidence, how exactly are boundaries being used by the parser on-line?

3.3. DISRUPTION HYPOTHESIS

A number of researchers have claimed that intonational phrases serve as the initial domain of syntactic analysis for the parser, and that this influences ambiguity resolution (Pynte & Priuer, 1996; Schafer, 1997; Speer, Kjelgaard, & Dobroth, 1996; Kjelgaard and Speer, 1999; Frazier & Clifton, 1998). Roughly, the claim is that words that occur within the same intonational phrase undergo syntactic analysis at the same stage of processing and words that occur in different intonational phrases are analyzed at different processing stages. Therefore constructing syntactic dependencies within an intonational phrase is less difficult than constructing dependencies between intonational phrases because the syntactic analysis in the former case involves words that are processed at roughly the same stage. Although these researchers state this hypothesis in different ways, the claims are essentially the same:

“In our view of the language processing system, a syllable-based prosodic representation maintains utterances in memory, providing an initial grouping structure for spoken language input.” Speer, Kjelgaard & Dobroth, 1996, p.251.

“Phonological phrases separate the input into domains of material. Attachments are made within a domain before they are made across domains.” Schafer, 1997, p. 48

“Visibility Hypothesis: In first analysis and reanalysis, attachment to a visible node is less costly in terms of processing/attentional resources than attachment to a less visible node. (i) Node X is more visible than node Y if X was postulated later than Y. (ii) Nodes within a *perceptually-given package* (e.g., intermediate phonological phrase) are more visible than nodes outside the package...” Frazier & Clifton, 1998, p.163. (emphasis added)

The above hypotheses are discussed in terms of domains of processing, but the claims boil down to the simplified hypothesis presented in (5).

(5) Disruption Hypothesis: The presence of an intervening intonational phrase boundary between two dependent heads results in an increase in processing difficulty.

This hypothesis simply states that sentences are more difficult to process when syntactic dependents do not occur within the same intonational phrase.

Evidence for the disruption hypothesis comes mainly from work on the influence of intonational phrases on ambiguity resolution. For example, (5) accounts for biases towards low attachment in globally ambiguous structures such as the one presented in (6) below:

(6) The bus driver angered // the rider with a mean look.

Schafer (1997) found that phonological phrase boundaries after the verb *angered* biased participants towards interpreting the rider as having the mean luck. Schafer argues that because *rider* is in the same phonological phrase as the prepositional phrase *with a mean look*, attaching the prepositional phrase to *rider* is easier than attaching to *angered*. The disruption hypothesis also accounts for the effects of prosodic structure in resolving NP/Z local ambiguities like the ones studied by Kjelgaard and Speer (1999) repeated below in (7).

(7) Whenever the guard checks the door [is / it's] locked.

Disruption based theories such as prosodic chunking provide a straightforward account of this effect. A boundary after the verb *checks* biases the listener towards an early closure interpretation because the noun *the door* is no longer within the same prosodic phrase. Thus, the direct object attachment is more difficult than it would be if the boundary were not present. When a boundary occurs after *door*, the late closure interpretation is preferred because the noun and the verb are in the same prosodic phrase, facilitating processing.

The disruption hypothesis is only a generalization about the effects of intonational boundaries on parsing. There still remains the question of which aspects of the parser's architecture accounts for the disruption hypothesis. There are at least two possibilities. One possibility is that (5) is related to a heuristic used by the parser in ambiguous contexts where there is more than one potential attachment site. Thus, when a word is encountered, the parser determines how many possible attachment sites there are in the syntactic structure constructed thus far. If there is more than one, the parser consults intonational phrasing information and attaches the word to the site that is in the same intonational phrase. In this case,

(5) is only relevant to ambiguity resolution. For ease of reference, this type of theory will be referred to as the ambiguity only model defined in (8).

(8) Ambiguity-Only Disruption Hypothesis: In cases where there is more than one potential attachment site for an incoming word, the presence of an intervening intonational phrase boundary between two dependent heads results in an increase in processing difficulty, biasing attachment towards the site in the same intonational phrase.

The second possibility is that prosodic chunking only indirectly affects syntactic parsing by serving as a domain over which syntactic processes operate. Intonational phrases serve as the units of input to the parser, such that operations involving constructing syntactic dependencies across these units of processing are more difficult than constructing dependencies within an intonational phrase. The difficulty could be attributed to memory or attentional limitations related to working with elements that are not in the same phonological phrase. Thus, intonational phrasing does not direct attachment decision, but rather influences attachment by delimiting domains of parsing that interact with the memory limitations of the parser. This type of theory predicts that the effects of intonational phrasing should affect parsing in both ambiguous and unambiguous sentences. This model will be referred to as the unambiguous disruption hypothesis defined in (9).

(9) Unambiguous Disruption Hypothesis: In all cases, the presence of an intervening intonational phrase boundary between two dependent heads results in an increase in processing difficulty.

Researchers such as Speer & Kjelgaard, Schafer, and Frazier & Clifton seem to intend this latter type of model. The theories all assume that memory, attention, or some other architectural limitation of the parser bias listeners against attachments that span prosodic phrases. This suggests that the effects are due to constraints that would apply to both unambiguous and ambiguous structures rather than a heuristic that only plays a role in ambiguity resolution. For example, Speer & colleagues have argued that prosodic structure is used as an early representation for storage that is later accessed by processes in syntactic processing (Speer, Crowder, & Thomas, 1993; Kjelgaard & Speer, 1999; Speer, Kjelgaard, & Dobroth,

1996). Similarly, Frazier & Clifton (1998) argue that limitations in attentional and memory resources are behind preferences towards attachment to heads that lie in the same phonological phrase.

If one follows these disruption-based models to their logical conclusions, they make rather unintuitive predictions regarding unambiguous sentences. The ambiguity only model makes no predictions for the effects of intonational phrasing in unambiguous structures. Because intonational phrasing information is used only when adjudicating between potential attachments sites, intonational phrase boundaries should play no role when there is only one attachment site.

The unambiguous model, on the other hand, predicts that the addition of intonational phrase boundaries to an unambiguous sentence will make the sentence more difficult to understand. The logic is as follows. The underlying claim of the general model is that establishing dependency relationships between lexical items across phonological phrases is more difficult than establishing dependency relationships within phonological phrases. In unambiguous structures, a phonological phrase boundary will inevitably interrupt a dependency relationship no matter where it is placed. Thus, a structure with an intonational phrase boundary interrupting a dependency relationship will be more difficult to process than the same structure without an intonational phrase boundary interrupting the same dependency relationship. Thus, (10a) is predicted to be more difficult than (10b):

(10a) The detective showed the blurry picture of the diamond // to the client.

(10b) The detective showed the blurry picture of the diamond to the client.

The prepositional phrase *to the client* is an argument of the verb *showed*, so the disruption hypothesis predicts that the intonational phrase boundary in (10a) will increase processing difficulty as compared to (10b) because the two dependents are not in the same intonational phrase.

Contrary to the predictions of the Disruption Hypothesis, intuitions suggest that (10a) is not more difficult than (10b). In fact, (10a) seems easier to process. In the next section, an alternate theory of intonational boundaries in comprehension is proposed and its predictions will be compared with those of the disruption hypothesis in Experiments 1 and 2.

3.4. ANTI-ATTACHMENT HYPOTHESIS

An alternate hypothesis is that listeners prefer not to attach upcoming constituents to lexical heads that are followed by an intonational phrase boundary. This hypothesis is presented below in (11).

(11) Anti-Attachment Hypothesis (AAH)

Listeners use intonational boundaries as cues to signal where not to make an attachment.

Listeners prefer not to attach an incoming word to a lexical head that is immediately followed by an intonational boundary.

The hypothesis in (11) is based on the notion that listeners have at least some knowledge of how syntactic structure affects intonational phrasing in language production, and use this information to infer syntactic structure. To illustrate, let us re-examine some of the predictions of the LRB in language production to see how a listener might use the heuristic in (11) to infer a speaker's intended structure. The LRB predicts that speakers tend to place intonational boundaries at the end of completed syntactic constituents.

(12) The cop shot [the spy]_{NP} // with the gun.

In (12), the LRB predicts that a speaker is more likely to place a boundary after the word *spy* in the VP attachment interpretation than in the NP attachment interpretation, because in the former, that particular word boundary coincides with the end of the completed object NP. Knowing that often times, intonational boundaries signal the end of a completed constituent, listeners use the AAH as a heuristic to prevent attachment to completed heads. In the case of (12), the AAH predicts that the listener will have a dispreference for making an attachment to *spy*, and will attach the PP to *shot*.

The AAH applies in the parsing of both ambiguous and unambiguous sentences. As listeners hear a sentence, they track the placement of intonational boundaries, and mark each head preceding the boundary as a dispreferred location for future attachment.

The AAH hypothesis seems to make the correct predictions for how intonational boundaries should bias the interpretation of the ambiguous sentences discussed above. For example, the AAH makes the correct predictions for the early vs. late closure ambiguities investigated by Speer and colleagues.

Early Closure

(13a) Whenever the guard checks // the door is locked.

Late Closure

(13b) Whenever the guard checks the door // it's locked.

In (13a), a boundary after *checks* biases the listener towards early closure because the presence of a boundary increases the difficulty of attaching *the door* to the verb *checks*. At this point in the structure, the parser has a preference to project the main clause of the sentence, interpreting *the door* as the subject of the matrix clause rather than as the direct object. This preference towards early closure disappears in (13b) when the boundary follows *door*. There is no longer any difficulty associated with an attachment to the verb *checks* because it is not followed by a *boundary*.

The AAH also makes the correct predictions for globally ambiguous PP attachment sentences studied by Schafer (1997) in (14a) and structures studied more recently by Carlson, Frazier & Clifton (2001) in (14b).

(14a) The bus driver angered // the rider with a mean look

(14b) Martin maintained // that the CEO lied when the investigation started.

The intonational boundary after *angered* and *maintained* increases the difficulty of attaching *with a mean look* and *when the investigation started* to these verbs. Thus, the easier attachments to *rider* and *lied* are preferred in (14a) and (14b) respectively.

In addition, the AAH accounts for a class of data that cannot be accounted for under the predictions of domain-based hypothesis:

(15) The cop shot the spy // with the gun.

In globally ambiguous structures such as (12) repeated as (15), a boundary before the PP *with the gun* biases listeners towards high attachment to the verb *shot* (Price et al., 1991; Pynte & Prieur, 1996; Schafer et al., 2001; Carlson, Frazier & Clifton, 2001). The AAH makes the correct prediction in this case because the boundary is interpreted as a cue not to attach to *spy*, biasing listeners towards high attachment. Disruption based theories incorrectly predict that the boundary should have no affect because neither of the attachment sites are in the same prosodic phrase as the ambiguous constituent. Thus, attaching to both sites should be equally difficult.

Thus, we have a set of theories that make differing predictions regarding how intonational phrasing and intonational boundaries should affect parsing. The ambiguity only disruption theory makes no predictions concerning intonational phrase boundaries in unambiguous sentences. The unambiguous disruption theory predicts that the presence of intonational phrase boundaries will increase the difficulty of processing unambiguous sentences because the boundaries interrupt dependency relationships. The AAH predicts that boundaries will facilitate processing when they correctly signal non-attachment to the preceding lexical head in both ambiguous and unambiguous structures.

In Experiment 1 the predictions of the different theories in unambiguous syntactic structures are tested in an off-line rating task. In Experiment 2, a more fine-grained measure is used to investigate the use of intonational boundary information on-line.

3.5. EXPERIMENT 1

The goal of Experiment 1 was to test whether the presence of an intonational boundary in unambiguous sentences increased the difficulty of processing the sentence. In this experiment, listeners rated the difficulty of sentences that varied in their intonational phrasing. The materials in Experiment 1 had the form of (13) in a 2x2 design, with intonational boundaries at (1) and/or (2):

(16) The detective showed the blurry picture of the diamond (1) to the client (2) who was in an office that was on the fourteenth floor.

The boundary at position (1) precedes *to the client*, the second obligatory argument of the verb *showed*.

The boundary at position (2) precedes a relative clause, disambiguating it towards a non-restrictive interpretation.

The crucial manipulation was the presence of an intonational boundary at position (1). The predictions of the theories are as follows. The ambiguity only theory makes no predictions for these structures because intonational phrasing information is only used when a word can attach to more than one possible site. The test sentences are not ambiguous.

The unambiguous theory predicts that the intonational phrase boundary at position (1) will increase the overall difficulty of processing (16) because the boundaries separate heads that have dependency relationships into different intonational phrases. The boundary at position (1) separates the verb *showed* from the indirect object *to the client*, increasing the difficulty of integration.

The AAH predicts that the intonational phrase boundary at position (1) will lower the complexity of the sentence. Upon hearing a boundary after the word *diamond*, the listener will predict that the upcoming material will not attach locally, so processing the non-locally attached prepositional phrase *to the client* will be facilitated.

The intonational boundary at position (2) served as a control. This intonational boundary was expected to facilitate processing because it disambiguated the relative clause towards a non-restrictive interpretation. Previous results suggest that non-restrictive relatives are easier to interpret in null context than restrictive relatives (Grodner, Gibson, & Watson, in press) because they presuppose a simpler discourse set.⁶ All of the items in this experiment were presented without a context, so the non-restrictive

⁶ As discussed in Chapter 2, a relative clause can either be restrictive or non-restrictive, and its status is disambiguated by an intonational boundary between the relative clause and the noun it modifies. Restrictive relative clauses serve as restrictors over the set of possible referents introduced by the head noun, indicating which referent in the discourse the speaker is referring to. Thus the restrictive interpretation of the relative clause in *the client who was in an office that was on the fourteenth floor* is that the client being referred to is the client who is located in an office on the fourteenth floor, and not, say, a client who is located in an office on the thirteenth floor. The listener

interpretation was expected to be rated as less complex. Thus, the intonational phrase boundary at position (2) was expected to facilitate processing for discourse reasons, and provided a good point of comparison for the uncertain effects of an intonational boundary at position (1).

3.5.1. METHOD

Subjects

Forty native English speakers from the MIT community participated in the study for \$5.00 each.

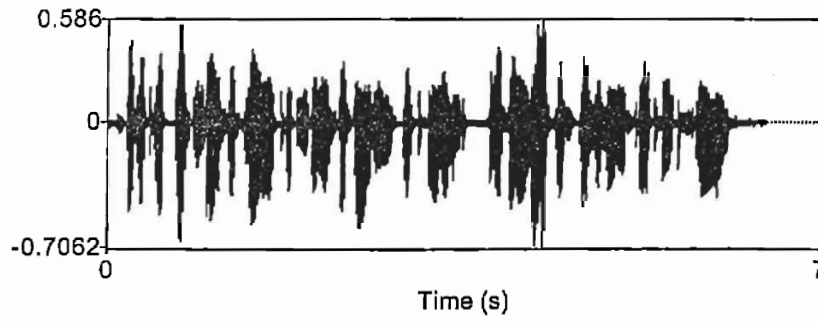
Materials

The target sentences had the form of (16), in which the verb of the sentence takes two arguments: a direct object, and an indirect object initiated by the dative preposition *to*. The first object was always a noun phrase which had an argument prepositional phrase initiated by the preposition *of*. The second argument was modified by a relative clause.

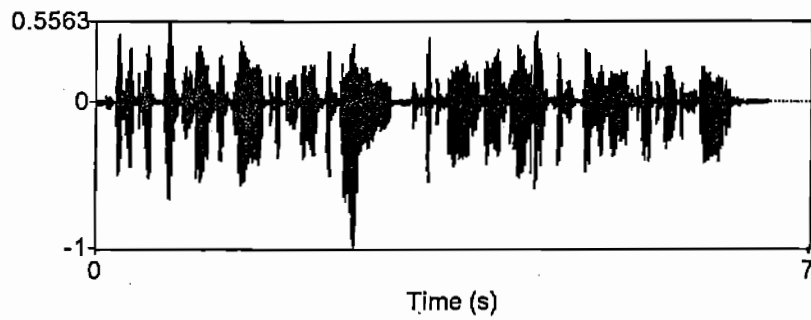
The experiment was a 2 X 2 design, varying the presence of an intonational boundary at the two locations indicated in (16). This resulted in four conditions: two conditions with a boundary at one of the locations indicated in (16), a condition with no boundaries, and a condition with boundaries at both locations. A total of 16 items were used in this experiment along with 30 fillers. The stimuli were presented in four counterbalanced lists in a Latin Square design.

(17a) No Boundaries

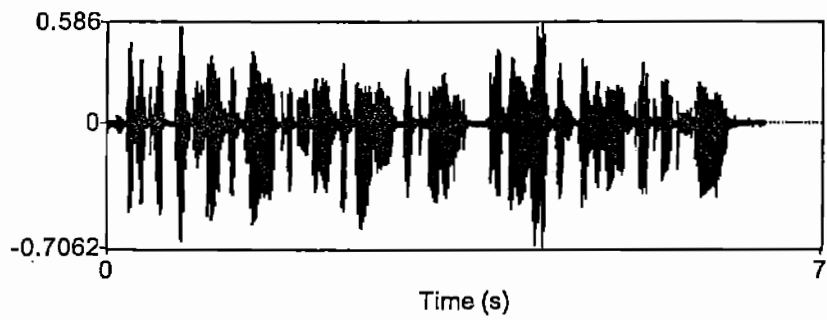
might already know the location of the client, but uses the information provided by the relative clause to figure out which referent is being referred to. A non-restrictive relative clause on the other hand, serves as an aside or provides new information about a referent rather than picking a referent out of a set of contrasting referents. A non-restrictive reading of the relative clause in *the client who was in an office that was on the fourteenth floor* would simply provide information about the location of the one referent (the client) in the discourse. Results from experiments in reading suggest that non-restrictives are easier to process than restrictives when they occur in sentences that are presented without a context, (Grodner, Gibson, & Watson, in press) presumably because restrictive relative clauses require a context, necessitating accommodation on the part of the listener.



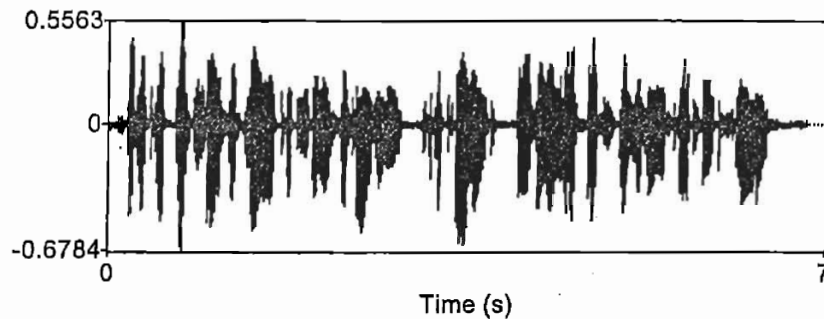
(17b) Boundary at position (1)



(17c) Boundary at position (2)



(17d) Boundary at positions (1) and (2)



The stimuli were created through digital editing. Each condition was produced and recorded independently. For each item, a control sentence was produced that contained no intonational boundaries. In order to control the prosody among the sentences, the relevant sections of each condition were spliced into the control condition. In particular, the auditory string *of the diamond to the client who was in an office* was extracted from each of the independent productions and spliced into the control. This was done in every condition, including the condition with no prosodic boundaries, to ensure that any differences in difficulty wouldn't be attributed to irrelevant differences in prosody between the conditions or in the splicing itself.

The conditions with intonational boundaries were produced such that the final segment of the intonational phrase was lengthened and was followed by a perceptually salient boundary. The pause between intonational phrases was approximately 200ms.

Procedure

The experiment was presented as a questionnaire on a web page in which participants were asked to rate sentences for comprehensibility on a 7-point scale where 1 was *easy to understand* and 7 was *hard to understand*. Participants clicked on a link for each item and then listened to the item on headphones. Participants were instructed to listen to each sentence only once. Then they clicked a button below the link to view a question about the sentence to be answered with either a *yes* or *no* on the web page. Four

example sentences were presented to the subject. Two of these sentences were relatively comprehensible with normal prosody, and it was suggested that they be rated with a 1 or a 2. One of the sentences was quite difficult and contained two embedded relative clauses: *The dog who the cat who the mouse bit scratched ran away*. It was suggested that this sentence be given a rating of 6 or 7. The final example sentence was difficult because it contained an intonational boundary in an unnatural location: *The judge trusted the witness // wouldn't run away*. It was suggested that this sentence be given a 6 or 7. No specific reasons were given for why the sentences deserved the suggested ratings, and the syntactic forms of the examples differed from those of the test items. Participants completed the task in 20-25 minutes.

3.5.2. RESULTS

The mean difficulty ratings and response accuracies to comprehension questions for the four conditions are presented in Table 1. Sentences with an intonational boundary at position (1) were rated as being significantly easier to understand than sentences without a pause at that location ($F_1(1,39) = 9.40, p < .005$; $F_2(1,15) = 14.30, p < .005$). Participants also rated sentences with an intonational boundary before the relative clause as being significantly easier than sentences without a pause at this location ($F_1(1,39) = 11.86, p < .005$; $F_2(1,15) = 11.87, p < .005$). There were no interactions.

Comparisons between individual conditions also revealed significant differences. Sentences containing intonational boundaries at both locations were rated as easier than sentences containing pauses at just the clause boundary ($F_1(1,39) = 6.28, p < .05$; $F_2(1,15) = 10.25, p < .01$) or just the position (1) boundary ($F_1(1,39) = 6.29, p < .05$; $F_2(1,15) = 5.19, p < .05$). Sentences containing intonational boundaries at either the integration point or the clause boundary were significantly easier than sentences with no boundary at all ($F_1(1,39) = 4.83, p < .05$; $F_2(1,15) = 4.98, p < .05$) and ($F_1(1,39) = 7.08, p < .05$; $F_2(1,15) = 10.46, p < .01$, respectively).

Experiment 1 Difficulty Ratings		
	Boundary at (2)	No Boundary at (2)
Boundary at (1)	3.85 (.18)	4.29 (.17)

No Boundary at (1)	4.28 (.17)	4.61 (.18)
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Table 3.1. The difficulty ratings and response accuracies to comprehension questions for each condition in Experiment 3. Standard errors are provided in parentheses.

The trends for response accuracy comparisons among the four conditions were all the same as for the difficulty ratings, although many of the response accuracy comparisons did not quite reach significance. In particular, participants tended to answer more questions correctly when there was an intonational boundary at the integration point ($F_1(1,39) = 3.26, p < .08$; $F_2(1,15) = 1.87, p < .20$), and when there was an intonational boundary before the relative clause ($F_1(1,39) = 3.48, p < .08$; $F_2(1,15) = 2.91, p < .11$).

3.5.3. DISCUSSION

The data for the current experiment suggests that the predictions of the disruption based theories of intonational phrasing are incorrect. Inserting an intonational phrase boundary between a head and its non-local argument did not increase the difficulty of processing the sentence. Instead, the presence of the intonational boundary a position (1) made the sentence easier to process.

The AAH correctly predicted that an intonational boundary before the non-locally attached prepositional phrase would lower the complexity of the sentence. The AAH predicts that at that intonational boundary, the listener is led to predict the non-local attachment of the upcoming constituents, which in turn, facilitates processing. In addition, the affect of the boundary at position (1) matched the facilitation of the control boundary at position (2), suggesting that the effect of the boundary at this position was comparable to the expected facilitation by the intonational boundary before the non-restrictive relative clause.

There are a few potential objections to the interpretation of the results of this experiment. First, this task was completely offline and grammaticality judgments and accuracy rates were the only measures of sentence complexity. It is possible that in an on-line task, these differences will disappear. A second

objection is that there were no control conditions to test the AAH's prediction that a boundary specifically at position (1), and not just any location, facilitated processing. It could be the case that an intonational boundary anywhere in a particularly long sentence will make the sentence easier to understand.

These objections are addressed in Experiment 2, using an on-line task to test the predictions of the three theories.

3.6. EXPERIMENT 2: ON-LINE PROCESSING

This experiment had two goals. The first was to explore whether intonational phrase information is used immediately in the on-line processing of a sentence. The second goal was to see whether it is the case that the presence of a boundary after a head that receives no future attachments facilitates processing or whether simply the presence of a boundary anywhere in a sentence facilitates processing.

These hypotheses were investigated using a cross-modal lexical decision task (Marslen-Wilson et al., 1992; Kjelgaard & Speer, 1999). In this paradigm, the participant is auditorily presented with a segment of a sentence, and then must perform a lexical decision on a word that could serve as a possible continuation of a sentence. The assumption behind this paradigm is that the speed of lexical decision reveals the degree to which the listener expects the continuation, and this expectation is a function of the material the participant hears in the auditory segment of the task (Marslen-Wilson et al., 1992; Kjelgaard & Speer, 1999). This paradigm allows us to directly explore effects of intonational phrasing by manipulating the presence of intonational phrase boundaries in the initial auditory segment.

The experiment was a 2x2 design crossing the presence of an intonational boundary with the attachment site of a preposition. Materials such as the one in (18) were used in this study:

(18) The museum lent the sculpture OF/TO

H*

H* L%

Participants listened to sentences such as (18), up to the word *sculpture*. The participants heard the word *sculpture* with a boundary tone or without a boundary tone. They then had to make a lexical decision on the visually presented words *OF* or *TO*, both of which are possible grammatical continuations of the sentence so far. The preposition *OF* unambiguously attaches as a prepositional phrase argument of *sculpture*, as in *sculpture of the deity*. The preposition *TO* unambiguously attaches as a prepositional phrase argument of the verb *lent*, as in *The museum lent the sculpture to the archaeologist*.

The four theories discussed above make the following predictions with respect to this experiment:

- 1) The ambiguity only disruption hypothesis makes no predictions for the structure in (18) because the sentence is unambiguous with respect to both continuations. The prepositions *OF* and *TO* can only attach to one of the previous lexical heads (*sculpture* and *lent* respectively), so intonational phrasing is not needed to adjudicate between sites.
- 2) The unambiguous disruption hypothesis predicts higher reaction times when there is a boundary present in both attachment conditions. In both cases, the prepositions *OF* and *TO* are no longer in the same prosodic phrase as their dependent lexical head (*sculpture* and *lent* respectively). Therefore, because these heads are less accessible by virtue of being in different intonational phrases, listeners should encounter more difficulty in attaching them than when there is no intonational boundary present.
- 3) In contrast, the AAH predicts that an intonational boundary after the word *sculpture* signals non-attachment to this lexical head. Thus, when there is a boundary present, the listener should be faster at performing a lexical decision on the word that does not attach to *sculpture* (*TO*) than a word that does (*OF*). When there is no boundary present, no difference is expected in these conditions. Therefore, the AAH predicts an interaction.

4) Finally, as discussed above in the Experiment 1 discussion, it is possible that intonational boundaries will always facilitate processing in long sentences. Such a theory would predict that lexical decision times will be faster in both the *TO* and *OF* conditions when an intonational phrase boundary is present than when an intonational boundary is not present, despite the syntactic differences between the two conditions.

3.6.1. METHOD

Materials

Twenty items with the same syntactic structure as (15) were used in this experiment. In all of the sentences, the word that the lexical decision was performed on was *OF* for the local attachment condition and *TO* for the non-local attachment condition. All of the direct objects in these conditions could potentially take an NP argument preceded by a case-marking preposition *of*, and none allowed for the attachment of prepositional phrases headed by *to*. All of the verbs allowed for an argument goal PP headed by *to* but none took a PP headed by *of* as an argument. Thus, the actual attachment site for the target preposition was completely unambiguous.

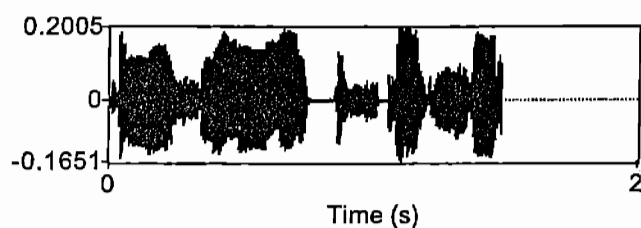
All of the items were recorded in a sound attenuated room. A speaker who was trained in the ToBI coding systems produced the boundary and the no boundary conditions individually along with a baseline condition with no intonational boundaries. The boundary condition was produced with a H* pitch accent on the final word in the speech segment and ended in a L% boundary tone. The boundary tone on the final word was signaled through lengthening. No pause was included at the end of the utterance. The No Boundary condition was produced with only a H* on the final word. Both conditions were spliced at the end of the word *sculpture* in (18).

In order to control for irrelevant differences in prosody, the final word in the speech segment (in this case *sculpture*) was extracted from each of the relevant conditions and spliced into the corresponding position in the baseline utterance. In order to reduce clicks, the splicing occurred at the zero crossing in the waveform closest to the final word so that in some conditions, words other than the final words were

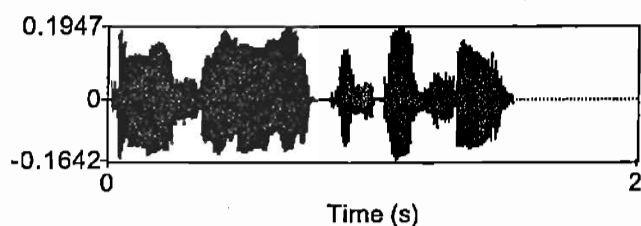
also spliced into the baseline. However, the spliced words were the same in both conditions for a given item. The exact point of splicing are indicated in Appendix G. The F_0 track for the conditions are presented in (19).

(19) The museum like the sculpture....

(19a) No boundary tone on the final word



(19b) Boundary tone on final word



Sixty fillers were included with the twenty experimental items. The sixty fillers had the same syntactic structure as the test items. Every sentence contained an unmodified definite subject followed by a verb that was followed by a direct object and a prepositional phrase. In half of the fillers, the PP modified the direct object, and in the other half, it modified the verb. *TO* and *OF* were only used as lexical decision targets in the experimental items. The non-word lexical decision targets in the fillers were English words that had one letter changed so that the word did not constitute a real word in English.

In addition, the point in the sentence at which the lexical decision task occurred varied across fillers, so that subjects could not predict the lexical decision point.

Procedure

Participants completed the experiment at a PC. They were given headphones and told that they would be listening to utterances that would end at a random point mid-sentence. Immediately following the speech segment, a word would appear on the screen, and they were to indicate whether the word was a real word in English by pressing a computer key for “yes” and another key for “no”. Participants were told to answer as quickly and as accurately as possible. They were also told to listen to the sentence, as it would help them in their task. Participants were also given five practice items that were similar in structure to the fillers, so that they would grow accustomed to the task.

Participants

Forty participants from the MIT community participated in the experiment. They were given \$5 for their participation.

3.6.2. RESULTS

Incorrect responses constituted 3.1% of the data set and were not included in the analyses. The remaining data was trimmed at 1000ms to reduce the effects of spurious outliers, eliminating 4.7% of the reaction times. The mean response times for the four conditions are presented in Table 2.

Analyses revealed a main effect of boundary type $F_1=6.52 (1,39), p <.05; F_2=3.547 (1,19), p=.07$. Reaction times were faster when there was an intonational boundary present than when there was not a boundary present although an analyses of the individual conditions (presented below) suggests that this effect was driven by effects of the intonational boundary in the non-local attachment condition. As predicted by the AAH, in the individual comparisons, reaction times to non-locally attached elements were faster than locally attached elements in the intonational boundary conditions. This difference was

significant by subjects, $F_1=9.05(1,39)$, $p<.01$ and marginal by items $F_2=4.26(1,19)$, $p=.05$. In the no intonational boundary conditions, reaction times to locally attached elements were numerically faster than non-locally attached elements, but this difference was not significant.

Overall, there was a significant interaction between the boundary condition and the attachment condition. As predicted by the AAH, participants were faster at performing a lexical decision on a word that was not locally attached than a word that was locally attached when an intonational boundary was present. This interaction was significant by subjects $F_1=7.78(1,39)$, $p<.01$ and by items $F_2=5.18(1,19)$, $p<.05$.

Experiment 2 Lexical Decision Times		
	Local Attachment (OF)	Non-Local Attachment (TO)
Intonational Boundary	583 (17)	555 (16)
No Intonational Boundary	587 (16)	598 (18)

Table 3.2. The lexical decision times for the conditions in Experiment 2. Standard errors are presented in parenthesis.

3.6.3. DISCUSSION

The data presented here strongly suggests that the presence of an intonational boundary after the direct object in the sentence facilitated processing of the non-locally attached argument of the verb. This finding is consistent with the predictions of the AAH. It is also not the case that a boundary placed anywhere in the sentence facilitates processing. The presence of this intonational boundary did not reduce lexical decision time on a word that attached locally to the direct object.

In contrast, the predictions of the disruption-based theories were not supported by the results. The ambiguity only theory made no predictions since the test structures were ambiguous. However, the unambiguous theory incorrectly predicted including an intonational boundary in a sentence should hinder processing. However, the results demonstrate that the presence of an intonational boundary actually decreases reaction times when a non-local integration occurs.

3.7. GENERAL DISCUSSION

The data presented above provide some initial evidence for the AAH hypothesis. Listeners appear to interpret intonational boundary information as a signal against future attachment to the head that immediately precedes it. Overall, the AAH hypothesis accounts for a wide array of results, and suggests that listeners' preferences for intonational boundaries tends to mirror preferences predicted by the LRB in sentence production.

An interesting question for future research is exploring if and how preferences for intonational boundary placement differ in language comprehension and production. The correspondence between these preferences might not necessarily be perfect. For instance, in a sentence like (20), the LRB predicts that a boundary between *shot* and *the* is not very likely under either interpretation because it would separate a head from its argument (i.e. the verb and its object).

(20) The cop shot // the spy with the gun.

However, the AAH predicts a boundary at this location will bias listeners toward low attachment. Here is a situation where a boundary would be informative for a listener, but is predicted to be a relatively unlikely place for a boundary to be produced. This raises the question as to whether speakers intentionally provide intonational boundaries as cues to listeners, or whether speakers involuntarily produce intonational boundaries as a function of production processes with listeners using these intonational boundaries to infer syntactic structure, knowing that they provide limited information.

Recent work by Snedecker and colleagues (2000) suggests that speakers do provide intonational boundary information as cues to listeners, but only when they are aware of the ambiguity. In her task, a speaker gave directions on manipulating a set of objects to a listener, who was separated from the speaker by a divider. In the first experiment, the participants were given identical bags of toys. The speaker was then shown an action by the experimenter and was provided with a card containing a sentence describing

the action that the speaker was supposed to convey to the listener. Speakers produced sentences such as the one below:

(21) Tap the frog with the flower.

This sentence is globally ambiguous, either meaning that the frog with the flower is to be tapped (modifier interpretation) or that a frog is to be tapped with the flower (instrument interpretation). Crucial conditions included contexts where the listener heard a sentence like the one in (21), and both of the possible actions were possible. In these situations, speakers were successful in disambiguating the sentence using prosody much of the time. When the instrument action was intended by the speaker, listeners performed that action 66% of the time. When the modifier interpretation was intended, listeners performed the instrument action only 24% of the time. An acoustic analysis revealed that speakers placed an intonational boundary after *tap* when they intended the modifier reading and placed a boundary after *frog* when they intended the instrument reading.

Interestingly, post-experiment interviews revealed that, for the most part, speakers and listeners were aware of the ambiguity. In the second experiment, Snedecker et al. were interested in studying whether speakers still used prosody to disambiguate structure when they were unaware of the ambiguity. The task in this experiment was the same as that in the first experiment, however the speaker and listener received a different set of toys. The listeners' set was identical to the set in Experiment 1. However, the speaker, unbeknownst to either participant, received a set of items that were slightly different. The speaker's set of items was devised such that it provided a context where only the instrument interpretation was possible. However, in the listener's set of items, both modifier and instrument interpretations were possible. Thus, the speaker was unaware of the ambiguity. Under these conditions, speakers did not use prosodic information to disambiguate the sentence and listeners were unable to use prosodic information to determine the correct interpretation.

Work by Albrighton, McKoon, & Ratcliff (1996) yielded similar results. In their experiment, listeners who read globally ambiguous sentences embedded in disambiguating contexts did not provide enough prosodic cues for listeners who heard the sentences out of context to determine the correct reading of the sentence. However, when speakers were explicitly made aware of the ambiguity, they produced sentences that could be disambiguated by listeners.

These data have a number of interesting implications. First of all, they suggest that in ambiguity resolution, prosodic cues provided by the speaker probably vary in their robustness. Given that in most situations, speakers are probably unaware of potential ambiguities, it is unlikely that speakers are consistently providing disambiguating cues to listeners. This is unsurprising given the wide degree of variability in intonational boundary placement. However, the fact that speakers can disambiguate sentences using prosody and listeners can use this information, suggests that prosodic cues must play at least some role in everyday speech.

3.8. EXPERIMENT 3: BOUNDARIES BEFORE LARGE SYNTACTIC CONSTITUENTS

In this section, I will argue that listeners prefer intonational boundaries before large syntactic constituents. A similar claim was made in Chapter 2 in reference to language production. However, in contrast to production, where it was proposed that speakers prefer boundaries before large syntactic constituents for planning reasons, here the hypothesis is that boundaries before larger constituents provide time to semantically consolidate the pre-boundary material, and that this semantic interpretation frees up resources for processing upcoming material. Consolidation at an intonational boundary should make more listener resources available for post-boundary processing because semantically unconsolidated material is more difficult to maintain in memory than consolidated material, and the more post-boundary material there is, the more resources are necessary for future processing.

The motivation for this claim stems from Schafer's (1997) interpretive domain hypothesis presented below in (22):

(22) Interpretive Domain Hypothesis

An intonational phrase boundary defines a point at which the processor performs any as yet outstanding semantic/pragmatic evaluation and integration of material within the intonational phrase. P. 85.

Schafer (1997) demonstrated that the presence of an intonational boundary after a context sensitive adjectives or lexically ambiguous nouns forced interpretation at the boundary. The current study extends these initial results by examining the effects of semantic consolidation on the processing of the words following the boundary.

As a first approximation at listener boundary preferences, the predictions of the right hand side constituent parameter (RHS) of the LRB will be used. As was discussed in Chapter 2, the value of the RHS is equal to the number of phonological phrases over which the largest right-hand-size syntactic constituent extends if it is not an argument of the most recent lexical head.

The structures that were tested in the current experiment are presented in (23). Below each sentence are the RHS predictions.⁷

Long Verbal Condition

(23a) The-detective (1) found (2) the-blurry-picture of-the-world's-biggest-diamond.
 4 1 1

Short Verbal Condition

(23b) The-detective (1) found (2) the-blurry-picture.
 2 0

The predictions are fairly straightforward. If listeners prefer an intonational boundary before long syntactic constituents, then an intonational boundary at position (1) (i.e. before the verb phrase) in the long verbal condition, should facilitate processing more than an intonational phrase at position (1) in the short verbal condition. In the former condition, the VP consists of four phonological phrases while in the latter condition, it consists of only (2).

The presence of a boundary at position (2) was added as an additional factor for two reasons. The first was simply to serve as a control. The RHS predicts that position (2) is a relatively unlikely place for

⁷ Word boundaries that are missing values have a value of 0.

a speaker to place a boundary because it occurs between a head, the verb, and its argument, the direct object. For the current experiment, it will be assumed that this preference holds in comprehension as well.

In addition, the manipulation of a boundary at position (2) allowed for the testing of theories by researchers who have argued that speakers place intonational phrase boundaries at points such that the resulting intonational phrases are equal in length (Grosjean, Grosjean, & Lane, 1978; Cooper & Paccia-Cooper, 1980; Gee & Grosjean, 1983) or are structured to fit some optimal length (Selkirk, 2000; Fodor, 1998). Existing empirical evidence challenges this claim. In a production task, Ferreira (1991) varied the syntactic complexity and phonological length of the subject and object in simple SVO sentences. She found that manipulating the size of the object resulted in larger pauses in pre-verbal position, but had no effect on pauses in post-verbal position, despite the fact that pauses at the latter site would result in intonational phrases that were more balanced in length. The current experiment further tests the predictions of the balancing hypothesis. An intonational boundary at position (2) produces intonational phrases that are more equal in length than the intonational phrases that result from a boundary at position (1)

3.8.1. METHOD

Subjects

A total of 47 English speakers from the MIT community participated in the study for \$5.00 each.

Materials

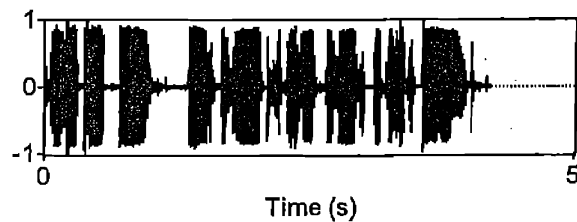
Twenty-eight items were used in this experiment, all with the same syntactic structure as the items in (20). In particular, the sentences consisted of a simple subject NP, a verb, and a direct object. All the sentences were of SVO order, and the object was modified by an adjective. In the long verbal conditions an additional prepositional phrases of the form *the Adj N* modified the object.

The experiment was a 2 x 3 design. The first factor was the size of the verb phrase: long vs short. The second factor was the presence of an intonational boundary in the sentence: pre-verbal boundary vs. post-verbal boundary vs. no boundaries. The no intonational boundary condition served as a baseline with which to compare the intonational boundary conditions. The items were presented to subjects on four counterbalanced lists and were randomized with 50 unrelated filler items.

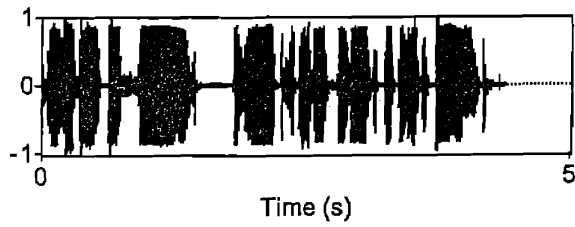
As in Experiment 1, the stimuli were created through digital editing. Each condition was produced and recorded independently by a speaker familiar with the ToBI labeling system. For each item, a control sentence was also produced that contained no intonational boundaries. In order to control the prosody among the sentences, the relevant sections of each condition were spliced into a long verbal condition control and a short verbal condition control that contained no boundary. For example, in (23) the segment *detective found* with its relevant intonational boundaries was extracted from each condition and spliced into the control. This was done in every condition, including the condition with no prosodic boundaries, to ensure that any differences in difficulty wouldn't be attributed to irrelevant differences in prosody between the conditions or in the splicing itself.

(24) The detective found the blurry picture (of the world's biggest diamond)

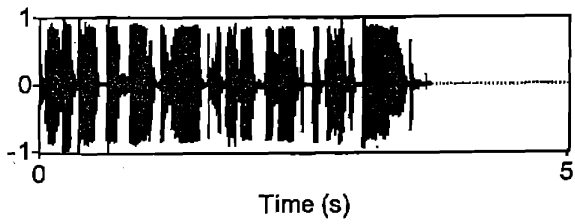
(24a) Long VP / Pre-Verbal Boundary



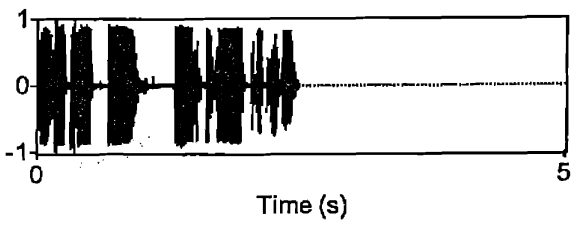
(24b) Long VP / Post-Verbal Boundary



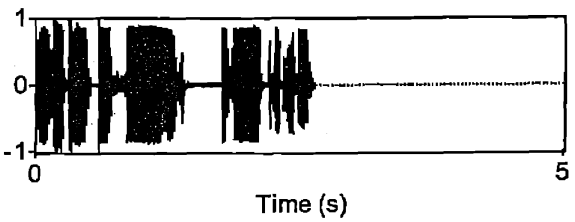
(24c) Long VP / No Boundary



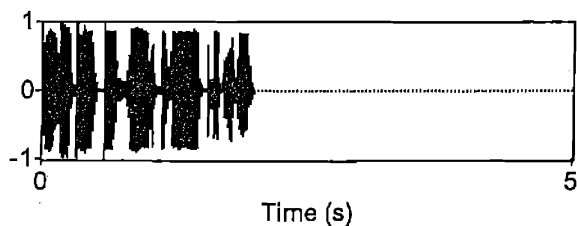
(24d) Short VP / Pre-Verbal Boundary



(24e) Short VP / Post-Verbal Boundary



(24f) Short VP / No Boundary



The conditions with intonational boundaries were produced such that the final segment of the intonational phrase was lengthened and was followed by a perceptually salient boundary. The pause between intonational phrases was approximately 200ms.

Procedure

The task was identical to the task in Experiment 1. Participants rated the difficulty of the test sentences, and answered yes/no questions about sentences they read.

3.8.2. RESULTS

In the accuracy data, there were no significant interactions, but there was a main effect of size with an average of 97% correct in the short verb condition and an average of 92% correct in the long verb condition, $F_1(1,46)=22.6$, $p<.001$ and $F_2(1,27)=3.82$, $p=.23$. Overall, accuracy was quite high

There was a main effect of verb phrase size. The long verb phrase conditions were rated as significantly more difficult than the short verb phrase conditions, both by subjects and items, $F_1(1,46)=71$, $p<.001$ and $F_2(1,27)=67.65$, $p<.001$, respectively.

The mean difficulty ratings for the items in Experiment 3 are graphed in figure (X). There was a significant interaction by subjects $F_1(1,92)=3.15$, $p<.05$ and marginal by items $F_2(1,54)=2.64$, $p=.08$.

A posthoc comparison of only the preverbal conditions and the no boundary conditions in the long and short conditions also showed an interaction that was significant by both subjects and items, $F_1(1,46)=6.18$, $p<.05$ and $F_2(1,27)=5.33$, $p<.05$, respectively. A comparison between

the postverbal condition and the no boundary condition yielded no significant difference either by subjects or items, $F_1(1,46)=.251$, $p=.62$ and $F_2(1,27)=.384$, $p=.54$, respectively.

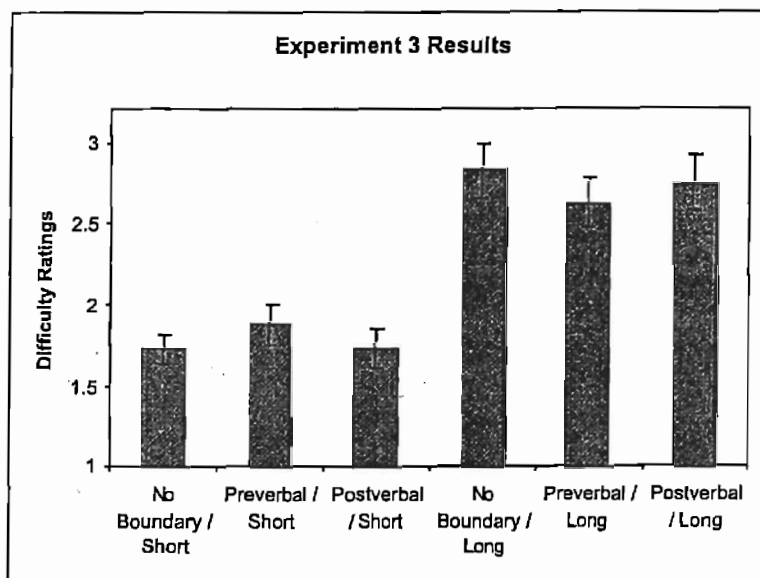


Figure 3.1. The mean difficulty ratings for the conditions in Experiment 3.

3.8.3 DISCUSSION

The results of this experiment suggest that listeners had a greater preference for an intonational boundary before a long verb phrase than a short verb phrase as predicted by the semantic processing hypothesis. One interpretation of these results is that the presence of an intonational boundary before the verb influenced the processing of post-boundary material. This could be due to semantic processing at the intonational boundary that frees up resources that aid in the processing of the post-boundary material, especially when the material is relatively long.

Contrary to the predictions of the balancing hypothesis, placing a boundary before the direct object, thereby creating intonational phrases of roughly equal length, did not facilitate processing. The post-verbal boundary did not differ significantly from the baseline condition

The results here raise a few interesting questions, one of which being whether the RHS parameter of the LRB is the proper measure of the size of upcoming constituents for listeners. As was discussed in Chapter 2, the value of the RHS parameter is a function of both the phonological size of the upcoming constituent as well as the semantic properties of the incoming word. If the incoming word is an argument of the most recent lexical head, its size in phonological phrases is not counted and it receives a value of 0. In production, the semantic factor is motivated by the observation that semantically related material tends to be produced within the same intonational phrase. Mirroring preferences seen in production, the data from the current experiment suggests that the presence of an intonational boundary between the verb and the object did not facilitate processing. However, it is not immediately clear why this semantic restriction should play any role in comprehension, and what implications it has for semantic consolidation. Future work should explore the relationship between possible semantic restrictions that influence preferences in comprehension, especially within the context of semantic consolidation at intonational phrase boundaries.

There is also the question of whether the length of the pre-boundary material influences the need for a boundary for semantic interpretation. If semantic interpretation is occurring at intonational phrase boundaries, one would expect that a listener might need an intonational phrase boundary if there is a large amount of material in need of consolidation. Thus, one would predict that the amount of material before *and* after the boundary would affect how useful a boundary will be.

Finally, there is the question of how the facilitative effect of semantic consolidation at intonational boundaries interacts with a heuristic like the anti-attachment hypothesis. These two factors are different in interesting ways. The AAH facilitates processing by influencing attachment decisions while semantic consolidation facilitates processing by freeing up resources. Understanding whether these two factors are independent and whether they can be pitted against each other would provide an interesting window into the parsing mechanism.

CHAPTER 4: CONCLUSION

4.1 SUMMARY

The central goal of this thesis has been to explore the factors that influence intonational phrasing preferences in language production and comprehension. Specifically, it was argued that the preferences for intonational boundary placement that are found in language production are related to processes involved in the production of syntactic and semantic structure.

The central claim of the LRB theory is that the likelihood of an intonational boundary at a phonological phrase boundary is a function of the phonological length of the most recently completed syntactic constituent and the phonological length of the constituent that is to be produced. Intonational boundaries after long constituent reflect a refractory period for the production mechanism while boundaries before long constituents reflect planning upcoming material. In addition, in the tradition of Selkirk (1984) and Ferreira (1988), it was hypothesized that semantic constraints play a role in intonational phrasing. Speakers tend not to place intonational boundaries between arguments and their preceding heads.

This theory was tested in a series of production experiments, the first of which (Experiment 1) was used to develop the parameters of the theory. The LRB, a theory with fewer parameters than previous models, performed as well as models proposed by Gee & Grosjean (1983) and Ferreira (1988). A second experiment (Experiment 3) teased apart the predictions of the three models, and its results suggest that the phonological size of the most recently completed constituent is a crucial factor in determining the likelihood of an intonational boundary. Because the LRB is the only model that instantiates this hypothesis, it accounted for a significantly larger portion of the variance than other models for this experiment. Experiment 4 confirmed that the relevant factor was, in fact, the size of the most recently processed constituent rather than the distance of integration of an incoming head to its attachment site in the syntactic representation constructed thus far, an equally plausible hypothesis given the data. Finally, Experiment 2 confirmed that non-structural factors also play an important role in

determining intonational phrasing. This experiment demonstrated that the restrictedness of a relative clause in a given sentence, as well as that sentence's intonational phrasing, can be manipulated by changing the context in which the sentence appears.

The second half of this thesis was concerned with understanding the role of intonational phrase boundaries in language comprehension. Given that there appears to be a link between intonational phrasing and syntactic structure, the question of interest was whether listeners use intonational boundary information to make inferences about a sentence's syntactic structure? Arguments were presented against proposals by researchers such as Schafer (1997) and Frazier & Clifton (1998) who have claimed that intonational phrase boundaries disrupt the processing of inter-intonational phrase dependency relationships. It was demonstrated that contrary to the predictions of these theories, adding intonational boundaries to unambiguous sentences do not make utterances more difficult to understand (Experiment 5). Instead, listeners use intonational boundary information to make attachment decisions. In particular, it was proposed that boundaries cue the listener to not make attachments to the lexical head that immediately precedes the boundary. This hypothesis was further supported by Experiment 6, which also suggested that intonational boundary information is used quite early in on-line processing. Finally, in Experiment 7, I investigated whether listeners prefer intonational boundaries before large syntactic constituents. Interestingly, the presence of an intonational boundary before a long syntactic constituents facilitated parsing more than the presence of a boundary before a short syntactic constituent, mirroring preferences found in production.

In the next two sections, I will argue that the LRB has some important implications for two topical areas of psycholinguistic research. The first relates to recent theories of language acquisition that have argued that prosodic structure plays an important role in the acquisition of syntactic structure. The second relates to recent claims that prosodic structure is implicitly generated in silent reading, and influences the parsing of a sentence.

4.2 PROSODIC BOOTSTRAPPING

A number of researchers in the field of language acquisition have argued that children use their knowledge of prosodic structure to learn the syntactic structure of their language. Arguments for prosodic bootstrapping stem mainly from three types of evidence: 1) Evidence suggesting that children can detect the prosodic properties of their language at a very young age (Hirsh-Pasek et al., 1987; Jusczyk et al., 1992), 2) evidence suggesting that a relationship between syntactic structure and intonational structure exists, and 3) the use of prosodic information by adults to infer syntactic structure in language comprehension.

The LRB has some important implications for prosodic bootstrapping theories. Although the LRB hypothesis proposes a link between intonational phrasing and syntactic structure, it is unclear whether this relationship as characterized by the LRB would be helpful to a child learning English syntax.

Some aspects of intonational phrasing might be useful. For example, the LRB predicts intonational boundaries are relatively likely between syntactic constituents. Because intonational boundaries reflect refractory and planning processes in language production, boundaries are predicted to occur before and after noun phrases, verb phrases, and clauses. This information might enable a child to determine the boundaries of various syntactic constituents. Morgan (1986) explored the learnability-theoretic consequences of adding syntactic bracket information to the input of a language learner. Earlier work had explored the learnability of grammars whose input did not include this surface bracketing information (Wexler & Culicover, 1980). Morgan found that adding syntactic bracketing information reduced the necessary complexity of the input, with learners requiring only Degree 1 input (i.e. sentences with only one level of embedding). Wexler & Culicover (1980) had found that learners required Degree 2 input. In addition, Morgan found that learnability could be assumed with a simpler theory of universal grammar.

However, a potential problem with using this sort of information to learn a grammar is the probabilistic nature of intonational phrasing. As discussed above, a given syntactic structure can have many different possible intonational phrasings. This many to one mapping between intonational phrase

structure and syntactic structure may complicate children's efforts to use prosody to learn a grammar. Of course, certain intonational phrase structures will be more likely for a given sentence than others. Thus, a child who tracks the intonational phrasing of a large number of utterances might be able to learn something about syntactic structure. For example, (1) shows the LRB predictions for a simple SVO sentence with a post-nominal prepositional phrase modifying the subject.

(1) The-man in-the-store stole a-banana
 2 5 1

In this sentence, the most likely place for an intonational boundary is between the noun phrase and verb phrase. A child who heard structures like the one in (1) multiple times would hear an intonational boundary between the verb phrase and the noun phrase most of the time, and might potentially use this information. Although there is variability in intonational phrasing, this variability is not random.

Of course, a child would also have to recognize similarity in structures across tokens to track the frequency of intonational phrase boundaries. Given that the child is ignorant of the language's grammar, this seems unlikely.

Another reason to be pessimistic about prosodic bootstrapping is the influence of non-syntactic information on intonational phrasing. This problem has been pointed out by a number of researchers (Pinker, 1995; Fernald & McRoberts, 1996). The LRB suggests that the phonological length of constituents, semantic structure, and phonological phrasing affect the likelihood of intonational phrase boundaries. In addition, discourse factors, affective state, and speaker style also play a role. These additional factors may reduce the amount of syntactic information intonational phrase boundaries might provide. Fernald & McRoberts (1996) point out that the reliability of prosodic structure signaling syntactic structure must be understood in terms of conditional probabilities. Much of the work in this area has focused on the $p(\text{intonational phrase} \mid \text{syntactic structure})$, that is, the likelihood of an intonational boundary given a certain syntactic structure. This probability is often quite high. However, the relevant probability for understanding the usefulness of intonational phrasing as a cue to syntactic structure is $p(\text{syntactic structure} \mid \text{intonational phrase})$ or the probability that an intonational phrase

signals a syntactic structure. Fernald & McRoberts point out that this number is probably quite low, given the large number of non-syntactic factors influencing intonational phrasing.

Thus, given the hypotheses of the LRB, the outlook for the use of intonational phrasing in learning a grammar seems somewhat bleak. Future research will have to determine how useful intonational phrasing information is for a child.

4.3 IMPLICIT PROSODY

The predictions of the LRB are particularly relevant to research in implicit prosody in reading. A number of researchers have claimed that readers construct a prosodic representation for a sentence as they read it, and that this prosodic representation can affect parsing decisions:

(2) The Implicit Prosody Hypothesis (IPH): In silent reading, a default prosodic contour is projected onto the stimulus, and it may influence syntactic ambiguity resolution. Other things being equal, the parser favors the syntactic analysis associated with the most natural (default) prosodic contour for the construction. (Fodor, 2002; p.1)

Interestingly, much of the work exploring this issue has been conducted without any explicit theory of what the most natural (default) prosody for an utterance should be. When authors argue for effects of implicit prosody, they generally assume a certain intonational phrasing or stress pattern for a target structure in the absence of a theory of why a given structure might have the prosodic pattern that it does. For obvious reasons, this is not an ideal research strategy. In the absence of constraints on what the default prosody for an utterance is, there is the danger that theories that appeal to implicit prosody will simply provide ad hoc explanations for any effect that found in sentence processing.

The LRB hypothesis is particularly useful because it provides a framework for determining likely places for readers to place intonational boundaries as they generate a prosodic structure on-line.

To illustrate, Bader (1998) claims that variance in re-analysis difficulty for different structures can be explained by readers' construction of implicit prosody. He argues that structures that require

reanalysis of both prosodic structure and syntactic structure will be more difficult to reanalyze than structures that only require re-analysis of syntactic structure.

NP/S Ambiguity

- (3a) Peter knew the answer immediately.
 (3b) Peter knew the answer would be false.

NP/Z Ambiguity

- (4a) In order to help the little boy // Jill put down the package she was carrying
 (4b) In order to help // the little boy put down the package he was carrying.

Both (3) and (4) are locally ambiguous. In (3), at the point of *the answer*, the noun phrase could be interpreted as either the direct object of *knew* (3a) or as the subject of an embedded clause (3b). There is also a local ambiguity in sentence (4). At the point of *the little boy*, it is unclear whether the noun phrase is the direct object of *help* (late closure- 4a), or the subject of the matrix clause (early closure-4b). In both the NP/S and NP/Z ambiguity, readers typically prefer the direct object continuation and experience difficulty when the sentence continues with the clausal continuation. Interestingly, readers experience greater difficulty when reanalyzing the NP/Z ambiguity than when they analyze the NP/S ambiguity.

Bader claims that this difference in difficulty is due to having to reanalyze both the prosodic structure and syntactic structure in the NP/Z sentence. The late closure case requires an intonational phrase boundary after *boy* whereas early closure requires a boundary before it. Thus, in reading, syntactic re-analysis towards an early closure interpretation would also require a re-analysis of the intonational phrasing of the sentence. This is not the case in the NP/S ambiguity. There is no obligatory difference in the intonational phrasing of the two continuations. Thus, Bader argues that re-analysis of NP/S structures is easier than re-analysis of NP/Z structures.

Independent of whether prosodic re-analysis is a viable explanation for differences in re-analysis difficulty, Bader provides little motivation for his claims regarding the prosody of the two structures. Nespor & Vogel (1986) are cited but they have little to say about these particular structures. There is

little controversy surrounding the obligatory intonational phrasing of NP/Z sentences; however it is unclear what the default intonational phrasing of NP/S is.

The LRB makes some straightforward predictions:

(5a) Peter 5 knew 1 the answer 2 immediately.

(5b) Peter 5 knew 1 the answer 2 would be false.

(6a) In order 1 to help 1 the little boy 8 Jill 5 put down 1 the package 2 she was carrying.

(6b) In order 1 to help 7 the little boy 5 put down 0 the package 2 he was carrying.

The LRB predicts that both of the NP/S interpretations will have roughly the same prosodic structure as is evident from the prediction in (5). Both continuations are roughly the same size and have the same argument structure. In contrast, NP/Z sentences have very different prosodic structures. In (6a), the most likely place for a boundary to occur is after *boy* because it coincides with the end of the old clause and the beginning of the new one. Both of these clauses are relatively long constituents, so the LRB predicts that this is a likely place for a boundary to occur. Similarly, the most likely place for a boundary to occur in (6b) is after *help*, because this location coincides with the clause boundary. Thus, by providing predictions about an utterance's default prosodic phrasing, the LRB can provide a helpful framework in which to test hypothesis appealing to implicit prosody.

Implicit prosody has also been used to explain a number of attachment preferences in first pass parsing in both English and Japanese (Fodor, 1998; Hirose, 1999; 2000; Fodor, 2002). One such case is relative clause attachment. Specifically, a number of researchers have found that in cases of ambiguous relative clause attachment (7), where the relative clause is a potential modifier of more than one noun, readers tend to attach a relatively long relative clause to N1 and a relatively short relative clause to N2 (Lovric et al., 2001; Fernandez & Bradley, 2000).

(7) N1 of N2 RC

Fodor (2002) argues that this stems from effects of phonological length on intonational phrasing, which in turn, influence attachment preferences. When the relative clause is long, the reader implicitly places an intonational boundary before the relative clause in order to balance the sentence in roughly equal intonational. Citing a finding by Maynell (1999) demonstrating that speakers prefer high attachment when a boundary precedes the relative clause, she claims that the implicit boundary before long relative clauses biases the reader towards high attachment. In cases where the relative clause is short, the reader does not insert a boundary before the relative clause, so there are no prosodic cues to high attachment.

Fodor (2002) provides few theoretical reasons for why the two interpretations of the sentence have the default prosody that they do other than for general reasons of balancing a sentence into intonational phrases of roughly equal length. The LRB provides straightforward predictions for how a long vs short relative clause might influence prosodic structure. One of the claims of the theory is that the likelihood of producing an intonational phrase boundary before a constituent is more likely when the constituent is longer. Thus, in implicit reading, listeners may act like speakers, placing intonational boundaries before long constituents as predicted by the LRB.⁸

These two cases should make the usefulness of LRB as a theory of intonational phrasing in implicit prosody quite clear. The theory provides straightforward predictions concerning where readers are most likely to implicitly place intonational phrase boundaries.

However, there are a few reasons to be pessimistic about how useful studying the role of implicit prosody in language comprehension will be. For one thing, all experiments that examine hypothesized effects of implicit prosody examine reading. No prosody is actually involved in the experiment. Thus, manipulating a sentence's implicit prosody necessarily requires manipulating the presence of some factor that is assumed to affect an utterances' prosody (e.g. constituent length, focus particles, etc...). Though a necessary aspect of the research program, a drawback to this approach is that one can never be sure whether any effect one gets is a result of manipulating implicit prosody or manipulating whatever factor

⁸ Fodor is somewhat vague on how a reader could know the length of an upcoming syntactic constituent given that they have not yet read the upcoming constituent at the point at which the boundary is inserted.

one was hoping would affect implicit prosody. For example, in Fodor's examples, she assumes that length is affecting intonational phrasing and that, in turn, affects attachment decisions. However, increasing the length of a constituent necessarily changes some non-prosodic property of the sentence, and this property may affect a reader's attachment preference. For example, a longer relative clause might, for instance, be more likely to be interpreted as new information than a short relative clause, and this might affect a reader's attachment decision. Of course, such an explanation would require a theory of why information structure might influence attachment preference, but the point is simply that it is impossible to rule out this explanation and others like it because there is no direct way to study implicit prosody.

A second reason to be pessimistic has to do with what implicit prosody might tell us about sentence processing. If it turns out that implicit prosody actually affects attachment decisions, it is unlikely that it is a core characteristic of language comprehension. Implicit prosody would have to be an epiphenomenal aspect of reading that does not play any role in natural auditory comprehension since in auditory comprehension, prosody is explicitly supplied by the speaker. Thus, the only clear message from work in implicit prosody is that psycholinguists should be studying auditory speech to understand the role of explicit prosody in language comprehension. If it is discovered that the effects that were attributed to the workings of the parser can be accounted for by implicit prosody, then work in read speech must be abandoned and a move should be made to study sentence processing in a more naturalistic domain.

4.4. CONCLUSIONS

Hopefully, the significance of the work presented thus far is clear. Previous theories of intonational phrasing and syntactic structure have been highly complex, very descriptive, and difficult to interpret in relation to the cognitive processes involved with language production. In this thesis, some of the factors that seem to be playing an important role in previous models were taken and integrated into a relatively simpler theory. This theory provides an explicit framework in which to understand the relationship between syntactic structure and intonational phrasing.

Future work should focus on how the syntactic factors proposed here interact with non-syntactic factors known to affect intonational phrasing and prosodic structure. In particular, a great deal of work has demonstrated that the discourse and information structure of a sentence plays an important role in determining its prosodic structure (Pierrehumbert & Hirschberg, 1990; Steedman, 2000). By providing an account of syntactic factors, the LRB provides an initial step in formulating a theory that gives a full account of how these multiple factors interact.

Appendix A: Phonological Phrasing

Prosodic constituents are represented in a hierarchical tree. Although it is superficially similar to a syntactic tree, the prosodic tree has very different properties. In every utterance, every level of the tree is represented, and a constituent at a given level of the prosodic tree is thought to be composed exclusively of elements at the next level down. The proposal that prosodic structure is configured in this way is called the strict layering hypothesis (Selkirk, 1984; Nespor & Vogel, 1986..although see Ladd, 1996 for a different view). A consequence of the strict- layering hypothesis is that, unlike syntactic structure, recursion is not a possibility in prosodic structure. The utterance phrase always and only dominates intonational phrases, and intonational phrases always and only dominate phonological phrases, and so on and so forth all the way down the prosodic tree.

The properties of the tree are the source of a great deal of controversy. Much of the controversy lies in understanding the nature of the constituents below the level of the intonational phrase and above the level of the foot because this is where it is believe morpho-syntactic structure interacts with prosodic structure. It is assumed that metrical phonology provides a reasonable account at the level of the foot and the syllable, and that the domain of intonational phrasing appears to be at the level of discourse and semantics.

The constituents at the intervening levels are defined with reference to the domains of various phonological rules (or constraints in an optimality theoretic framework). Typically, it is assumed that phonological rules such as vowel lengthening, deletion, tonal sandhi, stress shift, flapping, and other phonological changes apply conditionally within or at the borders of various prosodic constituents. It is also assumed that these phonological constituents are derived from syntactic structure. Hence, the method for understanding the derivation of these constituents is to understand the distribution of the phonological rules, and then to work backwards and see if a syntactic description can account for the composition of the phonological constituents that define the domain of the phonological rules.

For example, one of the motivations for phonological phrases in English is based on a phonological phenomenon called Iambic Reversal (IR) or stress shift (See Liberman and Prince, 1977). Iambic Reversal is the shifting or deletion of stress to avoid two stressed syllables occurring in succession.

a. thirTEEN MEN → THIRteen MEN

In (a), the stress that originally occurs on the last syllable of “thirteen” moves from “teen” to “thir-“ when the word is followed by a stressed syllable such as “man”. However, linguists have argued that this stress shift only occurs in certain contexts (Liberman & Prince, 1977; Nespor & Vogel, 1986). For example, the stress shift occurs in (Xa) but not in (Xb).

- a. He found THIRteen MEN for the job.
- b. When they are thirTEEN MEN become men.

Linguists have argued that stress shift is not optional, but only occurs within a phonological phrase.

Nespor & Vogel’s (NV) define a phonological phrase follows:

Phonological Phrase Domain: The domain of P consists of a C which contains a lexical head (X) and all C’s on its non-recursive side up to the C that contains another head outside of the maximal projection of X.⁹

Where P is the phonological phrase and C is a clitic group. Because stress shift only occurs within a phonological phrase, if two stressed syllables are adjacent in an utterance but are constituents of two different phonological phrases, stress shift will not occur. In (a) stress shift occurs because “thirteen men” constitutes a phonological phrase according to the definition above. “Thirteen” is an adjective on the non-recursive side of the lexical head “men” whose maximal projection ends at the verb “found”. In

⁹ In order for this analysis to work, it’s crucial that phonological phrases are parsed from the recursive side of the lexical heads to the non-recursive side. In English, this means parsing from right to left.

(b), “thirteen” is no longer within the maximal projection of “men”, so is counted as a lexical head and marks the end of a phonological phrase. Because “thirteen” and “men” are not in the same phonological phrase, stress shift does not occur. Stress shift is a phenomena specific to English, however other phonological phenomena have been used to motivate phonological phrases in other languages, and the definitions of these phonological phrases vary between languages.

The example above is paradigmatic of strategies for defining phonological phrases. First, a phonological rule is described (e.g. stress shift). Then its distribution in the language is determined (e.g. the occurrence of stress shift in (a) but not (b)). Finally, a syntactic definition of phonological phrasing is posited to account for the distributional facts (e.g. X)

There are a few different ongoing debates regarding the properties of phonological phrases. One problem involves understanding which aspects of syntax are available in prosodic phrase formation. Some researchers have suggested that syntax only interfaces with prosody in so far as it determines the domains of prosodic constituents. Once these constituents are derived, phonological rules such as stress shift can only make reference to these prosodic constituents, and no longer makes use of the information in syntactic structure (Selkirk, 1986; Hayes, 1989; Truckenbrodt, 1999). Others have proposed a slightly less constrained model, that allows for “direct reference”, or the use of syntactic information by phonological rules that goes beyond forming prosodic constituents (Chen, 1990; Odden, 1987). Phonological rules that seem contingent on properties of syntactic structure such as recursion (Chen, 1990) and syntactic branching (Bickmore, 1990) have been used to argue that phonological processes have access to syntactic information.

There is also a great deal of debate regarding the nature of the syntax – prosody interface in defining phonological phrases. In contrast to Nespor & Vogel (1986), Selkirk and others have argued for end-based models of prosodic structure where tree geometry and lexical category are disregarded. Prosodic constituents are defined using only two parameters: categorial rank and directionality (Selkirk, 1986). Specifically, prosodic boundaries align with either the right or left edge of either a lexical head X or a syntactic phrase XP. The relevant rank and direction vary parametrically across languages. This

type of end-based model has been applied to a large number of languages, and has been integrated into an Optimality Theoretic approach (Prince & Smolensky, 1993).

These models have been less successful in predicting intonational phrase boundaries. This is partly because syntax, although correlated with prosodic boundaries, seems to be one of many factors that are involved in determining intonational phrase structure.

Interestingly, the optionality that makes intonational phrasing so difficult to account for, in some cases, also appears to be a property of phonological phrasing. This is clearly a problem for a competence-based approach. Part of the reason linguists have had difficulty in formulating reasonable accounts of intonational phrasing is the fact that it is highly probabilistic. One cannot deterministically predict where an intonational boundary is going to occur in a given utterance. If this is also true within the realm of phonological phrasing, then it casts doubt on theories that attempt to provide grammaticalized accounts of prosodic phrasing.

For example, stress shift, the phonological rule that was discussed above, does not occur as deterministically as a follower of the linguistic literature might think. Although native speakers of English tend to have similar intuitions about where stress shift should and should not occur, Shattuck-Hufnagel (2000) points out that the empirical evidence for stress shift in natural speech is difficult to interpret. Cooper & Eady (1986) were unable to find any acoustic correlates of stress shift in contexts where the lack of a stress shift should have caused a clash, and Beckman et al. (1990) have found that stress shift can reliably occur in non-stress contexts (eg. *ChiNESE anTIQUES* becomes *CHInese anTIQUES*). Shattuck-Hufnagel (2000) argues that stress shift is more likely to occur on a word that coincides with the first accent in an intermediate phrase. A corpus study by Shattuck-Hufnagel and colleagues (1994) supports this hypothesis, showing that stress shifting is more likely to occur when the word contains the first accent in the intermediate phrase and when it is followed by word whose main stress syllable would result in a clash.

Shattuck-Hufnagel (2000) argues that this is evidence that prosodic structure can influence local phonological phenomena that are thought to be segment specific. However, this evidence also poses a

problem for researchers who have argued that phonological phrasing and the phonological rules that define their domain are purely a result of syntactic knowledge. That is, the same variance that has impeded syntactic accounts of intonational phrasing might also be a property of phonological phrasing. Intuitions regarding optionality in intonational phrasing may be more obvious than optionality in phonological phrases, which tend to only extend over a few words. It is possible that the performance factors that play a role in explaining the variance in intonational phrasing may also play a role in phonological phrasing. Clearly, more rigorous empirical work must be completed to determine the distribution of these various prosodic constituents.

Appendix B: Chapter 2 Experiment 1 Items

- 1a. The reporter ignored the judge who fired the secretary.
 - b. The senator attacked the reporter who ignored the judge who fired the secretary.
 - c. The judge who the reporter ignored fired the secretary.
 - d. The judge who the reporter who the senator attacked ignored fired the secretary.
 - e. The judge who the reporter who attacked the senator ignored fired the secretary.
 - f. The judge who the reporter for the newspaper in the capital ignored fired the secretary.
 - g. The judge who the reporter for the newspaper ignored fired the secretary.
 - h. The judge who ignored the reporter fired the secretary.
-
- 2a. The baby-sitter amused the child who was full of energy.
 - b. The parents liked the baby-sitter who amused the child who was full of energy.
 - c. The child who the baby-sitter amused was full of energy.
 - d. The child who the baby-sitter who the parents liked amused was full of energy .
 - e. The child who the baby-sitter who liked the parents amused was full of energy.
 - f. The child who the baby-sitter in the playroom at the preschool amused was full of energy.
 - g. The child who the baby-sitter at the preschool amused was full of energy.
 - h. The child who amused the baby-sitter was full of energy.
-
- 3a. The banker distrusted the broker who lost the company's investments.
 - b. The chairman praised the banker who distrusted the broker who lost the company's investments.
 - c. The broker who the banker distrusted lost the company's investments.
 - d. The broker who the banker who the chairman praised distrusted lost the company's investments.
 - e. The broker who the banker who praised the chairman distrusted lost the company's investments.
 - f. The broker who the banker at the table distrusted lost the company's investments.
 - g. The broker who the banker at the table near the window distrusted lost the company's investments.
 - h. The broker who distrusted the banker lost the company's investments.
-
- 4a. The violinist insulted the singer who hated the director.
 - b. The sponsor flattered the violinist who insulted the singer who hated the director.
 - c. The singer who the violinist insulted hated the director
 - d. The singer who the violinist who the sponsor flattered insulted hated the director.
 - e. The singer who the violinist who flattered the sponsor insulted hated the director.
 - f. The singer who the violinist in the orchestra for the opera insulted hated the director.
 - g. The singer who the violinist in the orchestra insulted hated the director.
 - h. The singer who insulted the violinist hated the director.
-
- 5a. The robber threatened the police who had sealed off the bank.
 - b. The dogs frightened the robber who threatened the police who had sealed off the bank.
 - c. The police who the robber threatened had sealed off the bank.
 - d. The police who the robber who the dogs frightened threatened had sealed off the bank.
 - e. The police who the robber who frightened the dogs threatened had sealed off the bank.
 - f. The police who the robber in the vault with the hostages threatened had sealed off the bank.
 - g. The police who the robber in the vault threatened had sealed off the bank.
 - h. The police who threatened the robber had sealed off the bank.
-
- 6a. The carpenter yelled at the painter who dropped his bucket.

- b. The plumber punched the carpenter who yelled at the painter who dropped his bucket.
- c. The painter who the carpenter yelled at dropped his bucket.
- d. The painter who the carpenter who the plumber punched yelled at dropped his bucket.
- e. The painter who the carpenter who punched the plumber yelled at dropped his bucket.
- f. The painter who the carpenter at the construction site for the bridge yelled at dropped his bucket.
- g. The painter who the carpenter at the construction site yelled at dropped his bucket.
- h. The painter who yelled at the carpenter dropped his bucket.

- 7a. The architect nagged the secretary who misplaced the files.
- b. The accountant hired the architect who nagged the secretary who misplaced the files.
- c. The secretary who the architect nagged misplaced the files.
- d. The secretary who the architect who the accountant hired nagged misplaced the files.
- e. The secretary who the architect who hired the accountant nagged misplaced the files.
- f. The secretary who the architect of the bridge in the city nagged misplaced the files.
- g. The secretary who the architect of the bridge nagged misplaced the files.
- h. The secretary who nagged the architect misplaced the files.

- 8a. The starlet teased the rock star who was throwing the Hollywood party.
- b. The journalist winked at the starlet who teased the rock star who was throwing the Hollywood party.
- c. The rock star who the starlet teased was throwing the Hollywood party.
- d. The rock star who the starlet who the journalist winked at teased was throwing the Hollywood party.
- e. The rock star who the starlet who winked at the journalist teased was throwing the Hollywood party.
- f. The rock star who the starlet in the new play in the park teased was throwing the Hollywood party.
- g. The rock star who the starlet in the new play teased was throwing the Hollywood party.
- h. The rock star who teased the starlet was throwing the Hollywood party.

- 9a. The teaching assistant reassured the student who was worried about his grade.
- b. The professor trusted the teaching assistant who reassured the student who was worried about his grade.
- c. The student who the teaching assistant reassured was worried about his grade.
- d. The student who the teaching assistant who the professor trusted reassured was worried about his grade.
- e. The student who the teaching assistant who trusted the professor reassured was worried about his grade.
- f. The student who the teaching assistant in the office near the classroom reassured was worried about his grade.
- g. The student who the teaching assistant in the office reassured was worried about his grade.
- h. The student who reassured the teaching assistant was worried about his grade.

- 10a. The mobster kidnapped the suspect who was going to testify at the trial.
- b. The media criticized the mobster who kidnapped the suspect who was going to testify at the trial.
- c. The suspect who the mobster kidnapped was going to testify at the trial.
- d. The suspect who the mobster who the media criticized kidnapped was going to testify at the trial.
- e. The suspect who the mobster who criticized the media kidnapped was going to testify at the trial.
- f. The suspect who the mobster in the restaurant near the crime kidnapped was going to testify at the trial.
- g. The suspect who the mobster in the restaurant kidnapped was going to testify at the trial.
- h. The suspect who kidnapped the mobster was going to testify at the trial.

- 11a. The player doubted the referee who made the bad call.
- b. The coach yelled at the player who doubted the referee who made the bad call.
- c. The referee who the player doubted made the bad call.
- d. The referee who the player who the coach yelled at doubted made the bad call.

- e. The referee who the player who yelled at the coach doubted made the bad call.
- f. The referee who the player on the bench by the Gatorade doubted made the bad call.
- g. The referee who the player on the bench doubted made the bad call.
- h. The referee who doubted the player made the bad call.

- 12a. The suitors wanted to see the princess who had gone to sleep before her sisters.
- b. The king entertained the suitors who wanted to see the princess who had gone to sleep before her sisters.
- c. The princess who the suitors wanted to see had gone to sleep before her sisters.
- d. The princess who the suitors who the king entertained wanted to see had gone to sleep before her sisters.
- e. The princess who the suitors who entertained the king wanted to see had gone to sleep before her sisters.
- f. The princess who the suitors at the festival in the market wanted to see had gone to sleep before her sisters.
- g. The princess who the suitors at the festival wanted to see had gone to sleep before her sisters.
- h. The princess who wanted to see the suitors had gone to sleep before her sisters.

- 13a. The widow resented the millionaire who didn't come to the funeral.
- b. The bachelor pursued the widow who resented the millionaire who didn't come to the funeral.
- c. The millionaire who the widow resented who didn't come to the funeral.
- d. The millionaire who the widow who the bachelor pursued resented didn't come to the funeral.
- e. The millionaire who the widow who pursued the bachelor resented didn't come to the funeral.
- f. The millionaire who the widow in the crowd by the pool resented didn't come to the funeral.
- g. The millionaire who the widow by the pool resented didn't come to the funeral.
- h. The millionaire who resented the widow didn't come to the funeral.

- 14a. The councilman proposed to the intern who wrote a book about the romance.
- b. The radio host provoked the councilman who had proposed to the intern who wrote a book about the romance.
- c. The intern who the councilman had proposed to wrote a book about the romance.
- d. The intern who the councilman who the radio host provoked proposed to wrote a book about the romance.
- e. The intern who the councilman who provoked the radio host proposed to wrote a book about the romance.
- f. The intern who the councilman at the meeting with the mayor proposed to wrote a book about the romance.
- g. The intern who the councilman at the meeting proposed to wrote a book about the romance.
- h. The intern who proposed to the councilman wrote a book about the romance.

- 15a. The talk show host embarrassed the guest who told a boring story.
- b. The cameraman whispered to the talk show host who had embarrassed the guest who told a boring story.
- c. The guest who the talk show host had embarrassed told a boring story.
- d. The guest who the talk show host who the cameraman whispered to had embarrassed told a boring story.
- e. The guest who the talk show host who whispered to the cameraman had embarrassed told a boring story.
- f. The guest who the talk show host in the chair near the director had embarrassed told a boring story.
- g. The guest who the talk show host in the chair had embarrassed told a boring story.
- h. The guest who had embarrassed the talk show host told a boring story.

- 16a. The child criticized the teacher who gave out a quiz.
- b. The school counselor shouted at the child who criticized the teacher who gave out a quiz
 - c. The teacher who the child criticized gave out a quiz.
 - d. The teacher who the child who the school counselor shouted at criticized gave out a quiz.
 - e. The teacher who the child who shouted at the school counselor criticized gave out a quiz.
 - f. The teacher who the child in the office with the counselor criticized gave out a quiz.
 - g. The teacher who the child in the office criticized gave out a quiz.
 - h. The teacher who criticized the child gave out a quiz.
- 17a. The bankrobber aimed at the deputy who fell to the ground.
- b. The sheriff shot the bankrobber who aimed at the deputy who fell to the ground.
 - c. The deputy who the bankrobber aimed at fell to the ground.
 - d. The deputy who the bankrobber who the sheriff shot aimed at fell to the ground.
 - e. The deputy who the bankrobber who shot the sheriff aimed at fell to the ground.
 - f. The deputy who the bankrobber at a table in the saloon aimed at fell to the ground.
 - g. The deputy who the bankrobber at a table aimed at fell to the ground.
 - h. The deputy who aimed at the bankrobber fell to the ground.
- 18a. The dictator insulted the diplomat who had been trying to make peace.
- b. The prime minister hated the dictator who had insulted the diplomat who had been trying to make peace.
 - c. The diplomat who the dictator insulted had been trying to make peace.
 - d. The diplomat who the dictator who the prime minister hated insulted had been trying to make peace.
 - e. The diplomat who the dictator who hated the prime minister insulted had been trying to make peace.
 - f. The diplomat who the dictator at the negotiations in the capitol insulted had been trying to make peace.
 - g. The diplomat who the dictator at the negotiations insulted had been trying to make peace.
 - h. The diplomat who insulted the dictator had been trying to make peace.
- 19a. The tourist waved to the nuns who were standing by the road.
- b. The priest assisted the tourist who waved to the nuns who were standing by the road.
 - c. The nuns who the tourist waved to were standing by the road.
 - d. The nuns who the tourist who the priest assisted waved to were standing by the road.
 - e. The nuns who the tourist who assisted the priest waved to were standing by the road.
 - f. The nuns who the tourist in the vineyard near the cathedral waved to were standing by the road.
 - g. The nuns who the tourist in the vineyard waved to were standing by the road.
 - h. The nuns who waved to the tourist were standing by the road.
- 20a. The politician appointed the minister who was very popular.
- b. The voters adored the politician who appointed the minister who was very popular.
 - c. The minister who the politician appointed was very popular.
 - d. The minister who the politician who the voters adored appointed was very popular.
 - e. The minister who the politician who adored the voters appointed was very popular.
 - f. The minister who the politician at the podium by the premier appointed was very popular.
 - g. The minister who the politician at the podium appointed was very popular.
 - h. The minister who appointed the politician was very popular.
- 21a. The farmer phoned the local journalist who ran a story about flying saucers.
- b. Some aliens contacted the farmer who phoned the local journalist who ran a story about flying saucers the next day.
 - c. The local journalist who the farmer phoned ran a story about flying saucers the next day.

- d. The local journalist who the farmer who some aliens contacted phoned ran a story about flying saucers the next day.
- e. The local journalist who the farmer who contacted some aliens phoned ran a story about flying saucers the next day.
- f. The local journalist who the farmer at the ranch near the woods phoned ran a story about flying saucers the next day.
- g. The local journalist who the farmer at the ranch phoned ran a story about flying saucers the next day.
- h. The local journalist who phoned the farmer ran a story about flying saucers the next day.

- 22a. The clerk smiled at the customer who was wearing a short skirt.
- b. The manager disliked the clerk who smiled at the customer who was wearing a short skirt.
- c. The customer who the clerk smiled at was wearing a short skirt.
- d. The customer who the clerk who the manager disliked smiled at was wearing a short skirt.
- e. The customer who the clerk who disliked the manager smiled at was wearing a short skirt.
- f. The customer who the clerk in the literature section of the book store smiled at was wearing a short skirt.
- g. The customer who the clerk in the literature section smiled at was wearing a short skirt.
- h. The customer who smile d at the clerk was wearing a short skirt.

- 23a. The guitarist despised the manager who was secretly stealing money.
- b. The drummer respected the guitarist who despised the manager who was secretly stealing money.
- c. The manager who the guitarist despised was secretly stealing money.
- d. The manager who the guitarist who the drummer respected was secretly stealing money.
- e. The manager who the guitarist who respected the drummer despised was secretly stealing money.
- f. The manager who the guitarist on the stage near the speaker despised was secretly stealing money.
- g. The manager who the guitarist on the stage despised was secretly stealing money.
- h. The manager who despised the guitarist was secretly stealing money.

- 24a. The salesman cheated the customers who were walking away happy.
- b. The cashier resented the salesman who was cheating the customers who were walking away happy.
- c. The customers who the salesman cheated were walking away happy.
- d. The customers who the salesman who the cashier resented cheated were walking away happy.
- e. The customers who the salesman who resented the cashier cheated were walking away happy.
- f. The customers who the salesman at the dealership near the gas station cheated were walking away happy.
- g. The customers who the salesman at the dealership cheated were walking away happy.
- h. The customers who cheated the salesman were walking away happy.

- 25a. The waiter ignored the busboy who always dropped the dishes.
- b. The cook liked the waiter who ignored the busboy who always dropped the dishes.
- c. The busboy who the waiter ignored always dropped the dishes.
- d. The busboy who the waiter who the cook liked ignored always dropped the dishes.
- e. The busboy who the waiter who liked the cook ignored always dropped the dishes.
- f. The busboy who the waiter by the counter near the knives ignored always dropped the dishes.
- g. The busboy who the waiter by the counter ignored always dropped the dishes.
- h. The busboy who ignored the waiter always dropped the dishes.

- 26a. The nurse scolded the medic who dropped the patient.
- b. The doctor worked with the nurse who scolded the medic who dropped the patient.
- c. The medic who the nurse scolded dropped the patient.
- d. The medic who the nurse who the doctor worked with scolded dropped the patient.

- e. The medic who the nurse who worked with the doctor scolded dropped the patient.
- f. The medic who the nurse from the ward on the next floor scolded dropped the patient.
- g. The medic who the nurse from the ward scolded dropped the patient.
- h. The medic who scolded the nurse dropped the patient.

- 27a. The passenger recognized the pilot who had been in a bar before the flight.
- b. The navigator greeted the passenger who recognized the pilot who had been in a bar before the flight.
- c. The pilot who the passenger recognized had been in a bar before the flight.
- d. The pilot who the passenger who the navigator greeted recognized had been in a bar before the flight.
- e. The pilot who the passenger who greeted the navigator recognized had been in a bar before the flight.
- f. The pilot who the passenger in the bathroom near the cockpit recognized had been in a bar before the flight.
- g. The pilot who the passenger in the bathroom recognized had been in a bar before the flight.
- h. The pilot who recognized the passenger had been in a bar before the flight.

- 28a. The dog scratched the cub that had wandered into the yard.
- b. The bear chased the dog who scratched the cub that had wandered into the yard.
- c. The cub that the dog scratched had wandered into the yard.
- d. The cub that the dog who the bear chased scratched had wandered into the yard.
- e. The cub that the dog who chased the bear scratched had wandered into the yard.
- f. The cub that the dog on the property by the woods scratched had wandered into the yard.
- g. The cub that the dog on the property scratched had wandered into the yard.
- h. The cub that scratched the dog had wandered into the yard.

- 29a. The writer mocked the councilman who had embezzled money.
- b. The editor admired the writer who mocked the councilman who had embezzled money.
- c. The councilman who the writer mocked had embezzled money.
- d. The councilman who the writer who the editor admired mocked had embezzled money.
- e. The councilman who the writer who admired the editor mocked had embezzled money.
- f. The councilman who the writer for the newspaper in the capitol mocked had embezzled money.
- g. The councilman who the writer for the newspaper mocked had embezzled money.
- h. The councilman who mocked the writer had embezzled money.

- 30a. The maid annoyed the cook who burned the cake.
- b. The butler helped the maid who annoyed the cook who burned the cake.
- c. The cook who the maid annoyed burned the cake.
- d. The cook who the maid who the butler helped annoyed burned the cake.
- e. The cook who the maid who helped the butler annoyed burned the cake.
- f. The cook who the maid in the kitchen by the stove annoyed burned the cake.
- g. The cook who the maid in the kitchen annoyed burned the cake.
- h. The cook who annoyed the maid burned the cake.

- 31a. The waitress loved the bouncer who was in charge of the front door.
- b. The bartender liked the waitress who loved the bouncer who was in charge of the front door.
- c. The bouncer who the waitress loved was in charge of the front door.
- d. The bouncer who the waitress who the bartender liked loved was in charge of the front door.
- e. The bouncer who the waitress who liked the bartender loved was in charge of the front door.
- f. The bouncer who the waitress at the table near the bar loved was in charge of the front door.
- g. The bouncer who the waitress at the table loved was in charge of the front door.
- h. The bouncer who loved the waitress was in charge of the front door.

- 32a. The actress admired the director who was recruited at the last minute.
- b. The playwright offended the actress who admired the director who was recruited at the last minute.
- c. The director who the actress admired was recruited at the last minute.
- d. The director who the actress who the playwright offended admired was recruited at the last minute.
- e. The director who the actress who offended the playwright admired was recruited at the last minute.
- f. The director who the actress on the stage near the lights admired was recruited at the last minute.
- g. The director who the actress on the stage admired was recruited at the last minute.
- h. The director who admired the actress was recruited at the last minute.

Appendix C: Chapter 2 Experiment 2 Items

- 1a. A group of film critics praised a director at a banquet and another director at a film premiere. The director that the critics praised at a banquet insulted an actor from an action movie during an interview.
- 1b. A group of film critics praised a director at a banquet and another director at a film premiere. An actor from an action movie insulted the director that the critics praised at a banquet during an interview.
- 1c. A group of film critics praised a director and a producer. The director who the critics praised at a banquet insulted an actor from an action movie during an interview.
- 1d. A group of film critics praised a director and a producer. An actor from an action movie insulted the director who the critics praised at a banquet during an interview.
2.
 - 2a. A vicious guard dog bit a postman on the leg and another postman on the arm. The postman that the dog bit on the leg saw a doctor from a nearby hospital but the bite got infected anyway.
 - 2b. A vicious guard dog bit a postman on the leg and another postman on the arm. A doctor from a nearby hospital saw the postman that the dog bit on the leg but the bite got infected anyway.
 - 2c. A vicious guard dog bit a postman and a milkman. The postman who the dog bit on the leg saw a doctor from a nearby hospital but the bite got infected anyway.
 - 2d. A vicious guard dog bit a postman and a milkman. A doctor from a nearby hospital saw the postman who the dog bit on the leg but the bite got infected anyway.
3.
 - 3a. A literary agent signed a novelist at a conference and another novelist at a seminar. The novelist that the agent signed at a conference married an actress from a Broadway play while writing his second novel about Vietnam.
 - 3b. A literary agent signed a novelist at a conference and another novelist at a seminar. An actress from a Broadway play married the novelist that the agent signed at a conference while writing his second novel about Vietnam.
 - 3c. A literary agent signed a novelist and a poet. The novelist who the agent signed at a conference married an actress from a Broadway play while writing his second novel about Vietnam.
 - 3d. A literary agent signed a novelist and a poet. An actress from a Broadway play married the novelist who the agent signed at a conference while writing his second novel about Vietnam.
4.
 - 4a. A hospital rewarded a psychiatrist with a promotion and another psychiatrist with a raise. The psychiatrist that the hospital rewarded with a promotion consulted the head of the emergency room despite their disagreements

4b. A hospital rewarded a psychiatrist with a promotion and another psychiatrist with a raise. The head of the emergency room consulted the psychiatrist that the hospital rewarded with a promotion despite their disagreements.

4c. A county hospital rewarded a psychiatrist and a cardiologist. The psychiatrist who the hospital rewarded with a promotion consulted the head of the emergency room despite their disagreements

4d. A county hospital rewarded a psychiatrist and a cardiologist. The head of the emergency room consulted the psychiatrist who the hospital rewarded with a promotion despite their disagreements other.

5.

5a. A painter sketched an actress in dark pencil and another actress in charcoal. The actress that the painter sketched in dark pencil seduced an assistant from the artist's studio after the two had begun to fall in love.

5b. A painter sketched an actress in dark pencil and another actress in charcoal. An assistant from the artist's studio seduced the actress that the painter sketched in dark pencil after the two had begun to fall in love.

5c. A painter sketched an actress and a model. The actress who was sketched in dark pencil seduced an assistant from the artist's studio after the two had begun to fall in love.

5d. A painter sketched an actress and a model. An assistant from the artist's studio seduced the actress who the painter sketched in dark pencil after the two had begun to fall in love.

6.

6a. An art professor read a paper in the library and another paper in a pub. The paper that the professor read in the library criticized an archaeologist at a Dutch university although some of the criticisms were unfounded.

6b. An art professor read a paper in the library and another paper in a pub. An archeologist at a Dutch university criticized the paper that the professor read in the library although some of the criticisms were unfounded.

6c. An art professor read a paper and a book review. The paper which the professor read in the library criticized an archeologist at a Dutch university although some of the criticisms were unfounded.

6d. An art professor read a paper and a book review. An archeologist at a Dutch university criticized the paper which the professor read in the library although some of the criticisms were unfounded.

7.

7a. An 18th century British admiral captured a pirate off the coast and another pirate near an island. The pirate that the admiral captured off the coast taunted an officer of the British navy before the pirate imprisoned.

7b. An 18th century British admiral captured a pirate off the coast and another pirate near an island. An officer of the British navy taunted the pirate that the admiral captured off the coast before the pirate was imprisoned.

7c. An 18th century British admiral captured a pirate and a smuggler near England. The pirate who the admiral captured off the coast taunted an officer of the British navy before the pirate imprisoned.

7d. An 18th century British admiral captured a pirate and a smuggler near England. An officer of the British navy taunted the pirate who the admiral captured off the coast before the pirate was imprisoned.

8.

8a. An executive hired an accountant for tax purposes and another accountant to organize sales. The accountant that the executive hired to organize sales disliked the people in the marketing department until they all met.

8b. An executive hired an accountant for tax purposes and another accountant to organize sales. The people in the marketing department disliked the accountant that the executive hired for the sales project until they all met.

8c. An executive hired an accountant and a secretary. The accountant who the executive hired for tax purposes disliked the people in the marketing department until they all met.

8d. An executive hired an accountant and a secretary. The people in the marketing department disliked the accountant who the executive hired for tax purposes until they all met.

9.

9a. A talk show host interviewed a celebrity at a wedding and another celebrity at a fund-raiser. The celebrity that the host interviewed at a wedding punched a cameraman with a red goatee after insults had been exchanged.

9b. A talk show host interviewed a celebrity at a wedding and another celebrity at a fund-raiser. A cameraman with a red goatee punched the celebrity that the host interviewed at a wedding after insults had been exchanged.

9c. A talk show host interviewed a celebrity and a politician. The celebrity who the host interviewed at a wedding punched a cameraman with a red goatee after insults had been exchanged.

9d. A talk show host interviewed a celebrity and a politician. A cameraman with a red goatee punched the celebrity who the host interviewed at a wedding after insults had been exchanged.

10.

10a. A clerk helped a customer at the register and another customer at the tie rack. The customer that the clerk helped at the register flirted with the owner of the clothing store while looking for a stack of sweaters.

10b. A clerk helped a customer at the register and another customer at the tie rack. The manager of the clothing store flirted with the customer that the clerk helped at the register while looking for a stack of sweaters.

10c. A clerk helped a customer and a cashier. The customer who the clerk helped at the register flirted with the manager of the clothing store while looking for a stack of sweaters.

10d. A clerk helped a customer and a cashier. The manager of the clothing store flirted with the customer who the clerk helped at the register while looking for a stack of sweaters.

11.

11a. An evil villain imprisoned a superhero in a fortress and another superhero in his hideout. The superhero that the villain imprisoned in a fortress kissed a woman with long blond hair after the hero escaped to safety.

11b. An evil villain imprisoned a superhero in a fortress and another superhero in his hideout. A woman with long blond hair kissed the superhero that the villain imprisoned in a fortress after the hero escaped to safety.

11c. An evil villain imprisoned a superhero and a police chief. The superhero who the villain imprisoned in a fortress kissed a woman with long blond hair after the hero escaped to safety.

11d. An evil villain imprisoned a superhero and a police chief. A woman with long blond hair kissed the superhero who the villain imprisoned in a fortress after the hero escaped to safety.

12.

12a. A dean misquoted a philosopher at a party and another philosopher at a meeting. The philosopher that the dean misquoted at a party wrote to a colleague in a different department because the dean's error upset him.

12b. A dean misquoted a philosopher at a party and another philosopher at a meeting. A colleague in a different department wrote to the philosopher that the dean misquoted at a party because the dean's error upset him.

12c. A dean misquoted a philosopher and a famous novelist. The philosopher who the dean misquoted at a party wrote to a colleague in a different department because the dean's error upset him.

12d. A dean misquoted a philosopher and a famous novelist. A colleague in a different department wrote to the philosopher who the dean misquoted at a party because the dean's error upset him.

13.

13a. A young woman carried a child in her arms and another child on her back as she walked through the airport. The child that the woman carried in her arms waved to a ticket agent at the gate before boarding the plane.

13b. A young woman carried a child in her arms and another child on her back as she walked through the airport. A ticket agent at the gate waved to the child that the woman carried in her arms before boarding the plane.

13c. A young woman carried a child and a backpack full of toys through the airport. The child who the woman carried in her arms waved to a ticket agent at the gate before boarding the plane.

13d. A young woman carried a child and a backpack full of toys through the airport. A ticket agent at the gate waved to the child who the woman carried in her arms before boarding the plane.

14.

14a. The owner of a mansion hired a sculptor for a fountain and another sculptor for a statue. The sculptor that the patron hired for a fountain talked to the gardener of the enormous estate because remodeling was needed.

14b. The owner of a mansion hired a sculptor for a fountain and another sculptor for a statue. The gardener of the enormous estate talked to the sculptor that the patron hired for a fountain because remodeling was needed.

14c. The owner of a mansion hired a sculptor and a landscaper. The sculptor who the patron hired for a fountain talked to the gardener of the enormous estate because remodeling was needed.

14d. The owner of a mansion hired a sculptor and a landscaper. The gardener of the enormous estate talked to the sculptor who the patron hired for a fountain because remodeling was needed.

15.

15a. A bully hit a student with a rock and another student with a binder. The student that the bully hit with a rock visited the nurse at the high school so that the injury could receive treatment.

15b. A bully hit a student with a rock and another student with a binder. The nurse at the high school visited the student that the bully hit with a rock so that the injury could receive treatment.

15c. A bully hit a student and a teacher after eating too much sugar. The student who the bully hit with a rock visited the nurse at the high school so that the injury could receive treatment.

15d. A bully hit a student and a teacher after eating too much sugar. The nurse at the high school visited the student who the bully hit with a rock so that the injury could receive treatment.

16.

16a. A movie studio sued a producer over a contract and another producer over a budget dispute. The producer that the studio sued over a contract confronted a lawyer from the legal department despite warnings from his friends.

16b. A movie studio sued a producer over a contract and another producer over a budget dispute. A lawyer from the legal department confronted the producer that the studio sued over a contract despite warnings from his friends.

16c. A movie studio sued a producer and a script writer. The producer who the studio sued over a contract confronted a lawyer from the legal department despite warnings from his friends.

16d. A movie studio sued a producer and a script writer. A lawyer from the legal department confronted the producer who the studio sued over a contract despite warnings from his friends.

17.

17a. A soccer coach scolded a player for being late and another player for poor defensive play. The player that the coach scolded for being late pushed an opponent from the other team because the two disliked each other.

17b. A soccer coach scolded a player for being late and another player for poor defensive play. An opponent from the other team pushed the player that the coach scolded for being late because the two disliked each other.

17c. A soccer coach scolded a player and a parent. The player who the coach scolded for being late pushed an opponent from the other team because the two disliked each other.

17d. A soccer coach scolded a player and a parent. An opponent from the other team pushed the player who the coach scolded for being late because the two disliked each other.

18.

18a. A senator attacked a reporter for bad journalism and another reporter for bribing a cop. The reporter that the senator attacked for bad journalism ignored the editor of the political news instead of addressing the claims.

18b. A senator attacked a reporter for bad journalism and another reporter for bribing a cop. The editor of the political news ignored the reporter that the senator attacked for bad journalism instead of addressing the claims.

18c. A senator attacked a reporter and a congressional leader. The reporter who the senator attacked for bad journalism ignored the editor of the political news instead of addressing the claims.

18d. A senator attacked a reporter and a congressional leader. The editor of the political news ignored the reporter who the senator attacked for bad journalism instead of addressing the claims.

19.

19a. An FBI agent pursued a kidnapper for two years and another kidnapper for six months. The kidnapper that the agent pursued for two years tackled a deputy with a black mustache after the police found him.

19b. An FBI agent pursued a kidnapper for two years and another kidnapper for six months. A deputy with a black mustache tackled the kidnapper that the agent pursued for two years after the police found him.

19c. An FBI agent pursued a kidnapper and a counterfeiter across the country. The kidnapper who the agent pursued for two years tackled a deputy with a black mustache after the police found him.

19d. An FBI agent pursued a kidnapper and a counterfeiter across the country. A deputy with a black mustache tackled the kidnapper who the agent pursued for two years after the police found him.

20.

20a. A soldier hated a diplomat for political reasons and another diplomat for personal reasons. The diplomat that the soldier hated for political reasons supported a general in the air force due to his military expertise.

20b. A soldier hated a diplomat for political reasons and another diplomat for personal reasons. A general in the air force supported the diplomat that the soldier hated for political reasons due to his military expertise.

20c. A soldier hated a diplomat and a pentagon official. The diplomat who the soldier hated for political reasons supported a general in the air force due to his military expertise.

20d. A soldier distrusted a diplomat and a pentagon official. A general in the air force supported the diplomat who the soldier hated for political reasons due to his military expertise.

Appendix D: Chapter 2 Experiment 3 Items

1. The secretary orchestrated the introduction of a guest of the host to a lawyer.
2. The contractor made a phone call about the accident on the site to the home office.
3. The mechanic looked for a connection from the engine of the tractor to a fuel tank.
4. The teacher planned a visit of the children of the class to the petting zoo.
5. The pagans made a sacrifice of the prisoners of war to the idol.
6. The courier made the delivery of the contracts for the new building to the architect.
7. The corporation approved the lease of the top floor of the building to the small company.
8. The child liked the book with the pictures of race cars from his sister.
9. An artist arranged a donation of the paintings of the landscape to the museum.
10. The environmentalists funded the distribution of the pamphlets about the ozone to the neighborhood.
11. The teacher made an announcement about the field trip in the country to the class.
12. The physicist ignored a report on the state of the field from a colleague.
13. The salesman cut off the warning on the label of the toy to the consumer.
14. The lawyers wanted a guarantee on the new tires of the cars to the consumers.
15. The platoon made a signal of the defeat of the enemy to the troop.
16. The secretary obeyed the order from the manager of the office to the staff.

Appendix E: Chapter 2 Experiment 4 Items

Xa. Left Branching Condition

Xb. Right Branching Condition

1a. The successful corporate executive's secretary was incompetent.

1b. The secretary of the successful corporate executive was incompetent.

2a. The eccentric Chilean politician's portrait was stolen.

2b. The portrait of the eccentric Chilean politician was stolen.

3a. The famous rock star's manager was arrested.

3b. The manager of the famous rock star was arrested.

4a. The unpopular office manager's memo was ignored.

4b. The memo from the unpopular office manager was ignored.

5a. The expensive French restaurant's chef was fired.

5b. The chef of the expensive French restaurant was fired.

6a. The spoiled child actor's father was disliked.

6b. The father of the spoiled child actor was disliked.

7a. The aging army colonel's order was disobeyed.

7b. The order from the aging army colonel was disobeyed.

8a. The overbooked seaside hotel's maid was exhausted.

8b. The maid of the overbooked seaside hotel was exhausted.

9a. The popular coffee shop's owner was rude.

9b. The owner of the popular coffee shop was rude.

10a. The used book store's manager was experienced.

10b. The manager of the used book store was experienced.

11a. The grizzled old composer's symphony was brilliant.

11b. The symphony of the grizzled old composer was brilliant.

12a. The legendary baseball pitcher's jersey was retired.

12b. The legendary baseball pitcher's jersey was retired.

13a. The young state senator's aide was enthusiastic.

13b. The aide of the young state senator was enthusiastic.

14a. The rusty old truck's engine was rebuilt.

14b. The engine of the rusty old truck was rebuilt.

15a. The huge abandoned mansion's gate was broken.

15b. The gate of the huge abandoned mansion was broken.

16a. The famous prize fighter's estate was sold.

16b. The estate of the famous prize fighter was sold.

Appendix F: Chapter 3 Experiment 1 Items

1. The detective showed the blurry picture of the diamond // to the client // who was in a office that was on the fourteenth floor.
2. The spy sent the secret message about the blueprint // to the general // who was at a base that was in the capitol
3. The writer loaned the interesting script for the screenplay // to the producer // who was on a set that was at the studio.
4. The cashier directed the exasperated mother of the child // to the manager // who was near a register that was by the door.
5. The agent mailed the critical review of the short story // to the author // who was at a conference that was in the hotel.
6. The manager distributed the thick manual for the software // to the employees // who were in a meeting that was for the product.
7. The publisher mentioned the war poem about the hero // to the editor // who worked for a newspaper that was against the war.
8. The senator left the ornate portrait of the Victorian mansion // to a foundation // that was on a street that was near the Chamber of Commerce.
9. The surgeon prescribed the small bottle of the pain medication // to the athlete // who was at a meet that was for the championships.
10. The housewife slipped the small vial of the poison // to the guest // who was at a table that was in the dining room.
11. The tutor explained the difficult chapter of the book // to the student // who was in a class that was about government.
12. The supervisor distributed the short memo about the hardware // to the employees // who worked with a drill that was by the workbench.
13. The firefighter mentioned the possible danger of the explosion // to the chief // who was near a child who was by the fire engine.
14. The musician provided the interactive webpage about the music // to the fans // who logged on to a website that was promoted in the newspaper.
15. The salesman gave the informative presentation about the product // to the customers // who were at a seminar that was in a local restaurant.
16. The mathematician clarified the convoluted logic of the puzzle // to the academics //who were at a lecture that was in the philosophy department.

Appendix G: Chapter 3 Experiment 2 Items

1. The grandfather offered [the gift].
2. The museum lent [the sculpture]
3. The teacher administered [a test].
4. The girl handed [the basket]
5. The witch brought [the cauldron]
6. The artist loaned [the painting]
7. The shopkeeper [gave the package]
8. The teacher brought [the bag]
9. The professor introduced [the topic]
10. The executive transferred [the manager]
11. The writer brought [the photo]
12. The giant fed [the princess]
13. The doctor referred [the mother]
14. The housewife contributed [the sculpture]
15. The boy gave [the bottle]
16. The author introduced [the friend]
17. The lawyer showed [the evidence]
18. The motorist [gave an explanation]
19. The witness gave [a description]
20. The student brought [the picture]

[] Indicate spliced region

Appendix H: Chapter 3 Experiment 3 Items

- Xa. Preverb boundary / long VP
- Xb. Postverb boundary / long VP
- Xc. long VP baseline
- Xd. Preverb boundary / short VP
- Xe. Postverb boundary / short VP
- Xf. Short VP baseline

- 1a. The detective // found the blurry picture of the world's biggest diamond.
- 1b. The detective found // the blurry picture of the world's biggest diamond.
- 1c. The detective found the blurry picture of the world's biggest diamond.
- 1d. The detective // found the blurry picture.
- 1e. The detective found // the blurry picture.
- 1f. The detective found the blurry picture.

- 2a. The collector // bought the expensive painting of the famous French king.
- 2b. The collector bought // the expensive painting of the famous French king.
- 2c. The collector bought the expensive painting of the famous French king.
- 2d. The collector // bought the expensive painting.
- 2e. The collector bought // the expensive painting.
- 2f. The collector bought the expensive painting.

- 3a. The IRS // audited the powerful CEO of the investment banking firm.
- 3b. The IRS audited // the powerful CEO of the investment banking firm.
- 3c. The IRS audited the powerful CEO of the investment banking firm.
- 3d. The IRS // audited the powerful CEO.
- 3e. The IRS audited // the powerful CEO.
- 3f. The IRS audited the powerful CEO.

- 4a. The owner // fired the incompetent manager of the store's night shift.
- 4b. The owner fired // the incompetent manager of the store's night shift.
- 4c. The owner fired the incompetent manager of the store's night shift.
- 4d. The owner // fired the incompetent manager.
- 4e. The owner fired // the incompetent manager.
- 4f. The owner fired the incompetent manager.

- 5a. The philosopher // attacked the new theory of the human conscious experience.
- 5b. The philosopher attacked // the new theory of the human conscious experience.
- 5c. The philosopher attacked the new theory of the human conscious experience.
- 5d. The philosopher // attacked the new theory.
- 5e. The philosopher attacked // the new theory.
- 5f. The philosopher attacked the new theory.
- 6a. The tenants // liked the new landlord of the small apartment complex.

- 6b. The tenants liked // the new landlord of the small apartment complex.
6c. The tenants liked the new landlord of the small apartment complex.
6d. The tenants // liked the new landlord.
6e. The tenants liked // the new landlord.
6f. The tenants liked the new landlord.
- 7a. The rebels // captured the brutal dictator of the small island country.
7b. The rebels captured // the brutal dictator of the small island country.
7c. The rebels captured the brutal dictator of the small island country.
7d. The rebels // captured the brutal dictator.
7e. The rebels captured // the brutal dictator.
7f. The rebels captured the brutal dictator.
- 8a. The commuter // tripped the clumsy conductor of the crowded evening train.
8b. The commuter tripped // the clumsy conductor of the crowded evening train.
8c. The commuter tripped the clumsy conductor of the crowded evening train.
8d. The commuter // tripped the clumsy conductor.
8e. The commuter tripped // the clumsy conductor.
8f. The commuter tripped the clumsy conductor.
- 9a. The prisoner // angered the irritable warden of the maximum security prison.
9b. The prisoner angered // the irritable warden of the maximum security prison.
9c. The prisoner angered the irritable warden of the maximum security prison.
9d. The prisoner // angered the irritable warden.
9e. The prisoner angered // the irritable warden.
9f. The prisoner angered the irritable warden.
- 10a. The mayor // thanked the young architect of the new city hall.
10b. The mayor thanked // the young architect of the new city hall.
10c. The mayor thanked the young architect of the new city hall
10d. The mayor // thanked the young architect.
10e. The mayor thanked // the young architect.
10f. The mayor thanked the young architect.
- 11a. The admiral // disliked the inexperienced captain of the aging nuclear submarine.
11b. The admiral disliked // the inexperienced captain of the aging nuclear submarine.
11c. The admiral disliked the inexperienced captain of the aging nuclear submarine.
11d. The admiral // disliked the inexperienced captain.
11e. The admiral disliked // the inexperienced captain.
11f. The admiral disliked the inexperienced captain.
- 12a. The teacher // complimented the happy mother of the gifted math student.
12b. The teacher complimented // the happy mother of the gifted math student.
12c. The teacher complimented the happy mother of the gifted math student.
12d. The teacher // complimented the happy mother.
12e. The teacher complimented // the happy mother.

12f. The teacher complimented the happy mother.

13a. The lawyer // emailed the wealthy client of the famous law firm.

13b. The lawyer emailed // the wealthy client of the famous law firm.

13c. The lawyer emailed the wealthy client of the famous law firm.

13d. The lawyer // emailed the wealthy client.

13e. The lawyer emailed // the wealthy client.

13f. The lawyer emailed the wealthy client.

14a. The sergeant // studied the secret map of the underground enemy headquarters.

14b. The sergeant studied // the secret map of the underground enemy headquarters.

14c. The sergeant studied the secret map of the underground enemy headquarters.

14d. The sergeant // studied the secret map.

14e. The sergeant studied // the secret map.

14f. The sergeant studied the secret map.

15a. The explorer // opened the dark tomb of the ancient Egyptian pharaoh.

15b. The explorer opened // the dark tomb of the ancient Egyptian pharaoh.

15c. The explorer opened the dark tomb of the ancient Egyptian pharaoh.

15d. The explorer // opened the dark tomb.

15e. The explorer opened // the dark tomb.

15f. The explorer opened the dark tomb.

16a. The professor // praised the brilliant inventor of the fuel efficient engine.

16b. The professor praised //the brilliant inventor of the fuel efficient engine.

16c. The professor praised the brilliant inventor of the fuel efficient engine.

16c. The professor // praised the brilliant inventor.

16d. The professor praised // the brilliant inventor.

16f. The professor praised the brilliant inventor.

17a. The guitarist // punched the sleazy manager of the glam rock band.

17b. The guitarist punched // the sleazy manager of the glam rock band.

17c. The guitarist punched the sleazy manager of the glam rock band.

17d. The guitarist // punched the sleazy manager.

17e. The guitarist punched // the sleazy manager.

17e. The guitarist punched the sleazy manager.

18a. The editor // disliked the new photos of the beautiful young model.

18b. The editor disliked // the new photos of the beautiful young model.

18c. The editor disliked the new photos of the beautiful young model

18d. The editor // disliked the new photos.

18e. The editor disliked // the new photos.

18f. The editor disliked the new photos.

19a. The actress // sued the unethical publisher of the local gossip tabloid.

19b. The actress sued // the unethical publisher of the local gossip tabloid.

- 19c. The actress sued the unethical publisher of the local gossip tabloid.
19d. The actress // sued the unethical publisher.
19e. The actress sued // the unethical publisher.
19f. The actress sued the unethical publisher
- 20a. The millionaire // complimented the tall curator of the natural history museum.
20b. The millionaire complimented // the tall curator of the natural history museum.
20c. The millionaire complimented the tall curator of the natural history museum.
20d. The millionaire // complimented the tall curator.
20e. The millionaire complimented // the tall curator.
20f. The millionaire complimented the tall curator.
- 21a. The banker // handled the large account of the miserly old widow.
21b. The banker handled // the large account of the miserly old widow.
21c. The banker handled the large account of the miserly old widow.
21d. The banker // handled the large account .
21e. The banker handled the large account .
21f. The banker // handled the large account .
- 22a. The student // broke the scale model of the human digestive system.
22b. The student broke // the scale model of the human digestive system.
22c. The student broke the scale model of the human digestive system.
22d. The student // broke the scale model.
22e. The student broke // the scale model.
22f. The student broke the scale model.
- 23a. The crew // respected the experienced commander of the space shuttle mission.
23b. The crew respected // the experienced commander of the space shuttle mission.
23c. The crew respected the experienced commander of the space shuttle mission.
23d. The crew // respected the experienced commander.
23e. The crew respected // the experienced commander.
23f. The crew respected the experienced commander.
- 24a. The artist // sold the beautiful statue of the cruel pagan god.
24b. The artist sold // the beautiful statue of the cruel pagan god.
24c. The artist sold the beautiful statue of the cruel pagan god.
24d. The artist // sold the beautiful statue.
24e. The artist sold // the beautiful statue.
24f. The artist sold the beautiful statue.
- 25a. The secretary // flattered the witty chairman of the Romance literature department.
25b. The secretary flattered // the witty chairman of the Romance literature department.
25c. The secretary flattered the witty chairman of the Romance literature department.
25d. The secretary // flattered the witty chairman.
25e. The secretary flattered // the witty chairman.
25f. The secretary flattered the witty head.

- 26a. The jury // studied the grisly evidence of the brutal double homicide.
26b. The jury studied // the grisly evidence of the brutal double homicide.
26c. The jury studied the grisly evidence of the brutal double homicide.
26d. The jury // studied the grisly evidence.
26e. The jury studied // the grisly evidence.
26f. The jury studied the grisly evidence.
- 27a. The actor // thanked the enthusiastic fan of the science fiction movie.
27b. The actor thanked // the enthusiastic fan of the science fiction movie.
27c. The actor thanked the enthusiastic fan of the science fiction movie.
27d. The actor // thanked the enthusiastic fan.
27e. The actor thanked // the enthusiastic fan.
27f. The actor thanked the enthusiastic fan.
- 28a. The cop // arrested the burly driver of the suspicious delivery truck.
28b. The cop arrested // the burly driver of the suspicious delivery truck.
28c. The cop arrested the burly driver of the suspicious delivery truck.
28d. The cop // arrested the burly driver.
28e. The cop arrested // the burly driver.
28f. The cop arrested the burly driver.
- 29a. The agent // bribed the casting director of the small independent film.
29b. The agent bribed // the casting director of the small independent film.
29c. The agent bribed the casting director of the small independent film.
29d. The agent // bribed the casting director.
29e. The agent bribed // the casting director.
29f. The agent bribed the casting director.
- 30a. The executive // ignored the annoying caterer of the album release party.
30b. The executive ignored // the annoying host of the album release party.
30c. The executive ignored the annoying host of the album release party.
30d. The executive // ignored the annoying host.
30e. The executive ignored // the annoying host.
30f. The executive ignored the annoying host.

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