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Prosodic Factors in Speechreading:
Visual Disambiguation of Syntactic Ambiguity

by

Josephine G. Porrazzo

A dissertation submitted
to the Graduate Faculty in Speech and Hearing Sciences
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy,
The City University of New York

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This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction for the dissertation requirement for the degree of Doctor of Philosophy.

April 26, 2000

Date

April 26, 2000

Date

Katherine S. Harris

Chair of Examining Committee

R. W. G. S. J.

Executive Officer

Katherine Harris, Ph.D.

Harry Levitt, Ph.D.

Lawrence Raphael, Ph.D.

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

Prosodic Factors in Speechreading: Visual Disambiguation of Syntactic Ambiguity

by

Josephine G. Porrazzo

Adviser: Katherine Safford Harris, Professor Emeritus

There is some evidence that observers are able to extract and make use of prosodic cues in speechreading. This study focuses on visual disambiguation of suprasegmental information. The purpose of the study was to investigate the role of the jaw in conveying suprasegmental information to the speechreader. Speech materials used consist of six productions of seven pairs of syntactically ambiguous sentences and their reiterant imitations, as spoken by two talkers, a male and a female. There are three parts to this experiment; a perceptual study, an acoustic study, and a study of jaw movement. For the perceptual study, subjects were asked to discriminate between the two interpretations of each ambiguous sentence pair presented in four conditions; audio-natural, audio-reiterant, visual-natural, and visual-reiterant. The acoustic study and movement study

focus on the reiterant utterances. The acoustic study reports on measurements of duration of the vowel portion for syllables critical to the disambiguation of the sentence. The movement study examines differences in jaw amplitude, and opening and closing duration for the key syllables as a function of sentence type. The main issue for this dissertation is whether the syntactic contrast in question is associated with systematic differences in the pattern of jaw movement which are perceptually identifiable.

Acknowledgement

This dissertation is dedicated to the memory
of
Professor Irving Hochberg; teacher, mentor, and friend.

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Chapter I.

Statement of Need

Considerable research has reported on segmental aspects in speechreading, with emphasis on visual confusions within vowel and consonant classes (Montgomery, Walden, & Prosek, 1987; Woodward & Barber, 1960). Investigations of the perceptual features underlying vowel lipreading performance and their correlation with measurements of static lip configurations have for the most part ignored articulatory characteristics such as rate and duration which may be more directly responsible for certain aspects of vowel perception (Jackson, Montgomery, & Binnie, 1976; Montgomery & Jackson, 1983). While a few studies have examined visual perception of suprasegmental speech characteristics (Berger, 1972a; Bernstein, Eberhardt, & Demorest, 1986; Brooke & Summerfield, 1987; Byers & Lieberman, 1959; Fisher, 1969; Green, 1987; Green & Miller, 1985; Risberg & Lubker, 1978; Thompson, 1934; none of these has evaluated the role of individual articulators in conveying suprasegmental information to the observer.

Several possible sources of prosodic cues operative in speechreading may be suggested, although this study will

focus only on those possibly ascribable to jaw movement. First, acoustic duration associated with stressed syllables tends to be longer than that for unstressed syllables (Fry, 1955; Klatt, 1976). It is possible that the temporal differences between stressed and unstressed syllables are visually discriminable as differences in the relative timing of jaw opening and closing, that is, it is the sub-syllabic differences rather than overall duration of jaw opening and closing which determine the perception.

Second, the articulatory correlates of stressed syllables include greater displacement from the neutral position, longer duration, and higher peak velocities for jaw opening and closing gestures than unstressed syllables (Kelso et al., 1985; Summers, 1987). The larger jaw amplitudes for stressed syllables and the associated differences in duration and/or peak velocities for jaw opening and closing may provide suprasegmental information to the speechreader.

Third, pausing and vowel lengthening is found at the boundaries of major syntactic phrases in speech (Cooper & Paccia-Cooper, 1980; Klatt, 1975). These effects could be visible in the ongoing pattern of jaw movement; brief periods of facial "silence" may act as visual "punctuation marks" and provide important information regarding phrase

boundaries to the speechreader. Intervals during which there is little relative change in jaw position may cue syntactic information to the speechreader.

Changes in the stress pattern and the insertion of pauses are typical devices which talkers may use to parse ambiguous sentences in order to convey the appropriate interpretation. As noted above, both acoustically defined segmental lengthening and pausing accompany major syntactic boundaries in speech (Klatt, 1976). These cues have been reported for alternative readings of structurally ambiguous sentences (Cooper & Paccia-Cooper, 1980; Klatt, 1976; Larkey, 1983; Lehiste, 1973b; Lehiste, Olive, & Streeter, 1976; O'Malley, Klocker, & Dara-Abrams, 1973).

Pausing is typically the more perceptible of the two but is reported to be more variable among speakers as measured acoustically (Cooper & Paccia-Cooper, 1980). The duration and location of pausing is dependent upon a variety of factors including word-finding difficulties, general hesitation, and drastic changes in the planning of the syntactic content of the utterance; pausing is also influenced by overall speaking rate and length of the constituent. Finally, although it is recognized that pausing may provide additional cues to the speechreader, its analogy is not measurable in the movement data and

therefore not analyzed in this dissertation. At issue here is whether durational differences are accessible to the speechreader through interpretation in the pattern of jaw movement over time.

To date, little is known about the observer's ability to extract prosodic cues from facial speech gestures. The goal of this dissertation is to report on the visibility of prosodic effects by exploring the relation between the spatiotemporal characteristics of jaw movement and listeners'/observers' ability to disambiguate a set of syntactically ambiguous sentences. An important consideration in the design of this study is that in natural speech there is a confounding of segmental information with prosody.

Jaw height is affected by phone identity. Kim (1972) measured jaw displacement in three subjects for 10 repetitions of the VCVs /apa/, /ata/, /aba/, and /ama/; the jaw exhibited a greater degree of involvement in elevating for the lingual-alveolar stop /t/ than for the bilabial stops. In addition, since the jaw is mechanically linked to the tongue its displacement is related to the positioning of the tongue during vowel production; the jaw is lowered to a low position for vowels requiring low tongue height and raised for vowels requiring high tongue height.

Specifically, greater jaw lowering distances have been reported for the progression from high-to-mid-to-low front vowel /I/ to /E / to /a / (Sussman, MacNeilage, & Hanson, 1973) .

The approach used in this study is to remove as much as possible the influence of segmental variation. First, the speech materials here consist of syntactically ambiguous sentences; these are sentences in which the lexical items are the same but have different phrase structures and may be discriminated only through prosodic information. Second, talkers were asked to reproduce each utterance reiterantly; that is, speakers JJ and LR substituted the syllable /ma/ for each real syllable in the utterance, while mimicking the utterances' normal prosodic structure. The combined use of the reiterant speech technique and ambiguous sentences will permit an analysis of prosodic effects on jaw displacement over time without the confounding influences of component segments. By minimizing segmental variability while preserving the prosodic pattern, suprasegmental cues should be more directly available in the reiterant form.

The purpose of this study is to investigate the role of the jaw in conveying suprasegmental information to the speechreader by focussing on visual disambiguation of

syntactic ambiguity through suprasegmental information. There are three parts to this experiment; a perceptual study, an acoustic study, and a study of jaw movement. For the perceptual study, subjects were asked to discriminate between two interpretations for six productions of each ambiguous sentence pair in four conditions for the two speakers; (1) audio-natural, (2) audio-reiterant, (3) visual- natural, and (4) visual-reiterant. The acoustic study and movement study focus on the reiterant utterances. The acoustic study reports on measurements of syllable duration for phrases critical to the disambiguation of the sentence. The movement study reports on differences in jaw duration and amplitude for the opening and closing gestures as a function of sentence type.

The specific hypotheses being tested are:

1. Suprasegmental information is available to speechreaders, as revealed by their ability to discriminate reiterant versions of ambiguous sentences with different syntactic structures presented without the audio signal. A prior study demonstrated that observers are able to accomplish visual disambiguation of reiterant utterances at well-above chance levels for different types of syntactic structures; **Attachment 1** contained in **Appendix A** is a

complete description of the pilot study for this dissertation. It is hypothesized that the relevant prosodic speech patterns are preserved and usable in the reiterant speech in the visual mode.

2. Observers are able to make use of visible prosodic features of stress, pattern, and rhythm to correctly disambiguate the reiterant sentences. Since segmental effects are absent from reiterant speech, observers should have less difficulty with discriminating ambiguous sentences in reiterant speech than in natural utterances. This effect should also be apparent in comparing the tracings of jaw movement for the natural and reiterant utterances. The reiterant patterns should demonstrate less variability when similar versions are compared, and larger differences when different versions are compared.
3. There are concomitant differences in jaw amplitude and duration for the opening and closing gestures associated with the two interpretations of each ambiguous sentence in the reiterant version. Each of these differences should be clearly discernible in the reiterant jaw movement data since confounding influences on jaw displacement due to segmental variability have been removed.

Figure 1.1 presents the time function of jaw displacement for a single repetition of the reiterant phrase DUKE JAMES as spoken by talker JJ by plotting the points of jaw height at 30.3 msec intervals. The heavy line displays her attempt to convey the interpretation that James is meeting the Duke. The meaning intended by JJ depicted by the thinner line is that the name of the Duke is James.

Figure 1.1 displays differences in the ongoing pattern of jaw movement for each version of the reiterant utterance. These differences might be associated in a systematic manner with the phrase structure of the sentence. If so, they could play a role in the observer's ability to discriminate between the two versions.

In summary, it is hypothesized that systematic differences in the pattern of jaw movement over time will differentiate the syntactic contrast in question for each ambiguous sentence pair.

Chapter II.

Review of Relevant Literature

In order to motivate the hypotheses this dissertation will test, I will first review lipreading research with emphasis on what is known about visual perception of speech prosody. I will then provide an overview of studies that report on the acoustic correlates of suprasegmental perception to examine what is known about the effects of syntax on acoustic duration. This will be followed by a discussion of reiterant speech as sentence material. Finally, I will discuss studies of jaw movement, which focus on differences in gestural patterns between stressed and unstressed utterances. The literature review in all four areas will be accomplished with inclusion of studies concerned with the influence of syntactic context on speech rhythm.

Part 1. Speechreading: Visual perception of speech rhythm

Early perceptual studies of speechreading have been concerned primarily with segmental characteristics. These experiments were designed in an attempt to uncover units of lipreading analogous to the phonemes derived from linguistic analysis. The phoneme has been considered the minimal dynamic unit of language and it was thought that one component of lipreading comprehension could be described in terms of the relative visibility of difference among phonemes; the term viseme--visible phoneme--refers to the minimal unit of visual perception of spoken language (Fisher, 1968). Woodward and Barber (1960) tested perceptual differences among English initial consonants and reported that lipreaders consistently identified only four visually-contrastive units which may be categorized as bilabial, labial, labiodental, and nonlabial. Across studies, the number of consonant visemes reported has ranged from 3 to 12 and for the most part appears to be disappointingly low (Berger, 1972b; Jeffers & Barley, 1971).

Some investigators have examined visual recognition of vowels in a neutral or consonantal context (Heider &

Heider, 1940; Jackson, Montgomery, & Binnie, 1976; Lesner & Kricos, 1981; Montgomery & Jackson, 1983; Wozniak & Jackson, 1979). In general, these studies have shown that vowels near each other in the vowel quadrilateral tend to be confused and the tense vowels are more intelligible than lax vowels. One study of the differences between vowel and diphthong speechreading performance reported predictable confusions which tend to shift toward the stressed vowel of the diphthong or to a vowel produced in a manner similar to the stressed element (Wozniak & Jackson, 1979). Visual perception of diphthongs has also been reported to be significantly better than visual perception of vowels (Lesner & Kricos, 1981).

The influence of phonetic environment on speechreading errors has been well documented with most studies noting the prominence of confusions among sounds produced in similar articulatory positions (Benguerel & Pichora-Fuller, 1982; Franks & Kimble, 1972; Montgomery, Walden, & Prosek, 1987). Franks and Kimble (1972) reported that lipreading confusions for consonant clusters in the initial position appeared to group into five essentially contrastive groups based on articulatory positions or movements appearing visually prominent: Group 1 included responses having /r/ and /w/ as components; Group 2, /b/, /m/, and /p/

components; Group 3, components having an alveolar or lingua-dental articulatory position; Group 4, /dz/ or /d/ components; and Group 5, /f/ components. In general, lipreaders have more difficulty interpreting stimuli that exhibit substantial coarticulatory effects with the features labial, rounded, and alveolar or palatal place of articulation found to transmit more information to lipreaders than did the feature continuant (Benguerel & Pichora-Fuller, 1982).

Another major factor contributing to the difficulty of the speechreading task is the range of talker differences. Relatively few systematic research studies have examined the effects of talker differences on visual intelligibility. All reports note that visual intelligibility as well as viseme production can differ as a function of talker (Kricos & Lesner, 1982; 1985; Stoker & French-St. George, 1984). These studies have found significant differences across talkers in terms of both their visual intelligibility for sentence-length material and the number and nature of visemes they produced. Furthermore, talkers who produced the most visemes also had the highest sentence perception scores when speechread by normal-hearing adults and hearing-impaired teenagers.

Speaker traits associated with improved visual

intelligibility include a slightly slower than normal speaking rate, precise and clear articulation rather than normal or conversational gestural patterns, and the inclusion of appropriate pauses (Kricos & Lesner, 1982; Picheny, Durlach & Braida, 1985; Tolhurst, 1957).

There is some evidence that speechreaders are able to make use of prosodic cues available from the talker's face. I will now summarize previous research on visual perception of suprasegmental information in light of what is known about articulatory and acoustic correlates of speech rhythm.

An early study by Thompson (1934) reported above-chance levels of performance for a task in which observers identified the location of stressed words in written sentences using live stimulus presentation. Fisher (1969) also reported above-chance accuracy for viewers' discrimination between declarative utterances and questions in a task that involved the labeling of videotaped sentences that terminated in either a rising or falling pitch contour. Berger (1972a) reported somewhat equivocal results in observers' ability to correctly identify disyllabic words in which half were presented with incorrect stress, but also noted significantly better than chance scores when the subject task was to differentiate

the stress pattern of spoken two- and three-numeral items.

Bernstein, Eberhardt, and Demorest (1986) have shown that information about stress, as well as intonation, is available from a talker's face, but stress is more visible than intonation. In this study, four basic sentences, such as "We owe you a yoyo" and "Chuck caught two cats," were produced with intonation appropriate for either a question or a statement and with stress on either word 1, 2, or 3. Bernstein et al. suggest that observers make use of intrinsic cues associated with the phonatory and articulatory maneuvers involved in producing these distinctions. Although the authors conclude that a likely contribution to stress judgements in speechreading is the visual rhythm of the mouth in open position during vowels versus closed position for consonants, no objective kinematic measure was included in their experiment.

The effect of rate on speechreading performance has been investigated in a number of studies, most of which alter the rate of presentation of filmed or videotaped utterances. Mulligan (1954) reported that college students achieved significantly higher scores on a filmed test of words projected at 16 frames per second compared to the normal rate for film of 24 frames per second. Frisina and Bernero (1958) found that profoundly hearing impaired

college students scored higher on a filmed sentence test presented at a slower-than-normal rate.

However, there are contradictory findings in studies of speech rate and visual discriminability. A statistically significant difference in speechreading accuracy was not found by Byers and Lieberman (1959) when they presented a filmed version of the Utley Test Sentences at slower-than-normal playback speeds. Black, O'Reilly, & Peck (1963) reported no significant improvement in speechreading scores by slowing the speed of filmed words. Despite the inconsistent evidence, reports of speechreaders indicate that speech produced at a normal rate is faster than they prefer (Berger, 1972a).

It seems logical to predict that a fast rate would not be an ideal speechreading condition, since as speech rate increases, the articulators tend to fall short of the intended target and may reduce phonetic cues in the visual signal. A related effect, formant frequency undershoot and centralization, occurs when vowels are produced at a quick tempo (Lindblom, 1963). However, studies attempting to account for rate-dependent effects on speechreading ability have artificially altered the talker's image by projecting the speech materials at a slower-than-normal playback speed.

This may not present a realistic approximation of what talkers actually do when they slow down. There is acoustic evidence that talkers tend not only to increase the duration of individual speech sounds when they speak slower, but they also insert pauses (Picheny, Durlach, & Braida, 1986). The presence of meaningful pauses can provide important cues for speechreaders. When they occur at the ends of phrases, pauses may act as a sort of visual punctuation mark, defining the presence of a major syntactic boundary marking of major syntactic boundaries and slowing of speech, this dissertation will not report on pauses. Very little is known about observers' ability to extract syntactic information from visible movement of the articulators. Geers (1978) suggested that advanced deaf lipreaders utilize visual durational cues to parse speech into major syntactic units. This conclusion was reached in a study showing that lipreaders misplace the location of a visual flash superimposed on a videotape of an individual talking. The signal was usually misplaced toward the location of durational cues that normally mark major syntactic boundaries, analogous to listeners' misplacement of the location of a superimposed auditory click (Fodor, Bever, & Garrett, 1974). We would anticipate that the misplacement effect noted by Geers disappears when the

visual cues for segmentation are displaced from the major syntactic boundary. In other words, if the signal is placed at a point that is discrepant to the mark of a major syntactic boundary, it seems unclear what that the effect noted by Geers would be present. To summarize, the ability of speechreaders to decode suprasegmental information in order to determine the presence of syntactic boundaries has been explored in a wide variety of studies using different methodologies. Most focus on the role of pausing and do not evaluate higher order interrelationships among the constituent structure or phrase structure of the language under study.

The results suggest that speechreaders normally utilize visual cues of duration to parse the speech into major syntactic units, in much the same manner that normal hearing listeners utilize auditory cues of duration in the acoustic speech wave.

Part 2. Acoustic correlates of suprasegmental perception

Suprasegmental characteristics of speech include stress and intonation. Acoustically, prosody is conveyed by variations in voice fundamental frequency (F0), duration, and amplitude. Emphatic or contrastive stress on words in sentences cues which words in an utterance are most important. The acoustic correlates of primary stress are increased duration, more extreme formant frequencies, and greater amplitude (Fry, 1955). Intonation, declination, and timing may also provide information about the syntactic structure of sentences (Cooper & Paccia-Cooper, 1980; O'Malley, Kloker, & Dara-Abrams, 1973; Streeter, 1978).

In this section of the literature review I will report on the use of sentences similar to those tested in this dissertation. The notion of using complex ambiguous sentences to investigate the role of acoustic duration in the talker's coding of syntax (Cooper & Paccia-Cooper, 1980) is not new to the literature. As noted, in order to study the influence of syntax on speech timing, controls must be put into place for extragrammatical influences that could account for systematic durational changes. These most often involve the phonetic structure of speech material,

such as neighboring key segments even when no pause is present (Klatt, 1975). For this reason, early studies investigated structurally ambiguous sentences. These sentences contain identical word strings, but have different phrase structures.

Most of these studies begin with a discussion of the phrase structure system of the language. The phrase structure system consists of a set of rules defining the constituents and their hierarchical interrelationships. The structural and diagrammatic representations for the sentences evaluated in this document are discussed in-depth later in the **Results** section. This review will emphasize what is known about the effects of constituent hierarchy on acoustic duration.

Duration of speech gestures and pauses are influenced by the speaker's speaker's syntactic intent (Cooper & Paccia-Cooper, 1980). Each of the ambiguities tested involve a dominance relation between a constituent and either of two possible constituents. The ambiguities tested by Cooper and Paccia-Cooper (1980) involve a right-branching rather than left branching modifying constituent, z , which is immediately dominated by one of two possible constituent nodes, w and x in the structural representations. This syntactic contrast has direct

consequences on the speaker's use of sonorant strategies, including differences in duration dependent upon level of dominance of key syllable, deceleration in pattern at end of clause and others. Figure 4.4 presents a schematization of this type of ambiguity.

One direct consequence of these differing phrase structures is that in the former case constituent *z* is immediately preceded by the end of two constituents, *x* and *y*. In the latter case only one constituent, *y*, ends just before *z*. Therefore, if it is true that speakers compute representations analogous to linguistic phrase structures, we would predict that the material immediately preceding *z* would be longer for the top version of the ambiguity corresponding to the diagram in Figure 4.4. This hypothesis is further tested in the Results section.

The results of the series of experiments performed by Cooper and Paccia-Cooper are discussed in-depth below, because these are the sentence types evaluated in this thesis. The Cooper work evaluated the sentences perceptually by presenting each sentence to 15 listeners in the "natural" auditory mode. This was an attempt to insure that the sentences were indeed perceptually identifiable, but the versions were not compared for equality of discrimination. The perceptual results from Cooper's study

are therefore not discussed here for the reasons cited above.

Experiment 1: Adverb Modification

Two sentences were used:

- My Uncle Abraham presented his talk naturally.
- Lieutenant Baker instructed his troop naturally.

In each of these sentences the adverb "naturally" can modify either the entire sentence or the verb phrase.

Acoustic measurements were obtained for the durations of the key segment /tau/ in "talk" in the first sentence and /tru/ in "troop" in the second. Additionally, the silent interval was measured beginning with the word-final voiceless stop to provide an index of pause duration.

As predicted by the phrase structure diagrams, the duration of the key segment in both ambiguities was longer for the reading in which the adverb "naturally" modified the entire sentence. The duration of the silent interval was also longer for this reading. However, this series of experiments demonstrated that pausing is an optional feature of speech, and its variability both within and across speakers is considerable.

Experiment 2: Vocative versus Head Noun

Two sentences were used:

- Here is the famous Duke James
- Here is the famous Pope Paul

In each sentence the proper noun "James" or "Paul" can serve as a vocative, designating the person to which the speech is directed, or as the head noun in the NP "the famous Duke James" or "the famous Pope Paul." The proper noun is attached to a higher constituent in the reading in which it functions as a vocative.

Acoustic duration measurements were obtained for the key segments /du/ in "Duke" and /po/ in "Pope" as well as for the pauses. Cooper found that for both sentences the duration of the key segment was significantly longer in the (a) version where the proper noun served as a vocative. As in Experiment 1, the results indicate that lengthening occurs when the key material marks the end of a relatively greater number of constituents.

Experiment 3: Prepositional Phrase Modification I

This experiment was designed to investigate whether the lengthening effects observed would generalize to a type of ambiguity involving constituent relations of dominance at a lower level in the syntactic structure.

The issue being tested is whether an account of the lengthening effect should be formulated in terms of the relative number of constituent boundaries or in terms of the absolute notion of immediate dominance by the S node. Two sentences were used in Experiment 3:

- Lieutenant Baker instructed the troop with a handicap.
- Jeffrey hit the cop with a stick.

In each sentence an ambiguity arises because the prepositional phrase beginning with "with" can modify either the verb phrase or the noun phrase dominated by the verb phrase. The prepositional phrase "with a handicap" can designate the manner in which the troop was instructed (VP modification), or it can designate the handicapped condition of the troop (NP modification). The prepositional phrase "with a stick" can designate that the cop was carrying the stick (VP modification), or it can designate that Jeffrey had the stick (NP modification).

Acoustic duration measurements were obtained for the key segments [TR00...] in "troop" and [KA...] in "cop" as well as for the following pauses. For both sentences, the duration of the key segment was longer for the (a) reading, in which the prepositional phrase modified the entire VP, with the effect being statistically significant for the first sentence, but not the second. The duration of the

pause was longer in the (a) version of both sentences, an effect that was statistically significant in both instances.

Experiment 4: Prepositional Phrase Modification II

Two ambiguous sentences were used in this experiment:

- I left Chuck with a better understanding of his problem.
- I saw Chuck looking through the window.

This series of tests evaluates a rather more complex sentence structure than in Experiment I. Here, in both sentences the proper noun "Chuck" can modify either the VP or the NP that the VP dominates, as in the prior experiment. Additionally, the prepositional phrase beginning with "with" can designate either the manner in which Chuck was left (I had a better understanding of his problem) or Chuck's condition (Chuck had a better understanding). Similarly, in the second sentence the adverbial phrase beginning with "looking" can designate either the manner which I saw Chuck (I was looking through the window) or Chuck's condition (Chuck was looking through the window).

Although more complex than those in the prior experiment, the same kind of ambiguity is involved.

Acoustic duration measurements were obtained for the key segment /ʌ/ in "Chuck" for both sentences, as well as for the duration of the following pause. For both versions the duration of the segment was significantly longer for version (a) in which the modifying phrase was attached to the VP rather than the NP. The duration of the following pause was also significantly longer in version (a) for both sentences.

Again, the lengthening effects obtained in this experiment further support the notion that constituent relations influence speech timing in structurally ambiguous sentences. The authors also investigated other types of ambiguities including Indirect Question versus Relative Clause, Scope of Negation, and Paragraph Contexts (Cooper, Paccia, & Lapointe; 1978).

The main question addressed in other papers concerns the nature of grammatical coding in speech production. It is known that some of the most salient acoustic properties of speech, particularly timing and fundamental frequency, are influenced by grammatical structure. Boundaries of clauses and major phrases are typically marked by a lengthening of the preceding syllable. The boundary may also be accompanied by an optional pause. Early work by Lehiste (1973a) showed that timing effects could be

produced for dichotomous bracketings of certain ambiguities. In this study Lehiste evaluated the temporal structure of fifteen ambiguous sentences to identify successful disambiguation strategies used by talkers. Lehiste (1973a) found that when speakers succeeded in disambiguating sentences, the duration of the given sequence of words was greater when the sequence contained a higher-level constituent boundary. Those that were disambiguated successfully differed primarily with regard to timing.

In later studies using computer-processed speech, the sentences tested were temporally manipulated in the following manner: the sentences were analyzed in terms of amplitude, pitch, and 12 linear predictive coding parameters. These analyses were necessary so that pitch and duration could be manipulated independently without altering other speech parameters (Lehiste, Olive, & Streeter; 1976). To remove all pitch cues the fundamental frequency of all voiced portions of the sentences was set to a constant 100 Hz. The ambiguities involved competing bracketing of phrase structures as in the string [[The old men and women] left early]. In one interpretation the syntactic bracketing reflects the fact that [old] modifies both [men and women] as in [[old] [[men] [and] [women]]]. In

the other interpretation the bracketing old modifies only [men] [[[old] [men]] [and] [women]]. For this type of ambiguity Lehiste (1973b) found that the total duration of phrases like men and women was longer when speakers intended to convey the second of the two readings. Lehiste noted that duration of the interstress interval spanning the boundary between "men and women" can effectively disambiguate syntactically ambiguous sentences, even in the absence of cues provided by fundamental frequency and pauses.

It is possible, however, that listener's judgements were determined by the absolute lengthening of a particular segment within the manipulated string (Cooper & Paccia-Cooper, 1980).

Speakers of English have at minimum four different strategies to indicate the presence of a syntactic boundary. These include:

1. Modification of segmental sounds at the boundary (Lehiste, 1972);
2. Insertion of pauses (O'Malley, Kloker, & Dara-Abrams; 1973);

3. Modification of the fundamental frequency contour (Lea, W.A., 1972; Lehiste, Olive, & Streeter, 1976);)
4. And deceleration; that is, lengthening of segments preceding a boundary (Gaitenby, 1965; Klatt, 1976).

Inserting a pause at the boundary and deceleration before the boundary have essentially the same effect. The result is an increase in interstress interval; that is, the time span between the two stresses.

Whether listeners use the prosodic variable, duration, to disambiguate syntactically ambiguous sentences was investigated by one study (Lehiste, Olive & Streeter; 1976). Ten sentences were selected from the earlier Lehiste study (Lehiste; 1973c). Some of the sentences could be represented by two distinct syntactic bracketings. Other sentences, while ambiguous, had a common syntactic bracketing. The duration of words corresponding to ambiguous constituents or containing ambiguous boundaries was varied systematically. Subjects listened to the sentences and selected one of the two meanings. The results indicated that only sentences in which the two meanings were represented by two distinct bracketings could be disambiguated by durational cues.

The authors suggest that when the interstress interval spanning a major syntactic boundary is increased, listeners perceive the boundary's presence.

Part 3. Reiterant speech in the study of prosodic effects

The technique of reiterant speech is that in which a nonsense syllable, such as /ma/ is substituted for each syllable in an "normal" utterance while following the suprasegmental aspects of the natural signal. Reiterant speech or "nonsense syllable mimicry" offers many advantages in the study of speech prosody, especially duration. In analytic studies, by eliminating segmental effects as a factor data collection becomes more efficient, and requires the designation of only one segmentation criterion. Thus the segmentation process can be automated without great difficulty, removing experimenter bias as an error source and expediting the data collection process. In perceptual studies, reiterant speech eliminates lexical information without unnatural distortion of the signal.

One series of validation experiments performed determined that the patterns of duration obtained by using the reiterant technique were stable within and across speakers, and mimicry of different natural models with identical stress patterns and constituent structures produced nearly indistinguishable nonsense-syllable duration patterns (Liberman & Streeter, 1978).

The technique has been used to study prosodic phenomena in several languages. Oller (1973) and Lehiste (1975) have used nonsense-syllable strings to study stress effects in English. Lindblom (1963) and Erickson and Rapp (1973) used the reiterant technique to investigate duration patterns in Swedish. This team used a technique in which a natural utterance, such as "this is an utterance," is imitated by substituting some nonsense syllable, such as [ma], for each syllable in the original utterance, i.e. "ma ma ma mamama."

Other studies have also validated the advantages of reiterant speech as a tool to examine prosody, particularly word and syllable durations, unconfounded by segmental influences since segmental influences on duration have been noted to be neutralized in reiterant speech (Larkey, 1983). As noted earlier, if reiterant speech is to be a useful tool in the study of prosody, it must also be demonstrated that it preserves the suprasegmental duration and intonation effects relevant to perception. Syllable durations for nonreiterant and reiterant ambiguous sentences were measured to evaluate the differences in duration which enable listeners to resolve structural ambiguities (Larkey, 1983). The perceptual study tested listeners' perception of ambiguous sentences as spoken by

four "good" speakers--speakers who neutralized intrinsic duration differences and whose sentences were independently rated by listeners as good imitations of normal speech. The listeners were able to choose the correct imitation when the ambiguous sentences were in reiterant form as well as they did when the sentences were spoke normally. These results support the notion that reiterant speech is like nonreiterant speech in aspects that are important to the study of prosody.

Part 4. Jaw movement and suprasegmental variation

Reiterant speech has been extensively used in studies which focus on articulatory gestures, specifically those investigating the jaw and tongue. In this section we present a review of studies focussing on what is known about jaw movement with emphasis on suprasegmental characteristics of speech. The use of reiterant speech provides advantages to studies whose goal is to model inter-relationships among the articulators in terms of dynamic task models by removing the "noise" of segmental information from the model.

Fowler (1979) argues that static experimental measurements in acoustics may be inappropriate for describing the natural, temporal structure of running speech since talking is a multidimensional process consisting of spatio-temporal overlap of the articulators. She notes that when segmental variation is minimized it is possible to identify relatively stable articulatory periodicity.

In theory, reiterant speech affords an analysis of articulator patterns by minimizing segmental variability while preserving the prosodic pattern thus providing the experimenter with the ability to measure movement of the

articulators (in this case the lips and jaw) that are consistently involved in the production of the nonsense syllable |ma|. This paper examined the movement of the lips and jaw in which the peaks and valleys denoted the high and low vertical position of the articulators. The peaks occur during the lip closure for the bilabial stop |m|. The valleys occur during production of the low vowel |a|. Velocity tracings were also examined.

The results are presented in terms of a control structure whose dynamic parameters may be described in terms of a mechanical mass spring model. The equilibrium (rest) position is the position at which the net force on the mass is 0 (zero). Linear stiffness is the reactive force per unit displacement and is a reflection of changes in rate.

The following section explores durational aspects of speech, with emphasis on studies of jaw movement. When applicable, contrasts between acoustic and mandibular duration will be reported on. However, it should be noted that several of the studies summarized here examine fundamental frequency patterns. These are noted although the distinction between F_0 contours and acoustic durations measured in this dissertation is recognized. We begin the

discussion with an overview of suprasegmental representations of speech and move on to experimental data.

Examination of phonologic patterns within and across languages demonstrates that suprasegmental aspects of an utterance, including phrasing and stress, can be specified without reference to the identity of the phoneme segment. Standard representations of rhythmic features remain controversial. Two devices have been proposed. One is the tree, which emphasizes the constituent organization of the stress feet and larger phrases. The other is the grid, which emphasizes the alternation of more stressed and less stressed syllables (Edwards & Beckman, 1988). Both devices describe speech rhythm independent of the associated phonemes.

However, this independence is not as clear at the level of phonetic representation. For example, F_0 is influenced by segmental identity. High vowels are associated with higher F_0 's than low vowels. Also, two syllables can present with different F_0 's as a function of their relative stress or distance from a phrase boundary. However, knowledge regarding the interactions among the two tiers can provide insight into rule-driven models of F_0 contours (Edwards & Beckman, 1988).

Independent segmental or suprasegmental levels of description have also been applied to the study of segment or syllable duration (Klatt, 1979). One of these effects is pronounced phrase-final lengthening accompanied by lower F_0 . Longer durations of stressed syllables relative to unstressed syllables is analogous to prosodically strong and weak pitch accents. "Intrinsic" durations of different segment types, high vowels being shorter in duration than low vowels, can be seen in the same light as segmental effects on F_0 . However, there are critical differences in parameterization of F_0 and duration models. Duration is always contextually modulated by something else in the utterance. In English, all suprasegmental effects refer to larger structural representations such as the stress patterns of syllables or the edges of phrases.

Van Summers (1987) looked at the time course of jaw position and first formant (F_1) values in syllables by varying the voicing the final consonant and in the stress pattern. Differences in the patterns were noted for the two effects. Stressed syllables, as compared to unstressed, presented with increased velocity, duration, and amplitude for both the opening and closing mandibular gestures. This was associated with longer, more rapid, and more extreme F_1 movement. Syllables ending in voiced obstruents were

produced with decreased velocity and decreased displacement for both opening and closing gestures. The effect was more pronounced in the closing gestures. This pattern of articulatory movement results in greater acoustic differences in the latter portion of the syllable. Final voiced obstruent syllables produce higher frequencies and briefer durations for F1 steady state portions.

One study explored the time-course of vowel-related opening and closing mandibular gestures in four different prosodic contexts (Edwards & Beckman, 1988). For intonation-phrase-final lengthening, longer acoustic durations were associated with a disproportionate lengthening of the latter part of the vocalic gesture. In contrast, the presence of nuclear stress was associated with a more even distribution of lengthening throughout the syllable. The authors conclude that the rhythmic effects of different prosodic contrasts can not be adequately described in terms of millisecond values or durational ratios for acoustic segments.

To summarize:

1. Information regarding suprasegmental factors operative in speechreading remains incomplete. Several possible sources of prosodic cues operative in speechreading may

be suggested, although this study will focus on those possibly ascribable to jaw movement. First, acoustic duration associated with stressed syllables tend to be longer than those for unstressed syllables (Fry, 1955; Klatt, 1976). It is possible that the temporal differences between stressed and unstressed syllables are visually discriminable as differences in the relative timing of jaw opening and closing, that is overall duration of jaw opening.

2. Second, the articulatory correlates of stressed syllables include greater displacement from the neutral position, longer duration, and higher peak velocities for jaw opening and closing gestures than unstressed syllables (Kelso et al., 1985; Summers, 1987). The larger jaw amplitudes for stressed syllable and the associated differences in duration and/or peak velocities for jaw opening and closing may provide suprasegmental information to the speechreader. This study will report on the variation in jaw height and duration in relation to stress.
3. Third, pausing and vowel lengthening is found at the boundaries of major syntactic phrases in speech (Cooper & Paccia-Cooper, 1980; Klatt, 1976). These effects could be visible in the ongoing pattern of jaw movement; brief

periods of facial "silence" may act as visual "punctuation marks" and provide important information regarding phrase boundaries to the speechreader. Intervals during which there is little relative change in jaw position may cue syntactic information to the speechreader.

This dissertation tests the typical devices which talkers may use to parse ambiguous sentences in order to convey the appropriate interpretation. As noted above, both acoustically defined segmental lengthening and pausing accompany major syntactic boundaries in speech (Klatt, 1975). These cues have been reported for alternative readings of structurally ambiguous sentences (Cooper & Paccia-Cooper, 1980; Klatt, 1976; Larkey, 1983; Lehiste, 1973a; Lehiste, Olive, & Streeter, 1976; O'Malley, Klover, & Dara-Abrams, 1973). Pausing is typically the more perceptible of the two but is reported to be more variable among speakers as measured acoustically (Cooper & Paccia-Cooper, 1980). At issue is whether similar differences are ascribable to the speechreader through interpretation in the pattern of jaw movement over time.

Chapter III.

Research Method

This dissertation reports on three experiments; a perceptual study, an acoustic study, and a study of jaw movement. Test materials for the main experiment consist of six productions of seven sets of syntactically ambiguous sentences and their reiterant counterparts as spoken by two talkers. For the perceptual study, subjects were asked to identify which version of the sentence was produced by the speaker in four conditions; audio-natural, audio-reiterant, visual-natural, and visual-reiterant. The acoustic and movement studies focus on the reiterant utterances. The acoustic study reports on measurements of syllable duration and pauses for phrases critical to disambiguation of the sentence. The movement study examines jaw displacement and its time derivatives for the opening and closing gestures of the key syllables. The main issue for this dissertation is whether perceptual discrimination of the syntactic contrast in question is associated with systematic differences in the pattern of jaw movement over time.

This study focuses on visual disambiguation of syntactic ambiguity through suprasegmental information. The purpose of the proposed study is to investigate the role of

the jaw in conveying suprasegmental information to the speechreader.

The **Pilot Study** contained in **Attachment 1** of **Appendix A** reports on a preliminary experiment to determine whether the stimuli are indeed identifiable in all four conditions for both talkers. The purpose of this test was to select a workable set of speech materials to use in the main experiment. The main experiment in which the selected set of stimuli are analyzed both acoustically and visually is described in this section.

Speech Materials

The primary interest here is the movement characteristics of a highly visible articulator in relation to observers' perception of sentence meaning. As described in Chapter 1, it is well documented that both segmental lengthening and pausing accompany major syntactic boundaries in speech. Therefore, aspects of the speaker's syntactic representation could be coded in the acoustic properties of the speech signal.

In order to evaluate syntactically determined speech-timing effects, one needs to control the extra-grammatical influences that could account for systematic durational differences. The use of structurally ambiguous sentences

circumvents influences involving phonetic structure of the material surrounding keyword segments. Ambiguous sentences contain identical word strings but have different phrase structures.

Seven pairs of ambiguous sentences and their reiterant imitations were selected as speech materials for this study. These sentences are listed in Table 1.4. Sentence type and predictions according to phrase structure are presented.

Speakers

Two talkers, one male and one female, both native New Yorkers, were selected to present the sentences. For each ambiguous pair, the speaker was given two cards, each with one annotated version of the ambiguous sentence. The specific instructions given to the speakers are documented in **Appendix B, Table IV**.

The reasons for the study were explained and the speaker was instructed to find a way to read the two sentences to convey the two different interpretations. They were asked to present each utterance in a conversational manner, and to avoid reading in a monotone. The speakers practiced saying each sentence until they were satisfied that they could say both interpretations in a fairly

natural way. Twelve repetitions of each sentence in the original version, separated by ten second pauses, were then recorded to audio-tape cassette by each talker.

Preparation of the Videotape

Using an insert earphone to monitor the audio tape recording of the "natural" sentences, the talker was then videotaped using a Panasonic WVD-5000 Digital camera. A twelve-to-one zoom lens (WV-LZ14/12A) captured a fullscreen image of the talker's face. Uniform and shadow-free lighting of the talker's face was provided by deflecting a 500 watt floodlight (Lowel Tota-Light TI-10) from each side, and one from above.

The camera and audio output was fed into a Sony VO-5800 U-matic SP videocassette recorder onto 3/4 inch Kodak tape (ESB-950, standard broadcast quality). The speech input was recorded through a Sennheiser uni-directional supercardioid microphone (K-3U with ME 40 Head) and passed through a Shure mixer (M-267) to insure a good quality audio signal. Use of the CUNY-TV sound studio assured superior quality audio and video.

The talkers were seated in a chair with a specially designed headrest adjusted to maintain a constant head position and to limit all superficial head movements.

A talker-to-lens distance of approximately 6 feet was employed to insure maximum contrast and project a life-size image on an 18 5/8 inch high resolution black-and-white monitor (Panasonic WV-5490). The image was centered on the monitor to provide head and neck-to-shoulder presentations. After repeating the natural version of the sentence, the talker was then instructed to replace each syllable in the sentence with the syllable /ma/, taking care to keep syllable number, rate, and degree of stress as close to the normal utterance as possible.

In this manner, the two talkers were videotaped as they spoke twelve repetitions of the normal sentence alternating with their reiterant counterparts. The twelve repetitions for each version were recorded in a block, rather than randomly interspersed among other sentences in the manner of Liberman and Streeter (1978). This strategy maximizes the likelihood of finding duration and jaw position differences between (a) and (b) versions, while minimizing superficial head movement within each block.

Preparation of the Video Laserdisc

Six out of the twelve repetitions videotaped were selected for dubbing to video laserdisc. A set was selected if the reiterant version of that repetition met the

criteria for "good" reiterant speech. That is, it was judged as a good imitation of the natural utterance by following the original closely in rate and stress and having the same number of syllables as the natural counterpart.

Instrumentation

Six repetitions of both versions of the seven test items were then dubbed to video laserdisc (Panasonic TQ-2027F) using the instrumentation depicted in Figure 2.3.

Advanced vertical sync was supplied by the timebase corrector (For-A Model FA-300) to the U-matic tape recorder (Sony VO-9800 U-matic SP) to provide a stable image and audio signal. The video levels were monitored on a video waveform monitor (Tektronix 1730) and vectorscope (Tektronix 1720) to insure standard NTSC parameters for video images. All necessary corrections of the luminance and chrominance aspects of the signal were accomplished using the video processing amplifier (Laird VC2000). The audio signal was passed through a high quality mixer (Shure M267) and recorded to a single channel on the laserdisc. The audio signal was monitored on an oscilloscope (Leader LBO-522) so that peak levels would not exceed 400 mv, the limits on the audio input of the laserdisc recorder.

Subjects in Perceptual Study

Twenty native speakers of American English served as subjects. None had participated in the pilot study. All subjects were normal hearing ($< 20\text{dB HL}$ at .25, .50, 1.0, 2.0, 4.0 and 8.0 Hz), and demonstrated a minimum of 20:20 corrected vision in both eyes as evaluated using a Snellen chart at a viewing distance of 20 feet in a darkened room.

Training

Instructions to the subjects were given orally and written in the **Informed Consent (Appendix B, Table I)**. The nature of reiterant speech productions was explained and examples were presented by the experimenter, first for the natural and then for the reiterant version of the sentence. Two response forms were used. Each response form was comprised of random presentations of six productions of the seven test sentences and their two interpretations, making a total of eighty-four items for each test run. Each subject participated in four runs for each speaker, eight test runs in all, using each form twice. Subjects were told that test sentences could appear more than once.

Task

Each test sentence was presented to the subject six times for each version in all four test conditions--audio-natural, audio-reiterant, visual-natural, and visual-reiterant. The order of presentation for the four conditions for each form was randomized for each subject and both talkers to reduce any sequencing or carry-over effects.

The audio signal was passed through a high quality audio mixer (Shure 270) and presented through standard audiometric headphones (TDH-49P) at a comfortable listening level selected by the subject. For the visual conditions, subjects were tested in a dimly lit room at a distance of about 6 feet from an 18 5/8 inch high resolution black and white monitor (Panasonic WV-5490).

Observers/listeners were asked to familiarize themselves with the different interpretations of each ambiguous pair. A set of six repetitions of both versions for the seven test sentences was presented to twenty subjects. At each presentation the subject indicated on the test form which version was being presented. At the end of each test condition, response sheets were collected and the subject rested several minutes before beginning the next

condition. Each test session consisted of no more than two runs. No information was given about the correct response.

Preparation and Measurement of the Acoustic Signal

Wideband spectrograms and waveforms were made of the reiterant utterances using the Kay DSP Model 5500. Segment boundaries of the /a/ portion in the /ma/ iterations are marked by the presence of the stop consonant /m/ on either side of the open vowel. Each segment boundary was identified acoustically as the time between transition from the closed portion /m/ through the open (/a/) phase to the closed (/m/) states of the vocal tract. Therefore, duration of segmental boundaries of the /a/ portion of /ma/ imitations in the syllables critical for disambiguation were noted from the low-amplitude voiced portion of the vowel to the onset of the stop.

Figures 3a and 3b present the waveform and spectrogram for each version of the reiterant phrase [HOW GOOD MEAT] as spoken by Talker LR.

Segments from syllables that are presumed to be critical to the disambiguation of the sentence are delimited. The individual measurement for each segment is indicated. The intent in Figure 3a is to convey the meaning that John has never tasted meat. The intent in Figure 3b is

to convey the meaning that John does not like meat. The segmental data were coded for syllable and version.

Measurement of Jaw Movement

The talker's image stored on video laserdisc (Panasonic TQ-2026F) was projected on a 22 inch black-and-white high-resolution monitor (Panasonic WV-5490). The start and end frames of the reiterant phrases critical to disambiguation were determined and documented. For these, vertical positions achieved by the jaw, and the frames at which these maximum and minimum displacements occur, were measured by hand by marking the distance between the tip of the chin and a fixed point on the bridge of the nose. This was accomplished using a transparent grid overlaid on the video monitor. In this manner, jaw height was measured at 30.3 msec intervals to the nearest tenth of a centimeter for the six productions of versions (a) and (b) for the reiterant utterances.

At this juncture, it should be mentioned that the precision of measurement for jaw amplitude is certainly not as accurate as the measurement of the acoustic signal. The sensitivity of the quantitative methods selected for this dissertation should provide reliable results in conclusions

regarding the roll of jaw height operative during the speechreading task.

To summarize, four measures of jaw movement were examined for syllables critical to the disambiguation of the sentence:

1. Duration

For the initial (opening) and final (closing) gestures, duration was measured as follows. For the initial opening) phase, duration was measured from the onset of jaw movement to the point of maximum displacement including any steady state period where jaw height remained constant. For the final (closing) phase, duration was measured as the time between the point of maximum inflection to the return to neutral position including any steady state period where jaw height remained constant in the neutral position.

2. Jaw amplitude

This was the maximum excursion achieved by the jaw in the opening and closing portions of the syllable. For the opening phase, the position of the jaw was tracked at 30.3 msec intervals to its maximum displacement from the neutral position. For the closing phase, the position of the jaw

was tracked from its point of maximum displacement to the highest point achieved before beginning its descent into the consonant /m/.

It should be noted here that the sensitivity of the measurements of jaw amplitude is less than that of the acoustic measures. This is due to the manual method in which height was measured across the screen of a monitor. It is also worth mentioning that jaw movement is describable across the dimension of forward thrust as well as amplitude. Three dimensional measures are not possible using a two dimensional screen in this experiment.

Analytic and Statistical Methods

This section discusses the analytic and statistical methods applied for each of the four experiments.

Experiment 1. Analysis of Structural Representations

The node height principle is defined and the sentences are analyzed by examination of the tree diagrams. Proceeding from the top-down, and, within each hierarchical level, from left-to-right, the phrase structure of each sentence is computed from the tree diagram. "Tree diagrams" are drawn. These depict the relationship between node

height for the key syllables for each version. Predictions based upon boundary "strength" are defined.

Comparisons among the structural representations are made to later determine whether similarities in constituent phrase structure are also reflected in the acoustic measurements, and which may account for the perceptual results.

Experiment 2. Perception Study

The main question for the perception study is whether subjects consistently identify each version presented at better than chance levels for each of the seven test sentences.

Experiment 2a. Analysis of Perceptual Scores using Binomial Exact Test

All scores in this experiment fall into two categories, version (a) or version (b). The binomial test informs whether the observed proportion of the two dependent categories is different from the proportion estimated by chance. The two proportions of the dependent categories must equal 100%.

This first part of the perception study was designed to determine objectively whether each of the two meanings

of each of the sentences was equally likely to be selected. The binomial test was applied to identify the 95% confidence intervals. The main question for this part of the dissertation is whether subjects are able to identify both forms of syntactically ambiguous sentences in all four conditions at greater than chance levels.

Experiment 2b. Descriptive Analysis of Perceptual results in Terms of Percent Correct Identification

The results of the perceptual study are summarized and described in terms of percent correct identification. By analyzing significant differences between talkers in relation to the acoustic and movement data associated with successful and unsuccessful reiterant utterances, factors important to subjects' identification could be revealed.

Experiment 3. Acoustic analysis of key segments in reiterant productions of syntactically ambiguous sentences

This experiment consists of two parts, a descriptive study and an analysis of variance. The following section discusses the methods used in each section.

Experiment 3a. Acoustic duration for key segments in relation to predictions made by the hierarchical principle

The acoustic measurements are presented and described in terms of the predictions derived from the structural representations and based upon the node height principle.

Experiment 3b. Analysis of variance of acoustic duration for key segments

The second part of this section presents the results of the Analysis of Variance of the acoustic duration data. The purpose here is to analyze the differences between the mean duration of the vowel portion corresponding to the key syllables. The analyses are generated independently for each syllable. The most significant F value reflects the greatest differences in mean duration between versions.

The Dependent Variable is Duration and the independent or Source Variable is Version. The Null Hypothesis being tested is that there is no difference in duration between version a and version b. Syllables critical to disambiguation should reflect larger F-Values and consequently be more significant in disambiguation of sentence type.

These results should be reflected in the perceptual study. This is the focal point of the perceptual study.

Experiment 4. Jaw movement correlates of syntactic contrasts

The model in this experiment compared the means for the four jaw variables, Jaw Duration and Jaw Displacement during opening and closing speech gestures (j1, j2, j3, j4), by version.

For the Manova portion of the test, several multivariate tests were performed. The analysis here is based upon a comparison of the results of the level of significance of the F-tests for the for the Wilks' Lambda as a test for the Null Hypothesis of no Overall Version Effect. A smaller Wilks' Value will present with a larger F and translates into a greater level of significance.

The statistical analysis in this dissertation uses the following methods. Each syllable is analyzed independently. The jaw movement means by version will first be described in comparison to each other. The results of the descriptive analysis will then be discussed in relation to the partial correlation coefficients from the error sums of squares and cross products matrices. The results of the F-test will be reported.

Finally, the syllables are compared by determining the smallest value of the Wilks' Lambda. This will identify the

vowel portion corresponding to the syllable critical to the disambiguation of the sentences. The results will be discussed in relation to predictions derived from the node height principle.

Chapter IV: Experiment 1.

Analysis of Structural Representations of Test Sentences

Intuitive listening reveals that perhaps the most readily perceptible effects in speech timing occur at major constituent boundaries. Duration is typically lengthened in clause-final position. The final segment may optionally be followed by a pause when occurring at the boundary between two major constituents. Pausing does not occur within a constituent (disregarding hesitation pauses that reflect wordfinding difficulty).

The basic question posed in this dissertation is whether there exists an organizing principle in the grammatical structure of the sentences tested that speakers are able to use to disambiguate between the two alternative meanings. If so, this principle should be present in both the audio and visual signal. Examination of the grammatical structure in a systematic fashion is the first step in addressing the issue posed by this dissertation. Each of the ambiguities tested involves a dominance relation between two constituents. Table 1.4 presents the seven sentences tested in this dissertation, sentence type, and

predictions made based upon the phrase structure of the sentence.

The timing effect studied here has been explained in terms of a **node height principle** that is shared by these ambiguities. This principle is stated below:

Node Height Principle

"...**Node Height Principle**. Given a structural ambiguity in which a Constituent Z is immediately dominated by one of two possible Constituent nodes X and Y in the structural representation, lengthen the segment(s) bordering Z when Z is immediately dominated by the higher of the two Constituent nodes X (Cooper, Paccia, & LaPointe (1978)..."

An important question here is what constitutes the difference between major and minor syntactic boundaries from the standpoint of their influence on speech properties? The following algorithm for determining boundary strength was applied (Cooper, & Paccia-Cooper, 1980) :

(see below)

Method for Determination of Phrase Structures

1. Diagram the structural representation of each version of the test sentences.
2. Compute the structural representation of the sentences tested from the "tree diagrams."
3. Locate the dominating nodes by finding the highest nodes that dominate the word to the immediate left or right of the key boundary but which do not dominate both of these words.
4. Determine whether the principle is applicable only to cases of immediate dominance or whether the effect is also noted in terms of relative node height.

In this section, the sentences are analyzed by analysis of tree diagrams. Proceeding from the top-down, and, within each hierarchical level, from left-to-right, the phrase structure of each sentence is computed from the

tree diagram. Predictions based upon boundary "strength" are defined. Comparisons among the structural representations are made to determine whether similarities in constituent phrase structure are also reflected in the acoustic measurements, and which may account for the perceptual results.

There are several types of ambiguities addressed by the sentences tested in this thesis. These are **Vocative versus Head Noun** (#1), **Adjective Modification** (#2), **Prepositional Phrase Modification** (#3), **Comparative Adverb Modification** (#4), **Prepositional Phrase Modification** (#6), and **Adverb Modification** (#5 and #7). According to the node height principle, certain predictions concerning acoustic timing effects of key segments can be made based upon the nature of the sentence's phrase structure. It will be interesting to compare the findings among sentences #3, and #6, as well as the findings for sentences #5 and #7 (**Adverb Modification**).

Timing effects produced for ambiguities in which the modifying constituent is immediately dominated by either the main S node or a lower node in the phrase structure representation are explored in the analysis of Sentence 1 and Sentence 5. This is seen in the tree diagrams by examining the point at which the node occurs.

Evaluation of Sentence 3 and Sentence 6 examines an ambiguity that involves constituent relations of dominance at a lower level in the syntactic structure than the main S'.

There is evidence that in addition to processing major constituents--such as clauses--as units, speakers appear able to compute representations of minor phrase nodes, such as that corresponding to [OLD MEN] tested in Sentence #2. These comparisons will be followed throughout the series of tests.

Analysis of Tree Diagrams and Phrase Structures

Table 1.4 documents the seven sentences, the sentence type, the two interpretations, and the predictions made based upon the node height principle. Figures 5 through 11 present the tree diagrams of these sentences. The upper figure depicts the speaker's intent to convey the version (a) interpretation of the ambiguity. The lower figure depicts the speaker's intent to convey the version (b) interpretation of the ambiguity.

Sentence 1. Vocative versus Head Noun

In this sentence, the proper name James can serve as a vocative, designating the person to whom the speech is directed (version (a)), or as a head noun in the noun phrase [THE FAMOUS DUKE JAMES] (version b). Figure 5.4 presents the structural representation of the syntax for this ambiguity.

The key words that determine the phrase boundary are [DUKE] and [JAMES]. Following the hierarchical principle, it is predicted that the keyword for delineation of the boundary is [DUKE]. It can be seen in the tree diagram and that the proper noun James is attached to a higher constituent (NP) in version (a) in which it functions as a vocative. The vowel portion corresponding to the /u/ in Duke should be longer in duration in version (a) due to phrase-final pre-pausal lengthening effects.

Additionally, lengthening effects should be present in version (a) for the vowel portion corresponding to the /djei/ in [JAMES] since it is attached to a higher constituent node as compared to version (b).

Sentence 2. Adjective Modification

In this sentence the ambiguity arises because the adjective [OLD] can modify either the noun [MEN] as in version (a), or the Noun Phrase "men and women" (b).

The key words that determine the phrase boundary are [OLD] and [MEN]. For the (a) reading [OLD] and [MEN] are immediately dominated by a Noun Phrase that dominates an additional Noun Phrase containing [MEN] [AND WOMEN] whereas in version (b), [OLD] and [MEN] are immediately dominated by the same noun phrase.

The adjective [OLD] modifies the Noun Phrase containing [MEN] [AND WOMEN] in version (a). It can be seen in the tree diagram (Figure 6.4) that [OLD] is dominated by a higher constituent in version (a). Therefore, we should predict a longer duration for the key vowel portion corresponding to [OLD] in version (a).

It is well documented that lengthening accompanies the ends of major phrases (Lehiste, 1973c). The Noun [MEN] marks the end of a Noun Phrase in version (b), whereas for version (a) [MEN] occurs in a non-final position. Lengthening should occur for the vowel portion corresponding to the key word [MEN] in (b) version.

Lengthening is often accompanied by the insertion of a pause. Although pauses may be important cues for the

speechreader, they appear to be more random in nature. Pauses were not analyzed here, since there is no analogy to them in the movement data.

Sentence 3. Prepositional Phrase Modification

This ambiguity involves constituent relations of dominance occurring at a lower level in the syntactic structure. The issue is to determine whether the effect can be discussed in terms of relative node height or in terms of immediate dominance.

In this sentence the ambiguity arises because the prepositional phrase [WITH A SMILE] can modify the Verb Phrase (version a) or the Noun Phrase (version b). For example, the prepositional phrase [WITH A SMILE] can designate the manner in which the hostess hostess greeted the girl [Verb Phrase modification]. It can also designate that the girl was smiling [Noun Phrase modification].

Examination of the tree diagram (Figure 7.4) for this sentence reveal that the boundary occurs at the vowel portion corresponding to [GREE...] in the word [GREETED]. Since the segment corresponding to the syllable [GREE...] is attached to equal node heights in both versions, we predict measurement of insignificant differences in acoustic duration.

It is predicted that the duration for the segment corresponding to the key word [GIRL] in version (a) will be longer in duration since the modifying phrase is attached to the entire Verb Phrase rather than the Noun Phrase (Cooper and Paccia-Cooper, 1978).

Sentence 4. Comparative Adverb Modification

The structural representation reveals that in the [a] reading of this sentence, the Comparative Adverb [HOW] is immediately dominated by a higher node than the *S* node which dominates the Noun Phrase of the constituents it modifies.

In the [b] version of this sentence, the comparative adverb [HOW] is immediately dominated by the same node as the Adverb and Noun Phrase it modifies, [GOOD MEAT].

The structural diagram (Figure 8.4) predicts that the acoustic duration of the vowel portions corresponding to the syllable [GOOD] should be longer in the [b] version since it is dominated by a higher node in this structure modifying the noun [MEAT] which is part of a lower NP. There should be insignificant differences between versions for the Noun [MEAT].

Early studies noted that listeners failed to identify the intended meanings for this sentence and yet assigned a confidence rating of 3 on a scale of 0 to 4 (Lehiste, 1973c). It was suggested that the instructions were not clear. Below is the relevant bracketing which could inform more on sentence structure.

John doesn't know [[[how] [good] [meat] [tastes.]]]

John doesn't know [[how] [[good meat]] [tastes.]]

Sentence 5. Adverb Modification

In this ambiguity, the adverb [NATURALLY] can modify either the entire sentence (version a) or the Verb Phrase (version b). The node height principle predicts that the duration of the segment corresponding to the Adverb [NA...] should be lengthened in version (a) in which the Adverb modifies the entire sentence. Additionally, the segment corresponding to the Noun "TROOP" should be longer in version (b) due to phrase-final pre-pausal effects.

Examination of the tree structure (Figure 9.4) reveals this.

Sentence 6. Prepositional Phrase Modification

As noted in the case of Sentence 3, this ambiguity involves constituent relations of dominance occurring at a lower level in the syntactic structure and so the analysis is similar. The issue is to determine whether the effect can be discussed in terms of relative node height or in terms of immediated dominance.

In this sentence the ambiguity arises because the prepositional phrase [WITH A STICK] can modify the Verb Phrase (version a) or the Noun Phrase (version b). For example, the prepositional phrase [WITH A STICK] can designate that Jeffrey held the stick [Verb Phrase modification]. It can also designate that the cop was holding the stick [Noun Phrase modification].

The approach to examine Prepositional Phrase Modification here is comparable to that used in testing Sentence 3. Examination of the tree diagram for this sentence (Figure 10.4) reveals that the boundary occurs at the word corresponding to [HIT]. The node height principle predicts that since the segment corresponding to the word [HIT] is attached to equal node heights in both versions, we predict negligible differences in measurements of acoustic duration.

It is predicted that the duration for the segment that corresponds to the key word [COP] in version (a) will be longer in duration since the modifying phrase is attached to the entire Verb Phrase rather than the Noun Phrase.

Sentence 7. Adverb Modification

In this sentence the ambiguity arises because the verb [IS] can modify the Verb Phrase (version a) or the entire sentence (version b).

The node height principle predicts that the duration of the segment corresponding to the Verb [IS] should be lengthened in version (b) in which it is attached to a higher constituent, the main S node, modifying the Sentence. This is revealed in the tree diagram (Figure 11.4)

The vowel portion corresponding to the syllable [MAR...] should be lengthened in the (b) version as it is attached to a higher constituent, the main S node of the sentence.

Chapter V: Experiment 2. Phrase boundary perception

Natural and reiterant speech: An auditory and visual study

The perceptual study is conducted to determine whether listeners/observers are able to correctly identify the intended interpretation of the ambiguous sentence in the normal and reiterant speech, in both the auditory and visual modalities. The main question posed here is whether the subjects are responding at better than chance level for each sentence for each version for each condition.

It is hypothesized that the relevant prosodic speech patterns are preserved and usable in the reiterant speech in both auditory and visual modes. Additionally, since suprasegmental information is available in the reiterant productions without conflicting segmental cues, it is predicted that listeners/observers should do better with the reiterant task.

Experiment 2a. Results of Binomial Exact Test

This first part of the perception study is designed to determine objectively whether each of the two meanings of each of the sentences is equally likely to be selected. To test whether the subjects were performing at chance or better than chance levels, the binomial exact test is applied to identify the 95% confidence intervals. The main question for this part of the dissertation is whether subjects are able to identify both forms of syntactically ambiguous sentences in all four conditions at greater than chance levels.

As stated, at each presentation the subject indicated on the test form that of two versions was being presented. Each correct identification was marked with a "1" and any incorrect selection was coded with a "0." By definition the response must assume one of two mutually exclusive outcomes. Each version was presented the same number of times during each run so that each choice allowed has an equal chance of being correct or incorrect. Therefore, the probability for the test was 50% correct and 50% incorrect, which could be achieved by guessing at all presentations ($p=.5$). The assumption is that there is an equal likelihood of both versions being selected.

Each version for the seven sentences was presented six times to twenty subjects for a total of 240 times in the series. The subjects' responses were evaluated as a group. By chance alone, 120 would be correct and 120 would be incorrect. The data for each talker were analyzed using the binomial exact test for each sentence and condition. The critical question is "Is the number of correctly identified versions out of 120 presentations significantly better than chance?" The null hypothesis states that the probability of being correct or incorrect is .5 ($p=0.5$).

Tables 2.5 through 9.5 document the 95% confidence intervals by sentence for each talker and condition. Figures 12.5 through 15.5 present the data graphically. For both talkers, the null hypothesis was rejected for all sentences and all conditions, at the .95 confidence interval. Both talkers scored at or above the .95 confidence interval for the auditory-normal condition.

Although performance was within the .95 confidence interval for the visual-natural condition, Talker JJ performed near chance for Sentence 2 version (b) at .6917, Sentence 3 version (a) at .6917, and Sentence 4 version (b) at .625. Talker LR also displayed performances near chance level with Sentence 1 version (a) at .4583 contrasting with version (b) at .9917. For Sentence 4 (b) Talker LR scored

.6833 and for Sentence 6 (a) he performed at .575, very close to chance levels. These issues are further analyzed in the discussion.

The visual-reiterant scores were more stable than the visual-natural mode with higher means in general. Talker JJ scored near chance at .6333 for Sentence 6 version (b). Talker LR showed a low score of .65 for Sentence 1 version (a). A comparison to the per cent correct scores for the cases that the subjects performed near chance according to the binomial confidence intervals will be presented in the **Discussion** section.

These several instances in which subjects performed near chance could be reflected in the movement data and will also be described in the **Discussion** section.

Experiment 2b. Descriptive Analysis of Perceptual Results in Terms of Percent Correct Identification

The results of the perceptual study are summarized and described in terms of percent correct identification. The results of this preliminary analysis do not inform on whether the dichotomous variable (version) was equally discriminable. That means that there is a 50-50 chance that the subject could identify the either version. Also, there is the possibility that one version **was not** equally identifiable as the other.

This issue provided the motivation to further explore the data by generating binomial confidence intervals. By analyzing those differences in the acoustic and movement data associated with successful and unsuccessful reiterant utterances, factors important to subjects' identification could be revealed. In summary, the main question for the perception study is whether subjects consistently identify each version presented at better than chance levels for each of the seven test sentences.

Tables 10.5 and 11.5 document the percent correct identification for each sentence set for each version and condition as spoken by each talker. Figures 16.5 though 22.5 present the data graphically.

As predicted, identification was greater in the visual-reiterant mode as compared to its natural analog. Viewers' discrimination of Sentence 1 for both talkers was variable across conditions. In all but one case, Talker LR, Sentence 4, subjects scored at or very near 100% correct identification in the audio-natural condition.

There was more of a range in performance in the audio-reiterant condition with subjects scoring at or near 90% correct identification to 100% correct identification with one exception, Talker LR sentence 4, both versions, a reflection of his performance in the audio-natural condition.

The overall pattern of discrimination was lowest for the visual-natural sentences. There was a significantly high degree of variability in viewers' scores in this condition. The median percent correct in the visual-reiterant condition ranged from 93% to 95% for both talkers as compared to 84% to 95% in the visual-natural condition.

Sentence 4 requires further analysis and comparison with the findings for Sentence 5. As previously noted, early studies reported that listeners failed to identify the intended meanings of Sentence 4 (John doesn't know how [GOOD] [MEAT] tastes) because the instructions were not clear in this case (Lehiste, 1973c).

Several interesting findings were noted in the current study in the visual-reiterant modality. First, in the case of Talker JJ, viewers consistently identified the ambiguity occurring in versions (a) and (b) of Sentence 4, 90 and 99.17 percent correct respectively. However, they were not consistent with correct identification in the case of Sentence 5, 80.83 and 63.33 percent correct.

There are contrasting findings in viewers' identification of the ambiguity presented in Sentence 4 by Talker LR, 82.5 and 74.17 percent correct scores. However, for Sentence 5, viewers scored consistently well for this talker, 93.33 and 99.17 for versions (a) and (b). This poses several issues that will be addressed at the end of the document in the Discussion section.

Finally, in the case of Talker JJ, surprisingly, the standard deviation for viewers' speechreading of the (b) version in the visual-reiterant condition was approximately double that of the (a) version for that condition and speaker. All other measures of variability appear constant, questioning the assumption of the true probability of each version being selected as being equal. Again, the binomial exact test demonstrated that each version was equally identifiable.

As hypothesized, listeners/viewers were able to make use of the salient prosodic speech patterns in both the audio and visual-only modes, with greater variability in the visual-reiterant modes. Talker LR demonstrated approximately twenty-five percent more variability than Talker JJ in the visual-natural modes. It is well-known that speaker differences do influence speechreader performance.

When discrimination is compared across sentences, it appears that although subjects' performance for both talkers in the audio condition was slightly better with presentation of the natural version of the sentences, this tendency is absent from the visual condition. For both talkers, subjects generally scored better in the visual-reiterant condition. Subjects were able to make more efficient use of the visible speech patterns in the absence of contextual cues. This occurrence was predicted since conflicting cues provided by production of individual segments could obscure the relevant prosodic speech patterns necessary for disambiguation by the speechreader.

Chapter VI: Experiment 3.

Acoustic Analysis of key segments in reiterant productions of syntactically ambiguous sentences

This section is discussed in two parts and presents the results for the **reiterant** utterances only. First, the descriptive data analysis is presented. The purpose of this section is to describe the data in terms of the predictions derived from analysis of the structural representations and rewrite rules. The second part of this section presents the results of the Analysis of Variance. The purpose here is to analyze the differences between the mean duration of the segments corresponding to the key words. Each segment was analyzed independently by speaker.

Experiment 3a. Acoustic duration for key segments in relation to predictions made by hierarchical principle

This section will discuss acoustic measurements of the reiterant /a/ segments in relation to predictions based upon sentence structure. Table 12.6 presents the means across six productions of each utterance, standard deviations, and standard errors of the acoustic duration measurements of the /a/ portions for each of the seven sentences for Talker JJ and LR.

Segment boundaries of the /a/ portion in the /ma/ iterations were marked by the presence of the stop consonant /m/ on either side of the open vowel. Each segment boundary was identified acoustically as the time between transition from the closed portion /m/ through the open (/a/) phase to the closed (/m/) states of the vocal tract. Therefore, duration of segmental boundaries of the /a/ portion of /ma/ imitations in the syllables critical for disambiguation were noted from the low-amplitude voiced portion of the vowel to the onset of the stop.

These results are in line with other reports of reiterant speech (Liberman & Streeter, 1978) which note the similar suprasegmental features between productions mimicing the same utterance. This is crucial since

differences in duration as little as 10 msec may provide cues to differentiate between segments and content. In the case of one speaker here, Talker JJ, the standard error for six repetitions is as little as 2.1 msec during production of the segment corresponding to the syllable [GOOD] in Sentence 4. For the second speaker, Talker LR, the minimum standard error is 2.4 msec, which occurs during the replications of the segment corresponding to the syllable [IS] in Sentence 5.

This first section will discuss acoustic measurements of duration for the /a/ portion of the /ma/ syllable in relation to predictions based upon sentence structure. The acoustic results for the seven sentences and both talkers are presented in Table 12.6 and are referred to in each section. The bar graphs illustrated in Figures 23 through 29 present the acoustic data for both Talkers. These are presented with asterisks (*) indicating level of significance of differences between versions obtained from the AVOVA. The effects presented in the ANOVA are discussed in Experiment 2b.

Sentence 1. Vocative versus Head Noun

In this sentence, the proper name James can serve as a vocative, designating the person to whom the speech is directed (version a), or as a head noun in the noun phrase [THE FAMOUS DUKE JAMES] (version b).

The key words that determine the phrase boundary are [DUKE] and [JAMES]. As seen in the tree diagram the proper noun James is attached to a higher constituent in the version in which it functions as a vocative, version (a). The hierarchical principle and application of the rewrite rules for Sentence 1 predicted that the duration for the segment corresponding to the keyword [JAMES] would be longer in version (a) in which it functions as a vocative, since it is attached to a higher constituent in the tree structure.

Acoustic measurements of duration were obtained for the vowel portions corresponding to the key syllables /du/ in [DUKE] and /djei/ in [JAMES]. Figure 23.6 is a bar graph presenting the acoustic means and standard deviations of the key syllables for Sentence 1 as spoken by Talker JJ and Talker LR.

For both talkers the duration of the key segment corresponding to the syllable /du/ is longer in the version a when the proper noun served as a vocative. In the case of

Talker JJ, the mean duration of the segment corresponding to the syllable /du/ is 295 msec in version (a) and 182.8 msec in version (b). In the case of Talker LR, the mean duration of the segment corresponding to the syllable /du/ is 188.8 msec in version (a) and 171.0 msec in version (b), a relatively small difference of 17.8 msec. The acoustic results for the syllable [DUKE] are in agreement with those documented in earlier studies (Cooper & Paccia-Cooper, 1980), with the difference between versions being greater in the case of Talker JJ. This finding is clearly visible in Figure 23.6.

Additionally, lengthening effects should be present in the version (a) for the vowel portion corresponding to the /djei/ in [JAMES] since it is attached to a higher constituent node as compared to version (b). This is consistent for Talker JJ but not for Talker LR. In the case of Talker JJ, the mean duration of the segment corresponding to the syllable /djei/ is 342.8 msec in version (a) and 299.2 msec in version (b). In the case of Talker LR, the mean duration of the segment corresponding to the syllable /djei/ is 278.8 msec in version (a) and 317.4 msec in version (b). For Talker LR the data for the syllable [JAMES] is in the opposite direction as predicted by the node height principle. This conflicting finding

between talkers for the syllable /djei/ is seen in Figure 23.6.

We should note the impact of two findings in the perception study and the analysis of variance. The first is the greater difference between versions for the vowel portion corresponding to the syllable [DUKE] as produced by Talker JJ. The second is the opposing direction in relation to the node height principle of Talker LR's productions of the vowel portion corresponding to the syllable [JAMES].

Sentence 2. Adjective Modification

The key words that determine the phrase boundary are [OLD] and [MEN]. It can be seen in both the tree diagram and rewrite rules that [OLD] is dominated by a higher constituent in version (a). Therefore, we should predict a longer duration for the vowel portion corresponding to [OLD] in version (a).

The Noun [MEN] marks the end of a Noun Phrase in version (b) whereas for version (a) [MEN] occurs in a non-final position. Lengthening should occur for the vowel portion corresponding to the key word [MEN] for version (b).

Acoustic measurements of duration were obtained for the vowel portions corresponding to the key syllables [OLD]

and [MEN]. Figure 24.6 presents a bar graph of the acoustic means and standard deviations of the key syllables for Sentence 2 as spoken by Talker JJ and Talker LR.

The findings for the segment corresponding to the syllable [OLD] were in agreement with the predictions in Talker JJ's production. Talker JJ demonstrated a mean duration of 227.6 msec for version (a) as compared to 138.8 msec for the version (b). This is not in accord with Talker LR who demonstrated a smaller difference in mean duration in the opposite direction. Talker LR presented with a mean duration of 160.4 msec for version (a) and 184.6 msec for the version (b).

The significant difference between versions as spoken by Talker JJ and the opposing direction of Talker LR's reiterant production of the syllable [OLD] is noted in Figure 24.6.

The Noun [MEN] marks the end of a Noun Phrase in version (b), whereas for version (a) [MEN] occurs in a non-final position. The Node Height Principle predicts that lengthening should occur for the vowel portion corresponding to the key word [MEN] for version (b). This prediction was consistent for both talkers, although much more pronounced for Talker JJ as can be seen in Figure 24.6. Talker JJ produced a mean acoustic duration of 142.7

msec for version (a) as compared to 348.4 msec for version (b). Talker LR produced a mean acoustic duration of 159.9 msec for version (a) as compared to 207.5 msec for version (b).

Sentence 3. Prepositional Phrase Modification

This ambiguity involves constituent relations of dominance occurring at a lower level in the syntactic structure. The issue is to determine whether the effect can be discussed in acoustic terms in connection to relative node height or in terms of immediate dominance.

In this sentence the ambiguity arises because the prepositional phrase [WITH A SMILE] can modify the Verb Phrase (version a) or the Noun Phrase (version b).

Examination of the tree diagram for this sentence revealed that the boundary occurs at the syllable corresponding to [GREE...] in the word [GREETED]. Since the segment corresponding to the syllable [GREE...] in this ambiguity is attached to equal relative node heights in both versions, we predicted measuring little difference in acoustic duration between versions. This was the case for both talkers.

Acoustic measurements of duration were made for the segments /a/ corresponding to the key syllables [GREE...] and

[GIRL]. Figure 25 presents a bar graph of the acoustic means and standard deviations of the key syllables for Sentence 3 as spoken by Talker JJ and Talker LR. As predicted, there were minimal differences between versions for the syllable [GREE...] for both talkers. Talker JJ presented with a mean duration of 109.6 msec for version (a) and 118.7 msec for version (b). Talker LR demonstrated even less difference between versions. He demonstrated a mean acoustic duration of 138.5 msec for version (a) and 133.6 msec for version (b). The slight differences between versions for the segment corresponding to [GREE...] is consistent between talkers and visible in Figure 25.

It was predicted that the duration for the segment corresponding to the key word [GIRL] in version (a) would be significantly longer in duration since the modifying phrase is attached to the entire Verb Phrase rather than the Noun Phrase. Again, both speakers demonstrated this effect.

Mean duration for the vowel portion is 258.9 msec for the version (a) as compared to 121.0 msec for version (b) as spoken by Talker JJ. Talker LR demonstrated similar effects. Mean duration for version (a) was 175.8 msec as compared to 111.8 msec for version (b). The findings of the

direction of duration is consistent for both speakers and is seen in Figure 25.

Sentence 4. Comparative Modification

The structural representation reveals that in version (a), the Comparative Adverb [HOW] is immediately dominated by a higher node than the string which dominates the Noun Phrase of the constituents it modifies.

In version (b), the comparative adverb [HOW] is immediately dominated by the same node as the Adverb and Noun Phrase it modifies, [GOOD] [MEAT].

The tree diagram predicts that the acoustic duration of the segment corresponding to the syllable [GOOD] should be longer in the version (b) since it is dominated by a higher node in this structure modifying the noun [MEAT] which is part of a lower NP. There should be insignificant differences between versions for the Noun [MEAT]. An additional effect predicted is that the acoustic duration of the segment corresponding to the syllable [GOOD] should be longer in version (b) as compared to version (a) due to the larger number of constituents that follow as part of the clause.

The findings are consistent with both talkers and in agreement with the Node Height principle. Acoustic

measurements of duration were obtained for the vowel portions corresponding to the key words [GOOD] and [MEAT]. Figure 26 presents a bar graph of the acoustic means and standard deviations of the key syllables for Sentence 4 as spoken by Talker JJ and LR.

The mean acoustic duration for version (a) corresponding to the word [GOOD] as produced by Talker JJ is 146.3 msec. For version (b) Talker JJ demonstrated a mean duration of 192.5 msec. Talker LR presented with a mean duration of 251.8 msec for version (b) as compared to 179.4 msec for version (a). The acoustic results for the first interpretation are consistent between talkers and the node height principle. The direction of the durational patterns is consistent between talkers for the segment corresponding to the syllable [GOOD] and is apparent in Figure 26.

The node height principle predicted that there should be insignificant differences in acoustic duration between versions for the segment corresponding to the word [MEAT]. This was again consistent for both talkers. Talker JJ demonstrated a mean acoustic duration of 176.6 msec for the version (a) and 174.5 msec for version (b). Talker LR presented with a mean acoustic duration of 191.4 msec for

version (a) and 201.0 msec for version (b). This pattern can be seen in Figure 26.

Sentence 5. Adverb Modification

In this ambiguity, the adverb [NATURALLY] can modify either the entire sentence (version a) or the Verb Phrase (version b).

The node height principle predicts that the duration of the segment corresponding to the Adverb [NA...] should be lengthened in version (a) in which the Adverb modifies the entire sentence. Additionally, the segment corresponding to the Noun [TROO...] should be longer in version (b) due to phrase-final pre-pausal effects.

Acoustic measurements of duration were obtained for the vowel portions corresponding to the key syllables [TROO...] in [TROO...] and [NA...] in [NATURALLY]. Figure 27.6 presents a bar graph of the acoustic means and standard deviations of the key syllables for Sentence 5 as spoken by

The node height principle was partially correct when applied here. Talker JJ produced a mean acoustic duration of 202.6 msec for version (a) of the segment corresponding to [TROO...] as compared to version (b), (192.4 msec) a small difference of 10.2 msec. Talker LR presented a mean acoustic duration of 199.7 msec for version (a) as compared

to 141.7 msec for version (b). This variation between speakers can be seen in Figure 27.6.

In the case of the segment corresponding to the syllable [NA...] in [NATURALLY] both talkers produced larger mean acoustic durations for version (a), although the differences were more pronounced for Talker LR and minimal for Talker JJ. Talker JJ's productions had a mean duration of 109.4 msec for version (a) as compared to 102.9 msec for version (b). As in the case of the syllable [TROO...], LR demonstrated greater differences for this utterance. He produced a mean acoustic duration of 171.9 msec for version (a) as compared to 82.0 msec for version (b).

We should see the effects of these differences in the perceptual results as well as the analysis of variance.

Sentence 6. Prepositional Phrase Modification

As noted in the discussion of Sentence 3, this ambiguity involves constituent relations of dominance occurring at a lower level in the syntactic structure. The issue is to determine whether the effect can be discussed in acoustic terms in connection to relative node height or in terms of immediate dominance.

In this sentence the ambiguity arises because the

prepositional phrase [WITH A STICK] can modify the Verb Phrase (version a) or the Noun Phrase (version b).

Examination of the tree diagram and rewrite rules for this sentence revealed that the boundary occurs at the segment corresponding to the word [HIT...]. Since the segment corresponding to the word [HIT] in this ambiguity is attached to equal relative node heights in both versions, we predicted seeing little difference in duration between versions as occurred in Sentence 3. This is the not the case in Sentence 6 *for both talkers and can most likely be explained by phrase boundary effects.*

Acoustic measurements of duration were made for the segments /a/ corresponding to the key words [HIT] and [COP]. Figure 28.6 presents a bar graph of the acoustic means and standard deviations of the key syllables for Sentence 6 as spoken by Talker JJ and LR.

There are significant differences in acoustic duration between version (a) and version (b), with version (b) being longer for both talkers. Talker JJ presented with a duration of 74.5 msec for version (a) and (262.5) msec for version (b). Talker LR presented a similar difference between versions. He produced a mean acoustic duration of 138.0 msec for version (a) and 283.8 msec for version (b). The significant difference between versions is consistent

between talkers. The consistent pattern in acoustic duration between speakers is clearly depicted in Figure 28.6. We should expect to see results of these large differences in the ANOVA for both talkers.

It was predicted that the duration for the segment corresponding to the key word [COP] in version (a) would be significantly longer in duration since the modifying phrase is attached to the entire Verb Phrase rather than the Noun Phrase. Again, this was demonstrated by both speakers, although the effect is more pronounced in the case of Talker JJ. Duration for the vowel portion is 236.0 msec for version (a) as compared to 124.0 msec for version (b) as spoken by Talker JJ. Talker LR demonstrated similar but smaller effects. Talker LR produced a mean acoustic duration of 153.0 msec for version (a) as compared to 138.8 msec for version (b).

Sentence 7. Adverb Modification

In this sentence the ambiguity arises because the verb [IS] can modify the Verb Phrase (version a) or the entire sentence (version b).

The node height principle predicts that the duration of the segment corresponding to the Verb [IS] should be lengthened in version (b) in which it is attached to a

higher constituent, the main S node, modifying the Sentence. In addition, the vowel portion corresponding to the syllable [MAR...] should be lengthened in version (b) as it is attached to a higher constituent, the main S node of the sentence.

Acoustic measurements of duration were made for the segments /a/ corresponding to the key word [IS] and syllable [MAR...]. Figure 29.6 presents a bar graph of the acoustic means and standard deviations of the key syllables for Sentence 7 as spoken by Talker JJ and LR.

The predictions derived from the node height principle proved partially correct in this sentence. Mean acoustic duration for the vowel portion corresponding to the word [IS] is longer for version (b) as produced by both talkers. Talker JJ presented a mean acoustic duration of 146.4 msec for version (a) as compared to 293.0 msec for version (b). Differences between versions were even greater for Talker LR who produced a mean acoustic duration of 99.2 msec for version (a) as compared to 439.1 msec for version (b).

These significant differences between versions and the similar direction of the durational pattern for both talkers are clearly seen in Figure 28.6 and should be apparent in the results of the analysis of variance.

There is less difference between versions for the

vowel portion corresponding to the syllable [MA...] in [MARRIED], although not in the direction predicted by the node height principle. Talker JJ presented a mean acoustic duration of 140.4 msec for both version (a) and version (b). Again, differences between versions were somewhat larger although far from significant for Talker LR. Talker LR produced a mean acoustic duration of 180.5 msec for version (a) as compared to 161.2 for version (b). Figure 29.6 clearly shows the slight differences in acoustic duration for the segment corresponding to the syllable [MAR...] for both talkers.

Experiment 3b. Analysis of variance of acoustic duration for key segments

The purpose here is to analyze the differences between the mean duration of the vowel portion corresponding to the key syllables. The analyses are generated independently for each syllable. The most significant F value reflects the greatest differences in mean duration between versions. The bar graphs presented earlier in the text depict these differences.

The Dependent Variable is Duration and the Independent Variable (Source Variable) is Version. The Null Hypothesis being tested is that there is no difference in Duration between Versions.

These results should be reflected in the perceptual study. This is one of the focal points of the perceptual study.

This part of the study looks at the relationship in duration between versions of the reiterant utterances in the acoustic modality. It is hypothesized that systematic differences in segmental duration due to syntactic intent of the speaker should occur in the critical syllables distinguishing the two versions and that reiterant speech

preserves the particular pattern of differences in duration found in the normal ambiguous version.

The comparison between the version (a) and version (b) interpretations will be presented in the Discussion section to determine whether the syntactic contrast in question resulted in qualitatively similar segmental duration effects for the two reiterant versions in the audio and visual modality across similar sentence types and speakers. Duration of pauses, although recognized as one important concomitant effect of the speaker's intent to mark syntactic boundaries, were not analyzed in this study, since their analogue does not exist in the movement data.

Each segment corresponding to a key syllable was analyzed independently by analysis of variance and will be discussed separately. The asterisk (*) on the accompanying Table and Figure denotes one or two levels of significance as determined by the analysis of variance.

Sentence 1: Here is the famous [DUKE] [JAMES].

- a. James meets the Duke.
- b. The name of the Duke is James.

As noted in the analysis of the structural diagrams and rewrite rules, the key words that determine the phrase boundary are [DUKE] and [JAMES]. Following the hierarchical principle, it is predicted that the keyword for delineation of the boundary is [DUKE].

Vowel portion corresponding to syllable [DUKE]

We reported that for both talkers the duration of the key segment corresponding to the syllable /du/ is longer in version (a) when the proper noun served as a vocative. However, in the case of Talker JJ, the mean duration of the vowel portion corresponding to the syllable /du/ is 295 msec in the version (a) and 182.8 msec in version (b). In the case of Talker LR, the mean duration of the segment corresponding to the syllable /du/ is 188.8 msec in version (a) and 171.0 msec in version (b), a relatively small difference of 17.8 msec as compared to the results of Talker JJ. We should see the results of the duration effects in the analysis of variance.

Table 13.6 presents the analysis of variance for the

acoustic duration of the vowel portion for Sentence 1 for Talker JJ and Talker LR and both syllables.

We will first examine the results in relation to the syllable [DUKE]. Results of the analysis of variance for the vowel portion corresponding to the syllable [DUKE] for Sentence 1 reveal significant effects on vowel portion Duration with Version as the Source variable for Talker JJ. The F-value for Talker JJ for the effect of Version for the syllable [DUKE] is 165.72 ($df=1,10$, $Pr > F = 0.0001$). For Talker JJ we reject the Null Hypothesis of no difference between Versions. This high level of significance can be accounted for by the large differences in acoustic duration between versions.

The effects were borderline significant for Talker LR. The F-value for Talker LR for the effect of Version for the syllable [DUKE] is 4.78 ($df=1,10$, $Pr > F = 0.0537$). For Talker LR we reject the Null Hypothesis of no difference between versions. We can account for the relatively small level of significance by the minimal differences in acoustic duration between versions.

The source of these effects can be visualized in Figure 23.6, the bar graph that depicts the acoustic means and standard spoken by Talker JJ and Talker LR. It is clear that there are significant differences between versions for

the vowel portion corresponding to the syllable [DUKE] as spoken by Talker JJ. The difference in acoustic duration between versions is minor as produced by Talker LR.

In summary, the effects of version on the vowel portion corresponding to the syllable [DUKE] were highly significant for Talker JJ, but borderline significant for Talker LR.

Vowel portion corresponding to syllable [JAMES]

Results of the analysis of variance for the vowel portion corresponding to the syllable [JAMES] in Sentence 1 reveal significant effects on vowel portion Duration with Version as the Source variable for both talkers. As noted earlier, the effects can be visualized in Figure 23.6, the bar graph that depicts the acoustic means and standard deviations of the key syllables for Sentence 1 as spoken by Talker JJ and Talker LR. We will now examine the results of the analysis of variance for the vowel portion corresponding to the syllable [djei] in [JAMES] presented in Table 13.6.

The F-value for Talker JJ for the effect of Version for the segment corresponding to the syllable [JAMES] is 18.85 ($df=1,10$, $Pr > F = 0.0015$). The F-value for Talker LR for the effect of Version for the segment corresponding to

the syllable [JAMES] is 12.47 ($df=1,10$, $Pr > F = 0.0054$). For both Talker JJ and Talker LR we therefore reject the Null Hypothesis of no difference in Duration between Versions.

We reported that for Talker LR the data for the syllable [JAMES] is in the opposite direction as predicted by the node height principle. This conflicting finding between talkers for the syllable /djei/ is seen in Figure 11.4 and could have impact on the perceptual study for Sentence 1.

Summary

In conclusion, following the hierarchical principle, it was predicted that the keyword for delineation of the boundary is [DUKE]. The results of analysis of variance reveal that for Talker JJ the vowel portion corresponding to the syllable [DUKE] was highly significant. The hierarchical principle of dominance supports this finding.

However, these results are not in agreement with those of Talker LR. For Talker LR the results of analysis of variance reveal that there was borderline significance Duration due to Version in the vowel portion corresponding to the syllable [DUKE]. In addition, the results test significant for the vowel portion corresponding to the

syllable [JAMES] for Talker LR but the direction of the durational pattern between versions conflicts with the results of Talker JJ.

It is interesting to note that despite the differences, the ambiguities were perceptually discriminable to listeners and disambiguated somewhat successfully as evident in the binomial tests. This suggests the implication of other strategies not measured in this experiment, such as fundamental frequency or pause duration as possible cues for disambiguation for this sentence.

In conclusion, the results obtained for Sentence 1 should have impact on the results of the perceptual study. These will be discussed in a later section.

Sentence 2: The [OLD] [MEN] and women stayed at home.

- a. The old people stayed at home.
- b. The old men and all the women stayed at home.

The key words that determine the phrase boundary are [OLD] and [MEN]. For the version (a) [OLD] and [MEN] are immediately dominated by a Noun Phrase that dominates an additional Noun Phrase containing [MEN] [AND WOMEN] whereas

in version (b), [OLD] and [MEN] are immediately dominated by the same noun phrase.

Independent of the phrase analysis, the tree structure identifies differences in node height for the key syllables [OLD] and [MEN]. These variations should be apparent in the differences in the Source variable in the analysis of variance. The adjective [OLD] is part of a NP that is dominated by a single NP in both Version (a) and (b). The Noun [MEN] in both the tree diagram and rewrite rules is part of a NP that is dominated by a NP dominated by another NP in Version (a). However, in Version (b) the Noun [MEN] is in the phrase-final position of a NP dominated by a single NP.

It is well documented that lengthening accompanies the ends of major phrases (Lehiste, 1973c). The Noun [MEN] marks the end of a Noun Phrase in version (b), whereas for version (a) [MEN] occurs in a non-final position. Therefore, we should predict critical differences occurring in the Dependent Variable, Duration, for the key vowel portion corresponding to [MEN] evident in the analyses of variance due to the Source variable, Version. The asterisk (*) on the accompanying Figure 23.6 denotes one or two levels of significance as determined by the analysis of variance.

Vowel portion corresponding to syllable [OLD]

Results of the analysis of variance for the vowel portion corresponding to the syllable [OLD] for Sentence 2 reveal significant effects on vowel portion Duration with Version as the Source variable for both Talkers.

Table 14.6 presents the results of the analysis of variance for acoustic duration of the vowel portion for Sentence 2 for both Talker JJ and Talker LR.

We will first examine the results in relation to the syllable [OLD]. The findings for the segment corresponding to the syllable [OLD] are in agreement with the node height predictions and the significant differences in mean acoustic durations between versions for this segment as produced by Talker JJ. Figure 24.6 clearly depicts these differences. We reported that Talker JJ demonstrated a mean duration of 227.6 msec for the version (a) as compared to 184.6 msec for version (b). The F-value for Talker JJ for the effect of Version is 52.29 ($df=1,10$, $Pr > F = 0.0001$). For Talker JJ we reject the Null Hypothesis of no difference between Versions.

We reported that Talker LR presented with a mean duration of 160.4 msec for version (a) and 184.6 msec for

the version (b), a less prominent difference between versions as compared to Talker JJ. The durational pattern is also in the opposite direction as compared to Talker JJ. This can be seen in Figure 23.6. The F-value for Talker LR for the effect of Version is 9.34 ($df=1,10$, $Pr > F = 0.0121$). For Talker LR we also reject the Null Hypothesis of no difference between Versions.

In summary, the effects of version on the vowel portion corresponding to the syllable [OLD] were highly significant for Talker JJ, and significant to a lesser degree for Talker LR. The significant difference between versions as spoken by Talker JJ and the opposing direction of Talker LR's reiterant production of the syllable [OLD] is depicted in Figure 24.6.

Vowel portion corresponding to syllable [MEN]

The Node Height Principle predicts that lengthening should occur for the vowel portion corresponding to the key word [MEN] for version (b). We reported that this prediction was consistent for both talkers, although much more pronounced for Talker JJ as can be seen in Figure 24.6.

The effects are apparent in the analysis of variance as well. Results of the analysis of variance for the vowel

portion corresponding to the syllable [MEN] for Sentence 2 reveal highly significant effects on vowel portion Duration with Version as the Source variable for both Talkers. Table 4 presents the results for the syllable [OLD].

We reported that Talker JJ produced a mean acoustic duration of 142.7 msec for version (a) as compared to 348.4 msec for the version (b). The F-value for Talker JJ for the effect of Version is 1197.5 ($df=1,10$, $Pr > F = 0.0001$). For Talker JJ we reject the Null Hypothesis of no difference between Versions. The source of the high level of significance is the difference between versions, and is clearly seen in Figure 24.6.

Talker LR produced a mean acoustic duration of 159.9 msec for version (a) as compared to 207.5 msec for version (b). The F-value for Talker LR for the effect of Version is 41.41 ($df=1,10$, $Pr > F = 0.0001$). For Talker LR we also reject the Null Hypothesis of no difference between between Versions. Again, the level of significance can be accounted for by the difference between versions and may be seen in Figure 24.6.

To summarize, results of the analysis of variance for the vowel portion corresponding to the syllable [MEN] for Sentence 2 reveal highly significant effects on vowel portion Duration with Version as the Source variable for

both Talkers. The direction of the durational pattern is the same. We would predict similar effects in the jaw movement data.

Sentence 3: The hostess [GREE]ted the [GIRL] with a smile.

a. The hostess was smiling

b. The girl was smiling.

As presented in analysis of the structural diagrams, the issue here is to determine whether the effect can be discussed in terms of relative node height or in terms of immediate dominance. In this sentence the ambiguity arises because the prepositional phrase [WITH A SMILE] can modify the Verb Phrase (version a) or the Noun Phrase (version b).

The asterisk (*) on the accompanying Figure 25 denotes one or two levels of significance as determined by the analysis of variance.

Vowel portion corresponding to syllable [GREE...]

Since the segment corresponding to the syllable [GREE...] in this ambiguity is attached to equal relative node heights in both versions, we predicted measuring little difference in acoustic duration between versions and therefore relatively small differences in the Dependent

Variable, Duration, due to the Source variable. This proved to be the case with both talkers demonstrating insignificant findings.

Table 15.6 presents the results of the analysis of variance for acoustic duration of the vowel portion for Sentence 3 for both Talker JJ and Talker LR and both syllables.

Results of the analysis of variance for the vowel portion corresponding to the syllable [GREE...] for Sentence 3 reveal relatively small effects on vowel portion Duration with Version as the Source variable for both Talkers.

We reported that Talker JJ presented with a mean duration of 109.6 msec for the first version (a) and 118.7 msec for the version (b). Figure 25 displays the small difference between versions for this syllable. The F-value for Talker JJ for the effect of Version is 5.58 ($df=1,10$, $Pr > F = 0.0398$), significant when tested at the .05 level. For Talker JJ we reject the Null Hypothesis of no difference between Versions.

We noted that Talker LR demonstrated even less difference between versions. He demonstrated a mean acoustic duration of 138.5 msec for version (a) and 133.6 msec for version (b). Figure 25 depicts the slight difference between versions. The F-value for Talker LR for

the effect of Version is 0.39 (df=1,10, $Pr > F = 0.5463$). For Talker LR we fail to reject the Null Hypothesis of no difference between Versions.

In summary, the results of the analysis of variance for the vowel portion corresponding to the syllable [GREE...] are in agreement with the predictions made by the node height principle for Talker LR. The results for Talker JJ are not.

Vowel portion corresponding to syllable [GIRL]

It was predicted that the duration for the segment corresponding to the key word [GIRL] in version (a) would be significantly longer in duration since the modifying phrase is attached to the entire Verb Phrase rather than the Noun Phrase. Both speakers demonstrated this finding.

We reported that the mean duration for the vowel portion is 258.9 msec for the first interpretation version (a) as compared to 121.0 msec for version (b) as spoken by Talker JJ. Mean duration for version (a) is 175.8 msec as compared to 111.8 msec for version (b) as spoken by Talker LR.

Results of the analysis of variance for the vowel portion corresponding to the syllable [GIRL] for Sentence 3 reveal highly significant effects on vowel portion Duration

with Version as the Source variable for both Talkers. Table 5 presents the results of the analysis of variance. The F-value for Talker JJ for the effect of Version is 230.78 ($df=1,10$, $Pr > F = 0.0001$). For Talker JJ we reject the Null Hypothesis of no difference between Versions. The source of the high level of significance, the large difference between versions, can be seen in Figure 25.

The F-value for Talker LR for the effect of Version is 133.67 ($df=1,10$, $Pr > F = 0.0001$). For Talker LR we also reject the Null Hypothesis of no difference between Versions. Again, the source of the high level of significance, the large difference between versions, can be seen in Figure 25.

To summarize, results of the analysis of variance for the vowel portion corresponding to the syllable [GIRL] for Sentence 3 reveal highly significant effects on vowel portion Duration with Version as the Source variable for both Talkers.

Sentence 4: John doesn't know how [GOOD] [MEAT] tastes.

- a. John has never tasted good meat.
- b. John doesn't like meat.

A review of the structural representation reveal that in version [a] of this sentence, the Adjective [GOOD] and the Noun [MEAT] are part of a NP phrase which is dominated by a *S* node dominated by a *S* node and finally dominated by the Sentence *S* node.

In version (b) of this sentence, the Adverb [GOOD] and the Noun [MEAT] are part of a VP that is immediately dominated by the *S* node dominated by the Sentence *S'* Node.

The tree structure predicts that the acoustic duration of the vowel portions corresponding to the syllable [GOOD] should be longer in the [b] version since it is dominated by a higher node in this structure modifying the noun [MEAT] which is part of a lower NP. There should be insignificant differences between versions for the Noun [MEAT]. This was found to be the case in the acoustic study and should be reflected in the Analysis of Variance for this sentence. The asterisk (*) on the accompanying Figure 26 denotes one or two levels of significance as determined by the analysis of variance.

Illustrations 3(a) and 3(b) are spectrographs of a single production of the phrase [HOW GOOD MEAT] as spoken by Talker LR. The vowel portion is delineated for the /a/ of the /ma/ syllables critical for disambiguation. Note that for version (a) there is a a greater difference in

duration for the vowel portion corresponding to the syllable [GOOD].

Vowel portion corresponding to syllable [GOOD]

It was predicted that the duration for the segment corresponding to the key syllable [GOOD] in the version (b) would be longer in duration since it is part of a VP that is immediately dominated by a S node dominated by the Sentence S Node. These findings should be apparent in the ANOVA as differences in the Dependent Variable, Duration, due to the Source Variable, Version. However, this was not the case for both talkers.

We reported that the mean acoustic duration for the version (a) corresponding to the word [GOOD] as produced by Talker JJ is 146.3 msec. For version (b) Talker JJ demonstrated a mean duration of 192.5 msec. Talker LR presented with a mean duration of 251.8 msec for version (b) as compared to 179.4 msec for the (a) version. The acoustic results for the first interpretation are consistent between both Talkers and the node height principle. We noted that the direction of the durational patterns is consistent between talkers for the segment corresponding to the syllable [GOOD] and is apparent in Figure 25. We should find evidence in the anova of the

effects of the difference in duration between versions as produced by both talkers.

Table 16.6 presents the analysis of variance for the acoustic duration of the vowel portion for Sentence 4 for Talker JJ and Talker LR and both syllables.

Results of the analysis of variance for the vowel portion corresponding to the syllable [GOOD] for Sentence 4 reveal no effect on vowel portion Duration with Version as the Source variable for Talker JJ. The F-value for Talker JJ for the effect of Version is 2.43 ($df=1,10$, $Pr > F = 0.1502$). For Talker JJ we fail to reject the Null Hypothesis of no difference between Versions. However, the F-value for Talker LR for the effect of Version is 170.01 and highly significant ($df=1,10$, $Pr > F = 0.0001$). For Talker LR we reject the Null Hypothesis of no Hypothesis of no difference between Versions.

Vowel portion corresponding to syllable [MEAT]

As noted, the node height principle predicted that there should be no effect on the Dependent Variable, Duration, due to the Source Variable, Version. We therefore expect to see no significant effects on the Dependent Variable, Duration, as a result of the Source Variable, Version. This proved to be the case.

Results of the analysis of variance for the vowel portion corresponding to the syllable [MEAT] for Sentence 4 presented in Table 16.6 reveal no significant effects on vowel portion Duration with Version as the Source variable for both Talkers. The F-value for Talker JJ for the effect of Version is 0.03 ($df=1,10$, $Pr > F = 0.8761$). For Talker JJ we fail to reject the Null Hypothesis of no difference between Versions. The F-value for Talker LR for the effect of Version is 1.14 ($df=1,10$, $Pr > F = 0.3113$). For Talker LR we also fail to reject the Null Hypothesis of no difference between Versions.

In summary, the results for this sentence vary in relation to predictions made by the node height principle between the two talkers. The results for the vowel portion corresponding to the syllable [GOOD] are significant for Talker LR and align to the node height principle. This was not the case for Talker JJ.

In terms of the vowel portion corresponding to the syllable [MEAT] both talkers demonstrated findings in agreement with the node height principle. This sentence presents surprising findings when analyzed in relation to the results of the perceptual study.

Sentence 5: Lt. Baker instructed his [TROO]P [NA]turally.

- a. Of course, Lt. Baker instructed his troop.
- b. Lt. Baker instructed his troop in a natural way.

The node height principle predicts that the duration of the segment corresponding to the syllable [NA...] should be lengthened in version (a) in which the Adverb modifies the entire sentence. Additionally, the segment corresponding to the Noun [TROO...] should be longer in version (b) due to phrase-final pre-pausal effects.

Results of the analysis of variance for Sentence 5 reveal different effects on vowel portion duration for both talkers for both syllables. The asterisk (*) on the accompanying Figure 27.6 denotes one or two levels of significance as determined by the analysis of variance.

Vowel portion corresponding to syllable [TROOP]

We reported that the node height principle was partially correct when applied to the acoustic analysis here. Talker JJ produced a mean acoustic duration of 202.6 msec for version (a) of the segment corresponding to [TROO...] as compared to version (b), 192.4 msec, a small difference of 10.2 msec. Talker LR presented a mean acoustic duration of 199.7 msec for version (a) as compared to 141.7 msec for version (b). This variation between

speakers is presented in Figure 27.6. We should see comparable effects in the results of the analysis of variance.

Table 17.6 presents the analysis of variance for the acoustic duration of the vowel portion for Sentence 5 for Talker JJ and Talker LR and both syllables.

Results of the analysis of variance for the vowel portion corresponding to the syllable [TROOP] for Sentence 5 reveal no significant effects on vowel portion Duration with Version as the Source variable for Talker JJ, although the results were significant for Talker LR. The F-value for Talker JJ for the effect of Version is 0.53 ($df=1,10$, $Pr > F = 0.4826$). For Talker JJ we fail to reject the Null Hypothesis of no difference between Versions. These results can be accounted for by the small differences between versions as produced by Talker JJ. In comparison, the F-value for Talker LR for the effect of Version is 41.18 ($df=1,10$, $Pr > F = 0.0001$). For Talker LR we therefore reject the Null Hypothesis.

In summary, the effects of version on the vowel portion corresponding to the syllable [TROOP] were highly significant for Talker LR, but not significant for Talker JJ. This effect may be accounted for by the significant differences in acoustic duration between versions as

produced by Talker LR, in comparison to the small differences produced by Talker JJ.

We should see the impact of these findings in the perceptual study.

Vowel portion corresponding to syllable [NA...]

We reported that in the case of the segment corresponding to the syllable [NA...] in [NATURALLY] both talkers produced larger mean acoustic durations for the first interpretation (version a), although the differences were more pronounced for Talker LR and minimal for Talker JJ. Talker JJ's productions had a mean duration of 109.4 msec for the first interpretation as compared to 102.9 msec for the second. As in the case of the syllable [TROO...], LR demonstrated greater differences for this utterance. Talker LR produced a mean acoustic duration of 171.9 msec for version (a) as compared to 82.0 msec for version (b). We should note the impact of these differences between talkers in the analysis of variance.

Table 17.6 presents the results of the analysis of variance of the second syllable analyzed for this sentence. Results of the analysis of variance for the vowel portion corresponding to the syllable [NA...] in Sentence 5 reveal no significant effects on vowel portion Duration with

Version as the Source variable for Talker JJ. The F-value for Talker JJ for the effect of Version is 1.86 ($df=1,10$, $Pr > F = 0.2027$). For Talker JJ we fail to reject the Null Hypothesis of no difference in Duration between Versions. This may be accounted for by the minimal differences in acoustic duration, approximately 7 msec, between versions as produced by this Talker JJ.

There were highly significant effects on the vowel portion Duration with Version as the Source variable for Talker LR. The F-value for Talker LR for the effect of Version is 333.62 ($df=1,10$, $Pr > F = 0.0001$). This result may be accounted for by the large differences in acoustic durations between versions as produced by Talker LR. We therefore reject the Null Hypothesis of no difference in Duration between Versions for Talker LR.

We should note the impact of negative findings for Talker JJ in the perceptual study.

Sentence 6: Jeffrey [HIT] the [COP] with a stick.

- a. Jeffrey had the stick.
- b. The cop had the stick.

As noted in the discussion of Sentence 3, this ambiguity involves constituent relations of dominance

occurring at a lower level in the syntactic structure. The issue is to determine whether the effect can be discussed in acoustic terms in connection to relative node height or in terms of immediate dominance. In this sentence the ambiguity arises because the prepositional phrase [WITH A STICK] can modify the Verb Phrase (version a) or the Noun Phrase (version b).

Examination of the tree diagram for this sentence revealed that the boundary occurs at the segment corresponding to the word [HIT]. Since the segment corresponding to the word [HIT] in this ambiguity is attached to equal relative node heights in both versions, we predicted seeing little difference in duration between versions as occurred in Sentence 3. We saw this is the not the case in Sentence 6 *for both talkers*. These results should be reflected in the analysis of variance.

The asterisk (*) on the accompanying Figure 28.6 denotes one or two levels of significance as determined by the analysis of variance.

Vowel portion corresponding to syllable [HIT]

Since the vowel corresponding to the syllable [HIT] in this ambiguity is attached to equal relative node heights in both versions, we predicted measuring little difference

in acoustic duration between versions and therefore relatively small differences in the Dependent Variable, Duration, due to the Source variable. This proved not to be the case with both talkers demonstrating highly significant findings.

There are significant differences in acoustic duration between the version (a) and version (b), with version (b) being longer for both talkers. Talker JJ presented with a duration of 74.5 msec for version (a) and (262.5) msec for version (b). Talker LR presented a similar difference between versions. He produced a mean acoustic duration of 138.0 msec for version (a) and 283.8 msec for version (b). The significant difference between versions is found to be consistent between talkers and is clearly depicted in Figure 28.6.

Table 18.6 presents the analysis of variance for the acoustic duration of the vowel portion for Sentence 6 for Talker JJ and Talker LR and both syllables.

Results of the analysis of variance for the vowel portion corresponding to the syllable [HIT] for Sentence 6 reveal highly significant effects on vowel portion Duration with Version as the Source variable for both Talkers. The F-value for Talker JJ for the effect of Version is 305.05

(df=1,10, $Pr > F = 0.0001$). For Talker JJ we reject the Null Hypothesis of no difference between Versions.

The F-value for Talker LR for the effect of Version is 94,77 (df=1,10, $Pr > F = 0.0001$). For Talker LR we also reject the Null Hypothesis of no difference between Versions.

The impact of the significant differences in acoustic duration between versions as produced by both Talkers may account for the results demonstrated in the analysis of variance.

Vowel portion corresponding to syllable [COP]

It was predicted that the duration for the segment corresponding to the key word [COP] in version (a) would be significantly longer in duration since the modifying phrase is attached to the entire Verb Phrase rather than the Noun Phrase. We reported that both speakers demonstrated this finding. Duration for the vowel portion is 236.0 msec for version (a) as compared to 124.0 msec for version (b) as spoken by Talker JJ. We noted that Talker LR demonstrated similar but smaller effects. Talker LR produced a mean acoustic duration of 153.0 msec for version (a) as compared to 138.8 msec for version (b). This difference should be reflected in the analysis of variance.

Table 18.6 presents the findings. Results of the analysis of variance for the vowel portion corresponding to the syllable [COP] for Sentence 6 reveal highly significant effects on vowel portion Duration with Version as the Source variable for Talker JJ. The F-value for Talker JJ for the effect of Version is 121.02 ($df=1,10$, $Pr > F = 0.0001$). These may be accounted for by the differences in acoustic duration between versions as produced by this talker. For Talker JJ we reject the Null Hypothesis of no difference between Versions.

The F-value for Talker LR for the effect of Version is 4.94 ($df=1,10$, $Pr > F = 0.0505$). For Talker LR we also reject the Null Hypothesis of no difference between Versions, although the effects of Version are not nearly as significant as they are in the case of Talker JJ. This may be accounted for by the smaller variation in acoustic duration between versions as produced by Talker LR.

Sentence 7: She [IS] unhappily [MAR]ried.

- a. She has an unhappy marriage.
- b. It is too bad that she is married.

In this sentence the ambiguity arises because the verb [IS] can modify the Verb Phrase (version a) or the entire sentence (version b).

The node height principle predicts that the duration of the segment corresponding to the Verb [IS] should be lengthened in version (b) in which it is attached to a higher constituent, the main S' node, modifying the Sentence. In addition, the vowel portion corresponding to the syllable [MAR...] should be lengthened in version (b) as it is attached to a higher constituent, the main S node of the sentence.

The predictions derived from the node height principle proved partially correct in the acoustic analysis for this sentence. The analysis of variance should follow this account.

The asterisk (*) on the accompanying Figure 22 denotes one or two levels of significance as determined by the analysis of variance.

Vowel portion corresponding to syllable [IS]

We reported that acoustic duration for the vowel portion is 146.4 msec for the first interpretation (version a) as compared to 293.0 msec for the second as spoken by Talker JJ. Talker LR demonstrated similar but much more

prominent effects. Talker LR produced a mean acoustic duration of 99.0 msec for version (a) as compared to 439.1 msec for version (b). The differences are clearly seen in Figure 28.6.

Since the segment corresponding to the syllable [IS] should be lengthened in version (b) in which it is attached to a higher constituent, we should see the effects of the Source Variable, Version, evident on the Dependent Variable, Duration.

Table 19.6 presents the analysis of variance for the acoustic duration of the vowel portion for Sentence 7 for Talker JJ and Talker LR and both syllables.

Results of the analysis of variance for the vowel portion corresponding to the syllable [IS] for Sentence 7 reveal highly significant effects on Vowel Duration with Version as the Source variable for Talker JJ. The F-value for Talker JJ for the effect of Version is 552.18 ($df=1,10$, $Pr > F = 0.0001$). This result may be accounted for by the large differences in acoustic duration between versions as produced by Talker JJ. For Talker JJ we reject the Null Hypothesis of no difference between Versions.

Results of the analysis of variance for the vowel portion corresponding to the syllable [IS] for Sentence 7 also reveal highly significant effects on vowel portion

Duration with Version as the Source variable for Talker LR. This result may be accounted for by the large differences in acoustic duration between versions as produced by Talker LR. The F-value for Talker LR for the effect of Version is 774.23 ($df=1,10$, $Pr > F = 0.0001$). For Talker LR we also reject the Null Hypothesis of no difference between Versions.

Vowel portion corresponding to syllable [MAR...]

In the acoustic findings we reported less difference between versions for the vowel portion corresponding to the syllable [MAR...] in [MARRIED], although not in the direction predicted by the node height principle. Talker JJ presented a mean acoustic duration of 140.4 msec for both version (a) and version (b). Again, differences between versions were somewhat larger although far from significant for Talker LR larger for Talker LR. Talker LR produced a mean acoustic duration of 180.5 msec for version (a) as compared to 161.2 for version (b). We anticipated similar findings in the Analysis of Variance.

Table 19.6 presents the results of the analysis of variance. There was no effect on Vowel Duration with Version as the Source variable for Talker JJ. The F-value for Talker JJ for the effect of Version is 0 ($df=1,10$, $Pr >$

$F = 1.0$). For Talker JJ we fail to reject the Null Hypothesis of no difference between Versions. This, of course, was anticipated by the zero variation in acoustic duration between versions as produced by this Talker JJ.

The analysis of variance for Talker LR revealed significant effects on Vowel Duration with Version as the Source variable for Talker LR. The F -value for Talker LR for the effect of Version is 16.81 ($df=1,10$, $Pr > F = 0.0021$). For Talker LR we reject the Null Hypothesis of no difference between Versions.

Summary and Implications of Acoustic ANOVA Findings

Results of the analysis of variance effects appear consistent with predictions based upon the tree structure of the ambiguity. Next we report the results of the movement study. The focus is to identify those factors that appear in the acoustic data, which could account for the perceptual scores.

Chapter VII: Experiment 4.

Jaw movement correlates of syntactic contrasts

It is predicted that jaw duration and displacement will vary at the presence of a syntactic boundary, but the manner in which articulatory organization within the syllable is effected and how pausing will be manifested remains unknown. As noted earlier, this paper will not report on pause duration as there was no analogue measured in the movement analysis of this study.

Specification of effects

Four different jaw movement variables as spoken by two talkers were measured. The dependent variables measured were jaw duration and amplitude for the opening phase of the cycle, and jaw duration and amplitude for the closing phase. The independent or classification variable is version. There are two levels of version, version (a) and version (b). The null hypothesis tested is that version does not effect nor interact with any of the four jaw variables.

It has been reported in the acoustic literature that there is minimal variability in "good" reiterant speech

(Lieberman & Streeter, 1978). At issue is whether differences among the six productions of each jaw movement variable within version are insignificant for both talkers and able to provide useful information to the speechreader for disambiguation of each sentence type.

To summarize the key issues for this analysis, the vowel portion corresponding to two key syllables for disambiguation were measured for four jaw variables, Jaw Duration and Jaw Amplitude during opening and closing, were measured under two conditions, versions (a) and (b).

The six productions for each version and sentence from two speakers, Talker JJ and LR, were analyzed to determine the following:

1. Are the variables related to each other and if so how?
2. Are there significant differences between versions and syllable?
3. Are there any trends or patterns in the data that point to a particular variable as key to the viewers' disambiguation of the sentence? This will be considered in the Discussion section.
4. Is there any recurrent jaw variable that is specific to the type of ambiguity tested, such as Prepositional Phrase Modification, Adverb Modification, etc.?

The most frequently used quantitative test in MANOVA is the Wilk's Lambda Manova Criterion that indicates the F Statistics for the Hypothesis being tested. Here we are testing the Hypothesis of No Overall VERSION Effect. This test is an indicator of the degree of inter-relation and correlation among the multiple dependent variables. Table 20.7 presents the Wilk's Test for both talkers and all seven sentences. One other way to examine the relationships and differences among the jaw variables is to compare the jaw movement means to determine whether a pattern exists in the data. We would be looking to determine whether a similarity exists in the direction of the trend of the versions; that is, for example, is an increase in the (b) version during opening duration reflected in the displacement data as well.

We can take this one step further by comparing the results to the partial correlation coefficients from the error sums of squares and crossproducts matrix. This statistic may be viewed as the correlation between two sets of residuals. The partial correlation is considered a measure of the residual unpredictability in Y from a linear prediction system based upon X_a (Winer; 1962, pp.111). Therefore the squared correlation represents the proportion of this residual that can be predicted by adding the

variable X_b to the proportion system. This analysis informs on the relationships among each of the jaw variables; a high negative correlation indicates degree of contribution to the model.

Finally, after examination of the partial correlations error sums of squares and crossproducts matrix, we will compare these findings to the results of multivariate F-tests. The highest F should be associated with the smallest value of the Wilks' Lambda Manova Test Criterion. The following section discusses the results of this analysis separately for each talker by sentence. Table 20.7 presents the Wilk's test for both talkers and all sentences. It is inserted early in the text to assist the reader in examination of patterns between speakers prominent in the results.

To summarize, first this section presents an overview of the descriptive analysis of the jaw movement variables for the opening and closing gestures. This section then presents the possible associations among the dependent variables by examining the partial correlation coefficients from the error sums of squares crossproducts matrices. Partial correlations were considered significant at the $p \geq .05$ level. We report on the partial correlation coefficients from the error sums of squares and

crossproducts matrices with the probability of $|r|$ as for the seven sentences spoken by both talkers.

We then look at the results of the Wilk's Lambda Manova Test Criterion for Talker JJ and Talker LR as presented in Table 20.7.

Univariate analyses were generated for both talkers for each of the seven sentences and versions. An examination of the univariate analyses is requisite in multivariate analysis. Univariate methods may prove more powerful than multivariate analysis and will serve as a check on the conclusions drawn in this study. Each vowel portion corresponding to the key segments was analyzed independently. The results are discussed by speaker and sentence.

Results of MANOVA for Jaw Movement Variables

Sentence 1. Here is the famous [DUKE] [JAMES].

Results for Vowel portion Corresponding to Syllable [DUKE]

Results for Talker JJ

Table 21.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [DUKE] in Sentence 1 as spoken by Talker JJ.

Figure 30.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [HERE IS THE FAMOUS DUKE JAMES] as spoken by Talker JJ are presented.

The symbol (*) indicates the level of significance as determined by the univariate ANOVA.

Jaw duration is longer for the (a) version as compared to the (b) version for both the opening and closing phase for Talker JJ, with differences being larger during the closing cycle. Jaw duration during opening for version (a) was 196.95 msec with a standard deviation of 55.69 msec as compared to 151.50 msec with a standard deviation of 0 for the version (b). Jaw duration during closing for version

(a) was 282.80 msec with a standard deviation of 45.62 msec as compared to 146.45 msec with a standard deviation of 12.37 for version (b).

Jaw displacement during the opening phase was 8.33 cm with a standard deviation of 1.21 for version (a), approximately the same displacement as version (b), which had a mean displacement of 9.83 cm and standard deviation of 0.98. The closing phase followed the same pattern. Jaw displacement during the closing phase was 10.50 cm with a standard deviation of 1.22 for version (a). This was equal to the displacement as version (b), which also had a mean amplitude of 10.50 cm with a standard deviation of 1.38.

In summary, we note large differences between versions for closing jaw duration for the vowel portion corresponding to the syllable [DUKE]. The large difference in duration during opening is affected by the large standard deviation and we do not expect to note any significance in the univariate analysis.

These findings are clearly seen in Figure 30.7. We should see the impact of closing duration in the univariate analysis of variance. Note that the standard deviations for jaw duration are extremely large in version (a) during both opening and closing gestures.

Durational patterns would appear to be responsible for the visual percept since the differences between jaw displacement during opening and closing phases were negligible for this segment.

Multivariate analysis of variance was applied. Table 22.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [DUKE] in Sentence 1 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant negative correlation between opening and closing jaw duration ($r = -0.685323$, $p = 0.0199$). Again, this reinforces the hypothesis that it is differences in closing jaw duration that signal the visual perception of prosody since a high negative correlation indicates the degree of contribution to the multivariate model.

The value of the Wilks' Lambda as seen in Table 3 was highly significant for Talker JJ for the segment /a/ corresponding to the syllable [DUKE] Wilks' value $= 0.06761674$, $F = 24.1312$, $Pr > F = 0.0003$).

The results of the univariate analysis help to identify which jaw movement variables had most impact on Version. Table 23.7 presents the Univariate Analysis of

Variance for jaw movement variables for the key syllable [DUKE] in Sentence 1 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance demonstrates that jaw duration for the closing phase is highly significant as compared to the other variables (F value =49.93, $Pr > F=0.0001$, $r^2=0.8333$). This may be accounted for by the large difference between versions discussed earlier for this variable as spoken by Talker JJ. The results are in agreement with the Partial Correlations Errors Sums of Squares.

Jaw displacement during the opening phase is also significant (F value =5.55, $Pr > F=0.0403$, $r^2=0.3568$). There were no significant findings for jaw displacement during the closing phase (F value =0.00, $Pr > F=1.0000$, $r^2=0.0000$). This result is accounted for by the zero variation between versions during the closing cycle.

The lack of significance in the amplitude data would suggest that whatever perceptual effects seen in the data are derived from jaw duration.

Results for Talker LR

We will now present the results of the analysis of the syllable [DUKE] for the second speaker, Talker LR. Table

21.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [DUKE] as spoken by Talker LR. Figure 31.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [HERE IS THE FAMOUS DUKE JAMES] as spoken by Talker LR are presented.

Jaw duration is about the same for version (b) as compared to version (a) for the opening phase for Talker LR. Jaw duration is longer for version (a) as compared to the version (b) for the closing phase for Talker LR. Jaw duration during opening for version (a) was 151.50 msec with a standard deviation of 19.16 msec as compared to 156.55 msec with a standard deviation of 12.37 for version (b). Jaw duration during closing for version (a) was 131.30 msec with a standard deviation of 31.29 msec as compared to 106.05 msec with a standard deviation of 16.60 for the second version (b). These findings are in the same direction as those of Talker JJ, but much less pronounced.

Jaw displacement during the opening phase was 8.33 cm with a standard deviation of 1.86 for version (a), approximately the same displacement as version (b), which

had a mean displacement of 10.72 cm and standard deviation of 1.72. The closing phase followed the same pattern. Jaw displacement during the closing phase was 8.50 cm with a standard deviation of 1.52 for version (a), as compared to version (b), which had a mean displacement of 8.17 cm and standard deviation of 1.33.

Given the results reported above, we expect to see negative findings in the univariate analysis of variance.

Multivariate analysis of variance was applied. Table 24.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [DUKE] in Sentence 1 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlation between opening jaw duration and opening jaw amplitude ($r=0.611033$, $p=0.0458$). There is a highly significant positive correlation between opening and closing jaw amplitude ($r=0.931918$, $p=0.0001$). These mixed findings should extend to the univariate analysis.

The value of the Wilks' Lambda was significant (Wilks' value = 0.20242087, $F=6.8954$, $Pr > F=0.0141$). The smaller Wilks' value identifies the greatest level of significance.

The difference in Wilks' values between talkers is evident for this segment, although both test significant.

We will now examine the results of the univariate analysis to identify which jaw movement variable, if any, had most impact on Version. Table 23.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [DUKE] in Sentence 1 as spoken by Talker LR. We do not expect to see any significant findings for Talker LR for this segment and this proves to be the case.

Results for Vowel portion Corresponding to Syllable [JAMES]

Results for Talker JJ

Table 25.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [JAMES] in Sentence 1 as spoken by Talker JJ. Figure 30.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [HERE IS THE FAMOUS DUKE JAMES] as spoken by Talker JJ are presented.

Jaw duration is longer for the version (a) for both the opening and closing phase for Talker JJ for the vowel

portion corresponding to the syllable [JAMES], with the relative difference in duration being more prominent during the closing phase. The standard deviation is large in version (a) during the opening gesture.

Jaw duration during opening for version (a) was 207.05 msec with a standard deviation of 58.81 msec as compared to 151.50 msec with a standard deviation of 19.16 for version (b). Jaw duration during closing for version (a) was 434.30 msec with a standard deviation of 24.74 msec as compared to 333.30 msec with a standard deviation of 19.16 for version (b).

Jaw displacement during the opening phase was 11.17 cm with a standard deviation of 1.17 for the version (a), approximately the same displacement as version (b), which had a mean displacement of 10.83 cm and standard deviation of 1.17. The closing phase followed the same pattern. Jaw displacement during the closing phase was 15.83 cm with a standard deviation of 1.72 for version (a), in comparison to the version (b), which had a mean displacement of 14.50 cm and standard deviation of 1.05.

In summary, we note significant differences between versions for closing jaw duration for the vowel portion corresponding to the syllable [JAMES] as spoken by Talker JJ. There is also some evidence of significant differences

between versions during opening jaw duration. These results are clearly seen in Figure 30.7. We should see the impact of these findings in the univariate analysis of variance. We also note that the standard deviations for jaw duration are extremely large in version (a) during opening reducing the significance of the findings.

Multivariate analysis of variance was applied.

Table 26.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [JAMES] in Sentence 1 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals several significant correlations. These occur between opening duration and opening amplitude ($r=0.721043$, $p=0.0123$), opening duration and closing amplitude ($r=0.720701$, $p=0.0123$), and opening and closing jaw amplitude ($r=0.879824$, $p=0.0004$).

The value of the Wilks' Lambda was highly significant (Wilks' value = 0.05207253, $F=31.8570$, $Pr > F=0.0001$).

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 27.7 presents the Univariate Analysis of Variance for jaw movement variables for the key

syllable [JAMES] in Sentence 1 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveal that jaw duration for the closing phase appears to be highly significant as compared to the other variables (F value =62.50, $Pr > F=0.0001$, $r^2=0.8621$). This is apparent in the difference between versions for this variable as presented in Figure 30.7. Jaw duration during the opening phase was moderately significant as well (F value =4.84, $Pr > F=0.0524$, $r^2=0.3261$).

Results for Talker LR

We will now present the results of the analysis of the syllable [JAMES] for the second speaker, Talker LR. Table 25.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [DUKE] as spoken by Talker LR. Figure 31.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [HERE IS THE FAMOUS DUKE JAMES] as spoken by Talker LR are presented.

Jaw duration is longer for the version (b) as compared to version (a) for the opening phase for Talker LR. Jaw duration is about the same for version (b) as compared to the (a) version for the closing phase for Talker LR. Jaw duration during opening for version (a) was 166.65 msec with a standard deviation of 16.60 msec as compared to 212.10 msec with a large standard deviation of 46.94 for the version (b). Jaw duration during closing for the version (a) was 212.10 msec with a standard deviation of 38.33 msec, very close to 227.25 msec with a standard deviation of 41.77 for version (b).

Jaw displacement during the opening phase was 6.67 cm with a standard deviation of 0.82 for version (a), as compared to version (b), which had a mean displacement of 5.5 cm and standard deviation of 0.55. The closing phase followed the same pattern. Jaw displacement during the closing phase was 11.0 cm with a standard deviation of 1.90 for version (a), as compared to version (b), which had a mean displacement of 9.83 cm and standard deviation of .98.

In summary, due to differences between versions evident in Figure 30.7 we could expect to see significant findings for jaw duration during the opening phase as well as jaw displacement during the opening cycle in the univariate analysis.

Multivariate analysis of variance was applied.

Table 28.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [JAMES] in Sentence 1 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlation between opening and closing jaw amplitude ($r=0.618736$, $p=0.0424$).

As expected, the value of the Wilks' Lambda was not significant (Wilks' value $=0.31819484$, $F=3.7498$, $Pr > F=0.0615$).

We will now examine the results of the univariate analysis to identify which jaw movement variable, if any, had most impact on Version. Table 23.7 presents the Univariate Analysis of Variance for jaw movement variables for the syllable [JAMES] in Sentence 1 as spoken by Talker LR. Evaluation of the results of the univariate analysis of variance for Talker LR reveal that jaw amplitude during the opening phase was most significant (F value $=8.45$, $Pr > F=0.0157$, $r^2=0.4578$). Jaw duration during the opening cycle was also significant (F value $=5.00$, $Pr > F=0.0493$, $r^2=0.3333$).

Summary

A comparison of the results of Wilk's test between the speakers reveals that Talker JJ tested highly significant for both key segments in comparison to Talker LR who tested significant for only one.

The jaw duration findings are in agreement with the predictions of the node height principle. In version (a) of Sentence 1, both [DUKE] and [JAMES] are dominated by higher nodes as compared to the version (b).

The tree structure of version (a), in which James meets the Duke, reveals the existence of a node between the two key segments. Effects on duration that occur in the acoustic data are reflected in the jaw movement data. In addition, for the vowel portion corresponding to the syllable [JAMES] there is a greater association among duration and amplitude as revealed in the partial correlations from the error sum of squares matrix.

Phrases with characteristics of right-branching sentence types are tested here. Figure 4.4 depicts the general features of this sentence type. Simply stated, the y node in the top figure (figure a) branches off to the right from the central node x. Node x is immediately dominated by the w node (S' node). In the bottom figure (figure b) the y node is not displaced horizontally but

instead branches off the central node x. Findings in the movement data due to sentence type will be presented in the **Discussion.**

Sentence 2. The [OLD] [MEN] and women stayed at home.

Results for Vowel portion Corresponding to Syllable [OLD]

Results for Talker JJ

Table 29.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [OLD] in Sentence 2 as spoken by Talker JJ. Figure 32.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [THE OLD MEN AND WOMEN STAYED AT HOME] as spoken by Talker JJ are presented.

Jaw duration is longer for the version (a) as compared to the version (b) for both the opening and closing phase for Talker JJ, with differences being larger during the closing cycle. Jaw duration during opening for version (a) was 161.60 msec with a standard deviation of 15.65 msec as compared to 121.20 msec with a standard deviation of 19.16

for version (b). Jaw duration during closing for version (a) was 156.55 msec with a standard deviation of 22.81 msec as compared to 106.05 msec with a standard deviation of 16.60 for version (b).

Jaw displacement during the opening phase was 7.83 cm with a standard deviation of .75 for version (a), in comparison to version (b), which had a mean displacement of 6.33 cm and standard deviation of 0.82. Jaw displacement during the closing phase was 9.17 cm with a standard deviation of .98 for version (a), and 8.83 cm with a standard deviation of 1.17 for version (b).

In summary, we note large differences between versions for opening and closing jaw duration for the vowel portion corresponding to the syllable [OLD], with the greater difference occurring during the closing phase. This finding is clearly seen in Figure 32.7. We should see the impact of this finding in the univariate analysis of variance.

Multivariate analysis of variance was applied. Table 30.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [OLD] in Sentence 2 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a

significant positive correlation between opening and closing jaw displacement ($r=0.648431$, $p=0.0309$).

The value of the Wilks' Lambda as presented in Table 20.7 was significant (Wilks' value $=0.12186715$, $F=12.6099$, $Pr > F=0.0026$).

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 31.7 presents the results of the Univariate Analysis of Variance.

Evaluation of the results of the univariate analysis of variance demonstrates that jaw duration for the closing phase is highly significant as compared to the other variables (F value $=19.23$, $Pr > F=0.0014$, $r^2=0.6579$). This may be accounted for by the large difference between versions for this variable as spoken by Talker JJ. Jaw duration during the opening phase is also significant (F value $=16.00$, $Pr > F=0.0025$, $r^2=0.6154$), as well as jaw displacement during the opening phase (F value $=10.95$, $Pr > F=0.0079$, $r^2=0.5226$).

Results for Talker LR

We will now present the results of the analysis of the syllable [OLD] for the second speaker, Talker LR. Table 29.7 presents the results of the analysis of the jaw

movement variables with the standard deviations for the key syllable [OLD]. Figure 33.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [THE OLD MEN AND WOMEN STAYED AT HOME] as spoken by Talker LR are presented.

Jaw duration is longer for version (b) as compared to version (a) for the opening phase for Talker LR. Jaw duration is somewhat longer for version (b) as compared to version (a) for the closing phase for Talker LR. Jaw duration during opening for version (a) was 131.30 msec with a standard deviation of 15.65 msec as compared to 161.60 msec with a standard deviation of 15.65 for version (b). Jaw duration during closing for version (a) was 95.95 msec with a standard deviation of 12.37 msec as compared to 106.05 msec with a standard deviation of 16.60 for the second version (b).

Jaw displacement during the opening phase was 5.50 cm with a standard deviation of 1.38 for version (a), approximately the same displacement as version (b), which had a mean displacement of 6.33 cm and standard deviation of .82. Jaw displacement during the closing phase was 5.50 cm with a standard deviation of 1.52 for version (a), as

compared to the longer version (b), which had a mean displacement of 7.33 cm and standard deviation of 1.03.

Given the differences between versions reported above, we expect to see an impact on the univariate analysis for jaw duration during the opening cycle and jaw amplitude during the closing cycle.

Multivariate analysis of variance was applied. Table 32.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [OLD] in Sentence 2 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlation between opening and closing jaw amplitude ($r=0.737068$, $p=0.0097$).

The value of the Wilks' Lambda as presented in Table 20.7 was significant (Wilks' value =0.27979260, $F=4.5046$, $Pr > F=0.0408$). The smaller Wilks' value identifies the greatest level of significance.

The difference in Wilks' values between talkers is evident for the vowel portion corresponding to this syllable, although both test significant.

We will now examine the results of the univariate analysis to identify which jaw movement variable, if any,

had most impact on Version. Table 31.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [OLD] in Sentence 2 as spoken by Talker JJ and Talker LR. We expected to see positive findings for jaw duration during the opening phase and jaw displacement during the closing cycle. Jaw duration during the opening phase is significant (F value =11.25, $Pr > F=0.0073$, $r^2=0.5294$). This may be accounted for by the relatively large difference between versions for this variable as spoken by Talker LR. Jaw displacement during the closing phase was also significant (F value =5.99, $Pr > F=0.0344$, $r^2=0.3726$). The bar graphs in Figure 37.7 depict these variations clearly.

Results for Vowel portion Corresponding to Syllable [MEN]

Results for Talker JJ

Table 33.7 presents the analysis of jaw movement variables with standard deviations for the vowel portion corresponding to the key syllable [MEN] in Sentence 2 as spoken by Talker JJ.

Figure 32.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and

closing phase of the key vowel portion in the ambiguous sentence [THE OLD MEN AND WOMEN STAYED AT HOME] as spoken by Talker JJ are presented.

Jaw duration is longer for version (b) for both the opening and closing phase for Talker JJ for the vowel portion corresponding to the syllable [MEN]. The relative difference in duration is minimal during the opening cycle and extremely prominent during the closing phase. Jaw duration during opening for the version (a) is 141.40 msec with a standard deviation of 15.65 msec as compared to 156.55 msec with a standard deviation of 29.79 for the version (b). Jaw duration during closing for the version (a) was 85.85 msec with a standard deviation of 12.37 msec as compared to 479.75 msec with a standard deviation of 52.19 for version (b). The difference between versions is evident for the closing phase in Figure 32.7.

Jaw displacement during the opening phase was 7.50 cm with a standard deviation of 1.05 for version (a), as compared to version (b), which had a mean displacement of 10.33 cm and standard deviation of .52. Jaw displacement during the closing phase was 6.50 cm with a standard deviation of .55 for the version (a), in comparison to version (b), which had a much longer mean displacement of 12.67 cm and standard deviation of 1.63.

In summary, we note significant differences between versions for closing jaw duration and jaw displacement for the vowel portion corresponding to the syllable [MEN]. There is also some evidence of significant differences between versions during opening jaw amplitude. These results are evident in Figure 32.7. We should see the impact of these findings in the univariate analysis of variance.

Multivariate analysis of variance was applied. Table 34.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [MEN] in Sentence 2 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals no significant correlations.

The value of the Wilks' Lambda was highly significant (Wilks' value = 0.00951436, $F=182.1824$, $Pr > F=0.0001$). As noted earlier, the smaller Wilks' value identifies the largest F-statistic and the greater level of significance.

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 35.7 presents the Univariate

Analysis of Variance for jaw movement variables for the key syllable [MEN] in Sentence 2 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveal that although several variables tested highly significant, jaw duration for the closing phase appears an outlier as compared to the other variables (F value =363.62, $Pr > F=0.0001$, $r^2=0.9700$). This is apparent in the difference between versions for this variable as presented in Figure 32.7. Jaw displacement during the closing phase was significant as well (F value =76.91, $Pr > F=0.0001$, $r^2=0.8849$), followed by jaw displacement during the opening cycle (F value =35.24, $Pr > F=0.0001$, $r^2=0.7790$).

Results for Talker LR

We will now present the results of the analysis of the syllable [MEN] for the second speaker, Talker LR. Table 33.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [MEN] as spoken by Talker LR. Figure 33.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key

vowel portion in the ambiguous sentence [THE OLD MEN AND WOMEN STAYED AT HOME] as spoken by Talker LR are presented.

Jaw duration is the same for version (b) as compared to version (a) for the opening phase for Talker LR. Jaw duration is significantly longer for version (b) as compared to version (a) for the closing phase for Talker LR. Jaw duration during opening for both versions is 106.05 msec with a standard deviation of 16.60. Jaw duration during closing for version (a) is 116.15 msec with a standard deviation of 35.42 msec, in comparison to 287.85 msec with a standard deviation of 1.10 for version (b).

Jaw displacement during the opening phase was 4.67 cm with a standard deviation of 1.51 for version (a), about equal to version (b), which had a mean displacement of 4.50 cm and standard deviation of 0.55. Jaw displacement during the closing phase was 6.0 cm with a standard deviation of 1.55 for version (a), as compared to version (b), which had a mean displacement of 9.00 cm and standard deviation of 1.10.

We should expect to note the influence of the large difference between versions for jaw duration during closing and jaw amplitude during closing in the univariate analysis.

Multivariate analysis of variance was applied. Table 36.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [MEN] in Sentence 2 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlation between opening and closing jaw amplitude ($r=0.723747$, $p=0.0118$).

The value of the Wilks' Lambda was significant (Wilks' value =0.09452306, $F=16.7640$, $Pr > F=0.0011$). We will now examine the results of the univariate analysis to identify which jaw movement variable, if any, had most impact on Version. Table 35.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [MEN] in Sentence 2 as spoken by Talker JJ and Talker LR.

Evaluation of the results of the univariate analysis of variance for Talker LR reveal that jaw duration during the closing phase appears to be highly significant as compared to the other variables (F value =93.23, $Pr > F=0.0001$, $r^2=0.9031$). Jaw amplitude during the closing cycle was also significant (F value =15.00, $Pr > F=0.0031$, $r^2=0.6000$). These results are aligned to the predictions we made earlier.

Summary

A comparison of the results of Wilk's test between the speakers reveals that Talker JJ tested highly significant for both key segments, in particular the syllable [MEN] in comparison to Talker LR.

Sentence 3. The hostess [GREE]ted the [GIRL] with a smile.

Results for Vowel portion Corresponding to Syllable [GREE...]

Results for Talker JJ

Table 37.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [GREE...] in Sentence 3 as spoken by Talker JJ.

Figure 34.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [THE HOSTESS GREETED THE GIRL WITH A SMILE] as spoken by Talker JJ are presented.

Jaw duration is slightly longer for the (a) version as compared to the (b) version for both the opening and closing phase for Talker JJ. Jaw duration during opening for version (a) was 126.25 msec with a standard deviation of 12.37 msec as compared to 111.10 msec with a standard deviation of 45.62 for version (b). Jaw duration during closing for version (a) was 85.85 msec with a standard deviation of 12.37 msec as compared to 75.75 msec with a standard deviation of 25.35 for version (b).

Jaw displacement during the opening phase was 8.67 cm with a standard deviation of 1.37 for version (a), in comparison to version (b), which had a mean displacement of 6.83 cm and standard deviation of 3.60. Jaw displacement during the closing phase was 7.33 cm with a standard deviation of 1.21 for version (a), and 5.83 cm with a standard deviation of 2.64 for version (b).

In summary, we do not note any large differences between versions for opening and closing jaw duration or amplitude for the vowel portion corresponding to the syllable [GREE...]. This report is displayed graphically in Figure 34.7. We should see the lack of significant findings in both the Wilks' Lambda Manova Test Criterion as well as the univariate analysis of variance.

Multivariate analysis of variance was applied.

Table 38.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [GREE...] in Sentence 3 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveal several significant positive correlations. These occur between opening jaw duration and opening amplitude ($r=0.798953$, $p=0.0032$), between opening duration and closing jaw displacement ($r=0.721115$, $p=0.0123$), opening and closing jaw amplitude ($r=0.956676$, $p=0.0001$), and closing duration and closing displacement ($r=0.875410$, $p=0.0004$). Note that several of the partial correlations are highly significant.

We now move on to the Wilk's Lambda. The value of the Wilks' Lambda was not significant (Wilks' value = 0.83057851, $F=0.3570$, $Pr > F=0.8318$). This is in line with our earlier findings.

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 39.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [GREE...] in Sentence 3 as spoken by Talker JJ.

As predicted, none of the jaw variables tested significant.

Results for Talker LR

We will now present the results of the analysis of the syllable [GREE...] for the second speaker, Talker LR. Table 37.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [GREE...] as spoken by Talker LR. Figure 35.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [THE HOSTESS GREETED THE GIRL WITH A SMILE] as spoken by Talker LR are presented.

Jaw duration is about the same for version (b) as compared to the version (a) for both the opening and closing phase. Jaw duration during opening for version (a) was 141.40 msec with a standard deviation of 15.65 msec as compared to 126.25 msec with a standard deviation of 22.81 for version (b). Jaw duration during closing for version (a) was 85.85 msec with a standard deviation of 22.81 msec as compared to 90.90 msec with a standard deviation of 0 for version (b).

Jaw displacement during the opening phase was 6.33 cm with a standard deviation of 1.51 for the version (a), approximately the same displacement as version (b), which had a mean displacement of 7.00 cm and standard deviation of 2.37. Jaw displacement during the closing phase was 5.00 cm with a standard deviation of .89 for version (a), as compared to the version (b), which had a mean displacement of 4.00 cm and standard deviation of .89.

Given the differences between versions reported above, we do not expect to see significant levels in the univariate analysis.

Multivariate analysis of variance was applied. Table 40.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [GREE...] in Sentence 3 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals no significant correlations between any of the jaw variables tested.

Table 20.7 presents the Wilks' Lambda Manova Test Criterion and F Statistics for the hypothesis of no Overall Version Effect as spoken by Talker JJ and Talker LR. The

value of the Wilks' Lambda was not significant (Wilks' value =0.46821989, $F=1.9876$, $Pr > F=0.2010$).

We will now examine the results of the univariate analysis to identify which jaw movement variable, if any, has most impact on Version. Table 39.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [GREE...] in Sentence 3 as spoken by Talker JJ and Talker LR. We did not expect to see significant findings for any of the jaw variables. This proved to be the case.

Results for Vowel portion Corresponding to Syllable [GIRL]

Results for Talker JJ

Table 41.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [GIRL] in Sentence 3 as spoken by Talker JJ and Talker LR.

Figure 34.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [THE HOSTESS GREETED THE GIRL WITH A SMILE] as spoken by Talker JJ are presented.

Jaw duration is pronouncedly shorter for the version (b) for both the opening and closing phase for Talker JJ for the vowel portion corresponding to the syllable [GIRL]. Jaw duration during opening for version (a) is 196.95 msec with a standard deviation of 16.60 msec as compared to 111.10 msec with a standard deviation of 36.70 for the second version (b). Jaw duration during closing for the version (a) was 131.30 msec with a standard deviation of 15.65 msec as compared to 90.90 msec with a standard deviation of 19.16 for version (b). The difference between versions is evident for the closing phase in Figure 34.7.

Jaw displacement during the opening phase was 9.00 cm with a standard deviation of 1.26 for the version (a), as compared to the second interpretation version (b), which had a mean displacement of 6.33 cm and standard deviation of 2.25. Jaw displacement during the closing phase was 9.17 cm with a standard deviation of .98 for version (a), in comparison to version (b), which had mean displacement of 5.83 cm and standard deviation of 2.04.

In summary, we note significant differences between versions for opening and closing jaw duration and jaw displacement for the vowel portion corresponding to the syllable [GIRL]. These results are evident in Figure 30.7.

We should see the impact of these findings in the univariate analysis of variance.

Multivariate analysis of variance was applied.

Table 42.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [GIRL] in Sentence 3 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals significant correlations between opening and closing jaw amplitude ($r=0.729348$, $p=0.0109$), and closing jaw duration and closing displacement ($r=0.612637$, $p=0.0451$).

Table 20.7 presents the Wilks' Lambda Manova Test Criterion and F Statistics for the Hypothesis of no Overall Version effect as spoken by Talker JJ and Talker LR. The value of the Wilks' Lambda was significant (Wilks' value = 0.23349633, $F=5.7448$, $Pr > F=0.0227$).

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 43.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [GIRL] in Sentence 3 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveal that although all four jaw

variables tested significant, jaw duration for the opening phase appears an outlier as compared to the other variables (F value =27.26, $Pr > F=0.0004$, $r^2=0.7316$). This is apparent in the difference between versions for this variable as presented in Figure 31.7. Jaw duration during the closing phase was significant as well (F value =16.00, $Pr > F=0.0025$, $r^2=0.6154$), followed by jaw displacement during the closing cycle (F value =12.99, $Pr > F=0.0048$, $r^2=0.5650$) and jaw displacement during the opening cycle (F value =6.40, $Pr > F=0.0200$, $r^2=0.3902$). The findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [GIRL] for the second speaker, Talker LR. Table 41.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [GIRL] as spoken by both Talker JJ and Talker LR. Figure 35.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [THE HOSTESS GREETED THE GIRL WITH A SMILE] as spoken by Talker LR are presented.

Jaw duration is longer in opening for version (a) as compared to version (b). Jaw duration is significantly longer for version (b) as compared to version (a) for the closing phase for Talker LR. Jaw duration during opening is 136.35 msec with a standard deviation of 25.35 for version (a) as compared to 101.00 msec with a standard deviation of 15.65 for version (b). Jaw duration during closing for the version (a) is 75.75 msec with a standard deviation of 25.35 msec, in comparison to 126.25 msec with a standard deviation of 65.63 for version (b). Although the differences between versions are large for the closing gestures, the gestures are highly variable as indicated by the large standard deviations. However, we should expect to see significant findings for jaw duration during the opening cycle, as is evident in the differences between versions depicted in Figure 35.7.

Jaw displacement during the opening phase was 6.67 cm with a standard deviation of 1.03 for version (a), about equal to version (b), which had a mean displacement of 7.17 cm and standard deviation of 2.32. Jaw displacement during the closing phase was 6.33 cm with a standard deviation of 2.80 for version (a), as compared to version (b), which had a mean displacement of 8.33 cm and standard deviation of 2.94.

To summarize, we should expect to note the influence of the difference between versions in the univariate analysis for jaw duration during opening.

Multivariate analysis of variance was applied. Table 44.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [GIRL] in Sentence 3 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a highly significant positive correlation between opening jaw duration and closing jaw amplitude ($r=0.881606$, $p=0.0003$).

The value of the Wilks' Lambda was significant (Wilks' value =0.30026302, $F=4.0782$, $Pr > F=0.0512$).

We will now examine the results of the univariate analysis to identify which jaw movement variable, if any, had most impact on Version. Table 43.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [GIRL] in Sentence 3 as spoken by Talker JJ and Talker LR. Evaluation of the results of the univariate analysis of variance for Talker LR reveals that jaw duration during the opening phase is significant (F value =8.45, $Pr > F=0.0157$, $r^2=0.4579$). These results are aligned to the predictions we made earlier.

Summary

A comparison of the results of Wilk's test between the speakers reveals that the Wilks' Value was not significant for either speaker for the first syllable [GREE...]. Both Talker JJ and Talker LR demonstrated significant Wilks' Values for the key syllable [GIRL].

Sentence 4. John doesn't know how [GOOD] [MEAT] tastes.

Results for Vowel portion Corresponding to Syllable [GOOD]

Results for Talker JJ

Table 45.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [GOOD] in Sentence 4 as spoken by Talker JJ.

Figure 36.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [JOHN DOESN'T KNOW HOW GOOD MEAT TASTES] as spoken by Talker JJ are presented.

Jaw duration is longer for version (b) as compared to the version (a) for both the opening and closing phase for

Talker JJ. This effect is much more pronounced during the closing phase. Jaw duration during opening for version (a) was 121.20 msec with a standard deviation of 0 msec as compared to 156.55 msec with a standard deviation of 22.81 for version (b). Jaw duration during closing for version (a) was 111.10 msec with a standard deviation of 15.65 msec as compared to the much longer mean duration of 267.65 msec with a standard deviation of 29.90 for version (b).

Jaw displacement was larger for version (b) during both the opening and closing phases. Jaw displacement during the opening phase was 10.50 cm with a standard deviation of 1.22 for version (a), in comparison to version (b), which had a mean displacement of 12.33 cm and standard deviation of 1.63. Jaw displacement during the closing phase was 10.33 cm with a standard deviation of 1.21 for version (a), in comparison to 15.67 cm with a standard deviation of 1.21 for version (b).

In summary, we note large differences between versions for opening and closing jaw duration and amplitude for the vowel portion corresponding to the syllable [GOOD]. This is consistent with predictions derived by the node height principle, as we should see the effect of version for this syllable. These findings are clearly displayed graphically in Figure 36.7.

We should note significant findings in both the Wilks' Lambda Manova Test Criterion as well as the univariate analysis of variance.

Multivariate analysis of variance was applied. Table 46.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [GOOD] in Sentence 4 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveal a significant positive correlation between opening and closing amplitude ($r=0.656626$, $p=0.0282$).

The value of the Wilks' Lambda was highly significant (Wilks' value = 0.03749633, $F=44.9212$, $Pr > F=0.0001$). This is in line with our earlier findings.

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 47.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [GOOD] in Sentence 4 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveal that although all four jaw variables tested significant, jaw duration for the closing phase appears an outlier as compared to the other variables

(F value =129.86, $Pr > F=0.0001$, $r^2=0.9285$). This is apparent in the difference between versions for this variable as presented in Figure 36.7. Jaw displacement during the closing cycle was significant as well (F value =67.37, $Pr > F=0.0001$, $r^2=0.9285$), followed by jaw duration during opening (F value =14.41, $Pr > F=0.0035$, $r^2=0.5904$), and jaw displacement during the opening cycle (F value =4.84, $Pr > F=0.0524$, $r^2=0.3261$). The findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [GOOD] for the second speaker, Talker LR. Table 45.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [GREE...] as spoken by Talker LR. Figure 39.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [JOHN DOESN'T KNOW HOW GOOD MEAT TASTES] as spoken by Talker LR are presented.

Jaw duration is longer for version (b) as compared to the version (a) for both the opening and closing phase for

Talker LR. Jaw duration during opening for version (a) was 121.20 msec with a standard deviation of 46.94 msec as compared to 196.95 msec with a standard deviation of 15.60 for the version (b). Jaw duration during closing for version (a) was 101.00 msec with a standard deviation of 36.70 msec as compared to 126.25 msec with a standard deviation of 12.37 for version (b).

Jaw displacement was longer for the version (b) during both opening and closing phases. Jaw displacement during the opening phase was 4.67 cm with a standard deviation of 2.16 for version (a), as compared to version (b), which had a mean displacement of 9.17 cm and standard deviation of 1.47. Jaw displacement during the closing phase was 4.33 cm with a standard deviation of 2.07 for version (a), as compared to version (b), which had a mean displacement of 9.33 cm and standard deviation of 1.03.

Given the differences between versions reported above, we do expect to see significant levels for opening jaw duration as well as opening and closing displacement in the univariate analysis.

Multivariate analysis of variance was applied. Table 48.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for

the segment corresponding to the syllable [GOOD] in Sentence 4 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals several significant positive correlations. These occur between opening jaw duration and opening amplitude ($r=0.721711$, $p=0.0122$), between opening and closing duration ($r=0.714286$, $p=0.0135$), opening and closing jaw amplitude ($r=0.839280$, $p=0.0012$), and closing duration and closing displacement ($r=0.745394$, $p=0.0085$).

The value of the Wilks' Lambda was significant (Wilks' value =0.12159110, $F=12.6425$, $Pr > F=0.0026$).

We will now examine the results of the univariate analysis to identify which jaw movement variable has most impact on Version. Table 47.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [GOOD] in Sentence 4 as spoken by Talker JJ and Talker LR. Evaluation of the results of the univariate analysis of variance for Talker LR reveals that jaw displacement during the closing phase appears most significant (F value =28.12, $Pr > F=0.0003$, $r^2=0.7377$). This is followed by jaw displacement during the opening phase (F value =17.78, $Pr > F=0.0018$, $r^2=0.6400$), and jaw duration during the opening phase is (F value =13.89, $Pr >$

$F=0.0039$, $r^2=0.5814$). These results are aligned to the predictions we made earlier.

Results for Vowel portion Corresponding to Syllable [MEAT]

Results for Talker JJ

Table 49.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [MEAT] in Sentence 4 as spoken by Talker JJ.

Figure 36.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [JOHN DOESN'T KNOW HOW GOOD MEAT TASTES] as spoken by Talker JJ are presented.

Jaw duration is longer for the version (b) during opening and shorter during closing phase for Talker JJ for the vowel portion corresponding to the syllable [MEAT]. Jaw duration during opening for version (a) is 126.25 msec with a standard deviation of 13.37 msec as compared to 146.45 msec with a standard deviation of 12.37 version (b). Jaw duration during closing for version (a) was 116.16 msec with a standard deviation of 14.6 msec as compared to 65.965 msec with a standard deviation of 12.37 for version

(b). The difference between versions is evident for duration during both the opening and closing phase in Figure 32.7, and is extremely pronounced during closing.

Jaw displacement is shorter for version (a) as compared to version (b) during opening. It is longer for version (a) for the closing cycle. Jaw displacement during the opening phase was 8.33 cm with a standard deviation of 1.17 for version (a), as compared to version (b), which had a mean displacement of 11.00 cm and standard deviation of 2.9. Jaw displacement during the closing phase was 9.5 cm with a standard deviation of 3.02 for the version (a), in comparison to version (b), which had mean displacement of 6.17 cm and standard deviation of 1.72. The differences between versions are evident in Figure 36.7 for both the opening and closing phases, but especially pronounced during closing.

In summary, we note significant differences between versions for opening and closing jaw duration and jaw displacement for the vowel portion corresponding to the syllable [MEAT]. These results are evident in Figure 36.7. We should see the impact of these findings in the univariate analysis of variance.

Multivariate analysis of variance was applied.

Table 50.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [MEAT] in Sentence 4 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals significant correlations between closing duration and closing jaw amplitude ($r=0.617174$, $p=0.0432$), and closing jaw duration and closing displacement ($r=0.728710$, $p=0.0110$).

The value of the Wilks' Lambda was significant (Wilks' value =0.21354104, $F=6.4451$, $Pr > F=0.0169$).

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 51.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [MEAT] in Sentence 4 as spoken by Talker JJ and Talker LR.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveal that three jaw variables tested significant. Jaw duration for the opening phase was significant (F value =8.00, $Pr > F=0.0179$, $r^2=0.4444$). Jaw duration during the closing phase was significant as well (F value =7.14, $Pr > F=0.0234$, $r^2=0.4167$), followed by jaw

displacement during the closing cycle (F value =5.52, $Pr > F=0.0406$, $r^2=0.3559$). The findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [MEAT] for the second speaker, Talker LR. Table 49.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [MEAT] as spoken by both Talker LR. Figure 37.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [JOHN DOESN'T KNOW HOW GOOD MEAT TASTES] as spoken by Talker LR are presented.

Jaw duration is about the same for version (a) as compared to the version (b) for both the opening and closing phase for Talker LR. Jaw duration during opening is 116.15 msec with a standard deviation of 29.79 for version (a) as compared to 126.25 msec with a standard deviation of 12.37 for version (b). Jaw duration during closing for version (a) is 85.85 msec with a standard deviation of 12.37 msec, in comparison to 80.80 msec with a standard

deviation of 15.65 for version (b). The differences between version are minimal for both the opening and closing gestures. We should not expect to see significant findings in the univariate analysis. The differences between versions is depicted in Figure 39.7.

Jaw displacement during the opening phase was 4.67 cm with a standard deviation of .82 for version (a), about equal to version (b), which had a mean displacement of 6.67 cm and standard deviation of 1.03. Jaw displacement during the closing phase was 3.67 cm with a standard deviation of 1.37 for version (a), as compared to version (b), which had a mean displacement of 5.17 cm and standard deviation of 1.67. Large differences between version during opening jaw displacement are seen in Figure 39.7 and should be evident in the univariate analysis.

Multivariate analysis of variance was applied. Table 52.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [MEAT] in Sentence 4 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlation between closing jaw duration and closing jaw amplitude ($r=0.675855$, $p=0.0224$).

The value of the Wilks' Lambda was not significant (Wilks' value =0.33807404, $F=3.4264$, $Pr > F=0.0745$).

We will now examine the results of the univariate analysis to identify which jaw movement variable, if any, had most impact on Version. Table 51.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [MEAT] in Sentence 4 as spoken by Talker LR. Evaluation of the results of the univariate analysis of variance for Talker LR reveals that jaw displacement during the opening phase is significant (F value =13.85, $Pr > F=0.0040$, $r^2=0.5806$). These results are aligned to the predictions we made earlier.

Summary

A comparison of the results of Wilk's test between the speakers reveals that the Wilks' Value was significant for both speakers for the first syllable [GOOD]. Only Talker JJ demonstrated a significant Wilks' Value for the syllable [MEAT].

Sentence 5. Lt. Baker instructed his [TROOP] [NA]turally.

Results for Vowel portion Corresponding to Syllable [TROO...]

Results for Talker JJ

Table 53.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [TROO...] in Sentence 5 as spoken by Talker JJ.

Figure 38.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [LT. BAKER INSTRUCTED HIS TROOP NATURALLY] as spoken by Talker JJ are presented.

Jaw duration is longer for version (a) as compared to version (b) for both the opening and closing phase for Talker JJ. This effect is more prominent during the closing phase. Jaw duration during opening for version (a) was 141.40 msec with a standard deviation of 15.65 msec as compared to 126.25 msec with a standard deviation of 12.37 for version (b). Jaw duration during closing for version (a) was 333.30 msec with a large standard deviation of 50.70 msec as compared to shorter mean duration of 237.35 msec with a standard deviation of 29.79 for version (b).

Jaw displacement was about the same for version (a) and version (b) during both the opening and closing phases. Jaw displacement during the opening phase was 7.50 cm with a standard deviation of 1.05 for version (a), in comparison to version (b), which had a mean displacement of 6.67 cm and standard deviation of 1.86. Jaw displacement during the closing phase was 11.67 cm with a standard deviation of 1.03 for version (a), with equal displacement in version (b) that had a standard deviation of 1.97.

In summary, we note large differences between versions for closing jaw duration for the vowel portion corresponding to the syllable [TROO...]. These findings are clearly displayed graphically in Figure 38.7. We should note significant findings for this variable in the univariate analysis of variance.

Multivariate analysis of variance was applied.

Table 54.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [TROO...] in Sentence 5 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveal a highly significant positive correlation between opening and closing jaw amplitude ($r=0.898915$, $p=0.0002$).

The value of the Wilks' Lambda was significant (Wilks' value =0.25298095, $F=5.1675$, $Pr > F=0.0294$).

We will now examine the results of the univariate analysis to identify which jaw movement variables had most impact on Version. Table 55.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [TROO...] in Sentence 5 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveals that jaw duration for the closing phase is significant (F value =15.97, $Pr > F=0.0025$, $r^2=0.6150$). This is apparent in the difference between versions for this variable as presented in Figure 33.7. The findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [TROO...] for the second speaker, Talker LR. Table 53.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [TROO...] as spoken by Talker LR. Figure 39.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [LT. BAKER

INSTRUCTED HIS TROOP NATURALLY] as spoken by Talker LR are presented.

Jaw duration is about the same for the version (a) and version (b) for the opening phase for Talker LR. Jaw duration during the closing cycle is significantly longer for the version (a) as compared to the version (b). Jaw duration during opening for version (a) was 156.55 msec with a standard deviation of 22.81 msec, close in duration as compared to 141.40 msec with a standard deviation of 15.65 for (version(b). Jaw duration during closing for version (a) was 257.55 msec with a standard deviation of 31.78 msec in contrast to 95.95 msec with a standard deviation of 12.37 for version (b). Figure 40.7 clearly displays the difference between versions for closing duration. We expect to see the results of these differences in the univariate analysis of variance.

Jaw displacement was slightly longer for version (b) during the opening cycle and much longer for version (a) during the closing phase. Jaw displacement during the opening phase was 7.17 cm with a standard deviation of 1.17 for version (a), close to version (b), which had a mean displacement of 8.50 cm and standard deviation of 1.38. Jaw displacement during the closing phase was 12.00 cm with a standard deviation of 2.37 for version (a), in contrast to

the version (b), which had a mean displacement of 8.67 cm and standard deviation of 1.03. These findings are evident in Figure 40.7. Given the differences between versions reported for jaw displacement during closing, we do expect to see significant levels in the univariate analysis.

Multivariate analysis of variance was applied.

Table 56.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [TROO...] in Sentence 5 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlations between closing jaw duration and closing amplitude ($r=0.848830$, $p=0.0010$).

The value of the Wilks' Lambda was highly significant (Wilks' value =0.01838157, $F=93.4540$, $Pr > F=0.0001$).

We will now examine the results of the univariate analysis to identify the jaw movement variable that has most impact on Version. Table 55.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [TROO...] in Sentence 5 as spoken by Talker LR. Evaluation of the results of the univariate analysis of variance for Talker LR reveals that jaw duration during the closing phase is highly significant (F value =134.74, $Pr >$

$F=0.0001$, $r^2=0.9309$). Jaw displacement during the closing phase was also significant (F value $=10.00$, $Pr > F=0.0101$, $r^2=0.5000$). These results are aligned to the predictions we made earlier.

Results for Vowel portion Corresponding to Syllable [NA...]

Results for Talker JJ

Table 57.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [NAT...] in Sentence 5 as spoken by Talker JJ.

Figure 38.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [LT. BAKER INSTRUCTED HIS TROOP NATURALLY] as spoken by Talker JJ are presented.

Jaw duration is the same for version (a) and version (b) during the opening cycle and very close during the closing phase for Talker JJ for the vowel portion corresponding to the syllable [NAT...]. Jaw duration during opening for version (a) 131.30 with a standard deviation of 15.65 and is the same for version (b) at 131.30 msec. With a standard deviation of 15.65. The lack of difference

between versions is evident for both the opening and closing phase and is seen in Figure 38.7. We do not to see any significant effects for these variables in the univariate analysis.

Jaw displacement is shorter for version (b) as compared to the version (a) during opening and about the same for both readings during the closing cycle. Jaw displacement during the opening phase was 12.17 cm with a standard deviation of .75 for version (a), as compared to version (b), which had a mean displacement of 13.17 cm and standard deviation of .75. Jaw displacement during the closing phase was 8.67 cm with a standard deviation of 1.37 for version (a), very close to version (b), which had mean displacement of 8.17 cm and standard deviation of .98.

There is some difference between versions evident in Figure 38.7 for the opening phase that might impact on the univariate analysis.

In summary, we note some difference between versions for opening jaw displacement for the vowel portion corresponding to the syllable [NA...]. These results are evident in Figure 38.7. We should see the impact of these findings in the univariate analysis of variance.

Multivariate analysis of variance was applied.

Table 58.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [NA...] in Sentence 5 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals no significant correlations between any of the jaw variables.

The value of the Wilks' Lambda was not significant (Wilks' value =0.43761108, $F=2.2490$, $Pr > F=0.1646$).

We will now examine the results of the univariate analysis. Table 59.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [NAT...] in Sentence 5 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveals that jaw displacement during the opening cycle tested significant (F value =5.29, $Pr > F=0.0442$, $r^2=0.3461$). The findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [NA...] for the second speaker, Talker LR. Table 57.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key

syllable [NAT...] as spoken by Talker LR. Figure 39.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the key vowel portion in the ambiguous sentence [LT. BAKER INSTRUCTED HIS TROOP NATURALLY] as spoken by Talker LR are presented.

Jaw duration is much larger for version (a) as compared to version (b) for both the opening and closing phase for Talker LR. Jaw duration during opening for version (a) is 165.65 msec with a standard deviation of 25.35 as compared to 60.60 msec with a standard deviation of 0 for version (b). Jaw duration during closing for version (a) is 101.00 msec with a standard deviation of 36.70 msec, in contrast to 65.65 msec with a standard deviation of 12.37 for version (b). These extremely large differences between versions for both the opening and closing gestures are clearly seen in Figure 39.7. We should expect to see significant findings in the univariate analysis.

Jaw displacement during the opening phase was 12.50 cm with a standard deviation of 2.43 for version (a), in contrast to version (b), which had a mean displacement of 2.17 cm and standard deviation of 1.17. Jaw displacement

during the closing phase was 9.17 cm with a standard deviation of 1.17 for version (a), in contrast to version (b), which had a mean displacement of 2.17 cm and standard deviation of .98. The large differences between versions during opening and closing jaw displacement are seen in Figure 39.7 and should be evident in the univariate analysis.

In summary, large differences between versions are apparent for all four jaw movement variables. These are clearly seen in Figure 39.7. We expect to see significance in the univariate analysis. In addition, these findings are opposite to those of Talker JJ for this syllable. While they are opposite, they are large, as compared to very small, a different state of affairs. We expect a significant Wilks' Lambda Value for Talker LR in contrast to the insignificant Wilks' Value achieved by Talker JJ.

Multivariate analysis of variance was applied. Table 60.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [NAT...] in Sentence 5 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a

significant positive correlation between opening jaw amplitude and closing jaw amplitude ($r=0.647609$, $p=0.0312$).

The value of the Wilks' Lambda was highly significant (Wilks' value $=0.02608467$, $F=65.3392$, $Pr > F=0.0001$).

We will now examine the results of the univariate analysis to identify jaw movement variable, if any, had most impact on Version. Table 59.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [NAT...] in Sentence 5 as spoken by Talker LR. Evaluation of the results of the univariate analysis of variance for Talker LR reveals several variables that were highly significant. These are jaw displacement during the closing phase (F value $=126.00$, $Pr > F=0.0001$, $r^2=0.9265$) and jaw duration during the opening phase (F value $=105.00$, $Pr > F=0.0001$, $r^2=0.9130$). In addition, jaw displacement during the opening phase was significant (F value $=88.17$, $Pr > F=0.0001$, $r^2=0.8981$) as well as jaw duration during the closing phase (F value $=5.00$, $Pr > F=0.0493$, $r^2=0.3333$). These results are aligned to the predictions we made earlier.

Summary

A comparison of the results of Wilk's test between the speakers reveals that the Wilks' Value was significant for

both speakers for the first syllable [TROO...], and highly significant for Talker LR in comparison to Talker JJ.

Several findings for Talker LR are opposite to those of Talker JJ for the syllable [NA...]. Talker LR demonstrated a significant Wilks' Value for the syllable [NA...] whereas Talker JJ did not. These findings should impact upon the results of the perceptual study.

Sentence 6. Jeffrey [HIT] the [COP] with a stick.

a. Jeffrey had the stick.

b. The cop had the stick.

Results for Vowel Portion Corresponding to Syllable [HIT]

Results for Talker JJ

Table 61.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [HIT] in Sentence 6 as spoken by Talker JJ.

Figure 40.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the vowel portion of the key syllables in the ambiguous sentence [JEFFREY HIT THE COP WITH A STICK] as spoken by Talker JJ are presented.

Jaw duration is longer for version (b) as compared to version (a) for both the opening and closing phase for Talker JJ. This effect is more prominent during the closing phase. Jaw duration during opening for version (a) was 95.95 msec with a standard deviation of 12.37 msec as compared to 166.65 msec with a standard deviation of 16.60 for version (b). Jaw duration during closing for version (a) was 70.70 msec with a standard deviation of 15.65 msec as compared to a much longer mean duration of 368.65 msec with a standard deviation of 35.42 for version (b).

Jaw displacement during the opening phase was 2.83 cm with a standard deviation of 1.17 for version (a), in comparison to version (b), which had a mean displacement of 9.67 cm and standard deviation of 1.03. Jaw displacement during the closing phase was 3.50 cm with a standard deviation of 1.05 for the version (a). Version (b) had a mean duration of 14.67 msec with a standard deviation of 0.52.

In summary, we note large differences between versions for closing jaw duration and amplitude for the vowel Portion corresponding to the syllable [HIT]. These findings are clearly displayed graphically in Figure 40.7. We should note significant findings for this variable in the univariate analysis of variance.

Multivariate analysis of variance was applied.

Table 62.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the vowel portion corresponding to the syllable [HIT] in Sentence 6 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveal a highly significant positive correlation between opening and closing jaw displacement ($r=0.859102$, $p=0.0007$), and a significant negative correlation between opening and closing duration ($r=-0.649063$, $p=0.0307$). This matrix is expected to yield a highly significant Wilks value.

The value of the Wilks' Lambda was highly significant (Wilks' value =0.00518181, $F=335.9698$, $Pr > F=0.0001$), an indication of significant difference between versions and interaction among variables.

We will now examine the results of the univariate analysis although all should be significant. Table 63.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [HIT] in Sentence 6 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveals that all four variables were highly significant, with jaw displacement for the

closing cycle contributing the most to the model (F value =547.44, $Pr > F=0.0001$, $r^2=0.9821$). Jaw duration for the closing phase was also highly significant (F value =355.20, $Pr > F=0.0001$, $r^2=0.9726$). Jaw duration during opening was significant (F value =70.00, $Pr > F=0.0001$, $r^2=0.8750$) as was jaw displacement during opening model (F value =115.14, $Pr > F=0.0001$, $r^2=0.9201$). These differences between versions for all four variables are easily seen in Figure 40.7. The findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [HIT] for the second speaker, Talker LR. Table 61.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [HIT] as spoken by Talker LR. Figure 41.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the vowel portion of the key syllables in the ambiguous sentence [JEFFREY HIT THE COP WITH A STICK] as spoken by Talker LR are presented.

Jaw duration and displacement vary slightly for version (a) and version (b) for the opening phase for Talker LR.

However, jaw duration and displacement during the closing cycle is significantly longer for version (b) as compared to version (a). Jaw duration during opening for version (a) was 156.55 msec with a standard deviation of 12.37 msec. This is close in duration when compared to 166.65 msec with a standard deviation of 16.60 for version (b). Jaw duration during closing for version (a) was 80.80 msec with a standard deviation of 15.65 msec in contrast to 368.65 msec with a standard deviation of 117.22 for version (b). Figure 41.7 clearly displays the difference between versions for closing duration and displacement. We expect to see the results of these differences in the univariate analysis of variance.

Given the differences between versions reported for jaw displacement during closing, we do expect to see significant levels in the univariate analysis.

Multivariate analysis of variance was applied. Table 64.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [HIT] in Sentence 6 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlation between opening and closing amplitude ($r=0.703783$, $p=0.0157$).

The value of the Wilks' Lambda was significant (Wilks' value =0.09928598, $F=15.8759$, $Pr > F=0.0013$).

Table 63.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [HIT] in Sentence 6 as spoken by Talker LR. Evaluation of the results of the univariate analysis of variance for Talker LR reveals that jaw displacement during the closing phase is highly significant (F value =41.54, $Pr > F=0.0001$, $r^2=0.8060$), as was jaw duration during the closing phase (F value =35.55, $Pr > F=0.0001$, $r^2=0.7804$). These results are aligned to the predictions we made earlier.

Results for Vowel Portion Corresponding to Syllable [COP]

Results for Talker JJ

Table 65.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [COP] in Sentence 6 as spoken by Talker JJ.

Figure 40.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the vowel portion of the key syllable in the ambiguous sentence [JEFFREY HIT THE COP WITH A STICK] as spoken by Talker JJ are presented.

Jaw duration is longer for the first reading (version a) during both the opening and closing phase. For version (a), jaw duration during opening is 146.45 msec with a standard deviation of 22.81 msec. During closing, jaw duration is 161.60 msec with a standard deviation of 24.74 msec. For version b, jaw duration during opening is 85.85 msec with a standard deviation of 22.81 msec. During closing, jaw duration is 90.0 msec with a standard deviation of 0.0 msec. In summary, there are significant differences in duration between the opening and closing gestures for both versions (a) and (b).

During the opening gesture, jaw displacement for version (a) is 9 cm with a standard deviation of 1.1 cm. During closing, jaw displacement is 11.17 cm with a standard deviation of .75 cm for version (a). For version b, jaw displacement during opening is 8.67 cm with a standard deviation of 1.03 cm, and for the closing cycle it is 8.00 cm with a standard deviation of 1.26 cm.

To summarize, there are visible differences between versions in duration for the opening and closing closing jaw gestures. There is a significant difference between versions in closing jaw displacement as well.

Multivariate analysis of variance was applied. Table 66.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [COP] in Sentence 6 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant correlation between opening and closing jaw amplitude ($r=0.721988$, $p=0.0121$).

The value of the Wilks' Lambda was significant (Wilks' value =0.05007333, $F=33.1987$, $Pr > F=0.0001$).

We will now examine the results of the univariate analysis. Table 67.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [COP] in Sentence 6 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveals that jaw duration during closing tested highly significant (F value =49.00, $Pr > F=0.0001$, $r^2=0.8305$) as did jaw displacement during the closing cycle (F value =27.77 $Pr > F=0.0004$, $r^2=0.7352$).

Jaw duration during opening also tested significant (F value = 21.18 $Pr > F = 0.0010$, $r^2 = 0.6792$). These findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [COP] for the second speaker, Talker LR. Table 65.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [COP] as spoken by Talker LR. Figure 41.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the vowel portion of the key syllables in the ambiguous sentence [JEFFREY HIT THE COP WITH A STICK] as spoken by Talker LR are presented.

Jaw duration is about the same for both versions during the opening gesture. Jaw duration during opening is 116.15 msec with a standard deviation of 22.81 msec for version (a) as compared to 111.10 msec with a standard deviation of 84.98 msec for version (b). Jaw duration during closing for version (a) is 126.25 msec with a standard deviation of 44.60 msec, in contrast to 95.95 msec with a standard deviation of 61.85 for version (b).

Jaw displacement during the opening phase was 8.33 cm with a standard deviation of 0.52 for version (a), in contrast to version (b), which had a mean displacement of 7.50 cm and standard deviation of 5.24. Jaw displacement during the closing phase was 9.00 cm with a standard deviation of 1.55 for version (a), as compared to version (b), which had a mean displacement of 7.5 cm and standard deviation of 4.04. The minimal differences between versions during opening and closing jaw displacement are seen in Figure 40.7 and should be evident in the univariate analysis.

In summary, differences between versions for the jaw movement variables appear minimal, with the exception of closing jaw amplitude. These are clearly seen in Figure 41.7. We expect to see little significance in the univariate analysis.

Multivariate analysis of variance was applied. Table 68.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [COP] in Sentence 6 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a highly significant positive correlation between opening

duration and opening amplitude duration ($r=0.853893$, $p=0.0008$) and opening and closing jaw duration ($r=0.752570$, $p=0.0075$). There was also a significant positive correlation between opening and closing jaw amplitude ($r=0.811875$, $p=0.0024$), and closing duration and closing amplitude duration ($r=0.652411$, $p=0.0296$).

The value of the Wilks' Lambda was not significant (Wilks' value =0.84056130, $F=0.3319$, $Pr > F=0.8483$).

We will now examine the results of the univariate analysis. Table 67.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [COP] in Sentence 6 as spoken by Talker LR. There were no significant findings for Talker LR. These results are aligned to the predictions we made earlier.

Summary

A comparison of the results of Wilk's test between speakers reveals that the Wilks' Value was significant for both speakers for the first syllable [HIT]. The Wilks was significant for Talker JJ for the Vowel Portion corresponding to [COP]. These findings should impact upon the results of the perceptual study.

Sentence 7. She [IS] unhappily [MAR...]ried.

Results for Vowel Portion Corresponding to Syllable [IS]

Results for Talker JJ

Table 69.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [IS] in Sentence 7 as spoken by Talker JJ.

Figure 42.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the vowel portion of the key syllables in the ambiguous sentence [SHE IS UNHAPPILY MARRIED] as spoken by Talker JJ are presented.

Jaw duration is longer for version (b) as compared to the version (a) for both the opening and closing phase for Talker JJ. Jaw duration during opening for version (a) was 131.30 msec with a standard deviation of 15.65 msec as compared to 166.65 msec with a standard deviation of 16.60 for version (b). Jaw duration during closing for version (a) was 126.25 msec with a standard deviation of 12.37 msec as compared to a much longer mean duration of 313.10 msec with a standard deviation of 24.74 for version (b).

Jaw displacement during the opening phase was 9.17 cm with a standard deviation of 1.17 for version (a), close in comparison to version (b), which had a mean displacement of 10.67 cm and standard deviation of 1.86. Jaw displacement during the closing cycle was 10.00 cm with a standard deviation of 1.79 for version (a). Version (b) had a mean amplitude of 16.33 cm with a standard deviation of 1.53 cm.

In summary, we note large differences between versions for closing jaw duration and displacement for the Vowel Portion corresponding to the syllable [IS], most clearly in closing jaw duration and amplitude for version (b). These findings are clearly displayed graphically in Figure 35.7. We should note significant findings for this variable in the univariate analysis of variance.

Multivariate analysis of variance was applied. Table 70.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [IS] in Sentence 7 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveal a highly significant positive correlation between opening and closing jaw displacement ($r=0.888890$, $p=0.0003$). In addition, there was a significant positive correlation

between closing duration and closing amplitude
($r=0.6663325$, $p=0.0261$).

The value of the Wilks' Lambda was highly significant (Wilks' value =0.01891343, $F=90.7768$, $Pr > F=0.0001$), an indication of significant difference between versions and interaction among variables.

We will now examine the results of the univariate analysis. We predict that several should be significant. Table 71.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [IS] in Sentence 7 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveals that three variables were significant, with jaw duration for the closing cycle contributing the most to the model (F value =273.80, $Pr > F=0.0001$, $r^2=0.9648$). Jaw displacement for the closing phase was also highly significant (F value =41.02, $Pr > F=0.0001$, $r^2=0.8040$). Jaw duration during opening was also significant (F value =14.41, $Pr > F=0.0035$, $r^2=0.5954$). These differences between versions for all four variables are easily seen in Figure 35.7. These findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [IS] for the second speaker, Talker LR. Table 69.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [IS] as spoken by Talker LR. Figure 43.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the vowel portion of the key syllables in the ambiguous sentence [SHE IS UNHAPPILY MARRIED] as spoken by Talker LR are presented.

Jaw duration is significantly greater for both the opening and closing cycle for version (b). Jaw duration during opening is 95.95 msec with a standard deviation of 12.37 for version (a) and 287.85 msec with a standard deviation of 87.29 msec for version (b). Jaw duration during closing is 65.65 msec with a standard deviation of 12.37 msec for version (a) as compared to 272.70 msec with a standard deviation of 63.56 msec for version (b). Note the relatively large standard deviations that accompany the large duration during production of version (b)

Jaw displacement during opening for version (a) was 3.00 cm with a standard deviation of 1.26 cm, close to the findings for version (b), which were 5.33 cm with a

standard deviation of 1.86. Differences between versions were significant for jaw displacement during closing. Version (a) presented with a mean amplitude of 3.17 and standard deviation of .75 cm, in contrast to version (b), which demonstrated a mean amplitude of 10.17 cm and a standard deviation of 1.33 cm. Figure 42.7 clearly displays the difference between versions for closing duration and displacement.

Given the differences between versions reported for jaw duration during opening and closing, as well as the accompanying differences between versions in amplitude, we expect to see significant levels in the univariate analysis.

Multivariate analysis of variance was applied. Table 72.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [IS] in Sentence 7 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a highly significant negative correlation between opening duration and opening amplitude and closing duration ($r = -0.905961$, $p = 0.0001$), and a significant positive correlation

between opening and closing jaw amplitude ($r=-0.736788$, $p=0.0097$).

The value of the Wilks' Lambda was highly significant (Wilks' value =0.00544838, $F=319.4464$, $Pr > F=0.0001$).

Table 71.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [IS] in Sentence 7 as spoken by Talker JJ. Evaluation of the results of the univariate analysis of variance for Talker LR reveals that all jaw variables tested at significant levels. Jaw displacement during the closing phase is highly significant (F value =126.00, $Pr > F=0.0001$, $r^2=0.9265$), as was jaw duration during the closing phase (F value =61.35, $Pr > F=0.0001$, $r^2=0.8598$). Jaw duration during the opening phase is highly significant (F value =28.43, $Pr > F=0.0003$, $r^2=0.7398$), and jaw displacement during opening phase was significant as well (F value =6.45, $Pr > F=0.0294$, $r^2=0.3920$). These results are aligned to the predictions we made earlier.

Results for Vowel Portion Corresponding to Syllable [MAR...]

Results for Talker JJ

Table 73.7 presents the analysis of jaw movement variables with standard deviations for the key syllable [MAR...] in Sentence 7 as spoken by Talker JJ.

Figure 42.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the opening and closing phase of the vowel portion of the key syllables in the ambiguous sentence [SHE IS UNHAPPILY MARRIED] as spoken by Talker JJ are presented.

Jaw duration is about the same during both the opening and closing phase. Jaw duration during opening for version (a) is 106.05 msec with a standard deviation of 16.60. This is equal to the closing phase, 106.05 msec with a standard deviation of 16.60. For version (b) during opening, jaw duration is 131.30 msec with a standard deviation of 24.74. During closing, duration for version (b) is 126.25 with a standard deviation of 48.54. In summary, there appears to be little difference in duration between the opening and closing gestures for version both versions (a) and (b), while the duration for version (b) is somewhat larger. We do not expect to see significant effects in the univariate analysis.

During the opening gesture, jaw displacement for version (a) is 8.17 cm with a standard deviation of 1.33 cm. During closing for version (a), jaw displacement is 7.50 cm with a standard deviation of 1.05. For version b, jaw displacement during opening is 15.0 cm with a standard deviation of 4.05 cm, and for the closing cycle it is 11.83 cm with a standard deviation of 1.83 cm. The differences between versions in amplitude and duration are therefore in the same direction, with the values for version (b) being larger.

To summarize, there are visible differences between displacement for both the opening and closing jaw gestures, and these appear to be in the same direction as duration. Given that the amplitude is almost double during version (b) for both the opening and closing phases, we predict significant effects for amplitude in the univariate analysis.

Multivariate analysis of variance was applied. Table 74.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [MAR...] in Sentence 7 as spoken by Talker JJ.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a

significant negative correlation between opening jaw amplitude and closing jaw duration ($r=-0.734429$, $p=0.0101$).

The value of the Wilks' Lambda was highly significant (Wilks' value =0.05444838, $F=319.4464$, $Pr > F=0.0001$).

We will now examine the results of the univariate analysis. Table 75.7 presents the Univariate Analysis of Variance for jaw movement variables for the key syllable [MAR...] in Sentence 7 as spoken by Talker JJ.

Evaluation of the results of the univariate analysis of variance for Talker JJ reveals that jaw displacement during the opening cycle tested significant (F value =15.42, $Pr > F=0.0028$, $r^2=0.6066$). Also, jaw displacement during the closing cycle tested significant (F value =23.15, $Pr > F=0.0007$, $r^2=0.6983$). These findings follow the predictions made earlier.

Results for Talker LR

We will now present the results of the analysis of the syllable [MAR...] for the second speaker, Talker LR. Table 73.7 presents the results of the analysis of the jaw movement variables with the standard deviations for the key syllable [MAR...] as spoken by Talker LR. Figure 42.7 displays a series of bar graphs depicting these data. Mean duration (msec) and mean jaw displacement (cm) with

standard deviations during the opening and closing phase of the vowel portion of the key syllables in the ambiguous sentence [SHE IS UNHAPPILY UNMARRIED] as spoken by Talker LR are presented.

Jaw duration for version (a) is somewhat greater during opening as compared to version (b). During opening, duration is 126.25 msec with a standard deviation of 22.81 for version (a). For version (b) jaw duration during opening is 95.95 msec with a standard deviation of 40.27. Jaw duration during closing is slightly longer for version (b) at 136.35 msec with a standard deviation of 85.16, as compared to version (a), which presented with a mean duration of 116.15 msec and a standard deviation of 35.42. We do not expect to see significant findings in the univariate analysis for these variables.

Jaw displacement during the opening phase was 8.17 cm with a standard deviation of 2.64 for version (a), and 7.33 cm with a standard deviation of 6.74 for version (b). Jaw displacement during the closing phase was 8.67 cm with a standard deviation of 0.82 for version (a), as compared to version (b), which had a mean displacement of 9.17 cm and standard deviation of 2.64. The minimal differences between versions during opening and closing jaw displacement and the large standard deviations are clearly seen in Figure

42.7. As with duration, we should not see significant findings in the univariate analysis.

In summary, differences between versions for the jaw movement variables appear minimal as seen in Figure 42.7. We expect to see little significance in the univariate analysis.

Multivariate analysis of variance was applied. Table 76.7 presents the partial correlation coefficients from the Error Sum of Squares and Cross Products Matrix for the segment corresponding to the syllable [MAR...] in Sentence 7 as spoken by Talker LR.

Analysis of the partial correlations from the error sum of squares matrix of the multivariate test reveals a significant positive correlation between opening duration and opening jaw amplitude ($r=0.804633$, $p=0.0028$) as well as a significant positive correlation between closing duration and closing jaw amplitude ($r=0.764922$, $p=0.0061$).

The value of the Wilks' Lambda was not significant (Wilks' value =0.51737521, $F=1.6325$, $Pr > F=0.2679$).

We will now examine the results of the univariate analysis. Table 75.7 presents the Univariate Analysis of Variance for jaw movement variables for syllable [MAR] in Sentence 7 as spoken by Talker LR. There were no

significant findings for Talker LR. These results are aligned to the predictions we made earlier.

Summary

A comparison of the results of Wilk's test between the speakers reveals that the Wilks' Value was highly significant for both speakers for the first syllable [IS]. For the vowel portion of the second syllable, the Wilks was significant for Talker JJ.

The overall pattern of significance across sentences and sentence types will be presented in the **Discussion**.

Chapter 8.

Discussion

In order to motivate the discussion of the results of this dissertation, I will first present the purpose of the study, the hypotheses tested and concomitant results, and inferences for further study.

Purpose of the Study

The goal of this study was to investigate the role of the jaw in conveying suprasegmental information to the speechreader. We focussed on disambiguation of syntactic ambiguity through underlying cues for visual suprasegmental information. There were three parts to this experiment; a perceptual study, an acoustic study, and a study of jaw movement.

For the perceptual study, subjects were asked to discriminate between two interpretations for six productions of each ambiguous sentence pair in four conditions for the two speakers; (1) audio-natural, (2) audio-reiterant, (3) visual-natural, and (4) visual-reiterant.

The acoustic study and movement study focus on the reiterant utterances. The acoustic study reported on

measurements of syllable duration for phrases critical to the disambiguation of the sentence.

The movement study reported on differences in jaw duration and amplitude for the opening and closing gestures as a function of sentence type.

Prior to these studies, an analysis of seven sentences was performed to determine the phrase structure of each. To eliminate the effects of context on segmental duration, the sentences were produced in non-sentence reiterant mode; that is, the speakers mimicked the sentences with "ma" substituted for each syllable. The acoustic and jaw movement measurements examined the reiterant utterances.

The primary hypothesis tested was that suprasegmental information is available to speechreaders, as revealed by their ability to discriminate reiterant versions of ambiguous sentences with different syntactic structures presented without the audio signal. This was proved in the perceptual study.

Predictions Compared with Results of Acoustic and Movement Data

The results of a per cent correct distribution in isolation do not inform on a dichotomous variable; that is, a study in which there are two equally probable outcomes (version in this study). This issue provided the motivation to further explore the data by generating binomial confidence intervals. Twenty subjects participated in the perceptual task. The first test performed was a binomial exact test to determine whether both versions of the test sentences were equally discriminable for each of the four conditions.

In brief, for both talkers, the null hypothesis was rejected for all sentences and all conditions, at the .95 confidence interval. However, there were several findings worth pursuing.

Table 77.8 was designed to present these results. The columns are numbered and labeled. Remember that the purpose of generating Binomial Confidence Intervals was to assure that the versions for each sentence were equally discriminable. The table is designed to be read vertically, and each column is numbered comparing version (a) to version (b).

Table 77.8 first compares the Binomial Mean for the Visual-Natural condition (column 4) version (a) to the Binomial Mean to the Visual-Natural condition (column 4) for version (b). For Sentence 1 Talker JJ, there is a discrepancy between versions for the Binomial Mean Visual-Natural Condition version (a) (.7167) and the Binomial Mean Visual-Natural version (b) (.9583), suggesting that although these results fell within the 95% Confidence Interval, the results may not be reliable. The same pattern is found for the Binomial Means in the the Visual-Natural Condition for Sentences 2, 3, and 4. For Talker JJ, Sentence 6, there was a large discrepancy between the Binomial Mean between versions for the Visual-Reiterant condition.

In comparison with the Per Cent Correct Scores, Talker JJ demonstrates a larger difference between versions for Sentence 4 for the Visual-Natural condition (column 8) and Visual-Reiterant condition (column 9).

Talker LR demonstrated a wide discrepancy in Binomial Means between versions for Sentence 1 in the Visual-Natural and Visual-Reiterant Conditions. This was reflected in the Per Cent Correct scores for this sentence in the Visual-Natural Condition. Talker LR also demonstrated a large discrepancy in Binomial Means between

versions for the Visual-Natural Condition for Sentence 4. This was reflected in his performance in the Visual-Natural Per Cent Correct condition. Talker LR performed at near chance levels for Sentence 6 in the Binomial Means Visual-Natural test.

To summarize, there is some question whether the Binomial Confidence Interval is a valid measure of equal discrimination between versions. Also, note that the discrepancies occurred for Sentences 1, 4, and 6 for both Talkers.

Comparison of Visual-Natural and Visual-Reiterant Results

The low means for the visual-natural condition were very near to chance, although within the 95% binomial confidence intervals. The large difference between versions (a) and (b) for the visual natural condition for Sentence 1 as spoken by Talker LR suggests that the binomial exact test was not sensitive enough to identify unequal proportions, as a score of .4583 is extremely close to chance.

The results of the perceptual study were then summarized and described in terms of percent correct identification. By analyzing those differences in the

acoustic and movement data associated with successful and unsuccessful reiterant utterances, factors important to subjects' identification could be revealed. In summary, the main question for the perception study was whether subjects consistently identify each version presented at better than chance levels for each of the seven test sentences and whether their scores was related to predictions made by phrase structure rules in light of the jaw movement data.

As predicted, discrimination was greater in the visual-reiterant mode as compared to its natural analog. Viewers' discrimination of Sentence 1 for both talkers was variable across conditions. In all but one case, Talker LR, **Sentence 4**, subjects scored at or very near 100% correct identification in the audio-natural condition. This was surprising, since Talker LR presented mean acoustic duration in the correct direction as predicted by the node height principle. This suggests that another parameter not measured in this experiment played a role in listeners' disambiguation, such as intonation.

There was more of a range in performance in the audio-reiterant condition with subjects scoring at or near 90% correct identification to 100% correct identification with one exception, Talker LR **Sentence 4**, both versions. The overall pattern of discrimination was lowest for the

visual-natural sentences. There was a significantly high degree of variability in viewers' scores in this condition. The median percent correct in the visual-reiterant condition ranged from 93% to 95% for both talkers.

Sentence 4 requires further analysis and comparison with the findings for **Sentence 5**. As previously noted, early studies reported that listeners failed to identify the intended meanings of **Sentence 4** (John doesn't know how [GOOD] [MEAT] tastes) because the instructions were not clear in this case (Lehiste, 1973c).

Next, suprasegmental information is better conveyed in reiterant speech than in natural speech. It was hypothesized that the relevant prosodic speech patterns are preserved and more usable in the reiterant speech in the visual mode as compared to the video-natural modality. Several interesting findings were noted in the current study in the visual-reiterant modality. First, in the case of Talker JJ, viewers consistently identified versions (a) and (b) of Sentence 4, 90 and 99.17 percent correct respectively. However, they were not consistent with correct identification in the case of Sentence 5, 80.83 and 63.33 percent correct. There are contrasting findings in viewers' identification of the ambiguity presented in Sentence 4 by Talker LR, 82.5 and 74.17 percent correct

scores. However, for Sentence 5, viewers scored consistently well for this talker, 93.33 and 99.17 for versions (a) and (b). This poses several issues that were addressed in the discussion of the Movement Analysis.

To summarize, listeners/viewers were able to make use of the salient prosodic speech patterns in both the visual-only modes, with greater variability in the visual-reiterant modes. Talker LR demonstrated approximately twenty-five percent more variability than Talker JJ in the visual-natural modes. It is known that speaker differences do influence speechreader performance.

For both talkers, subjects generally scored better in the visual-reiterant condition than in the visual-natural condition. Subjects were able to make more efficient use of the visible speech patterns in the absence of contextual cues. This occurrence was predicted since conflicting cues provided by production of individual segments could obscure the relevant prosodic speech patterns necessary for disambiguation by the speechreader.

Observers are able to make use of visible prosodic features of stress, pattern, and rhythm to correctly disambiguate the reiterant sentences. Since segmental effects are absent from reiterant speech, observers have less difficulty with discriminating ambiguous sentences in

reiterant speech than in natural utterances. This effect was apparent in comparing the visual perception of jaw movement for the natural and reiterant utterances.

Speechreaders' performance on the reiterant patterns were better for the reiterant utterances as compared to the natural sentences.

Analysis of Results of Predictions from Sentences Compared to Acoustic Analysis

Table 78.8 presents the results of comparison of the acoustic duration measures and ANOVA results with the predictions of the derived by the node height principle. The Syllable is identified. Its **Prediction** states the direction of the acoustic duration of the version. Levels of significance are presented in the ANOVA column.

Overall, Talker JJ performed better than Talker LR in terms of the direction of the prediction. However, in terms of the null hypothesis of no difference between Versions, Talker LR performed equally well. This suggests that Talker LR was using a strategy not measured in this study, such as intonation or pausing.

Comparisons of Predictions with Perceptual, Acoustic and Jaw Movement Data

According to the node height principle, certain predictions concerning acoustic timing effects of key segments can be made based upon the nature of the

Table 79.8 summarizes the relationships between the results of the perceptual study, the acoustic and jaw data and talkers. In summary, it was hypothesized that systematic differences in the pattern of jaw movement over time will differentiate the phrase structure in question for each ambiguous sentence pair. This methodology did provide additional information, as can be seen in the similar pattern of Sentences falling within each matrix square.

Although speechreading performance varied according to speaker, there are obvious patterns in the data which are aligned to speechreading performance.

Inferences for Further Study

There are several interesting findings in this thesis worth follow-up. Both are based on the work in the visual-reiterant mode.

Appendix A describes the experiment from which the sentences for the main project were selected. Prior to this pre-study, a small experiment was performed which included subjects with varying degrees of eighth nerve hearing impairment, ranging from mild to moderate age-induced to severe deafness from birth.

It was observed that unlike the normal hearing adults, the hearing impaired depended more on the contextual environment in identifying whether the version presented was (a) or (b). In fact, the greater the degree of hearing loss, the greater the degree of difficulty of the task.

This is a study that could be done by repeating the protocol with standardized levels of hearing impairment. Also, it is well known that prosody is affected by degree of hearing impairment, adding to the theory of the relationship between speech perception and speech production.

The second area of interest worth exploring is to determine what minimal difference in visual jaw duration cues the presence of a phrase boundary. This can be accomplished through visual speech synthesis using the same talkers and adding or deleting frames at the join-points. Here I would use the most open portion of the lips indicating the steady state position of the vowel

(Unpublished results, J. Porrazzo). This experiment can explore whether visual phrase boundary perception is a discrimination or categorical task. These are areas worth exploring, with clinical implications.

Appendix A: Pilot Study

Attachment 1

This section presents the procedure and results of an earlier experiment. The purpose of the pilot study was to validate the use of reiterant speech in the study of speechreading as well as selection of the test materials to be used in the main experiment.

Research Method

Speech materials used consisted of two sets of 19 ambiguous sentences in which the words were composed of identical lexical items, and might be disambiguated only through prosodic information. Table I presents these nineteen sentences and interpretations. These sentences were gathered from previous studies of syntactically determined timing effects in speech (Cooper & Paccia-Cooper, 1980; Lehisté, 1973c; Lehisté, Olive, & Streeter, 1976). The sentences varied in length and syntactic structure.

Speakers

Two talkers, one male and one female, both native New Yorkers, were selected to present the sentences. Details of the specific instructions given to the speakers is documented in **Attachment I** in **Appendix B**.

Preparation of the Video Laserdisc

Two out of the twelve repetitions videotaped were selected for dubbing to video laserdisc. The fifth and eleventh sets were used when possible. A set was selected if the reiterant version of that repetition met the criteria for "good" reiterant speech. That is, being judged as a good imitation of the natural utterance by following the original sentence closely in rate and stress and having the same number of syllables as the natural counterpart.

Instrumentation

Two repetitions of both versions of the nineteen test items were then dubbed to video laserdisc (Panasonic TQ-2027F). Details of the procedure for laserdisc recording and instrumentation Block Diagram are presented in the main section.

Subjects

Ten subjects viewed and listened to the sentences. Nine, all female, were students or graduates in speech pathology and audiology; the tenth, a male, held a degree in psychology. Eight were native speakers of American English, and two spoke a British dialect. All ten subjects

were normal-hearing ($< 20\text{dB HL}$ at .25, .50, 1.0, 2.0, 4.0 and 8.0 Hz), and demonstrated a minimum of 20:20 corrected vision in both eyes as evaluated using a Snellen chart at a viewing distance of 20 feet in a darkened room.

All signed a **Subject Consent Form** as required by the University. **Attachment II** in **Appendix B** presents this form.

Training

Instructions to the subjects were given orally. The type of stimulus item was explained and examples were presented by the experimenter, first for the natural and then for the reiterant communication. Subjects were given response sheets containing a randomized order of the nineteen test sentences and their two interpretations. The first six and test items twenty-six through thirty-one were duplicate "foils" and not analyzed. Subjects were told that test sentences could appear more than once to insure against responses based on sentence order.

Attachment III of **Appendix B** presents one of the four test forms used in the main study.

Task

Two different productions of interpretations (a) and (b) for each of the nineteen sentences were presented in

all four test conditions--audio-natural, audio-reiterant, visual-natural, and visual-reiterant--for each speaker. The order of presentation for the four conditions for each form was randomized for each subject and both talkers to reduce any sequencing or carry-over effects.

The audio signal was presented through standard headphones (Radio Shack Nova-40) at a comfortable listening level selected by the subject. For the visual conditions, subjects were tested in a dimly lit room at a distance of about 6 feet from an 18 5/8 inch high resolution black and white monitor (Panasonic WV-5490).

Observers/listeners were asked to familiarize themselves with the different interpretations of each ambiguous pair and to mark which version was presented. At the end of each test condition, response sheets were collected and the subject rested several minutes before beginning the next condition. No information was given about the correct response.

Results of the Pilot Study

The first question to be resolved for the pilot study is whether the sentences in their natural and reiterant form are auditorally and visually discriminable for both talkers. Table II presents the percent correct score and

summary statistics for each sentence set collapsed across the two versions for each talker.

The next step in selection of sentences for the main experiment was to determine which of the sentences met the following criteria for both talkers:

90% correct or above correct discrimination in the audio-normal condition, and
balanced selection of (a) and (b) versions for all other conditions

The scores were sorted in descending order for the audio-natural (primary) and audio-reiterant (secondary) conditions. For talker JJ, nine sentence pairs presented with > 90% correct discrimination for the audio natural condition, and were balanced in the other conditions.

Twelve sentence pairs met these criteria for talker LR. The sorted list was then compared across talkers and seven matches were found. The sentences identified as meeting the specified criteria for both talkers were 2, 4, 11, 12, 14, 15, and 17. Tables III and IV present the

complete results for the selected sentences, broken down for each version by speaker.

Table I. Ambiguous sentences used in the pilot study and their interpretations

1. I SAW CHUCK LOOKING THROUGH THE WINDOW
 - a. I was looking through the window.
 - b. Chuck was looking through the window.

2. HERE IS THE FAMOUS DUKE JAMES
 - a. James meets the Duke.
 - b. The name of the Duke is James.

3. PAM ASKED JAKE WHO THE COP CONFRONTED
 - a. Pam asked Jake "Who did the cop confront?"
 - b. The cop confronted Jake.

4. THE OLD MEN AND WOMEN STAYED AT HOME
 - a. The old people stayed at home.
 - b. The old men and all the women stayed at home.

Table I (cont'd)

Table I (cont'd)

5. STEVE OR SAM AND BOB WILL COME
 - a. Either Steve or both Sam and Bob will come.
 - b. Either Steve or Sam will come with Bob.

6. I KNOW MORE BEAUTIFUL WOMEN THAN MARY
 - a. The women I know are more beautiful than Mary.
 - b. I know more beautiful women than Mary knows.

7. CHRIS THE LAST HOLDOUT CONSENTED
 - a. Chris finally consented.
 - b. Tell Chris that everyone consented.

8. HERMAN THE LOSER GOES FIRST
 - a. Herman is the loser.
 - b. Tell Herman that the loser goes first.

9. MARY TAKES THE BUS ANDORA (AND DORA) DRIVES TO WORK.
 - a. Mary takes the bus to work that Andora drives.
 - b. Mary and Dora commute differently to work.

Table I (cont'd)

10. MARY WAS LISTENING TO THE SONG ANN DELLA (AND ELLA)
WAS SINGING

- a. Mary was listening to the song that Ann Della was singing.
- b. Mary was listening and Ella was singing.

11. THE HOSTESS GREETED THE GIRL WITH A SMILE

- a. The hostess was smiling.
- b. The girl was smiling.

12. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES

- a. John has never tasted good meat.
- b. John does not like meat.

13. THE POLICE STOPPED FIGHTING AFTER DARK

- a. The police were fighting.
- b. The police stopped the fighting.

4. LT. BAKER INSTRUCTED HIS TROOP NATURALLY

- a. Of course, Lt. Baker instructed his troop.
- b. Lt. Baker instructed his troop in a natural way.

Table I (cont'd)

15. JEFFREY HIT THE COP WITH A STICK
- a. Jeffrey had the stick.
 - b. The cop had the stick.
16. JOHN DIDN'T DATE PAT BECAUSE OF HER BODY
- a. John did not date Pat because of her body.
 - b. John did date Pat, but not because of her body.
17. SHE IS UNHAPPILY MARRIED
- a. She has an unhappy marriage.
 - b. It is too bad that she is married.
18. THAT'S JUST INSIGHT
- a. It's just in view.
 - b. It's just an educated guess.
19. BUY BOBBY A PUPPY
- a. Buy a puppy for Bobby, not Jimmy.
 - b. Buy a puppy for Bobby, not a kitten.

Table II. Percent correct identification scores and summary statistics for each condition collapsed across two productions and two versions in the pilot study (Subject N = 10)

	Speaker JJ				Speaker LR			
	A-N	A-R	V-N	V-R	A-N	A-R	V-N	V-R
1	77.50	67.50	72.50	52.50	90.00	67.50	60.00	55.00
2	97.50	100.00	60.00	87.50	100.00	90.00	42.50	50.00
3	75.00	75.00	60.00	77.50	60.00	47.50	57.50	50.00
4	97.50	95.00	90.00	97.50	100.00	92.50	100.00	97.50
5	95.00	92.50	97.00	85.00	87.50	67.50	77.50	90.00
6	77.50	77.50	52.50	70.00	55.00	70.00	60.00	45.00
7	72.50	67.50	72.50	70.00	100.00	95.00	50.00	77.50
8	87.50	95.00	90.00	87.50	97.50	97.50	92.50	97.50
9	72.50	70.00	70.00	85.00	55.00	47.50	65.00	47.50
10	82.50	47.50	45.00	42.50	87.50	52.50	77.50	80.00
11	95.00	85.00	85.00	80.00	97.50	72.50	75.00	97.50
12	95.00	67.50	67.50	72.50	92.50	50.00	60.00	60.00
13	82.50	67.50	65.00	82.50	80.00	65.00	67.50	87.50
14	90.00	85.00	57.50	65.00	97.50	92.50	67.50	87.50
15	97.50	87.50	85.00	85.00	95.00	75.00	85.00	65.00
16	90.0	80.00	40.00	55.00	85.00	60.00	47.50	60.00
17	97.50	100.00	95.00	95.00	97.50	100.00	92.50	95.00
18	85.00	90.00	72.50	65.00	95.00	85.00	65.00	85.00
19	87.50	85.00	72.50	82.50	97.50	95.00	70.00	67.50
<u>Mn.</u>	87.10	80.79	71.03	75.66	87.89	74.87	69.08	73.42
<u>Mdn.</u>	87.50	85.00	72.50	80.00	95.00	72.50	67.50	77.50
<u>Std.</u>	8.95	13.82	16.38	14.67	14.98	18.23	15.71	18.93
V-N = Audio-Natural								
A-R = Audio-Reiterant								
V-N = Visual-Natural								
V-R = Visual-Reiterant								

Table III. Percent correct identification for sentences selected from pilot study as test materials as spoken by Talker JJ for each condition and version across two productions (Subject N = 10)

Set	Audio-N		Audio-R		Visual-N		Visual-R		
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	
2	100.00	95.00	100.00	90.00	60.00	80.00	100.00	75.00	
4	100.00	95.00	95.00	95.00	90.00	90.00	100.00	95.00	
11	100.00	95.00	85.00	85.00	90.00	80.00	90.00	60.00	
12	95.00	95.00	60.00	75.00	45.00*	90.00	60.00	75.00	
14	95.00	85.00	95.00	75.00	45.00*	70.00	55.00	75.00	
15	100.00	95.00	95.00	80.00	90.00	80.00	90.00	80.00	
17	100.00	95.00	100.00	100.00	95.00	95.00	90.00	100.00	
<u>Mn.</u>	98.57	93.57	90.00	85.71	73.57		83.57	83.57	80.00
<u>Mdn.</u>	100.00	95.00	95.00	85.00	90.00		90.00	90.00	75.00
<u>Std.</u>	2.44	3.78	14.14	9.76	22.68		8.52	18.42	13.54

Audio-N = Audio-Natural

Audio-R = Audio Reiterant

Visual-N = Visual Natural

Visual-R = Visual Reiterant

* indicates sentence was selected based upon auditory performance

Table IV. Percent correct discrimination for sentences selected from pilot study as test material for Talker LR for each condition and version across two productions (Subject N = 10)

<u>Set</u>	<u>Audio-N</u>		<u>Audio-R</u>		<u>Visual-N</u>		<u>Visual-R</u>	
	<u>(a)</u>	<u>(b)</u>	<u>(a)</u>	<u>(b)</u>	<u>(a)</u>	<u>(b)</u>	<u>(a)</u>	<u>(b)</u>
1								
2	100.00	100.00	80.00	100.00	45.00	40.00	35.00*	65.00
4	100.00	100.00	85.00	100.00	100.00	100.00	95.00	100.00
11	100.00	95.00	90.00	55.00	65.00	85.00	95.00	100.00
12	90.00	95.00	45.00	55.00	50.00	60.00	55.00	65.00
14	100.00	95.00	95.00	90.00	55.00	80.00	80.00	95.00
15	90.00	100.00	50.00	100.00	75.00	95.00	40.00*	100.00
17	100.00	95.00	100.00	100.00	90.00	95.00	90.00	100.00
<u>Mn.</u>	97.14	97.14	77.86	85.71	68.57	79.29	70.00	89.29
<u>Mdn.</u>	100.00	95.00	85.00	100.00	65.00	85.00	80.00	100.00
<u>Std.</u>	4.88	2.67	21.77	21.30	20.76	21.88	26.14	16.69

Audio-N = Audio-Natural

Audio-R = Audio Reiterant

Visual-N = Visual Natural

Visual-R = Visual Reiterant

* = Sentence selected based upon audio-natural performance

Appendix B: Relevant Documents

Attachment I. Specific instructions given to speakers

For each sentence pair, you have been given two cards, one with each annotated version of the ambiguous sentence. There are two sentences on each card. The first sentence is enclosed in brackets, and will inform on the intent of the target sentence. The second sentence on the card is the target and is written entirely in uppercase letters. You are to find a way to speak the target sentence to convey the appropriate interpretation.

First, silently read the bracketed sentence. Then, read the second sentence aloud. Repeat, looking into the camera, taking care to limit as much head movement as possible. Be sure to close your mouth at the end of each sentence and pause before continuing.

Next, repeat the sentence, but this time substitute the syllable /ma/ for each syllable in the original, taking care to follow the same rate and degree of stress used in the original.

You may practice each sentence as often as you wish until you are satisfied that you have solved the task. We will then videotape twelve repetitions of each version.

Attachment II. Subject Consent Form

This experiment is designed to assess visible information that could provide cues regarding the talker's intent or the meaning of a sentence to a speechreader. During the experiment you will be asked to listen or observe a talker saying one of two possible interpretations of an ambiguous sentence. In some conditions, the speaker will be mimicking the sentence using a string of the nonsense syllable /ma/. Your task will be to report which interpretation of the ambiguous sentence the talker intended to convey by marking the appropriate selection on the test form. Nothing you will do represents a potential health hazard.

While the results of this study will be reported at professional meetings and maybe published, subject anonymity will be protected. Subjects will be paid \$5.00 per hour for each hour of participation. In addition, subway or bus fare will be reimbursed. Payment will be received through the mail after the final testing session.

Please note that the Graduate School has a committee that safeguards your interests. This committee requires us to point out that the research done here is of experimental nature and is done in a university and not a clinical

setting. If you have any questions regarding your participation as an experimental subject, please feel free to ask us or to contact the Office of Sponsored Research at the Graduate School at (212) 642-2059.

I agree to participate in the experimental investigation described above. I understand that my participation is voluntary and that I may withdraw at any time without penalty.

NAME: _____ DATE: _____

ADDRESS: _____

SIGNATURE: _____

SOCIAL SECURITY #: _____

DATE OF BIRTH: _____

Attachment III. Test Form used in Main Study

*late
entered
1/5/91*

Talker
Form 2
Date
Subject

(A) | V | (N) | R

 Anna 12/21

1. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
 - a. John has never tasted good meat.
 - ☒ b. John does not like meat.
2. THE HOSTESS GREETED THE GIRL WITH A SMILE
 - a. The hostess was smiling.
 - ☒ b. The girl was smiling.
3. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
 - a. Of course, Lt. Baker instructed his troop.
 - ☒ b. Lt. Baker instructed his troop in a natural way.
4. SHE IS UNHAPPILY MARRIED
 - a. She has an unhappy marriage.
 - ☒ b. It is too bad that she is married.
5. THE HOSTESS GREETED THE GIRL WITH A SMILE
 - a. The hostess was smiling.
 - b. The girl was smiling.
6. SHE IS UNHAPPILY MARRIED
 - a. She has an unhappy marriage.
 - b. It is too bad that she is married.
7. HERE IS THE FAMOUS DUKE JAMES
 - a. James meets the Duke.
 - ☒ b. The name of the Duke is James.
8. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
 - a. Of course, Lt. Baker instructed his troop.
 - ☒ b. Lt. Baker instructed his troop in a natural way.
9. SHE IS UNHAPPILY MARRIED
 - a. She has an unhappy marriage.
 - b. It is too bad that she is married.
10. JEFFREY HIT THE COP WITH A STICK
 - a. Jeffrey had the stick.
 - b. The cop had the stick.
11. THE HOSTESS GREETED THE GIRL WITH A SMILE
 - a. The hostess was smiling.
 - b. The girl was smiling.
12. JEFFREY HIT THE COP WITH A STICK
 - a. Jeffrey had the stick.
 - b. The cop had the stick.

17

13. THE HOSTESS GREETED THE GIRL WITH A SMILE
a. The hostess was smiling.
b. The girl was smiling.
14. THE OLD MEN AND WOMEN STAYED AT HOME
a. The old people stayed at home.
b. The old men and all the women stayed at home.
15. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
b. The cop had the stick.
16. SHE IS UNHAPPILY MARRIED
a. She has an unhappy marriage.
b. It is too bad that she is married.
17. HERE IS THE FAMOUS DUKE JAMES
a. James meets the Duke.
b. The name of the Duke is James.
18. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
b. The cop had the stick.
19. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
b. The cop had the stick.
20. HERE IS THE FAMOUS DUKE JAMES
a. James meets the Duke.
b. The name of the Duke is James.
21. HERE IS THE FAMOUS DUKE JAMES
a. James meets the Duke.
b. The name of the Duke is James.
22. THE OLD MEN AND WOMEN STAYED AT HOME
a. The old people stayed at home.
b. The old men and all the women stayed at home.
23. HERE IS THE FAMOUS DUKE JAMES
a. James meets the Duke.
b. The name of the Duke is James.
24. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a. John has never tasted good meat.
b. John does not like meat.
25. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
a. Of course, Lt. Baker instructed his troop.
b. Lt. Baker instructed his troop in a natural way.

26. THE OLD MEN AND WOMEN STAYED AT HOME
☒ a. The old people stayed at home.
b. The old men and all the women stayed at home.
27. THE OLD MEN AND WOMEN STAYED AT HOME
a. The old people stayed at home.
b. The old men and all the women stayed at home.
28. THE OLD MEN AND WOMEN STAYED AT HOME
a. The old people stayed at home.
☒ b. The old men and all the women stayed at home.
29. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
b. The cop had the stick.
30. THE OLD MEN AND WOMEN STAYED AT HOME
a. The old people stayed at home.
b. The old men and all the women stayed at home.
31. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
☒ b. The cop had the stick.
32. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
a. Of course, Lt. Baker instructed his troop.
☒ b. Lt. Baker instructed his troop in a natural way.
33. THE HOSTESS GREETED THE GIRL WITH A SMILE
a. The hostess was smiling.
☒ b. The girl was smiling.
34. HERE IS THE FAMOUS DUKE JAMES
a. James meets the Duke.
☒ b. The name of the Duke is James.
35. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
☒ b. The cop had the stick.
36. THE OLD MEN AND WOMEN STAYED AT HOME
☒ a. The old people stayed at home.
b. The old men and all the women stayed at home.
37. SHE IS UNHAPPILY MARRIED
a. She has an unhappy marriage.
b. It is too bad that she is married.
38. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a. John has never tasted good meat.
b. John does not like meat.

39. SHE IS UNHAPPILY MARRIED
a. She has an unhappy marriage.
b. It is too bad that she is married.
40. THE HOSTESS GREETED THE GIRL WITH A SMILE
a. The hostess was smiling.
b. The girl was smiling.
41. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a. John has never tasted good meat.
b. John does not like meat.
42. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
a. Of course, Lt. Baker instructed his troop.
b. Lt. Baker instructed his troop in a natural way.
43. THE OLD MEN AND WOMEN STAYED AT HOME
a. The old people stayed at home.
b. The old men and all the women stayed at home.
44. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
b. The cop had the stick.
45. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a. John has never tasted good meat.
b. John does not like meat.
46. SHE IS UNHAPPILY MARRIED
a. She has an unhappy marriage.
b. It is too bad that she is married.
47. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a. John has never tasted good meat.
b. John does not like meat.
48. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a. John has never tasted good meat.
b. John does not like meat.
49. THE HOSTESS GREETED THE GIRL WITH A SMILE
a. The hostess was smiling.
b. The girl was smiling.
50. HERE IS THE FAMOUS DUKE JAMES
a. James meets the Duke.
b. The name of the Duke is James.
51. SHE IS UNHAPPILY MARRIED
a. She has an unhappy marriage.
b. It is too bad that she is married.
52. SHE IS UNHAPPILY MARRIED
a. She has an unhappy marriage.
b. It is too bad that she is married.

53. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
a) Of course, Lt. Baker instructed his troop.
b. Lt. Baker instructed his troop in a natural way.
54. JEFFREY HIT THE COP WITH A STICK
a) Jeffrey had the stick.
b. The cop had the stick.
55. THE HOSTESS GREETED THE GIRL WITH A SMILE
a. The hostess was smiling.
b) The girl was smiling.
56. THE OLD MEN AND WOMEN STAYED AT HOME
a. The old people stayed at home.
b) The old men and all the women stayed at home.
57. HERE IS THE FAMOUS DUKE JAMES
a) James meets the Duke.
b. The name of the Duke is James.
58. THE OLD MEN AND WOMEN STAYED AT HOME
a) The old people stayed at home.
b. The old men and all the women stayed at home.
59. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a) John has never tasted good meat.
b. John does not like meat.
60. SHE IS UNHAPPILY MARRIED
a. She has an unhappy marriage.
b) It is too bad that she is married.
61. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
a) Of course, Lt. Baker instructed his troop.
b. Lt. Baker instructed his troop in a natural way.
62. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
a) Of course, Lt. Baker instructed his troop.
b. Lt. Baker instructed his troop in a natural way.
63. THE HOSTESS GREETED THE GIRL WITH A SMILE
a. The hostess was smiling.
b. The girl was smiling.
64. JEFFREY HIT THE COP WITH A STICK
a. Jeffrey had the stick.
b. The cop had the stick.
65. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
a. John has never tasted good meat.
b. John does not like meat.

66. HERE IS THE FAMOUS DUKE JAMES
 a) James meets the Duke.
 b. The name of the Duke is James.
67. HERE IS THE FAMOUS DUKE JAMES
 a) James meets the Duke.
 b. The name of the Duke is James.
68. HERE IS THE FAMOUS DUKE JAMES
 a) James meets the Duke.
 b. The name of the Duke is James.
69. SHE IS UNHAPPILY MARRIED
 a. She has an unhappy marriage.
 b. It is too bad that she is married.
70. JEFFREY HIT THE COP WITH A STICK
 a) Jeffrey had the stick.
 b. The cop had the stick.
71. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
 a. Of course, Lt. Baker instructed his troop.
 b. Lt. Baker instructed his troop in a natural way.
72. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
 a. John has never tasted good meat.
 b. John does not like meat.
73. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
 a. John has never tasted good meat.
 b. John does not like meat.
74. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
 a) Of course, Lt. Baker instructed his troop.
 b. Lt. Baker instructed his troop in a natural way.
75. LT. BAKER INSTRUCTED HIS TROOP NATURALLY
 a) Of course, Lt. Baker instructed his troop.
 b. Lt. Baker instructed his troop in a natural way.
76. JOHN DOESN'T KNOW HOW GOOD MEAT TASTES
 a. John has never tasted good meat.
 b. John does not like meat.
77. HERE IS THE FAMOUS DUKE JAMES
 a. James meets the Duke.
 b) The name of the Duke is James.
78. THE HOSTESS GREETED THE GIRL WITH A SMILE
 a. The hostess was smiling.
 b) The girl was smiling.
79. THE OLD MEN AND WOMEN STAYED AT HOME
 a. The old people stayed at home.
 b. The old men and all the women stayed at home.

Table 1.4 Sentences tested, interpretations, type, and predictions based upon phrase structure.

1. HERE IS THE FAMOUS [DUKE] [JAMES]

VOCATIVE vs. HEAD NOUN

a. James meets the Duke.

b. The name of the Duke is James.

Predictions:

DUKE

a > b

JAMES

a > b

2. THE [OLD] [MEN] AND WOMEN STAYED AT HOME

ADJECTIVE MODIFICATION

a. The old people stayed at home.

b. The old men and all the women stayed at home.

Predictions:

OLD

a > b

MEN

b > a

Table 1.4 (cont'd)

Table 1.4 (cont'd)

3. THE HOSTESS [GREE...]TED THE [GIRL] WITH A SMILE

PREPOSITIONAL PHRASE MODIFICATION

a. The hostess was smiling.

b. The girl was smiling.

Predictions:

GREE...

a = b

GIRL

a > b

4. JOHN DOESN'T KNOW HOW [GOOD] [MEAT] TASTES

COMPARATIVE ADVERB MODIFICATION

a. John has never tasted good meat.

b. John does not like meat.

Predictions:

GOOD

b > a

MEAT

a = b

Table 1.4 (cont'd)

Table 1.4 (cont'd)

5. LT. BAKER INSTRUCTED HIS [TROO...] P [NA...]TURALLY

ADVERB MODIFICATION

a. Of course, Lt. Baker instructed his troop.

b. Lt. Baker instructed his troop in a natural way.

Predictions:

TROO...

b > a

NA...

a > b

6. JEFFREY [HIT] THE [COP] WITH A STICK

PREPOSITIONAL PHRASE MODIFICATION

a. Jeffrey had the stick.

b. The cop had the stick.

Predictions:

HIT

a = b

COP

a > b

Table 1.4 (cont'd)

Table 1.4 (cont'd)

7. SHE [IS] UNHAPPILY [MAR...] RIED
ADVERB MODIFICATION

- a. She has an unhappy marriage.
- b. It is too bad that she is married.

Predictions:

IS

b > a

MAR...

b > a

**Table 2.5 Binomial exact test for audio-normal condition
for Talker JJ**

(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	1	0	.9697	1*
	b	120	.9333	.0227	.8729	.9708
2	a	120	.9833	.0117	.9411	.9980
	b	120	.9667	.0164	.9169	.9909
3	a	120	.9917	.0083	.9544	.9998
	b	120	1	0	.9697	1*
4	a	120	.9917	.0083	.9544	.9998
	b	120	.9917	.0083	.9544	.9998
5	a	120	.9833	.0117	.9411	.9980
	b	120	.9833	.0117	.9411	.9980
6	a	120	.9417	.0214	.8835	.9762
	b	120	.9083	.0263	.8418	.9534
7	a	120	.9833	.0117	.9411	.9980
	b	120	1	0	.9697	1*

(*) one-sided , 97.5% confidence interval

**Table 3.5 Binomial exact test for audio-normal condition
for Talker LR**

(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	1	0	.9697	1*
	b	120	.9917	.0083	.9544	.9998
2	a	120	.9417	.0214	.8835	.9762
	b	120	.8667	.0310	.7926	.9212
3	a	120	1	0	.9697	1*
	b	120	.9833	.0117	.9411	.9980
4	a	120	1	0	.9697	1*
	b	120	1	0	.9697	1*
5	a	120	1	0	.9697	1*
	b	120	.9833	.0117	.9411	.9980
6	a	120	.9083	.0263	.8418	.9534
	b	120	1	0	.9697	1*
7	a	120	1	0	.9697	1*
	b	120	1	0	.9697	1*

(*) one-sided , 97.5% confidence interval

**Table 4.5 Binomial exact test for audio-reiterant condition
for Talker JJ**

(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	.95	.0199	.8443	.9814
	b	120	.9917	.0083	.9544	.9998
2	a	120	.9667	.0164	.9169	.9909
	b	120	.9	.0274	.8319	.9473
3	a	120	.9167	.0252	.8520	.9593
	b	120	.975	.0143	.9287	.9948
4	a	120	.975	.0143	.9287	.9948
	b	120	.9833	.0117	.9411	.9980
5	a	120	.9917	.0083	.9544	.9998
	b	120	.9583	.0182	.9055	.9863
6	a	120	.9083	.0263	.8418	.9534
	b	120	.8833	.0293	.8120	.9347
7	a	120	.9917	.0083	.9544	.9998
	b	120	1	0	.9697	1*

(*) one-sided , 97.5% confidence interval

**Table 5.5 Binomial exact test for audio-reiterant condition
for Talker LR**

(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	.9667	.0164	.9167	.9910
	b	120	.9917	.0083	.9544	.9998
2	a	120	.875	.0302	.8022	.9283
	b	120	.775	.0381	.6899	.8462
3	a	120	1	0	.9697	1*
	b	120	.8	.0365	.7172	.8674
4	a	120	.9833	.0117	.9411	.9980
	b	120	1	0	.9697	1*
5	a	120	.9667	.0164	.9169	.9909
	b	120	.9583	.0182	.9055	.9863
6	a	120	.7333	.0404	.6449	.8099
	b	120	.9917	.0083	.9544	.9998
7	a	120	.9833	.0117	.9411	.9980
	b	120	.975	.0143	.9287	.9948

(*) one-sided , 97.5% confidence interval

**Table 6.5 Binomial exact test for visual-natural condition
for Talker JJ**
(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	.7167	.0411	.6271	.7952
	b	120	.9583	.0182	.9055	.9863
2	a	120	.8667	.0310	.7926	.9219
	b	120	.6917	.0422	.6001	.7727
3	a	120	.6917	.0422	.6008	.7727
	b	120	.9583	.0182	.9055	.9863
4	a	120	.9583	.0182	.9055	.9863
	b	120	.625	.0442	.5319	.7118
5	a	120	1	0	.9697	1*
	b	120	.8667	.0310	.7926	.9219
6	a	120	.825	.0347	.7450	.8882
	b	120	.8333	.0340	.7544	.8952
7	a	120	.95	.0199	.8943	.9814
	b	120	.975	.0143	.9287	.9948

(*) one-sided , 97.5% confidence interval

**Table 7.5 Binomial exact test for visual-natural condition
for Talker LR**

(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	.4583	.0455	.3670	.5517
	b	120	.9917	.0083	.9544	.9998
2	a	120	.78333	.0376	.6988	.8534
	b	120	.7833	.0376	.6988	.8534
3	a	120	.8417	.0333	.7638	.9020
	b	120	.875	.0302	.8022	.9283
4	a	120	.975	.0143	.9287	.9948
	b	120	.6833	.0425	.5922	.7653
5	a	120	.9833	.0117	.9411	.9980
	b	120	.9583	.0182	.9055	.9863
6	a	120	.575	.0451	.4816	.6646
	b	120	.8917	.0284	.8218	.9411
7	a	120	.95	.0199	.8943	.9814
	b	120	.975	.0143	.9287	.9948

(*) one-sided , 97.5% confidence interval

**Table 8.5 Binomial exact test for visual-reiterant
condition for Talker JJ**
(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	.95	.0199	.8943	.9814
	b	120	.95	.0199	.8943	.9814
2	a	120	.9667	.0164	.9169	.9909
	b	120	.9	.0274	.8319	.9473
3	a	120	.8083	.0359	.7264	.8744
	b	120	.95	.0199	.8943	.9814
4	a	120	.9917	.0083	.9544	.9998
	b	120	.8333	.0340	.7544	.8952
5	a	120	.9917	.0083	.9544	.9998
	b	120	.9167	.0252	.8520	.9593
6	a	120	.9917	.0083	.9544	.9998
	b	120	.6333	.0440	.5410	.7194
7	a	120	.95	.0199	.8943	.9814
	b	120	.975	.0143	.9287	.9948

(*) one-sided , 97.5% confidence interval

Table 9.5 Binomial exact test for visual-reiterant condition for Talker LR

(95% confidence interval)

Set #	Type	Obs.	Mean	Std.	Binomial Exact	
				Err.	95% Conf.	Int.
1	a	120	.65	.044	.5576	.7348
	b	120	.9667	.0164	.9169	.9909
2	a	120	.9417	.0214	.8835	.9762
	b	120	.825	.0347	.745	.8882
3	a	120	.9333	.0228	.8729	.9708
	b	120	.8083	.0359	.7264	.8744
4	a	120	.975	.0143	.9287	.9948
	b	120	.7417	.0400	.6537	.8174
5	a	120	.9917	.0083	.9544	.9998
	b	120	.9333	.0228	.8729	.9708
6	a	120	.7417	.0400	.6537	.8174
	b	120	.9917	.0083	.9544	.9998
7	a	120	.95	.0199	.8943	.9814
	b	120	.9833	.0117	.9411	.9980

(*) one-sided , 97.5% confidence interval

Table 10.5 Percent correct discrimination between "a" and "b" versions by sentence for each condition with summary statistics as spoken by Talker JJ

<u>Set</u>	<u>Audio</u>		<u>Audio</u>		<u>Visual</u>		<u>Visual</u>	
	<u>Natural</u>		<u>Reit.</u>		<u>Natural</u>		<u>Reit</u>	
	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>
<u>1</u>	<u>100.00</u>	<u>99.17</u>	<u>95.00</u>	<u>98.33</u>	<u>71.67</u>	<u>63.50</u>	<u>95.00</u>	<u>83.33</u>
<u>2</u>	<u>93.33</u>	<u>98.33</u>	<u>99.17</u>	<u>99.17</u>	<u>95.83</u>	<u>100.00</u>	<u>95.00</u>	<u>99.17</u>
<u>3</u>	<u>98.33</u>	<u>98.33</u>	<u>96.67</u>	<u>95.83</u>	<u>86.67</u>	<u>86.67</u>	<u>96.67</u>	<u>91.67</u>
<u>4</u>	<u>96.67</u>	<u>94.17</u>	<u>90.00</u>	<u>90.83</u>	<u>69.17</u>	<u>82.50</u>	<u>90.00</u>	<u>99.17</u>
<u>5</u>	<u>99.17</u>	<u>90.83</u>	<u>91.67</u>	<u>88.33</u>	<u>69.17</u>	<u>83.33</u>	<u>80.83</u>	<u>63.33</u>
<u>6</u>	<u>100.00</u>	<u>98.33</u>	<u>97.50</u>	<u>99.17</u>	<u>95.83</u>	<u>95.00</u>	<u>95.00</u>	<u>95.00</u>
<u>7</u>	<u>99.17</u>	<u>100.00</u>	<u>97.50</u>	<u>100.00</u>	<u>95.83</u>	<u>97.50</u>	<u>99.17</u>	<u>97.50</u>
<u>Mn.</u>	<u>98.10</u>	<u>97.02</u>	<u>95.36</u>	<u>95.95</u>	<u>83.45</u>	<u>86.79</u>	<u>93.10</u>	<u>89.88</u>
<u>Mdn.</u>	<u>99.17</u>	<u>98.33</u>	<u>96.67</u>	<u>98.33</u>	<u>86.67</u>	<u>86.67</u>	<u>95.00</u>	<u>95.00</u>
<u>Std.</u>	<u>2.39</u>	<u>3.29</u>	<u>3.36</u>	<u>4.60</u>	<u>13.02</u>	<u>12.76</u>	<u>6.06</u>	<u>12.96</u>

Table 11.5 Percent correct discrimination between "a" and "b" versions by sentence for each condition with summary statistics as spoken by Talker LR

Set	<u>Audio</u>		<u>Audio</u>		<u>Visual</u>		<u>Visual</u>	
	<u>Normal</u>		<u>Reit.</u>		<u>Natural</u>		<u>Reit.</u>	
	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>	<u>a</u>	<u>b</u>
<u>1</u>	<u>100.00</u>	<u>100.00</u>	<u>96.67</u>	<u>100.00</u>	<u>45.83</u>	<u>68.33</u>	<u>65.00</u>	<u>74.17</u>
<u>2</u>	<u>99.17</u>	<u>100.00</u>	<u>99.17</u>	<u>96.67</u>	<u>99.17</u>	<u>98.33</u>	<u>96.67</u>	<u>99.17</u>
<u>3</u>	<u>94.17</u>	<u>98.33</u>	<u>87.50</u>	<u>95.83</u>	<u>78.33</u>	<u>95.83</u>	<u>94.17</u>	<u>93.33</u>
<u>4</u>	<u>86.67</u>	<u>90.83</u>	<u>77.50</u>	<u>73.33</u>	<u>78.33</u>	<u>57.50</u>	<u>82.50</u>	<u>74.17</u>
<u>5</u>	<u>100.00</u>	<u>100.00</u>	<u>100.0</u>	<u>99.17</u>	<u>84.17</u>	<u>89.17</u>	<u>93.33</u>	<u>99.17</u>
<u>6</u>	<u>98.33</u>	<u>100.00</u>	<u>80.00</u>	<u>98.33</u>	<u>87.50</u>	<u>95.00</u>	<u>80.83</u>	<u>95.00</u>
<u>7</u>	<u>100.00</u>	<u>100.00</u>	<u>98.33</u>	<u>97.50</u>	<u>97.50</u>	<u>97.50</u>	<u>97.50</u>	<u>98.33</u>
<u>Mn.</u>	<u>96.91</u>	<u>98.45</u>	<u>91.31</u>	<u>94.40</u>	<u>81.55</u>	<u>85.95</u>	<u>87.14</u>	<u>90.48</u>
<u>Mdn.</u>	<u>99.17</u>	<u>100.00</u>	<u>96.67</u>	<u>97.50</u>	<u>84.17</u>	<u>95.00</u>	<u>93.33</u>	<u>95.00</u>
<u>Std.</u>	<u>4.97</u>	<u>3.42</u>	<u>9.56</u>	<u>9.40</u>	<u>17.81</u>	<u>16.31</u>	<u>11.81</u>	<u>11.35</u>

**Table 12.6 Acoustic duration means, standard deviations,
and standard errors of key segments by version for Talker
JJ and Talker LR**

	Mean	Std. Dev.	Std. Err.	Mean	Std. Dev.	Std. Err.
Sentence 1	[DUKE]			[JAMES]		
Talker JJ						
A	295.0	17.8	7.3	342.8	12.3	5
B	182.8	11.8	4.8	299.2	20.9	8.5
Talker LR						
A	188.8	17.7	7.2	278.0	25.3	10.3
B	171.0	9.0	3.7	317.4	10.2	4.2
Sentence 2	[OLD]			[MEN]		
Talker JJ						
A	227.6	27.6	11.3	142.7	10.8	4.4
B	138.8	11.9	4.9	348.4	9.8	4
Talker LR						
A	160.4	12.2	5	159.9	14.4	5.9
B	184.6	15.1	6.2	207.5	11.1	4.5
Sentence 3	[GREE...]			[GIRL]		
Talker JJ						
A	109.6	8.5	3.5	258.9	19.6	8
B	118.7	4.1	1.7	121.0	10.4	4.2
Talker LR						
A	138.5	11.7	4.8	175.8	10.5	4.3
B	133.6	15.6	6.4	111.8	8.6	3.5
Sentence 4	[GOOD]			[MEAT]		
Talker JJ						
A	146.3	5.2	2.1	176.6	26	10.6
B	192.5	7.2	2.9	174.5	18.6	7.6
Talker LR						
A	179.4	8.6	3.5	191.4	17.2	7
B	251.8	10.6	4.3	201.0	13.8	5.6

Table 12.6 (cont'd.).

Table 12.6 (cont'd.).

	<i>Mean</i>	<i>Std. Dev.</i>	<i>Std. Err.</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Std. Err.</i>
Sentence 5	[TROO...]			[NA...]		
Talker JJ						
A	202.6	31.1	12.7	109.4	10	4.1
B	192.4	14	5.7	102.9	6.1	2.5
Talker LR						
A	199.7	20.3	8.3	171.9	8.1	3.3
B	141.7	8.8	3.6	82.0	8.9	3.6
Sentence 6	[HIT]			[COP]		
Talker JJ						
A	74.5	8.8	3.6	236.0	19.4	7.9
B	262.5	24.9	10.2	114.8	18.7	7.6
Talker LR						
A	138.0	27.1	11.1	153.1	13.0	5.3
B	283.8	24.8	10.1	138.6	9.4	3.8
Sentence 7	[IS]			[MAR...]		
Talker JJ						
A	146.4	9.1	3.7	140.4	9.9	4
B	293	12.3	5	140.4	3.7	1.5
Talker LR						
A	99.2	5.8	2.4	180.5	7.6	3.1
B	439.1	29.4	12	161.2	8.7	3.6

**Table 13.6 Analysis of variance table for acoustic duration
of the vowel portion for Sentence 1 for Talker JJ and
Talker LR**

Syllable /Talker	Source	DF	SS	MS	F Value	Pr > F
[DUKE]						
Talker JJ						
	Version	1	0.03781141	0.03781141	165.72	<u>0.0000**</u>
	Error	10	0.00228160	0.00028160		
	Total	11	0.04009302			
Talker LR						
	Version	1	0.00094164	0.00094164	4.78	<u>0.0537*</u>
	Error	10	0.00196992	0.00019699		
	Total	11	0.00291156			
[JAMES]						
Talker JJ						
	Version	1	0.00553411	0.00553411	18.85	<u>0.0015**</u>
	Error	10	0.00293552	0.00029355		
	Total	11	0.00846963			
Talker LR						
	Version	1	0.00463740	0.00463740	12.47	<u>0.0054**</u>
	Error	10	0.00371981	0.00037198		
	Total	11	0.00835721			

* indicates one level of significance

** indicates two levels of significance

**Table 14.6 Analysis of variance table for acoustic duration
of the vowel portion for Sentence 2 for Talker JJ and
Talker LR**

Syllable/ Talker	Source	DF	SS	MS	F Value	Pr > F
[OLD]						
Talker JJ						
	Version	1	0.02367408	0.02367408	52.29	<u>0.0001**</u>
	Error	10	0.00452766	0.00045277		
	Total	11	0.02820174			
Talker LR						
	Version	1	0.00175934	0.00175934	9.34	<u>0.0121*</u>
	Error	10	0.00188296	0.00018830		
	Total	11				
[MEN]						
Talker JJ						
	Version	1	0.12695804	0.12695804	1197.5	<u>0.0001**</u>
	Error	10	0.00106019	0.00010602		
	Total	11	0.12801823			
Talker LR						
	Version	1	0.00680680	0.00680680	41.41	<u>0.0001**</u>
	Error	10	0.00164357	0.00016436		
	Total	11	0.00845038			

* indicates one level of significance

** indicates two levels of significance

**Table 15.6 Analysis of variance table for acoustic duration
of the vowel portion for Sentence 3 for Talker JJ and
Talker LR**

Syllable/ Talker	Source	DF	SS	MS	F Value	Pr > F
[GREE...]						
Talker JJ						
	Version	1	0.00024843	0.00024843	5.58	<u>0.0398*</u>
	Error	10	0.00044541	0.00004454		
	Total	11				
Talker LR						
	Version	1	0.00007351	0.00007351	0.39	0.5463
	Error	10	0.00188482	0.00018848		
	Total	11	0.00195833			
[GIRL]						
Talker JJ						
	Version	1	0.05693896	0.05593896	230.78	<u>0.0001**</u>
	Error	10	0.00246725	0.00024673		
	Total	11	0.05940622			
Talker LR						
	Version	1	0.01231297	0.01231297	133.67	<u>0.0001**</u>
	Error	10	0.00092115	0.00009211		
	Total	11	0.01323412			

* indicates one level of significance

** indicates two levels of significance

**Table 16.6 Analysis of variance table for acoustic duration
of the vowel portion for Sentence 4 for Talker JJ and
Talker LR**

Syllable/ Talker	Source	DF	SS	MS	F Value	Pr > F
[GOOD]						
Talker JJ						
	Version	1	0.00638024	0.00638024	2.43	0.1502
	Error	10	0.02626881	0.00262688		
	Total	11	0.03264905			
Talker LR						
	Version	1	0.01572528	0.01572528	170.01	<u>0.0001**</u>
	Error	10	0.00092497	0.00009250		
	Total	11	0.01665025			
[MEAT]						
Talker JJ						
	Version	1	0.00001302	0.00001302	0.03	0.8761
	Error	10	0.00509294	0.00050929		
	Total	11	0.00510596			
Talker LR						
	Version	1	0.00027648	0.00027648	1.14	0.3113
	Error	10	0.00243074	0.00024307		
	Total	11	0.00270722			

* indicates one level of significance

** indicates two levels of significance

Table 17.6 Analysis of variance table for acoustic duration of the vowel portion for Sentence 5 for Talker JJ and Talker LR

Syllable/ Speaker	Source	DF	SS	MS	F Value	Pr > F
[TROO...]						
Talker JJ						
	Version	1	0.00031008	0.00031008	0.53	0.4826
	Error	10	0.00583223	0.00058322		
	Total	11	0.00614232			
Talker LR						
	Version	1	0.01012102	0.01012102	41.18	<u>0.0001**</u>
	Error	10	0.00245771	0.00024577		
	Total	11	0.01257873			
[NAT...]						
Talker JJ						
	Version	1	0.00012740	0.00012740	1.86	0.2027
	Error	10	0.00068537	0.00006854		
	Total	11	0.00081277			
Talker LR						
	Version	1	0.02421098	0.02421098	333.62	<u>0.0001**</u>
	Error	10	0.00072570			
	Total	11	0.0249669			

* indicates one level of significance

** indicates two levels of significance

**Table 18.6 Analysis of variance table for acoustic duration
of the vowel portion for Sentence 6 for Talker JJ and
Talker LR**

Syllable	Source	DF	SS	MS	F Value	Pr > F
[HIT]						
Talker JJ	Version	1	0.10605832	0.10605832	306.05	<u>0.0001**</u>
	Error	10	0.00347670	0.00034767		
	Total	11	0.10953502			
Talker LR	Version	1	0.06378750	0.06378750	94.97	<u>0.0001**</u>
	Error	10	0.00673090	0.00067309		
	Total	11	0.07051840			
[COP]						
Talker JJ	Version	1	0.04400169	0.04400169	121.02	<u>0.0001**</u>
	Error	10	0.00363580	0.00036358		
	Total	11	0.4763748			
Talker LR	Version	1	0.00063656	0.00063656	4.94	<u>0.0505*</u>
	Error	10	0.00128903	0.00012890		
	Total	11	0.00192560			

* indicates one level of significance

** indicates two levels of significance

**Table 19.6 Analysis of variance table for acoustic duration
of the vowel portion for Sentence 7 for Talker JJ and
Talker LR**

Syllable	Source	DF	SS	MS	F Value	Pr > F
[IS]						
Talker JJ						
	Version	1	0.06447468	0.06447468	552.18	<u>0.0001**</u>
	Total	10	0.00116765	0.00011676		
	Total	11	0.06564233			
Talker LR						
	Version	1	0.34650086	0.34650086	774.23	<u>0.0001**</u>
	Error	10	0.00447540			
	Total	11	0.35097627			
[MAR...]						
Talker JJ						
	Version	1	0.00000000	0.00000000	0.0000	1.0000
	Error	10	0.00055564	0.00005556		
	Total	11	0.00055564			
Talker LR						
	Version	1	0.00111361	0.00111361	16.81	<u>0.0021*</u>
	Error	10	0.00066263	0.00006626		
	Total	11	0.00177625			

* indicates one level of significance

** indicates two levels of significance

Table 20.7 Wilks' Lambda Manova Test Criterion and F

Statistics for the hypothesis of no Overall VERSION Effect
as spoken by Talker JJ and Talker LR

	Syllable	Talker	Wilks' Value	F Value	Num DF	Den DF	Pr > F
<u>1</u>	[DUKE]	Talker JJ	0.06761674	24.1312	4	7	<u>0.0003**</u>
		Talker LR	0.20242087	6.8954	4	7	<u>0.0141*</u>
	[JAMES]	Talker JJ	0.05207253	31.8570	4	7	<u>0.0001**</u>
		Talker LR	0.31819484	3.7498	4	7	0.0615
<u>2</u>	[OLD]	Talker JJ	0.12186715	12.6099	4	7	<u>0.0026**</u>
		Talker LR	0.27979260	4.5046	4	7	<u>0.0408*</u>
	[MEN]	Talker JJ	0.00951436	182.1824	4	7	<u>0.0001**</u>
		Talker LR	0.09452306	16.7640	4	7	<u>0.0011*</u>
<u>3</u>	[GREE...]	Talker JJ	0.83057851	0.3570	4	7	0.8318
		Talker LR	0.46821989	1.9876	4	7	0.2010
	[GIRL]	Talker JJ	0.23349633	5.7448	4	7	<u>0.0227*</u>
		Talker LR	0.30026302	4.0782	4	7	0.0512
<u>4</u>	[GOOD]	Talker JJ	0.03749633	44.9212	4	7	<u>0.0001**</u>
		Talker LR	0.12159110	12.6425	4	7	<u>0.0026*</u>
	[MEAT]	Talker JJ	0.21354104	6.4451	4	7	<u>0.0169*</u>
		Talker LR	0.33807402	3.4264	4	7	0.0745
<u>5</u>	[TROO...]	Talker JJ	0.25298095	5.1675	4	7	<u>0.0294*</u>
		Talker LR	0.01838157	93.4540	4	7	<u>0.0001**</u>
	[NA...]	Talker JJ	0.43761108	2.2490	4	7	0.1646
		Talker LR	0.02608467	65.3392	4	7	<u>0.0001**</u>
<u>6</u>	[HIT]	Talker JJ	0.00518181	335.9698	4	7	<u>0.0001**</u>
		Talker LR	0.09928598	15.8759	4	7	<u>0.0013**</u>
	[COP]	Talker JJ	0.05007333	33.1987	4	7	<u>0.0001**</u>
		Talker LR	0.84056130	0.3319	4	7	0.8483
<u>7</u>	[IS]	Talker JJ	0.01891343	90.7768	4	7	<u>0.0001**</u>
		Talker LR	0.00544838	319.4464	4	7	<u>0.0001**</u>
	[MAR...]	Talker JJ	0.09388347	16.8901	4	7	<u>0.0011**</u>
		Talker LR	0.51737521	1.6325	4	7	0.2679

* indicates one level of significance

** indicates two levels of significance

**Table 21.7 Jaw movement variables with standard deviations
for key syllable [DUKE] in Sentence 1 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[DUKE]	Talker JJ	Duration—	(a)	196.95	56.69
		Opening cycle (j1)	(a)	8.33	1.21
		Amplitude—	(a)	8.33	1.21
		Opening cycle (j2)	(a)	282.80	45.62
		Duration—	(a)	282.80	45.62
		Closing cycle (j3)	(a)	10.50	1.22
		Amplitude—	(a)	10.50	1.22
		Closing cycle (j4)	(a)	10.50	1.22
		Duration—	(b)	151.50	0
		Opening cycle (j1)	(b)	151.50	0
		Amplitude—	(b)	9.83	.98
		Opening cycle (j2)	(b)	9.83	.98
		Duration—	(b)	146.45	12.37
		Closing cycle (j3)	(b)	146.45	12.37
		Amplitude—	(b)	10.50	1.38
		Closing cycle (j4)	(b)	10.50	1.38
	Talker LR	Duration—	(a)	151.50	19.16
		Opening cycle (j1)	(a)	151.50	19.16
		Amplitude—	(a)	8.33	1.86
		Opening cycle (j2)	(a)	8.33	1.86
		Duration—	(a)	131.3	31.29
		Closing cycle (j3)	(a)	131.3	31.29
		Amplitude—	(a)	8.50	1.52
		Closing cycle (j4)	(a)	8.50	1.52
		Duration—	(b)	156.55	12.37
		Opening cycle (j1)	(b)	156.55	12.37
		Amplitude—	(b)	10.17	1.72
		Opening cycle (j2)	(b)	10.17	1.72
		Duration—	(b)	106.05	16.60
		Closing cycle (j3)	(b)	106.05	16.60
		Amplitude—	(b)	8.17	1.33
		Closing cycle (j4)	(b)	8.17	1.33

Table 22.7 Sentence 1. Partial correlation coefficients from the Error SS&CP Matrix / Prob = $|r|$ for segment corresponding to syllable [DUKE] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	-0.548258 0.0808	-0.685323 <u>0.0199*</u>	-0.028989 0.9326
j2	-0.548258 0.0808	1.000000 0.0001	0.260274 0.4395	0.243365 0.4708
j3	-0.685323 0.0199	0.260274 0.4395	1.000000 0.0001	0.034766 0.9192
j4	-0.028989 0.9326	0.243365 0.4708	0.034766 0.9192	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 23.7 Univariate Analysis of Variance for jaw movement variables for syllable [DUKE] in Sentence 1 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	6197.1075	6197.1075	3.86	0.0779
		Error	10	16066.5750	1606.6575		
		Total	11	22263.6825		r2=	0.2783
	j2	Version	1	6.7500	6.7500	5.55	<u>0.0403*</u>
		Error	10	12.1667	1.2167		
		Total	11	18.9167		r2=	0.3568
	j3	Version	1	55773.9675	55773.9675	49.93	<u>0.0001**</u>
		Error	10	11170.0950	1117.0095		
		Total	11	66944.0625		r2=	0.8331
	j4	Version	1	0.0000	0.0000	0.00	1.00
		Error	10	17.0000	1.7000		
		Total	11	17.0000		r2=	0.0000
Talker LR	j1	Version	1	76.5075	76.5075	0.29	0.5995
		Error	10	2601.2550	260.1255		
		Total	11	2677.7625		r2=	0.0286
	j2	Version	1	10.0833	10.0833	3.13	0.1071
		Error	10	32.1667	3.2167		
		Total	11	42.2500		r2=	0.2387
	j3	Version	1	1912.6875	1912.6875	3.05	0.1114
		Error	10	6273.6150	627.3615		
		Total	11	8186.3025		r2=	0.2336
	j4	Version	1	0.3333	0.3333	0.16	0.6941
		Error	10	20.3333	2.0333		
		Total	11	20.6666		r2=	0.0161

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 24.7 Sentence 1. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for segment
corresponding to syllable [DUKE] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000	0.611033	0.113633	0.505037
	0.0001	<u>0.0458*</u>	0.7394	0.1131
j2	0.611033	1.000000	-0.281041	0.931918
	0.0458	0.0001	0.4025	<u>0.0001**</u>
j3	<u>0.113633</u>	-0.281041	1.000000	-0.212090
	0.7394	0.4025	0.0001	0.5313
j4	0.505037	0.931918	-0.212090	1.000000
	0.1131	0.0001	0.5313	0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 25.7 Jaw movement variables with standard deviations
for key syllable [JAMES] in Sentence 1 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[JAMES]	Talker JJ	Duration- Opening cycle (j1)	(a)	207.05	58.81
		Amplitude- Opening cycle (j2)	(a)	11.17	1.17
		Duration- Closing cycle (j3)	(a)	434.30	24.74
		Amplitude- Closing cycle (j4)	(a)	15.83	1.72
		Duration- Opening cycle (j1)	(b)	151.50	19.16
		Amplitude- Opening cycle (j2)	(b)	10.83	1.17
		Duration- Closing cycle (j3)	(b)	333.30	19.16
		Amplitude- Closing cycle (j4)	(b)	14.50	1.05
		Duration- Opening cycle (j1)	(a)	166.65	16.60
		Amplitude- Opening cycle (j2)	(a)	6.67	.82
		Duration- Closing cycle (j3)	(a)	212.10	38.33
		Amplitude- Closing cycle (j4)	(a)	11.00	1.90
		Duration- Opening cycle (j1)	(b)	212.10	46.94
		Amplitude- Opening cycle (j2)	(b)	5.50	.55
		Duration- Closing cycle (j3)	(b)	227.25	41.77
		Amplitude- Closing cycle (j4)	(b)	9.83	.98

Table 26.7 Sentence 1. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [JAMES] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
DF = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.721043 <u>0.0123*</u>	-0.252982 0.4529	0.720701 <u>0.0123*</u>
j2	0.721043 0.0123	1.000000 0.0001	-0.156174 0.6466	0.879824 <u>0.0004**</u>
j3	-0.252982 0.4529	-0.156174 0.6466	1.000000 0.0001	-0.448129 0.1669
j4	0.720701 0.0123	0.879824 0.0004	-0.448129 0.1669	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 27.7 Univariate Analysis of Variance for jaw movement variables for syllable [JAMES] in Sentence 1 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	9257.4075	9257.4075	4.84	<u>0.0524*</u>
		Error	10	19126.8750	1912.6875		
		Total	11	28384.2825		r2=	0.3261
	j2	Version	1	0.3333	0.3333	0.24	0.6321
		Error	10	13.6667	1.3667		
		Total	11	14.0000		r2=	0.0238
	j3	Version	1	30603.0000	30603.0000	62.50	<u>0.0001**</u>
		Error	10	4896.4800	489.6480		
		Total	11	35499.4800		r2=	0.8621
	j4	Version	1	5.3333	5.3333	2.62	0.1364
		Error	10	20.3333	2.0333		
		Total	11	25.6666		r2=	0.2078
Talker LR	j1	Version	1	6197.1075	6197.1075	5.00	<u>0.0493*</u>
		Error	10	12394.2150	1239.4215		
		Total	11	18591.3225		r2=	0.3333
	j2	Version	1	4.0833	4.0833	8.45	<u>0.0157*</u>
		Error	10	4.8333	0.4833		
		Total	11	8.9166		r2=	0.4578
	j3	Version	1	688.5675	688.5675	0.43	0.5275
		Error	10	16066.5750	1606.6575		
		Total	11	16755.1425		r2=	0.0411
	j4	Version	1	4.0833	4.0833	1.79	0.2108
		Error	10	22.8333	2.2833		
		Total	11	26.9166		r2=	0.1517

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 28.7 Sentence 1. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [JAMES] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	J3	j4
j1	1.000000 0.0001	-0.123797 0.7169	-0.455420 0.1592	-0.056957 0.8679
j2	-0.123797 0.7169	1.000000 0.0001	0.380562 0.2482	0.618736 <u>0.0424*</u>
j3	-0.455420 0.1592	0.380562 0.2482	1.000000 0.0001	0.325169 0.3292
j4	-0.056957 0.8679	0.618736 0.0424	0.325169 0.3292	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 29.7 Jaw movement variables with standard deviations
for key syllable [OLD] in Sentence 2 as spoken by Talker JJ
and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[OLD]	Talker JJ	Duration- Opening cycle (j1)	(a)	161.60	15.65
		Amplitude- Opening cycle (j2)	(a)	7.83	.75
		Duration- Closing cycle (j3)	(a)	156.55	22.81
		Amplitude- Closing cycle (j4)	(a)	9.17	.98
		Duration- Opening cycle (j1)	(b)	121.20	19.16
		Amplitude- Opening cycle (j2)	(b)	6.33	.82
		Duration- Closing cycle (j3)	(b)	106.05	16.60
		Amplitude- Closing cycle (j4)	(b)	8.83	1.17
		Duration- Opening cycle (j1)	(a)	131.30	15.65
		Amplitude- Opening cycle (j2)	(a)	5.50	1.38
		Duration- Closing cycle (j3)	(a)	95.95	12.37
		Amplitude- Closing cycle (j4)	(a)	5.50	1.52
		Duration- Opening cycle (j1)	(b)	161.60	15.65
		Amplitude- Opening cycle (j2)	(b)	6.33	.82
		Duration- Closing cycle (j3)	(b)	106.05	16.60
		Amplitude- Closing cycle (j4)	(b)	7.33	1.03

Table 30.7 Sentence 2. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [OLD] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
DF = 20	j1	j2	j3	j4
j1	1.000000 0.0001	-0.588172 0.0570	-0.087706 0.7976	0.374166 0.2569
j2	-0.588172 0.0570	1.000000 0.0001	0.419137 0.1994	0.648431 <u>0.0309*</u>
j3	-0.087706 0.7976	0.419137 0.1994	1.000000 0.0001	0.187523 0.5809
j4	0.374166 0.2569	0.648431 0.0309	0.187523 0.5809	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 31.7 Univariate Analysis of Variance for jaw movement variables for syllable [OLD] in Sentence 2 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	4896.4800	4896.4800	16.00	<u>0.0025**</u>
		Error	10	3060.3000	306.0300		
		Total	11	7956.7800		r2=	0.6154
	j2	Version	1	6.7500	6.7500	10.95	<u>0.0079**</u>
		Error	10	6.1667	0.6167		
		Total	11	12.9167		r2=	0.5226
	j3	Version	1	7650.7500	7650.7500	19.23	<u>0.0014**</u>
		Error	10	3978.3900	397.8390		
		Total	11	11629.1400		r2=	0.6579
	j4	Version	1	0.3333	0.3333	0.29	0.6047
		Error	10	11.6667	1.1667		
		Total	11	12.0000		r2=	0.0278
Talker LR	j1	Version	1	2754.2700	2754.2700	11.25	<u>0.0073**</u>
		Error	10	2448.2400	244.8240		
		Total	11	5202.5100		r2=	0.5294
	j2	Version	1	2.0833	2.0833	1.62	0.2314
		Error	10	12.8333	1.2833		
		Total	11	14.9166		r2=	0.1397
	j3	Version	1	306.0300	306.0300	1.43	0.2596
		Error	10	2142.2100	214.2210		
		Total	11	2448.2400		r2=	0.1250
	j4	Version	1	10.0833	10.0833	5.99	<u>0.0344*</u>
		Error	10	16.8333	1.6833		
		Total	11	26.9166		r2=	0.3746

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw duration during closing

* indicates one level of significance

** indicates two levels of significance

Table 32.7 Sentence 2. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = |r| for vowel portion
corresponding to syllable [OLD] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.398862 0.2243	-0.534522 0.0903	0.199007 0.5575
j2	0.398862 0.2243	1.000000 0.0001	-0.091372 0.7893	0.737068 <u>0.0097**</u>
j3	-0.534522 0.0903	-0.091372 0.7893	1.000000 0.0001	0.239341 0.4784
j4	0.199007 0.5575	0.737068 0.0097	0.239341 0.4784	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 33.7 Jaw movement variables with standard deviations
for key syllable [MEN] in Sentence 2 as spoken by Talker JJ
and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[MEN]	Talker JJ	Duration- Opening cycle (j1)	(a)	141.40	15.65
		Amplitude- Opening cycle (j2)	(a)	7.50	1.05
		Duration- Closing cycle (j3)	(a)	85.85	12.37
		Amplitude- Closing cycle (j4)	(a)	6.50	.55
		Duration- Opening cycle (j1)	(b)	156.55	29.79
		Amplitude- Opening cycle (j2)	(b)	10.33	.52
		Duration- Closing cycle (j3)	(b)	479.75	52.19
		Amplitude- Closing cycle (j4)	(b)	12.67	1.63
		Duration- Opening cycle (j1)	(a)	106.05	16.60
		Amplitude- Opening cycle (j2)	(a)	4.67	1.51
		Duration- Closing cycle (j3)	(a)	116.15	35.42
		Amplitude- Closing cycle (j4)	(a)	6.00	1.55
		Duration- Opening cycle (j1)	(b)	106.05	16.60
		Amplitude- Opening cycle (j2)	(b)	4.50	.55
		Duration- Closing cycle (j3)	(b)	287.85	25.35
		Amplitude- Closing cycle (j4)	(b)	9.00	1.10

Table 34.7 Sentence 2. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [MEN] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
DF = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.102699 0.7638	-.525650 0.0968	0.139410 0.6827
j2	0.102699 0.7638	1.000000 0.0001	0.177189 0.6022	0.314533 0.3462
j3	-.525650 0.0968	0.177189 0.6022	1.000000 0.0001	-.448255 0.1667
j4	0.139410 0.6827	0.314533 0.3462	-.448255 0.1667	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 35.7 Univariate Analysis of Variance for jaw movement variables for syllable [MEN] in Sentence 2 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	688.5675	688.5675	1.22	0.2959
		Error	10	5661.5550	566.1555		
		Total	11	6350.1225		r2=	0.1084
	j2	Version	1	24.0833	24.0833	35.24	<u>0.0001**</u>
		Error	10	6.8333	0.6833		
		Total	11	30.9166		r2=	0.7790
	j3	Version	1	465471.6300	465471.6300	363.62	<u>0.0001**</u>
		Error	10	14383.4100	1438.3410		
		Total	11	479855.0400		r2=	0.9700
	j4	Version	1	114.0833	114.0833	76.91	<u>0.0001**</u>
		Error	10	14.8333	1.4833		
		Total	11	128.9166		r2=	0.8849
Talker LR	j1	Version	1	0.0000	0.0000	0.00	1.0000
		Error	10	2754.2700	275.4270		
		Total	11	2754.2700		r2=	-0.0000
	j2	Version	1	0.0833	0.0833	0.06	0.8040
		Error	10	12.8333	1.2833		
		Total	11	12.9166		r2=	0.0065
	j3	Version	1	88442.6700	88442.6700	93.23	<u>0.0001**</u>
		Error	10	9486.9300	948.6930		
		Total	11	97929.6000		r2=	0.9031
	j4	Version	1	27.0000	27.0000	15.00	<u>0.0031**</u>
		Error	10	18.0000	1.8000		
		Total	11	45.0000		r2=	0.6000

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

**Table 36.7 Sentence 2. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [MEN] as spoken by Talker LR**

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.564076 0.0707	0.000000 .	0.544331 0.0834
j2	0.564076 0.0707	1.000000 0.0001	-0.159203 0.6401	0.723747 <u>0.0118*</u>
j3	0.000000 .	-0.159203 0.6401	1.000000 0.0001	0.293294 0.3814
j4	0.544331 0.0834	0.723747 0.0118	0.293294 0.3814	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 37.7 Jaw movement variables with standard deviations
for key syllable [GREE...] in Sentence 3 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[GREE...]	Talker JJ	Duration-	(a)	126.25	12.37
		Opening cycle (j1)			
		Amplitude-	(a)	8.67	1.37
		Opening cycle (j2)			
		Duration-	(a)	85.85	12.37
		Closing cycle (j3)			
		Amplitude-	(a)	7.33	1.21
		Closing cycle (j4)			
		Duration-	(b)	111.10	45.62
		Opening cycle (j1)			
		Amplitude-	(b)	6.83	3.60
		Opening cycle (j2)			
		Duration-	(b)	75.75	25.35
		Closing cycle (j3)			
		Amplitude-	(b)	5.83	2.64
		Closing cycle (j4)			
	Talker LR	Duration-	(a)	141.40	15.65
		Opening cycle (j1)			
		Amplitude-	(a)	6.33	1.51
		Opening cycle (j2)			
		Duration-	(a)	85.85	22.81
		Closing cycle (j3)			
		Amplitude-	(a)	5.00	.89
		Closing cycle (j4)			
		Duration-	(b)	126.25	22.81
		Opening cycle (j1)			
		Amplitude-	(b)	7.00	2.37
		Opening cycle (j2)			
		Duration-	(b)	90.90	0
		Closing cycle (j3)			
		Amplitude-	(b)	4.00	.89
		Closing cycle (j4)			

Table 38.7 Sentence 3. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [GREE...] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.798953 <u>0.0032**</u>	0.573841 0.0649	0.721115 <u>0.0123*</u>
j2	0.798953 0.0032	1.000000 0.0001	0.901789 <u>0.0001**</u>	0.956676 <u>0.0001**</u>
j3	0.573841 0.0649	0.901789 0.0001	1.000000 0.0001	0.875410 <u>0.0004**</u>
j4	0.721115 0.0123	0.956676 0.0001	0.875410 0.0004	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 39.7 Univariate Analysis of Variance for jaw movement variables for syllable [GREE...] in Sentence 3 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	688.5675	688.5675	0.62	0.4506
		Error	10	11170.0950	1117.0095		
		Total	11	11858.6625		r2=	0.0580
	j2	Version	1	10.0833	10.0833	1.36	0.2707
		Error	10	74.1667	7.4167		
		Total	11	84.2500		r2=	0.1197
	j3	Version	1	306.0300	306.0300	0.77	0.4010
		Error	10	3978.3900	397.8390		
		Total	11	4284.4200		r2=	0.0714
	j4	Version	1	6.7500	6.7500	1.60	0.2345
		Error	10	42.1667	4.2167		
		Total	11	48.9167		r2=	0.1380
Talker LR	j1	Version	1	688.5675	688.5675	1.80	0.2094
		Error	10	3825.3750	382.5375		
		Total	11	4513.9425		r2=	0.1525
	j2	Version	1	1.3333	1.3333	0.34	0.5733
		Error	10	39.3333	3.9333		
		Total	11	40.6666		r2=	0.0328
	j3	Version	1	76.5075	76.5075	0.29	0.5995
		Error	10	2601.2550	260.1255		
		Total	11	2677.7625		r2=	0.0286
	j4	Version	1	3.0000	3.0000	3.75	0.0816
		Error	10	8.0000	0.8000		
		Total	11	11.0000		r2=	0.2727

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 40.7 Sentence 3. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [GREE...] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.520756 0.1005	0.194029 0.5675	0.519615 0.1014
j2	0.520756 0.1005	1.000000 0.0001	0.221028 0.5137	0.563735 0.0709
j3	0.194029 0.5675	0.221028 0.5137	1.000000 0.0001	0.420084 0.1983
j4	0.519615 0.1014	0.563735 0.0709	0.420084 0.1983	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 41.7 Jaw movement variables with standard deviations
for key syllable [GIRL] in Sentence 3 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[GIRL]	Talker JJ	Duration-	(a)	196.95	16.60
		Opening cycle (j1)			
		Amplitude-	(a)	9.00	1.26
		Opening cycle (j2)			
		Duration-	(a)	131.30	15.65
		Closing cycle (j3)			
		Amplitude-	(a)	9.17	.98
		Closing cycle (j4)			
		Duration-	(b)	111.10	36.70
		Opening cycle (j1)			
		Amplitude-	(b)	6.33	2.25
		Opening cycle (j2)			
		Duration-	(b)	90.90	19.16
		Closing cycle (j3)			
		Amplitude-	(b)	5.83	2.04
		Closing cycle (j4)			
	Talker LR	Duration-	(a)	136.35	25.35
		Opening cycle (j1)			
		Amplitude-	(a)	6.67	1.03
		Opening cycle (j2)			
		Duration-	(a)	75.75	25.35
		Closing cycle (j3)			
		Amplitude-	(a)	6.33	2.80
		Closing cycle (j4)			
		Duration-	(b)	101.00	15.65
		Opening cycle (j1)			
		Amplitude-	(b)	7.17	2.32
		Opening cycle (j2)			
		Duration-	(b)	126.25	67.53
		Closing cycle (j3)			
		Amplitude-	(b)	8.33	2.94
		Closing cycle (j4)			

Table 42.7 Sentence 3. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [GIRL] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	J1	j2	j3	j4
j1	1.000000 0.0001	0.038851 0.9097	0.552866 0.0777	0.409547 0.2110
j2	0.038851 0.9097	1.000000 0.0001	0.474342 0.1405	0.729348 <u>0.0109*</u>
j3	0.552866 0.0777	0.474342 0.1405	1.000000 0.0001	0.612637 <u>0.0451*</u>
j4	0.409547 0.2110	0.729348 0.0109	0.612637 0.0451	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 43.7 Univariate Analysis of Variance for jaw movement variables for syllable [GIRL] in Sentence 3 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	22110.6675	22110.6675	27.26	<u>0.0004**</u>
		Error	10	8109.7950	810.9795		
		Total	11	30220.4625		r2=	0.7316
	j2	Version	1	21.3333	21.3333	6.40	<u>0.0200*</u>
		Error	10	33.3333	3.3333		
		Total	11	54.6666		r2=	0.3902
	j3	Version	1	4896.4800	4896.4800	16.00	<u>0.0025**</u>
		Error	10	3060.3000	306.0300		
		Total	11	7956.7800		r2=	0.6154
	j4	Version	1	33.3333	33.3333	12.99	<u>0.0048**</u>
		Error	10	25.6667	2.5667		
		Total	11	59.0000		r2=	0.5650
Talker LR	j1	Version	1	3748.8675	3748.8675	8.45	<u>0.0157*</u>
		Error	10	4437.4350	443.7435		
		Total	11	8186.3025		r2=	0.4579
	j2	Version	1	0.7500	0.7500	0.23	0.6396
		Error	10	32.1666	3.2166		
		Total	11	32.9166		r2=	0.0228
	j3	Version	1	7650.7500	7650.7500	2.94	0.1171
		Error	10	26012.5500	2601.2550		
		Total	11	33663.3000		r2=	0.2273
	j4	Version	1	12.0000	12.0000	1.45	0.2560
		Error	10	82.6667	0.8267		
		Total	11	94.6667		r2=	0.1268

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 44.7 Sentence 3. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [GIRL] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.053457 0.8759	0.270601 0.4209	0.566982 0.0689
j2	0.053457 0.8759	1.000000 0.0001	0.027604 0.9358	0.200388 0.5547
j3	0.270601 0.4209	0.027604 0.9358	1.000000 0.0001	0.881606 <u>0.0003**</u>
j4	0.566982 0.0689	0.200388 0.5547	0.881606 0.0003	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 45.7 Jaw movement variables with standard deviations
for key syllable [GOOD] in Sentence 4 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[GOOD]	Talker JJ	Duration-	(a)	121.20	0
		Opening cycle (j1)			
		Amplitude-	(a)	10.50	1.22
		Opening cycle (j2)			
		Duration-	(a)	111.10	15.65
		Closing cycle (j3)			
		Amplitude-	(a)	10.33	1.03
		Closing cycle (j4)			
		Duration-	(b)	156.55	22.81
		Opening cycle (j1)			
		Amplitude-	(b)	12.33	1.63
		Opening cycle (j2)			
		Duration-	(b)	267.65	29.80
		Closing cycle (j3)			
		Amplitude-	(b)	15.67	1.21
		Closing cycle (j4)			
	Talker LR	Duration-	(a)	121.20	46.94
		Opening cycle (j1)			
		Amplitude-	(a)	4.67	2.16
		Opening cycle (j2)			
		Duration-	(a)	101.00	36.70
		Closing cycle (j3)			
		Amplitude-	(a)	4.33	2.07
		Closing cycle (j4)			
		Duration-	(b)	196.95	15.60
		Opening cycle (j1)			
		Amplitude-	(b)	9.17	1.47
		Opening cycle (j2)			
		Duration-	(b)	126.25	12.37
		Closing cycle (j3)			
		Amplitude-	(b)	9.33	1.03
		Closing cycle (j4)			

Table 46.7 Sentence 4. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [GOOD] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	-.043386 0.8992	-0.438599 0.1772	0.055641 0.8709
j2	-.043386 0.8992	1.000000 0.0001	0.029409 0.9316	0.656626 <u>0.0282*</u>
j3	-0.438599 0.1772	0.029409 0.9316	1.000000 0.0001	0.150863 0.6579
j4	0.055641 0.8709	0.656626 0.0282	0.150863 0.6579	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 47.7 Univariate Analysis of Variance for jaw movement variables for syllable [GOOD] in Sentence 4 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	3748.8675	3748.8675	14.41	<u>0.0035**</u>
		Error	10	2601.2550	260.1255		
		Total	11	6350.1225		r2=	0.5904
	j2	Version	1	10.0833	10.0833	4.84	0.0524
		Error	10	20.8333	2.0833		
		Total	11	30.9166		r2=	0.3261
	j3	Version	1	73523.7075	73523.7075	129.86	<u>0.0001**</u>
		Error	10	5661.5550	566.1555		
		Total	11	79185.2625		r2=	0.9285
	j4	Version	1	85.3333	85.3333	67.37	<u>0.0001**</u>
		Error	10	12.6667	1.2667		
		Total	11	98.0000		r2=	0.8707
Talker LR	j1	Version	1	17214.1875	17214.1875	13.89	<u>0.0039**</u>
		Error	10	12394.2150	1239.4215		
		Total	11	29608.4025		r2=	0.5814
	j2	Version	1	60.7500	60.7500	17.78	<u>0.0018**</u>
		Error	10	34.1666	3.4166		
		Total	11	94.9166		r2=	0.6400
	j3	Version	1	1912.6875	1912.6875	2.55	0.1413
		Error	10	7497.7350	749.7735		
		Total	11	9410.4225		r2=	0.2033
	j4	Version	1	75.0000	75.0000	28.12	<u>0.0003**</u>
		Error	10	26.6667	2.6667		
		Total	11	101.6667		r2=	0.7377

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

**Table 48.7 Sentence 4. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [GOOD] as spoken by Talker LR**

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.721711 <u>0.0122*</u>	0.714286 <u>0.0135*</u>	0.579751 0.0616
j2	0.721711 0.0122	1.000000 0.0001	0.568722 0.0679	0.839280 <u>0.0012**</u>
j3	0.714286 0.0135	0.568722 0.06	1.000000 0.0001	0.745394 <u>0.0085**</u>
j4	0.579751 0.0616	0.839280 0.0012	0.745394 0.0085	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 49.7 Jaw movement variables with standard deviations
for key syllable [MEAT] in Sentence 4 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[MEAT]	Talker JJ	Duration-	(a)	126.25	12.37
		Opening cycle (j1)			
		Amplitude-	(a)	8.33	1.17
		Opening cycle (j2)			
		Duration-	(a)	116.16	44.6
		Closing cycle (j3)			
		Amplitude-	(a)	9.5	3.02
		Closing cycle (j4)			
		Duration-	(b)	146.45	12.37
		Opening cycle (j1)			
		Amplitude-	(b)	11.00	2.9
		Opening cycle (j2)			
		Duration-	(b)	65.65	12.37
		Closing cycle (j3)			
		Amplitude-	(b)	6.17	1.72
		Closing cycle (j4)			
	Talker LR	Duration-	(a)	116.15	29.79
		Opening cycle (j1)			
		Amplitude-	(a)	4.67	.82
		Opening cycle (j2)			
		Duration-	(a)	85.85	12.37
		Closing cycle (j3)			
		Amplitude-	(a)	3.67	1.37
		Closing cycle (j4)			
		Duration-	(b)	126.25	12.37
		Opening cycle (j1)			
		Amplitude-	(b)	6.67	1.03
		Opening cycle (j2)			
		Duration-	(b)	80.80	15.65
		Closing cycle (j3)			
		Amplitude-	(b)	5.17	1.67
		Closing cycle (j4)			

Table 50.7 Sentence 4. Partial correlation coefficients from the Error SS&CP Matrix / Prob = $|r|$ for segment corresponding to syllable [MEAT] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
DF = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.240165 0.4769	0.302372 0.3661	0.365652 0.2688
j2	0.240165 0.4769	1.000000 0.0001	0.286287 0.3934	0.617174 <u>0.0431*</u>
j3	0.302372 0.3661	0.286287 0.3934	1.000000 0.0001	0.728710 <u>0.0110*</u>
j4	0.365652 0.2688	0.617174 0.0431	0.728710 0.0110	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 51.7 Univariate Analysis of Variance for jaw movement variables for syllable [MEAT] in Sentence 4 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	1224.1200	1224.1200	8.00	<u>0.0179*</u>
		Error	10	1530.1500	153.0150		
		Total	11	2754.2700		r2=	0.4444
	j2	Version	1	14.0833	14.0833	2.88	0.1203
		Error	10	48.8333	4.8833		
		Total	11	62.9166		r2=	0.2238
	j3	Version	1	7650.7500	7650.7500	7.14	<u>0.0234*</u>
		Error	10	10711.0500	1071.1050		
		Total	11	18361.8000		r2=	0.4167
	j4	Version	1	33.3333	33.3333	5.52	<u>0.0406*</u>
		Error	10	60.3333	6.0333		
		Total	11	93.6666		r2=	0.3559
Talker LR	j1	Version	1	306.0300	306.0300	0.59	0.4608
		Error	10	5202.5100	520.2510		
		Total	11	5508.5400		r2=	0.0556
	j2	Version	1	12.0000	12.0000	13.85	<u>0.0040**</u>
		Error	10	8.6666	8.6666		
		Total	11	20.6666		r2=	0.5806
	j3	Version	1	76.5075	76.5075	0.38	0.5490
		Error	10	1989.1950	198.9195		
		Total	11	2065.7025		r2=	0.0370
	j4	Version	1	6.7500	6.7500	4.18	0.0683
		Error	10	16.1667	1.6167		
		Total	11	22.9167		r2=	0.2945

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

**Table 52.7 Sentence 4. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [MEAT] as spoken by Talker LR**

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.428086 0.1890	-0.523217 0.0986	0.052239 0.8788
j2	0.428086 0.1890	1.000000 0.0001	0.000000 .	0.563213 0.0712
j3	-0.523217 0.0986	0.000000 .	1.000000 0.0001	0.675855 <u>0.0224*</u>
j4	0.052239 0.8788	0.563213 0.0712	0.675855 0.0224	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 53.7 Jaw movement variables with standard deviations
for key syllable [TROO...] in Sentence 5 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[TROO...]	Talker JJ	Duration-	(a)	141.40	15.65
		Opening cycle (j1)			
		Amplitude-	(a)	7.50	1.05
		Opening cycle (j2)			
		Duration-	(a)	333.30	50.70
		Closing cycle (j3)			
		Amplitude-	(a)	11.67	1.03
		Closing cycle (j4)			
		Duration-	(b)	126.25	12.37
		Opening cycle (j1)			
		Amplitude-	(b)	6.67	1.86
		Opening cycle (j2)			
		Duration-	(b)	237.35	29.79
		Closing cycle (j3)			
		Amplitude-	(b)	11.67	1.97
		Closing cycle (j4)			
	Talker LR	Duration-	(a)	156.55	22.81
		Opening cycle (j1)			
		Amplitude-	(a)	7.17	1.17
		Opening cycle (j2)			
		Duration-	(a)	257.55	31.78
		Closing cycle (j3)			
		Amplitude-	(a)	12.00	2.37
		Closing cycle (j4)			
		Duration-	(b)	141.40	15.65
		Opening cycle (j1)			
		Amplitude-	(b)	8.50	1.38
		Opening cycle (j2)			
		Duration-	(b)	95.95	12.37
		Closing cycle (j3)			
		Amplitude-	(b)	8.67	1.03
		Closing cycle (j4)			

Table 54.7 Sentence 5. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [TROO...] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.189565 0.5767	-0.287000 0.3922	-0.045596 0.8941
j2	0.189565 0.5767	1.000000 0.0001	-0.257188 0.4452	0.898915 <u>0.0002**</u>
j3	-0.287000 0.3922	-0.257188 0.4452	1.000000 0.0001	-0.201050 0.5533
j4	-0.045596 0.8941	0.898915 0.0002	-0.201050 0.5533	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 55.7 Univariate Analysis of Variance for jaw movement variables for syllable [TROO...] in Sentence 5 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	688.5675	688.5675	3.46	0.0924
		Error	10	1989.1950	198.9195		
		Total	11	2677.7625		r2=	0.2571
	j2	Version	1	2.0833	2.0833	0.91	0.3620
		Error	10	22.8333	2.2833		
		Total	11	24.9166		r2=	0.0836
	j3	Version	1	27619.2075	27619.2075	15.97	<u>0.0025**</u>
		Error	10	17290.6950	1729.0695		
		Total	11	44909.9025		r2=	0.6150
	j4	Version	1	0.0000	0.0000	0.00	1.00
		Error	10	24.6667	2.2667		
		Total	11	24.6667		r2=	-0.0000
Talker LR	j1	Version	1	688.5675	688.5675	1.80	0.2094
		Error	10	3825.3750	382.5375		
		Total	11	4513.9425		r2=	0.1525
	j2	Version	1	5.3333	5.3333	3.27	0.1009
		Error	10	16.3333	1.6333		
		Total	11	21.6666		r2=	0.2462
	j3	Version	1	78343.6800	78343.6800	134.74	<u>0.0001**</u>
		Error	10	5814.5700	581.4570		
		Total	11	84158.2500		r2=	0.9309
	j4	Version	1	33.3333	33.3333	10.00	<u>0.0101*</u>
		Error	10	33.3333	3.3333		
		Total	11	66.6666		r2=	0.5000

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 56.7 Sentence 5. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [TR00...] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.343452 0.3011	-0.421776 0.1963	-0.480833 0.1343
j2	0.343452 0.3011	1.000000 0.0001	0.491605 0.1246	0.514286 0.1056
j3	-0.421776 0.1963	0.491605 0.1246	1.000000 0.0001	0.848838 <u>0.0010**</u>
j4	-0.480833 0.1343	0.514286 0.1056	0.848838 0.0010	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 57.7 Jaw movement variables with standard deviations
for key syllable [NA...] in Sentence 5 as spoken by Talker JJ
and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[NAT...]	Talker JJ	Duration- Opening cycle (j1)	(a)	131.30	15.65
		Amplitude- Opening cycle (j2)	(a)	12.17	.75
		Duration- Closing cycle (j3)	(a)	75.75	16.60
		Amplitude- Closing cycle (j4)	(a)	8.67	1.37
		Duration- Opening cycle (j1)	(b)	131.30	24.74
		Amplitude- Opening cycle (j2)	(b)	13.17	.75
		Duration- Closing cycle (j3)	(b)	85.85	12.37
		Amplitude- Closing cycle (j4)	(b)	8.17	.98
		Duration- Opening cycle (j1)	(a)	166.65	25.35
		Amplitude- Opening cycle (j2)	(a)	12.50	2.43
		Duration- Closing cycle (j3)	(a)	101.00	36.70
		Amplitude- Closing cycle (j4)	(a)	9.17	1.17
		Duration- Opening cycle (j1)	(b)	60.60	0
		Amplitude- Opening cycle (j2)	(b)	2.17	1.17
		Duration- Closing cycle (j3)	(b)	65.65	12.37
		Amplitude- Closing cycle (j4)	(b)	2.17	.98

Table 58.7 Sentence 5. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [NA...] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.453743 0.1610	0.101015 0.7676	0.040996 0.9047
j2	0.453743 0.1610	1.000000 0.0001	-.091670 0.7887	0.241821 0.4738
j3	0.101015 0.7676	-.091670 0.7887	1.000000 0.0001	0.202920 0.5496
j4	0.040996 0.9047	0.241821 0.4738	0.202920 0.5496	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 59.7 Univariate Analysis of Variance for jaw movement variables for syllable [NA...] in Sentence 5 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	0.0000	0.0000	0.00	1.0000
		Error	10	4284.4200	428.4420		
		Total	11	4284.42		r2=	0.0000
	j2	Version	1	3.0000	3.0000	5.29	<u>0.0442*</u>
		Error	10	5.6667	0.5667		
		Total	11	8.6667		r2=	0.3461
	j3	Version	1	306.0300	306.0300	1.43	0.2596
		Error	10	2142.2100	214.2210		
		Total	11	2448.2400		r2=	0.1250
	j4	Version	1	0.7500	0.7500	0.53	0.4835
		Error	10	14.1667	1.4167		
		Total	11	14.9167		r2=	0.0503
Talker LR	j1	Version	1	33739.8075	33739.8075	105.00	<u>0.0001**</u>
		Error	10	3213.3150	321.3315		
		Total	11	36953.1225		r2=	0.9130
	j2	Version	1	320.3333	320.3333	88.17	<u>0.0001**</u>
		Error	10	36.3333	3.6333		
		Total	11	356.6666		r2=	0.8981
	j3	Version	1	3748.8675	3748.8675	5.00	<u>0.0493*</u>
		Error	10	7497.7350	749.7735		
		Total	11	11246.6025		r2=	0.3333
	j4	Version	1	147.0000	147.0000	126.00	<u>0.0001**</u>
		Error	10	11.6667	1.1667		
		Total	11	158.6667		r2=	0.9265

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 60.7 Sentence 5. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [NA...] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.310371 0.3529	0.187044 0.5818	-0.234738 0.4872
j2	0.310371 0.3529	1.000000 0.0001	0.803067 <u>0.0029**</u>	0.647609 <u>0.0312*</u>
j3	0.187044 0.5818	0.803067 0.0029	1.000000 0.0001	0.461017 0.1535
j4	-0.234738 0.4872	0.647609 0.0312	0.461017 0.1535	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 61.7 Jaw movement variables with standard deviations
for key syllable [HIT] in Sentence 6 as spoken by Talker JJ
and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[HIT]	Talker JJ	Duration- Opening cycle (j1)	(a)	95.95	12.37
		Amplitude- Opening cycle (j2)	(a)	2.83	1.17
		Duration- Closing cycle (j3)	(a)	70.70	15.65
		Amplitude- Closing cycle (j4)	(a)	3.50	1.05
		Duration- Opening cycle (j1)	(b)	166.65	16.60
		Amplitude- Opening cycle (j2)	(b)	9.67	1.03
		Duration- Closing cycle (j3)	(b)	368.65	35.42
		Amplitude- Closing cycle (j4)	(b)	14.67	.52
		Duration- Opening cycle (j1)	(a)	156.55	12.37
		Amplitude- Opening cycle (j2)	(a)	7.67	2.80
		Duration- Closing cycle (j3)	(a)	80.80	15.65
		Amplitude- Closing cycle (j4)	(a)	5.17	1.17
		Duration- Opening cycle (j1)	(b)	166.65	16.60
		Amplitude- Opening cycle (j2)	(b)	8.00	1.79
		Duration- Closing cycle (j3)	(b)	368.65	117.22
		Amplitude- Closing cycle (j4)	(b)	13.33	2.88

Table 62.7 Sentence 6. Partial correlation coefficients from the Error SS&CP Matrix / Prob = $|r|$ for segment corresponding to syllable [HIT] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.218964 0.5177	-0.649063 <u>0.0307*</u>	0.375653 0.2549
j2	0.218964 0.5177	1.000000 0.0001	0.066881 0.8451	0.859102 <u>0.0007**</u>
j3	-0.649063 0.0307	0.066881 0.8451	1.000000 0.0001	-0.089242 0.7941
j4	0.375653 0.2549	0.859102 0.0007	-0.089242 0.7941	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 63.7 Univariate Analysis of Variance for jaw movement variables for syllable [HIT] in Sentence 6 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	14995.4700	14995.4700	70.00	<u>0.0001**</u>
		Error	10	2142.2100	214.2210		
		Total	11	17137.6800		r2=	0.8750
	j2	Version	1	140.0833	140.0833	115.14	<u>0.0001**</u>
		Error	10	12.1667	1.2167		
		Total	11	152.2500		r2=	0.9201
	j3	Version	1	266322.6075	266322.6075	355.20	<u>0.0001**</u>
		Error	10	7497.7350	749.7735		
		Total	11	273820.3425		r2=	0.9726
	j4	Version	1	374.0833	374.0833	547.44	<u>0.0001**</u>
		Error	10	6.8333	0.6833		
		Total	11	380.9166		r2=	0.9821
Talker LR	j1	Version	1	306.0300	306.0300	1.43	0.2596
		Error	10	2142.2100	214.2210		
		Total	11	2448.2400		r2=	0.1250
	j2	Version	1	0.3333	0.3333	0.06	0.8111
		Error	10	55.3333	5.5333		
		Total	11	55.6666		r2=	0.0060
	j3	Version	1	248572.8675	248572.8675	35.55	<u>0.0001**</u>
		Error	10	69927.8550	69927.8550		
		Total	11	318500.7225		r2=	0.7804
	j4	Version	1	200.0833	200.0833	41.54	<u>0.0001**</u>
		Error	10	48.1667	4.8167		
		Total	11	248.2500		r2=	0.8060

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 64.7 Sentence 6. Partial correlation coefficients from the Error SS&CP Matrix / Prob = $|r|$ for segment corresponding to syllable [HIT] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	-0.498707 0.1184	-0.087514 0.7981	-0.487359 0.1284
j2	-0.498707 0.1184	1.000000 0.0001	0.143768 0.6732	0.703783 <u>0.0157*</u>
j3	-0.087514 0.7981	0.143768 0.6732	1.000000 0.0001	0.544826 0.0831
j4	-0.487359 0.1284	0.703783 0.0157	0.544826 0.0831	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 65.7 Jaw movement variables with standard deviations
for key syllable [COP] in Sentence 6 as spoken by Talker JJ
and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[COP]	Talker JJ	Duration- Opening cycle (j1)	(a)	146.45	22.81
		Amplitude- Opening cycle (j2)	(a)	9.00	1.1
		Duration- Closing cycle (j3)	(a)	161.60	24.74
		Amplitude- Closing cycle (j4)	(a)	11.17	.75
		Duration- Opening cycle (j1)	(b)	85.85	22.81
		Amplitude- Opening cycle (j2)	(b)	8.67	1.03
		Duration- Closing cycle (j3)	(b)	90.90	0
		Amplitude- Closing cycle (j4)	(b)	8.00	1.26
		Duration- Opening cycle (j1)	(a)	116.15	22.81
		Amplitude- Opening cycle (j2)	(a)	8.33	.52
		Duration- Closing cycle (j3)	(a)	126.25	44.60
		Amplitude- Closing cycle (j4)	(a)	9.0	1.55
		Duration- Opening cycle (j1)	(b)	111.10	84.98
		Amplitude- Opening cycle (j2)	(b)	7.50	5.24
		Duration- Closing cycle (j3)	(b)	95.95	61.85
		Amplitude- Closing cycle (j4)	(b)	7.5	4.04
	Talker LR	Duration- Opening cycle (j1)	(a)	116.15	22.81
		Amplitude- Opening cycle (j2)	(a)	8.33	.52
		Duration- Closing cycle (j3)	(a)	126.25	44.60
		Amplitude- Closing cycle (j4)	(a)	9.0	1.55
		Duration- Opening cycle (j1)	(b)	111.10	84.98
		Amplitude- Opening cycle (j2)	(b)	7.50	5.24
		Duration- Closing cycle (j3)	(b)	95.95	61.85
		Amplitude- Closing cycle (j4)	(b)	7.5	4.04

Table 66.7 Sentence 6. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [COP] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.207973 0.5394	0.076696 0.8227	0.276533 0.4104
j2	0.207973 0.5394	1.000000 0.0001	0.488094 0.1277	0.721988 <u>0.0121*</u>
j3	0.076696 0.8227	0.488094 0.1277	1.000000 0.0001	0.110940 0.7454
j4	0.276533 0.41	0.721988 0.0121	0.110940 0.7454	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 67.7 Univariate Analysis of Variance for jaw movement variables for syllable [COP] in Sentence 6 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	11017.0800	11017.0800	21.18	<u>0.0010**</u>
		Error	10	5202.5100	520.2510		
		Total	11	16219.5900		r2=	0.6792
	j2	Version	1	0.3333	0.3333	0.29	0.5995
		Error	10	11.3333	1.3333		
		Total	11	11.6666		r2=	0.0286
	j3	Version	1	14995.4700	14995.4700	49.00	<u>0.0001**</u>
		Error	10	3060.3000	306.0300		
		Total	11	18055.7700		r2=	0.8305
	j4	Version	1	30.0833	30.0833	27.77	<u>0.0004**</u>
		Error	10	10.8333	1.0833		
		Total	11	40.9166		r2=	0.7352
Talker LR	j1	Version	1	76.5075	76.5075	0.02	0.8910
		Error	10	38712.7950	3871.2795		
		Total	11	38789.3025		r2=	0.0020
	j2	Version	1	2.0833	2.0833	0.15	0.7066
		Error	10	138.8333	13.8833		
		Total	11	140.9166		r2=	0.0148
	j3	Version	1	2754.2700	2754.2700	0.95	0.3533
		Error	10	29072.8500	2907.2850		
		Total	11	31827.1200		r2=	0.0865
	j4	Version	1	6.75	6.75	0.72	0.4154
		Error	10	93.5000	9.3500		
		Total	11	100.2500		r2=	0.0673

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 68.7 Sentence 6. Partial correlation coefficients from the Error SS&CP Matrix / Prob = $|r|$ for segment corresponding to syllable [COP] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.853893 <u>0.0008**</u>	0.752570 <u>0.0075**</u>	0.541488 0.0854
j2	0.853893 0.0008	1.000000 0.0001	0.696274 <u>0.0173*</u>	0.811875 <u>0.0024**</u>
j3	0.752570 0.0075	0.696274 0.0173	1.000000 0.0001	0.652411 <u>0.0296*</u>
j4	0.541488 0.0854	0.811875 0.0024	0.652411 0.0296	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 69.7 Jaw movement variables with standard deviations
for key syllable [IS] in Sentence 7 as spoken by Talker JJ
and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[IS]	Talker JJ	Duration-	(a)	131.30	15.65
		Opening cycle (j1)			
		Amplitude-	(a)	9.17	1.17
		Opening cycle (j2)			
		Duration-	(a)	126.25	12.37
		Closing cycle (j3)			
		Amplitude-	(a)	10.00	1.79
		Closing cycle (j4)			
		Duration-	(b)	166.65	16.60
		Opening cycle (j1)			
		Amplitude-	(b)	10.67	1.86
		Opening cycle (j2)			
		Duration-	(b)	313.10	24.74
		Closing cycle (j3)			
		Amplitude-	(b)	16.33	1.63
		Closing cycle (j4)			
	Talker LR	Duration-	(a)	95.95	12.37
		Opening cycle (j1)			
		Amplitude-	(a)	3.00	1.26
		Opening cycle (j2)			
		Duration-	(a)	65.65	12.37
		Closing cycle (j3)			
		Amplitude-	(a)	3.17	.75
		Closing cycle (j4)			
		Duration-	(b)	287.85	87.29
		Opening cycle (j1)			
		Amplitude-	(b)	5.33	1.86
		Opening cycle (j2)			
		Duration-	(b)	272.70	63.56
		Closing cycle (j3)			
		Amplitude-	(b)	10.17	1.33
		Closing cycle (j4)			

Table 70.7 Sentence 7. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [IS] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	-0.161132 0.6360	-0.388057 0.2383	0.000000 .
j2	-0.161132 0.6360	1.000000 0.0001	0.548100 0.0809	0.888890 <u>0.0003**</u>
j3	-0.388057 0.2383	0.548100 0.0809	1.000000 0.0001	0.663325 <u>0.0261*</u>
j4	0.000000 .	0.888890 0.0003	0.663325 0.0261	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 71.7 Univariate Analysis of Variance for jaw movement variables for syllable [IS] in Sentence 7 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	3748.8675	3748.8675	14.41	<u>0.0035**</u>
		Error	10	2601.2550	260.1255		
		Total	11	6350.1225		r2=	0.5904
	j2	Version	1	6.7500	6.7500	2.79	0.1256
		Error	10	24.1666	2.4166		
		Total	11	30.9166		r2=	0.2183
	j3	Version	1	104738.7675	104738.7675	273.80	<u>0.0001**</u>
		Error	10	3825.3750	382.5375		
		Total	11	108564.1425		r2=	0.9648
	j4	Version	1	120.3333	120.3333	41.02	<u>0.0001**</u>
		Error	10	29.3333	2.9333		
		Total	11	149.6666		r2=	0.8040
Talker LR	j1	Version	1	110476.8300	110476.8300	28.43	<u>0.0003**</u>
		Error	10	38865.8100	3886.5810		
		Total	11	149342.6400		r2=	0.7398
	j2	Version	1	16.3333	16.3333	6.45	<u>0.0294*</u>
		Error	10	25.3333	2.5333		
		Total	11	41.6666		r2=	0.3920
	j3	Version	1	128609.1075	128609.1075	61.35	<u>0.0001**</u>
		Error	10	20963.0550	2096.3055		
		Total	11	149572.1625		r2=	0.8598
	j4	Version	1	147.0000	147.0000	126.00	<u>0.0001**</u>
		Error	10	11.6667	1.1667		
		Total	11	158.6667		r2=	0.9265

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 72.7 Sentence 7. Partial correlation coefficients from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion corresponding to syllable [IS] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.213752 0.5280	-0.905961 <u>0.0001</u> **	-0.299981 0.3701
j2	0.213752 0.5280	1.000000 0.0001	-0.374207 0.2569	0.736788 <u>0.0097</u> **
j3	-0.905961 0.0001	-0.374207 0.2569	1.000000 0.0001	0.112327 0.7423
j4	-0.299981 0.3701	0.736788 0.0097	0.112327 0.7423	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

**Table 73.7 Jaw movement variables with standard deviations
for key syllable [MAR...] in Sentence 7 as spoken by Talker
JJ and Talker LR**

Syllable	Talker	Jaw Variable	Version	Mean	Std. Dev.
[MAR...]	Talker JJ	Duration-	(a)	106.05	16.60
		Opening cycle (j1)			
		Amplitude-	(a)	8.17	1.33
		Opening cycle (j2)			
		Duration-	(a)	106.05	16.60
		Closing cycle (j3)			
		Amplitude-	(a)	7.50	1.05
		Closing cycle (j4)			
		Duration-	(b)	131.30	24.74
		Opening cycle (j1)			
		Amplitude-	(b)	15.0	4.05
		Opening cycle (j2)			
		Duration-	(b)	126.25	48.54
		Closing cycle (j3)			
		Amplitude-	(b)	11.83	1.94
		Closing cycle (j4)			
	Talker LR	Duration-	(a)	126.25	22.81
		Opening cycle (j1)			
		Amplitude-	(a)	8.17	2.64
		Opening cycle (j2)			
		Duration-	(a)	116.15	35.42
		Closing cycle (j3)			
		Amplitude-	(a)	8.67	.82
		Closing cycle (j4)			
		Duration-	(b)	95.95	40.27
		Opening cycle (j1)			
		Amplitude-	(b)	7.33	6.74
		Opening cycle (j2)			
		Duration-	(b)	136.35	85.16
		Closing cycle (j3)			
		Amplitude-	(b)	9.17	2.64
		Closing cycle (j4)			

Table 74.7 Sentence 7. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [MAR...] as spoken by Talker JJ

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
<i>DF</i> = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.596574 0.0527	-0.580697 0.0610	-0.107578 0.7529
j2	0.596574 0.0527	1.000000 0.0001	-0.734429 <u>0.0101*</u>	0.138258 0.6852
j3	-0.580697 0.0610	-0.734429 0.0101	1.000000 0.0001	-0.285578 0.3946
j4	-0.107578 0.7529	0.138258 0.685	-0.285578 0.3946	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 75.7 Univariate Analysis of Variance for jaw movement variables for syllable [MAR...] in Sentence 7 as spoken by Talker JJ and Talker LR

Talker	Jaw Var.	Source	DF	SS	MS	F Value	Pr > F
Talker JJ	j1	Version	1	1912.6875	1912.6875	4.31	0.0646
		Error	10	4437.4350	443.7435		
		Total	11	6350.1225		r2=	0.3012
	j2	Version	1	140.0833	140.0833	15.42	<u>0.0028**</u>
		Error	10	90.8333	9.0833		
		Total	11	230.9166		r2=	0.6066
	j3	Version	1	1224.1200	1224.1200	0.93	0.3575
		Error	10	13159.2900	1315.9290		
		Total	11	14383.4100		r2=	0.0851
	j4	Version	1	56.3333	56.3333	23.15	<u>0.0007**</u>
		Error	10	24.3333	2.4333		
		Total	11	80.6666		r2=	0.6983
Talker LR	j1	Version	1	2754.2700	2754.2700	2.57	0.1399
		Error	10	10711.0500	1071.1050		
		Total	11	13465.3200		r2=	0.4444
	j2	Version	1	2.0833	2.0833	0.08	0.7838
		Error	10	262.1667	26.2167		
		Total	11	264.2500		r2=	0.0079
	j3	Version	1	1224.1200	1224.1200	0.29	0.6034
		Error	10	42538.1700	4253.8170		
		Total	11	43762.2900		r2=	0.0280
	j4	Version	1	0.7500	0.7500	0.20	0.6670
		Error	10	38.1667	3.8167		
		Total	11	38.9167		r2=	0.0193

j1 = jaw duration during opening

j2 = jaw amplitude during opening

j3 = jaw duration during closing

j4 = jaw amplitude during closing

* indicates one level of significance

** indicates two levels of significance

Table 76.7 Sentence 7. Partial correlation coefficients
from the Error SS&CP Matrix / Prob = $|r|$ for vowel portion
corresponding to syllable [MAR...] as spoken by Talker LR

	Opening Duration	Opening Amplitude	Closing Duration	Closing Amplitude
DF = 20	j1	j2	j3	j4
j1	1.000000 0.0001	0.804633 <u>0.0028**</u>	-0.057348 0.8670	0.055288 0.8717
j2	0.804633 0.0028	1.000000 0.0001	-0.397712 0.2258	-0.099970 0.7699
j3	-0.057348 0.8670	-0.397712 0.2258	1.000000 0.0001	0.764922 <u>0.0061**</u>
j4	0.055288 0.8717	-0.099970 0.7699	0.764922 0.0061	1.000000 0.0001

* indicates one level of significance

** indicates two levels of significance

Table 77.8 Comparison of Binomial Test Scores and Per Cent Correct Identification by Subjects (N=20)

1	2	3	4	6	7	8	9
Talker	Set	Vers.	Binomial Mean Visual- Nat.	Vers.	Binomial Mean Visual- Reit.	Visual- Nat. Per Cent Correct	Visual- Reit. Per Cent Correct
Talker JJ							
	1	(a)	.7167	(a)	.9500	71.67	95.00
	1	(b)	.9583	(b)	.9500	63.50	99.17
	2	(a)	.8667	(a)	.9667	95.83	95.00
	2	(b)	.6917	(b)	.9000	100.00	99.17
	3	(a)	.6917	(a)	.8083	86.67	96.67
	3	(b)	.9583	(b)	.9500	86.67	91.67
	4	(a)	.9583	(a)	.9917	69.17	80.83
	4	(b)	.6250	(b)	.8333	82.50	99.17
	6	(a)	.8250	(a)	.9917	95.83	95.00
	6	(b)	.8667	(b)	.6333	95.00	95.00
Talker LR							
	1	(a)	.4583	(a)	.6500	45.83	65.00
	1	(b)	.9917	(b)	.9667	68.33	74.17
	4	(a)	.9750	(a)	.9750	78.33	82.50
	4	(b)	.6833	(b)	.7417	57.50	74.17
	6	(a)	.5750	(a)	.8917	87.50	80.83
	6	(b)	.5750	(b)	.9917	95.00	95.00

Table 78.8 Results of Predictions from Sentences, Compared with Results from Acoustic Analysis

			Talker JJ		Talker LR	
Sentence	Syllable	Prediction		ANOVA *		ANOVA *
1	DUKE	a > b	✓	**	✓	—
	JAMES	a > b	✓	**	×	**
2	OLD	a > b	✓	**	×	*
	MEN	b > a	✓	**	✓	**
3	GREE...	a = b	✓	**	✓	—
	GIRL	a > b	✓	**	✓	**
4	GOOD	b > a	✓	—	✓	**
	MEAT	a = b	✓	—	✓	—
5	TROO...	a > b	—	—	×	**
	NA...	b > a	✓	—	×	**
6	HIT	a = b	×	**	×	**
	COP	a > b	✓	**	✓	*
7	IS	b > a	✓	**	✓✓✓✓	**
	MAR...	b > a	—	—	×	**
Overall			<u>11</u> ✓	<u>9</u> **	<u>8</u> ✓	<u>9</u> **
			<u>1</u> ×		<u>6</u> ×	<u>2</u> *
			<u>2</u> —	<u>5</u> —	<u>= 14</u>	<u>3</u> —
			<u>= 14</u>	<u>= 14</u>		<u>= 14</u>

- ✓ correct direction according to sentence structure
- × incorrect direction according to sentence structure
- no significant findings
- * indicates one level of significance
- ** indicates two levels of significance

**Table 79.8 Comparisons of Predictions from Sentences with
Results from Audio-Reiterant and Visual-Reiterant
Perceptual Tasks**

#	Syll.	Pred.	JJ	A-R	ANOVA *	JAW *	LR	A-R	ANOVA *	JAW *
1	DUKE	a > b	✓	<u>238.5</u>	**	*	✓	<u>179.9</u>	—	*
	JAMES	a > b	✓	<u>321</u>	**	*	×	<u>297.7</u>	**	—
2	OLD	a > b	✓	<u>183.2</u>	**	*	×	<u>172.5</u>	*	*
	MEN	b > a	✓	<u>245.5</u>	**	*	✓	<u>183.7</u>	**	*
3	GREE...	a = b	✓	<u>114.2</u>	**	—	✓	<u>136.1</u>	—	—
	GIRL	a > b	✓	<u>190</u>	**	—	✓	<u>143.8</u>	**	*
4	GOOD	b > a	✓	<u>169.4</u>	—	*	✓	<u>215.6</u>	**	*
	MEAT	a = b	✓	<u>175.6</u>	—	*	✓	<u>196.2</u>	—	—
5	TROO...	a > b	—	<u>197.5</u>	—	*	×	<u>170.7</u>	**	*
	NA...	b > a	✓	<u>106.2</u>	—	—	×	<u>127.0</u>	**	*
6	HIT	a = b	×	<u>168.5</u>	**	*	×	<u>210.9</u>	**	*
	COP	a > b	✓	<u>175.4</u>	**	*	✓	<u>145.9</u>	*	—
7	IS	b > a	✓	<u>219.7</u>	**	*	✓	<u>269.2</u>	**	*
	MAR	b > a	—	<u>140.4</u>	—	*	×	<u>170.9</u>	**	—
	<u>Totals</u>		<u>11</u> ✓		<u>9</u> **	<u>11</u> *	<u>8</u> ✓		<u>9</u> **	<u>9</u> **
			<u>1</u> ×		<u>5</u> —	<u>3</u> —	<u>6</u> ×		<u>2</u> *	<u>5</u> —
			<u>2</u> —						<u>3</u> —	

* level of significance

— not significant

✓ correct direction according to sentence structure

× incorrect direction according to sentence structure

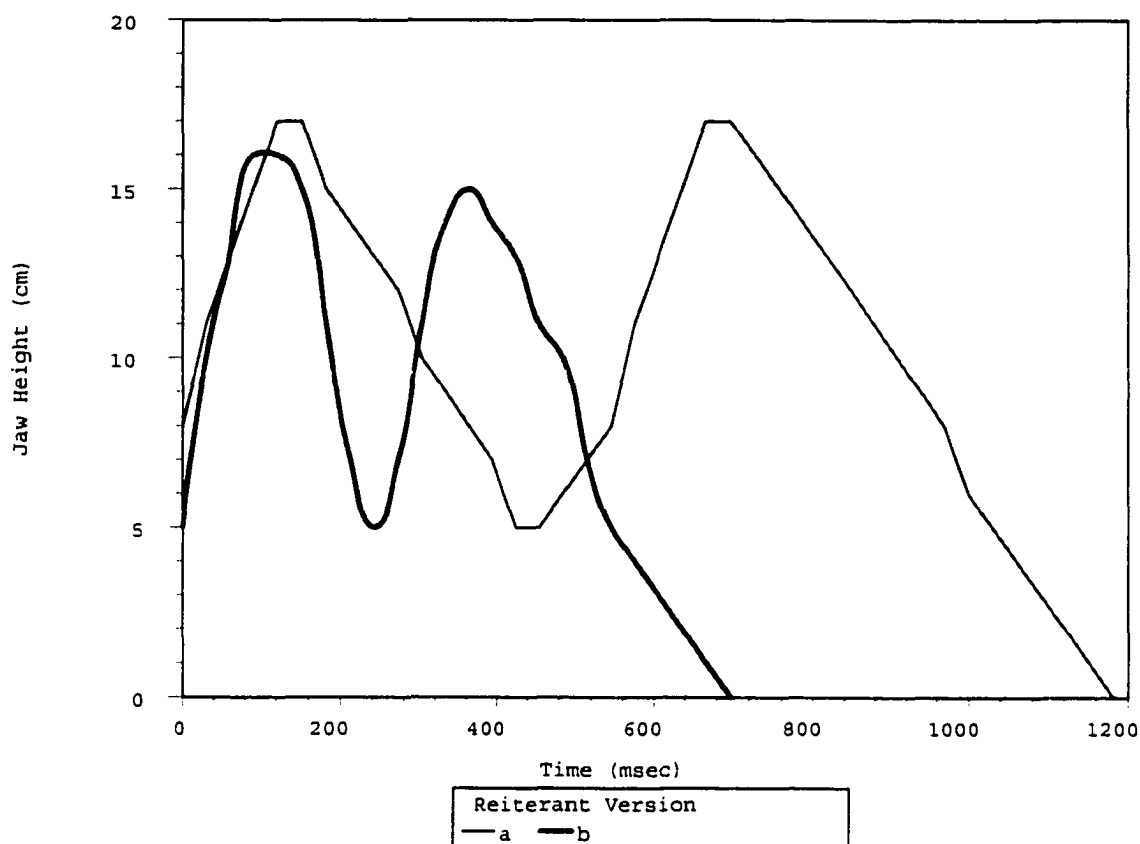


Figure 1.1 This figure displays a tracing from data obtained during the reiterant production of version (a) and version (b) of the syllable [DUKE] as spoken by Talker JJ.

The movement of the jaw is presented in which the peaks and valleys denote the high and low vertical position of this articulator. The peaks occur during the lip closure for the bilabial stop [m] and the valleys occur during production of the low vowel [a].

Figure 2.3 Flow diagram of video and audio signal and instrumentation used for dubbing from videotape to optical laser disc.

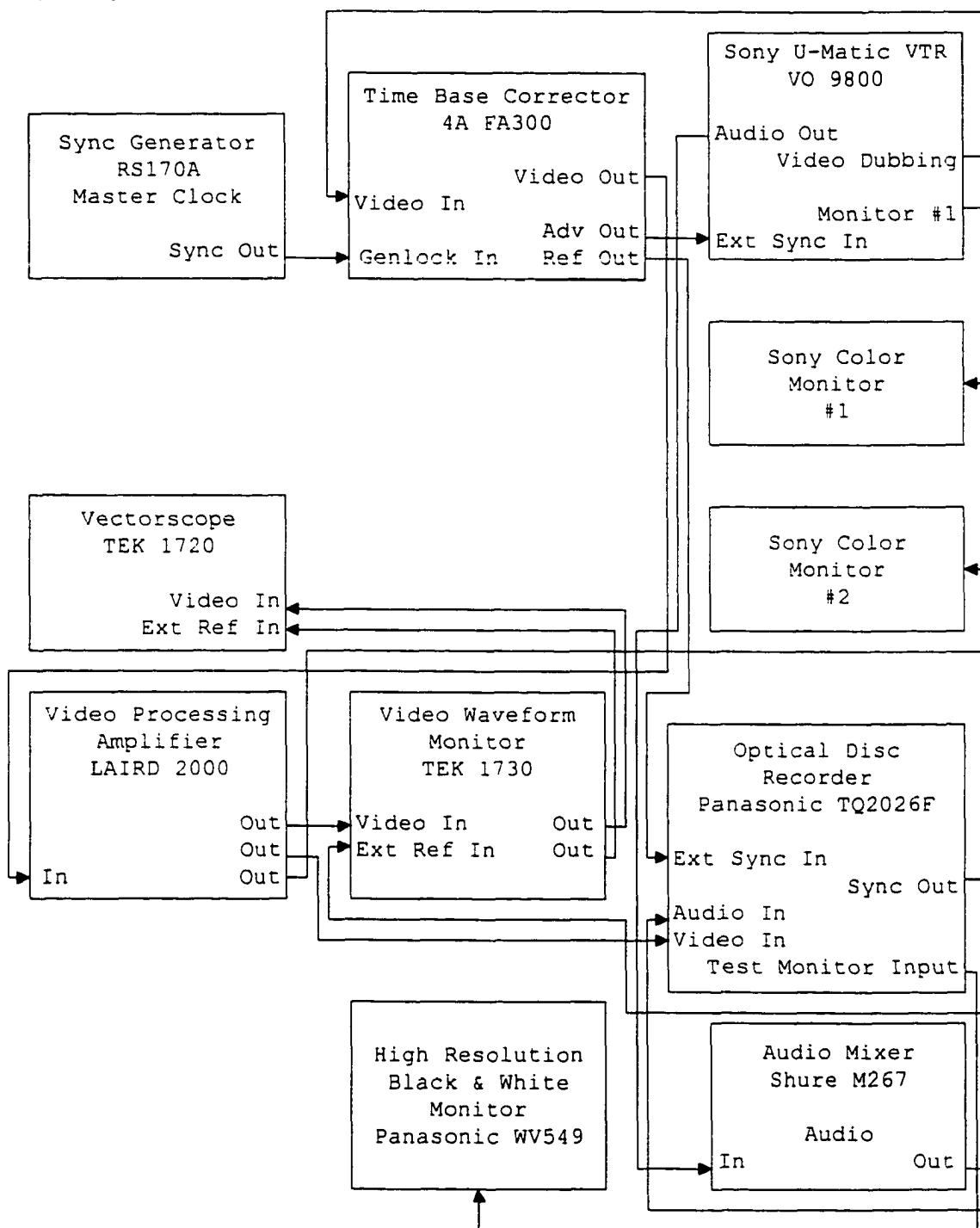


Figure 3(a).

Spectrogram and waveform of reiterant phrase
[HOW GOOD MEAT] as spoken by Talker LR. The
intent of the talker is to convey the meaning
that John has never tasted meat.

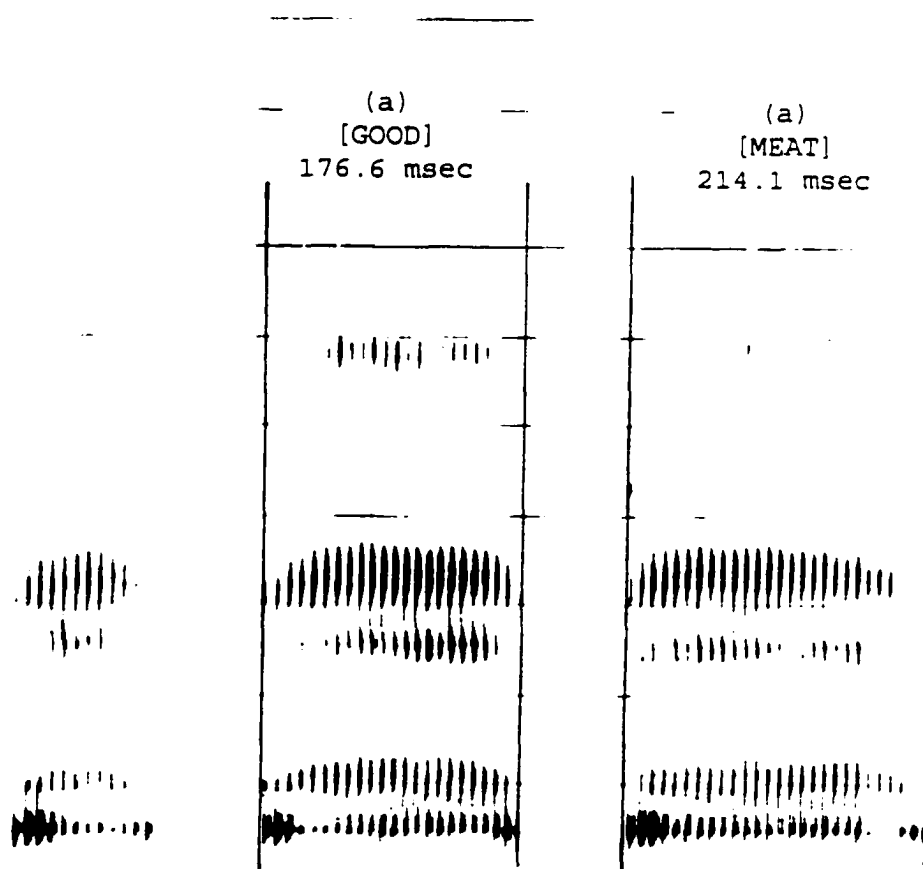


Figure 3(b).

Spectrogram and waveform of reiterant phrase
[HOW GOOD MEAT] as spoken by Talker LR. The
intent of the talker is to convey the meaning
that John does not like meat.

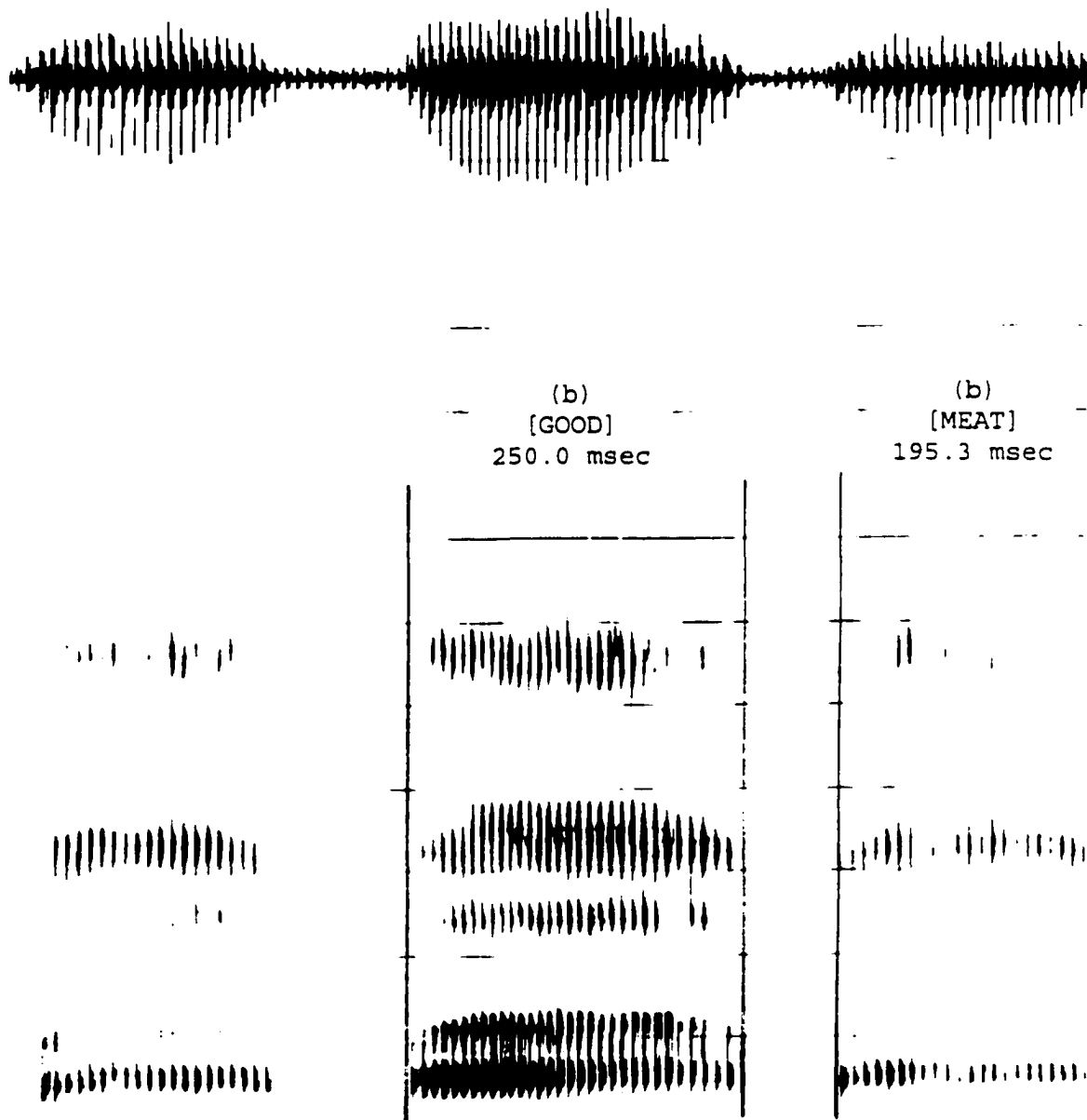


Figure 4.4 Two structural representations of an ambiguous sentence of the general type studied here.

This figure is revised from Cooper, Paccia, and Lapointe (Cooper and Paccia-Cooper, 1980).

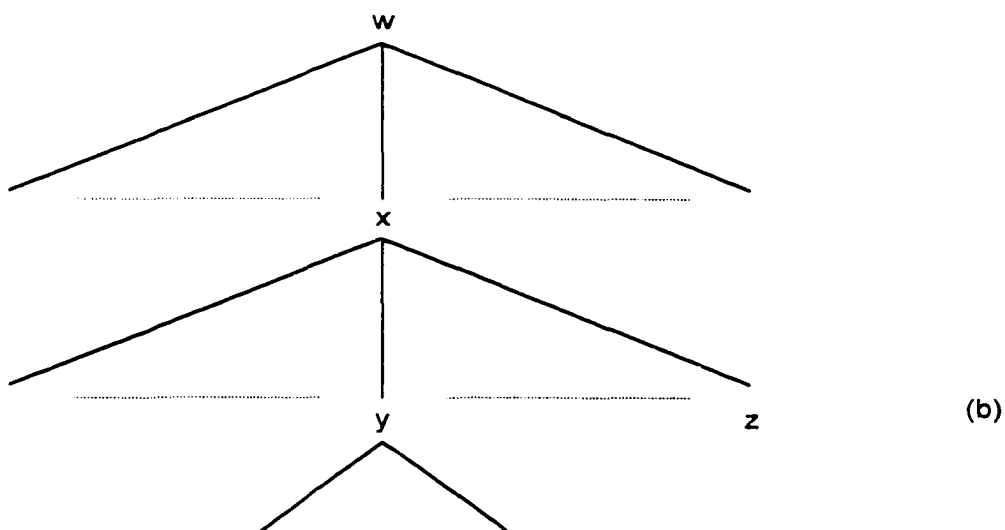
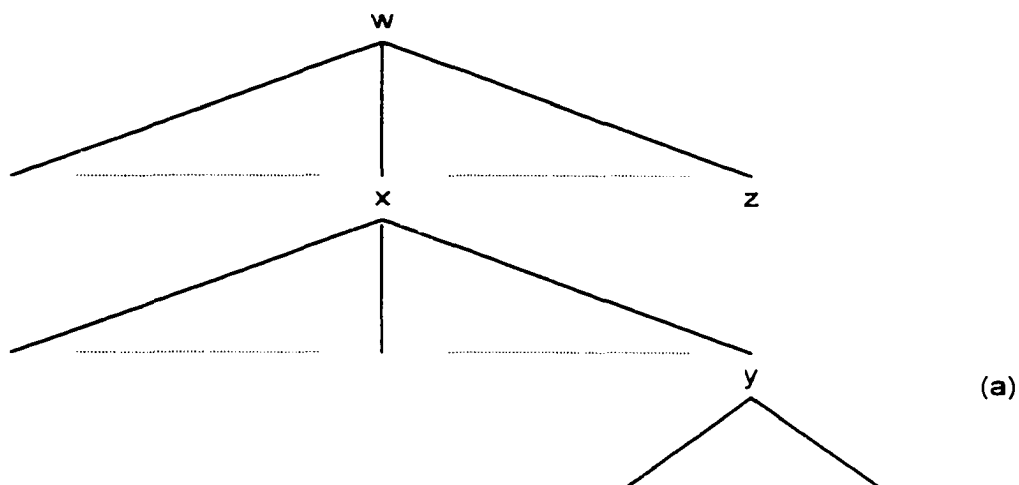


Figure 5.4 Sentence 1. Two structural representations of the sentence **HERE IS THE FAMOUS [DUKE] [JAMES]**.

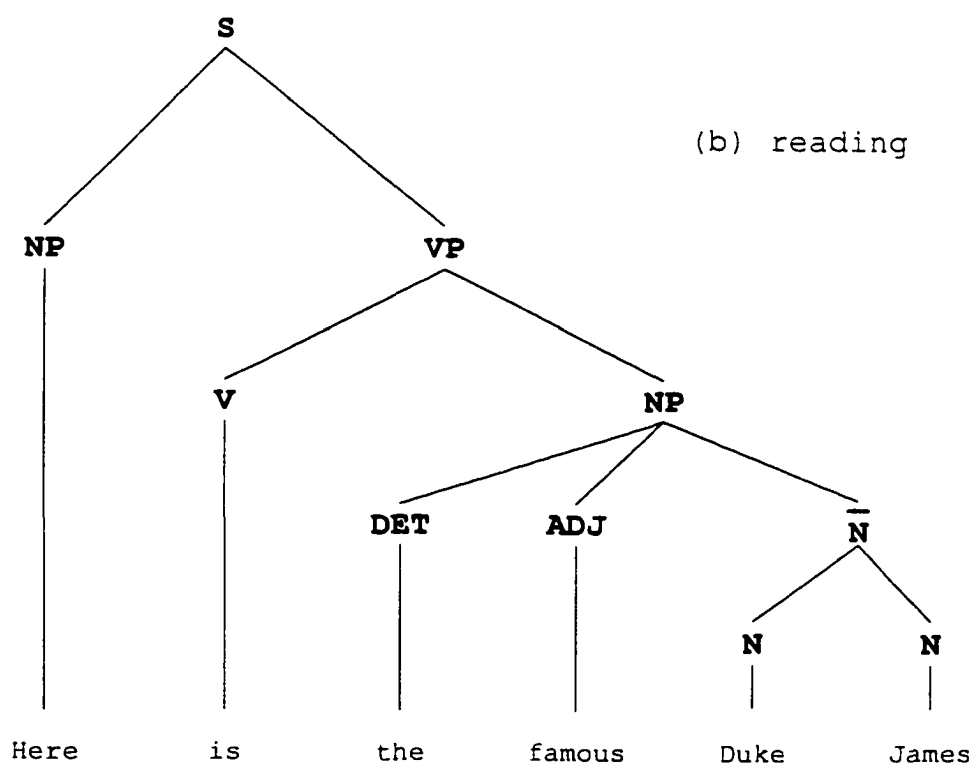
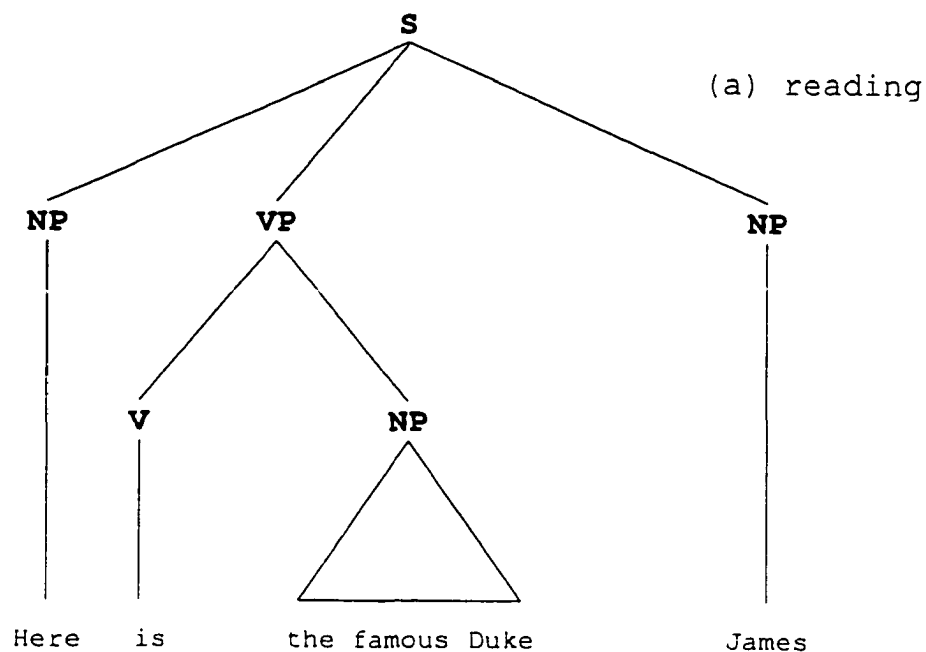


Figure 6.4 Sentence 2. Two structural representations of the ambiguous sentence THE [OLD] [MEN] AND WOMEN STAYED AT HOME.

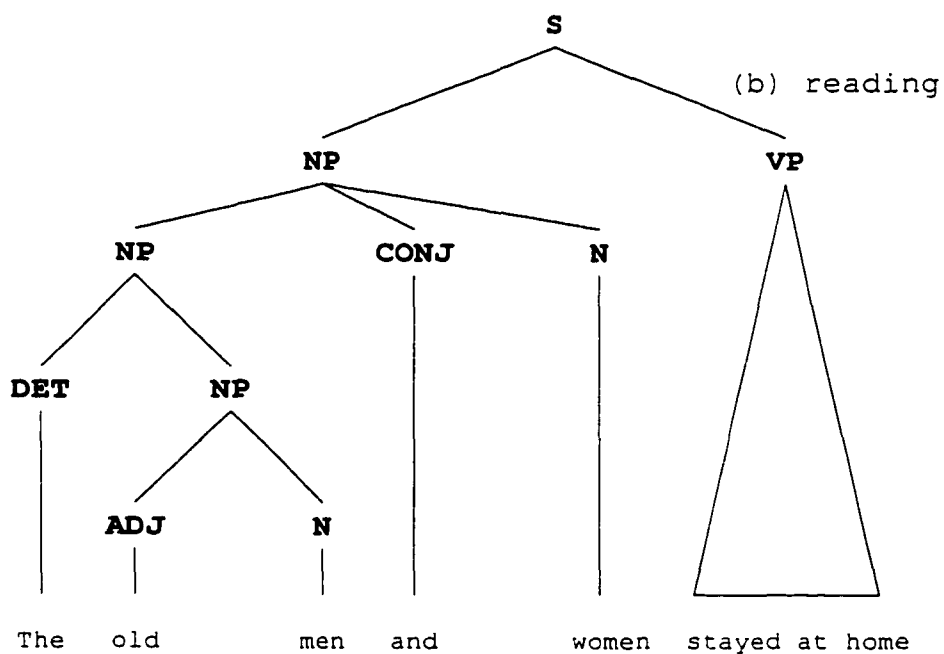
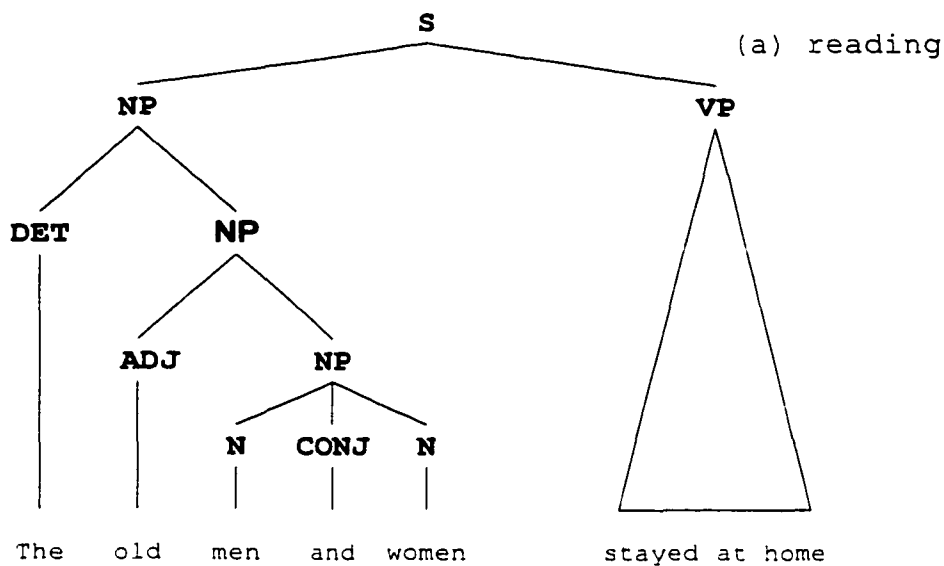


Figure 7.4 Sentence 3. Two structural representations of the ambiguous sentence THE HOSTESS [GREE]TED THE [GIRL] WITH A SMILE.

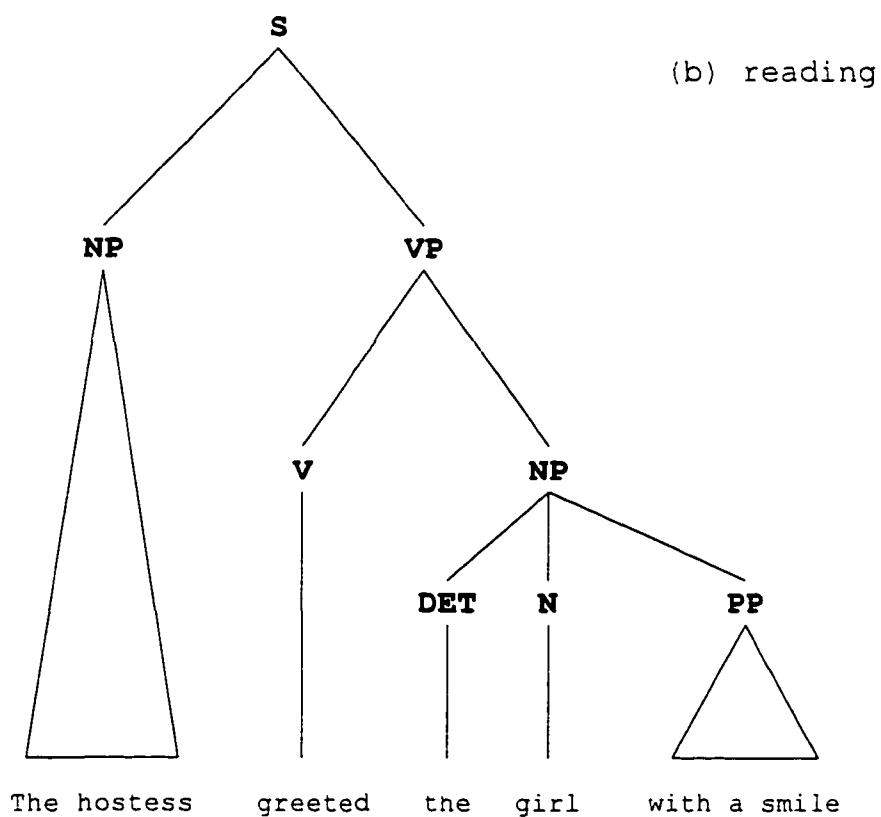
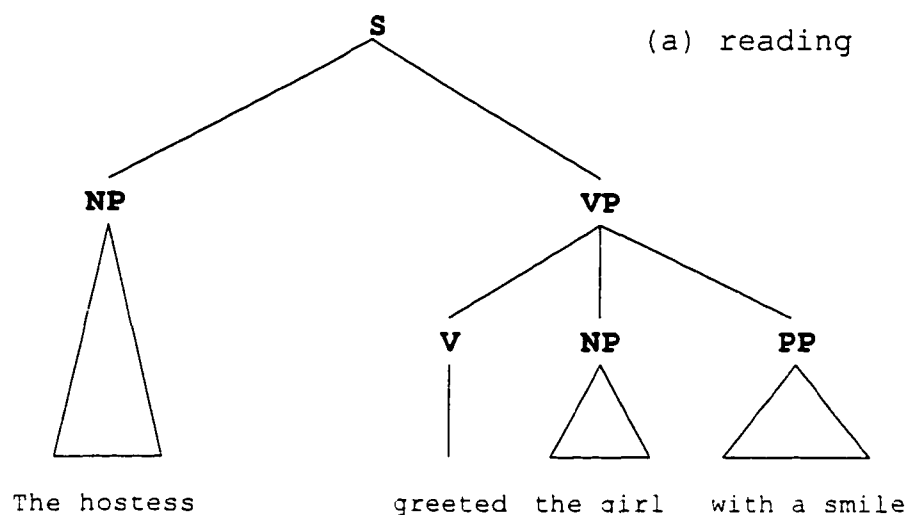


Figure 8.4 Sentence 4. Two structural representations of the ambiguous sentence JOHN DOESN'T KNOW HOW [GOOD] [MEAT] TASTES.

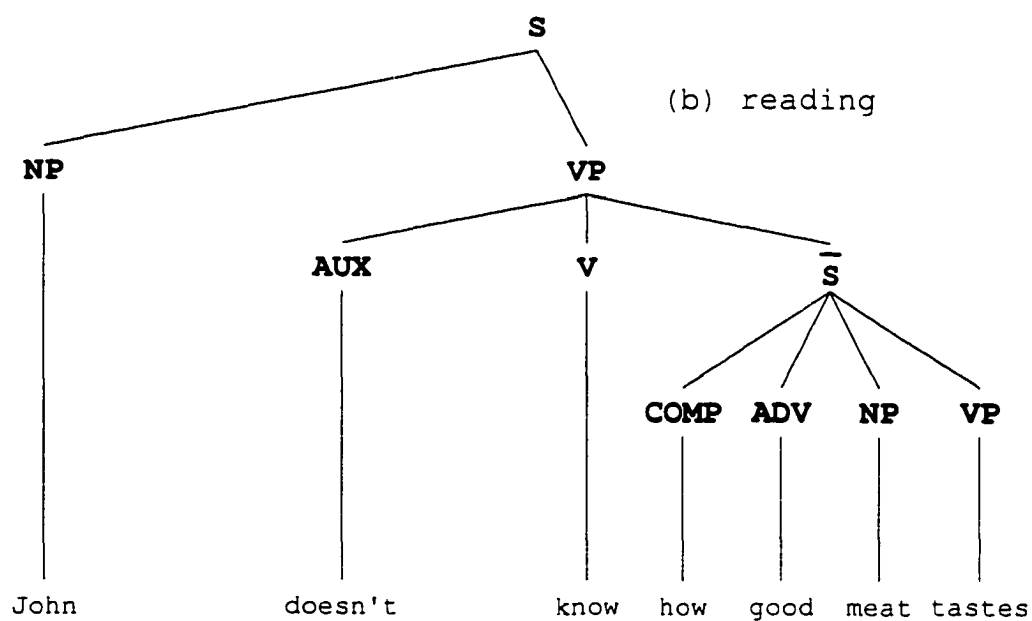
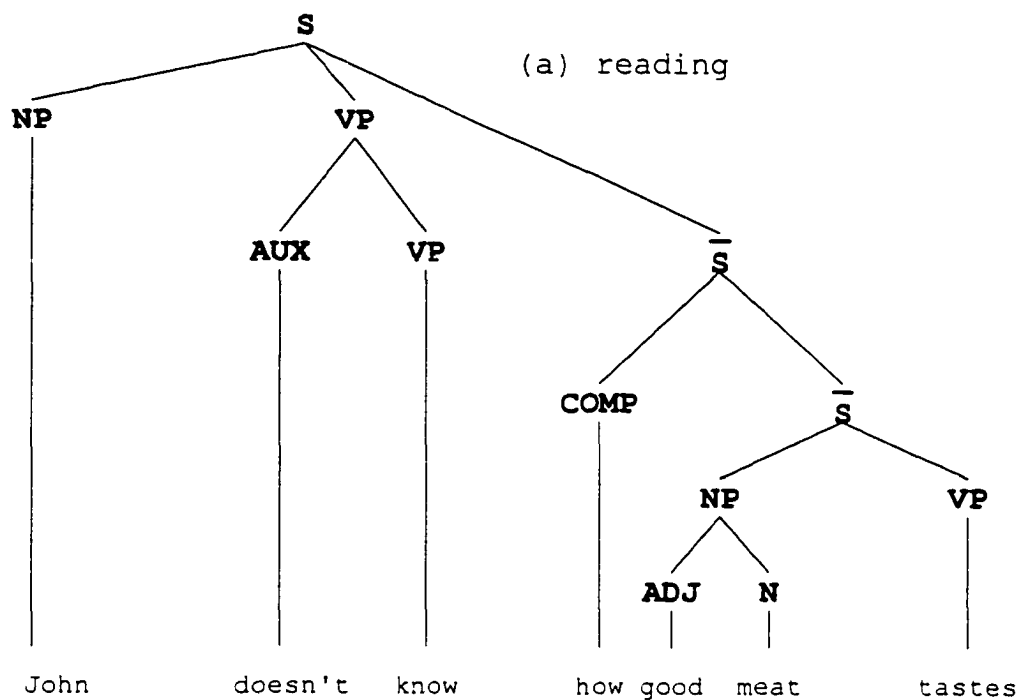


Figure 9.4 Sentence 5. Two structural representations of the ambiguous sentence LT. BAKER INSTRUCTED HIS [TROO]P [NA]TURALLY.

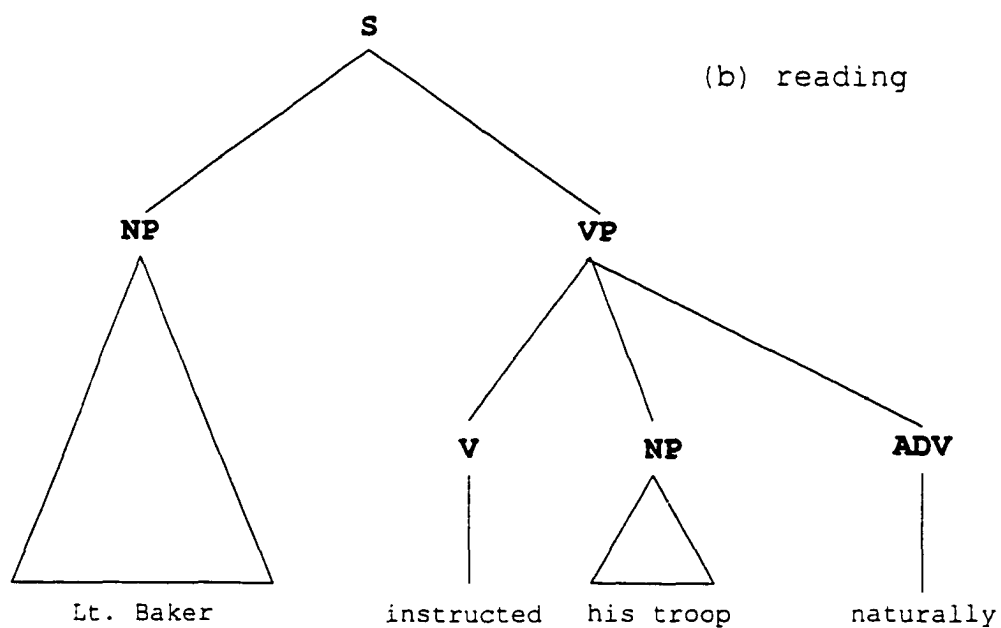
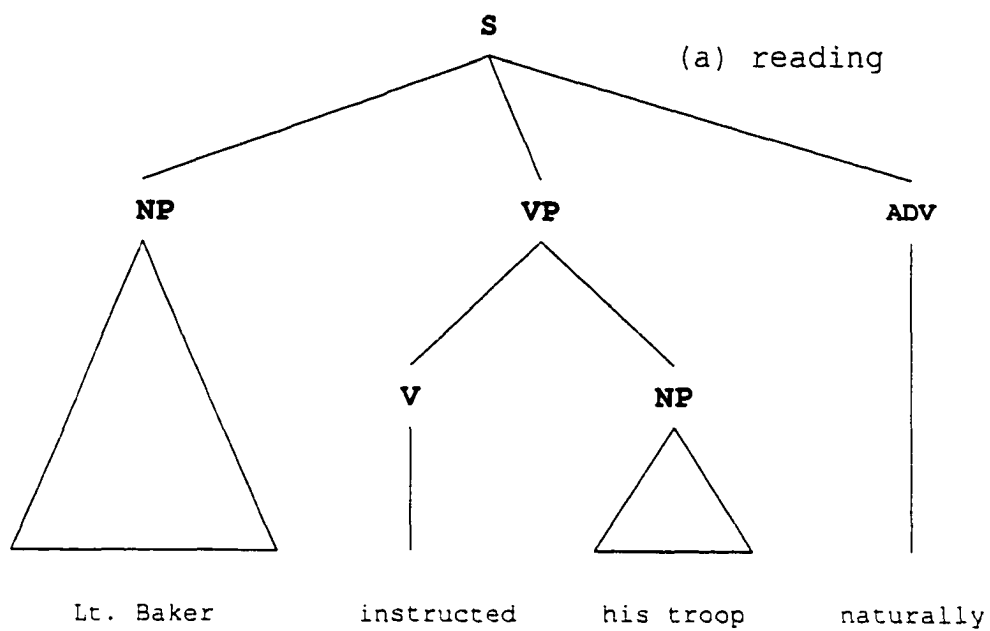


Figure 10.4 Sentence 6. Two structural representations of the ambiguous sentence JEFFREY [HIT] THE [COP] WITH A STICK.

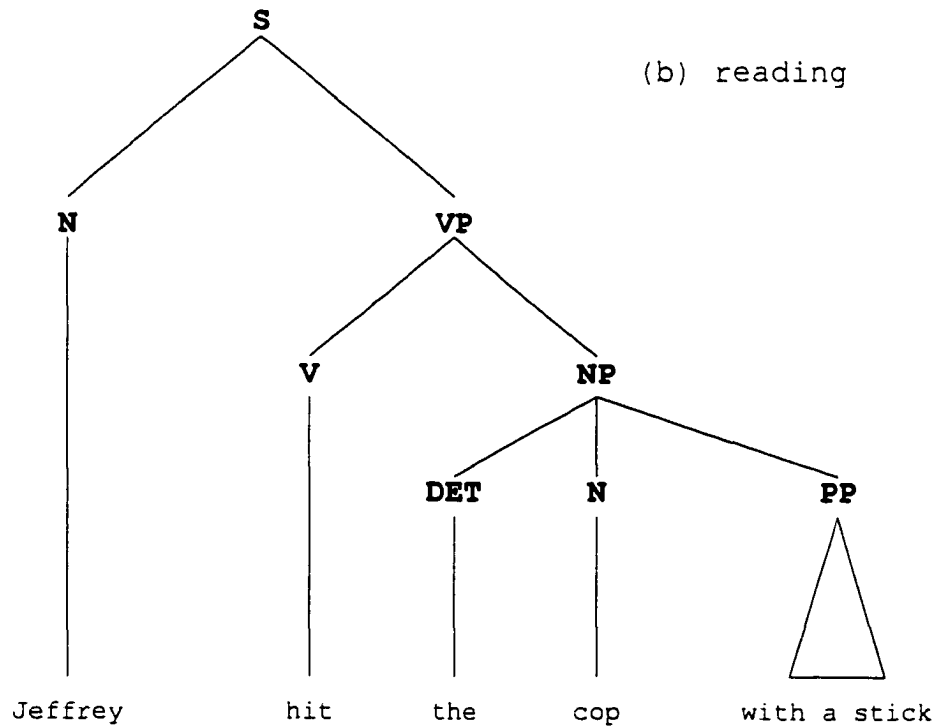
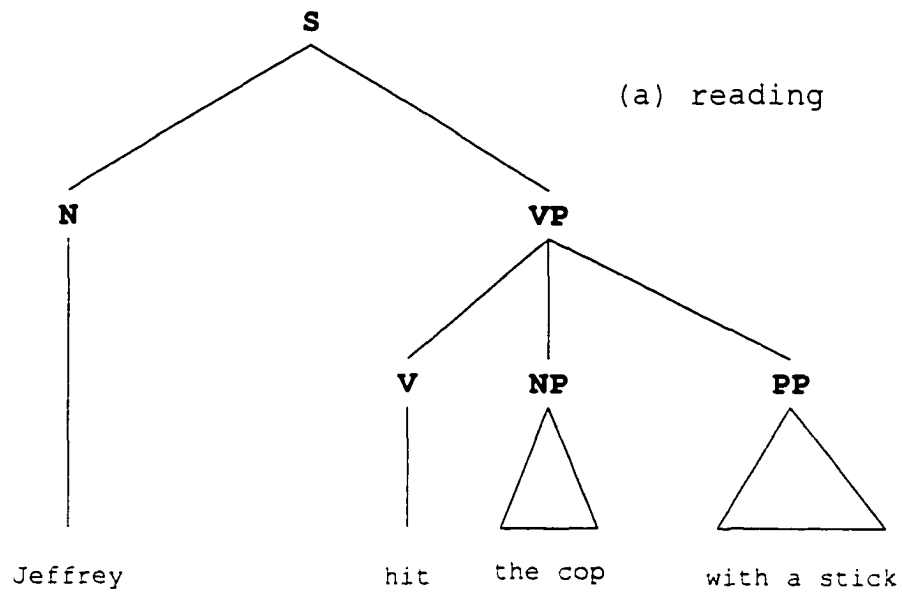


Figure 11.4 Sentence 7. Two structural representations of the ambiguous sentence SHE [IS] UNHAPPILY MARRIED.

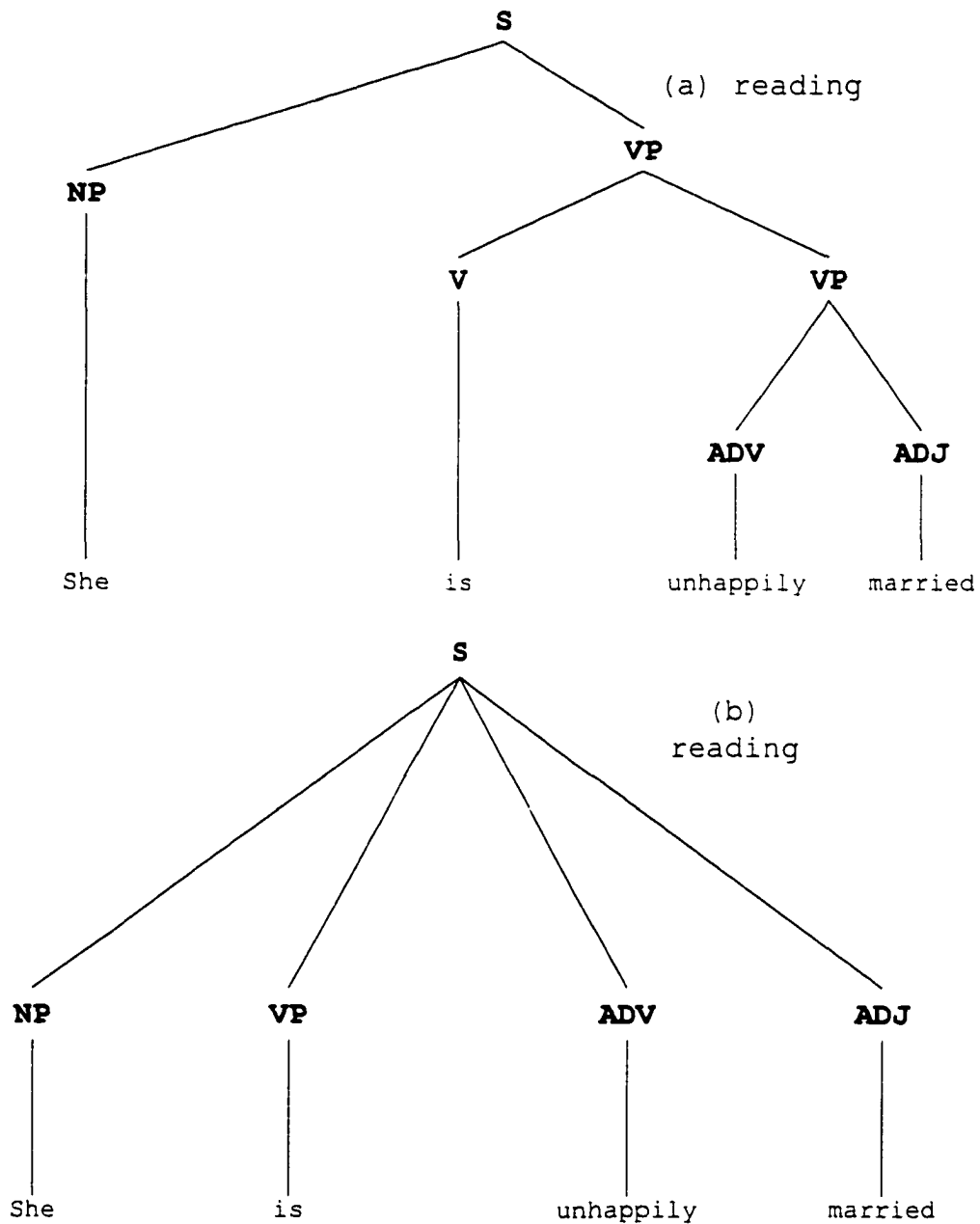


Figure 12.5 Talker JJ. Proportions used to test binomial exact 95% confidence interval for auditory normal and reiterant conditions.

Counts reflect number of occurrences in which version (a) was identified despite version presented.

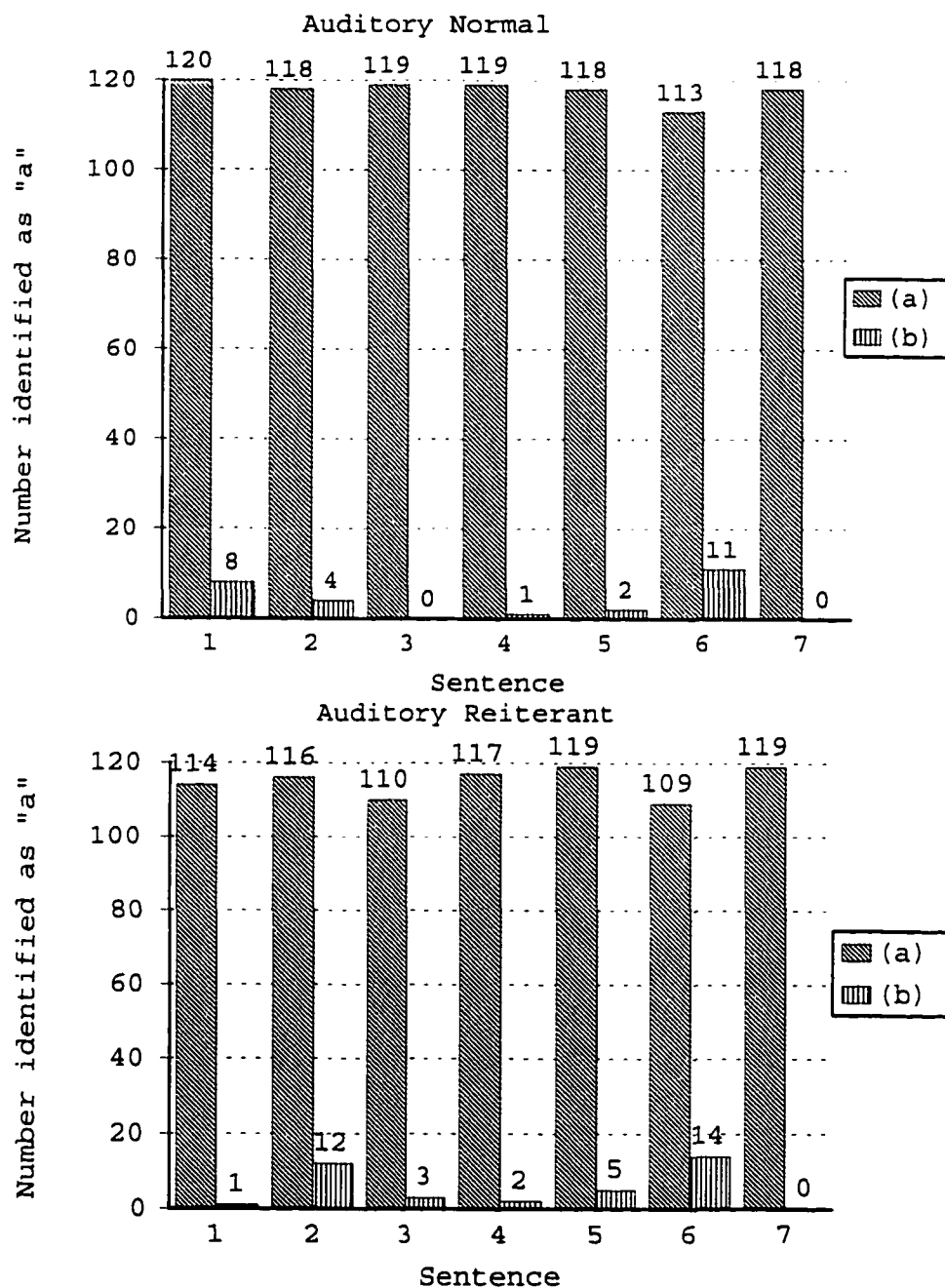


Figure 13.5 Talker LR. Proportions used to test binomial exact 95% confidence interval for auditory normal and reiterant conditions.

Counts reflect number of occurrences in which version (a) was identified despite version presented.

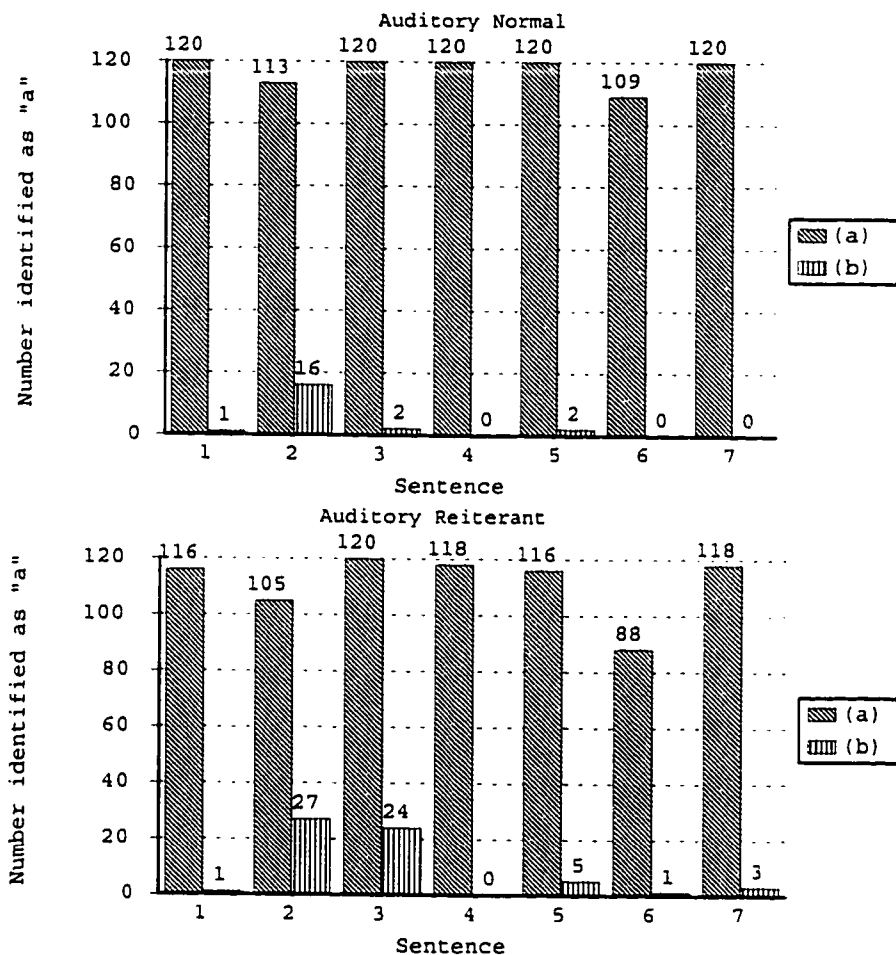


Figure 14.5 Talker JJ. Proportions used to test binomial exact 95% confidence interval for visual-normal and reiterant conditions.

Counts reflect number of occurrences in which version (a) was identified despite version presented.

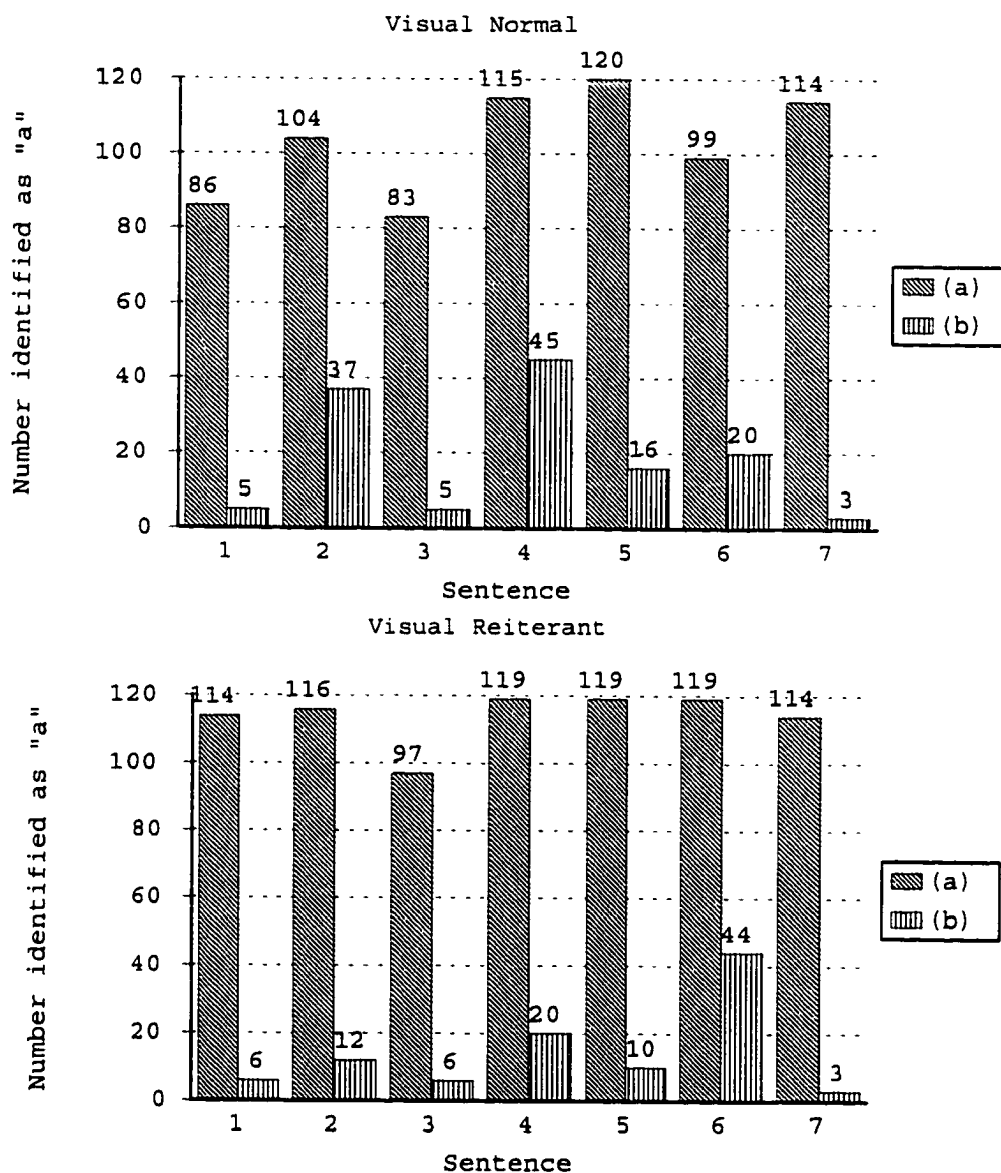


Figure 15.5 Talker LR. Proportions used to test binomial exact 95% confidence interval for visual-normal and reiterant conditions.

Counts reflect number of occurrences in which version (a) was identified despite version presented.

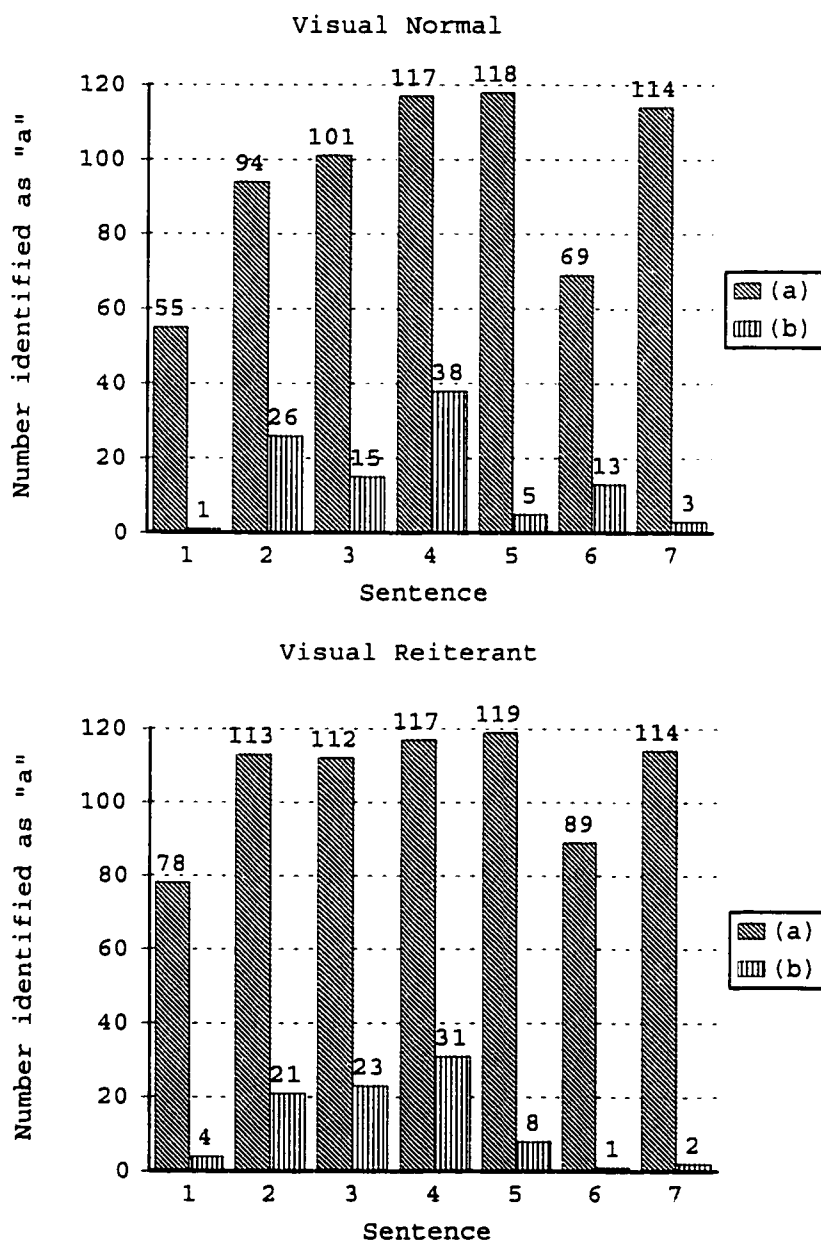


Figure 16.5 Sentence 1. Per cent correct identification of version by test condition in ambiguous sentence HERE IS THE FAMOUS [DUKE] [JAMES].

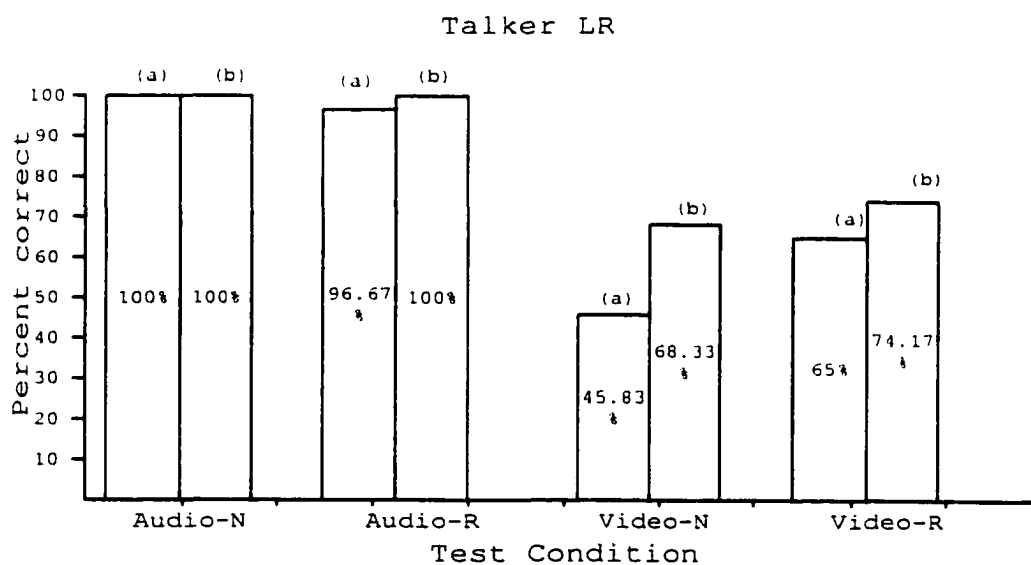
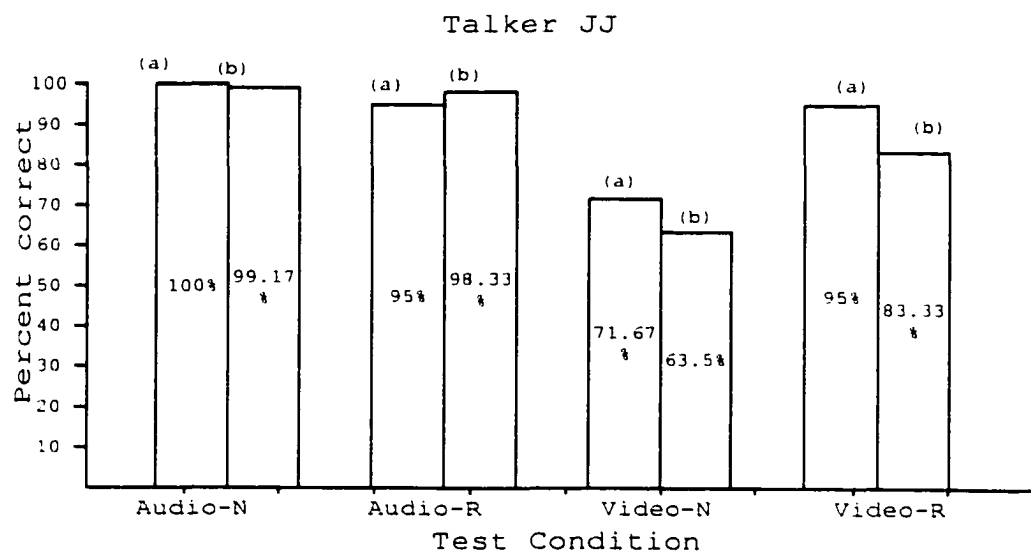


Figure 17.5 Sentence 2. Per cent correct identification of version by test condition in ambiguous sentence THE [OLD] [MEN] AND WOMEN STAYED AT HOME.

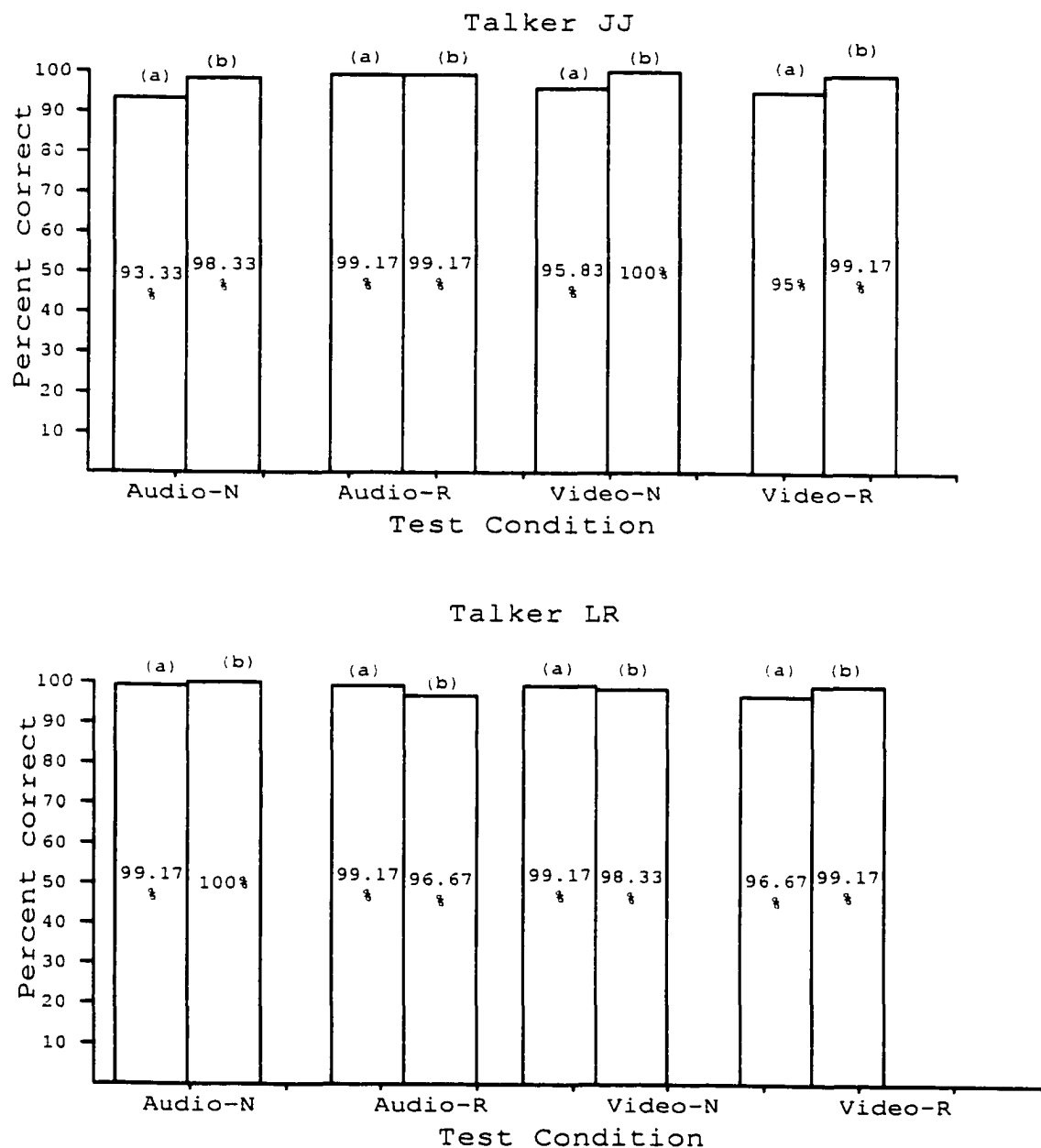


Figure 18.5 Sentence 3. Per cent correct identification of version by test condition in ambiguous sentence THE HOSTESS [GREE]TED THE [GIRL] WITH A SMILE.

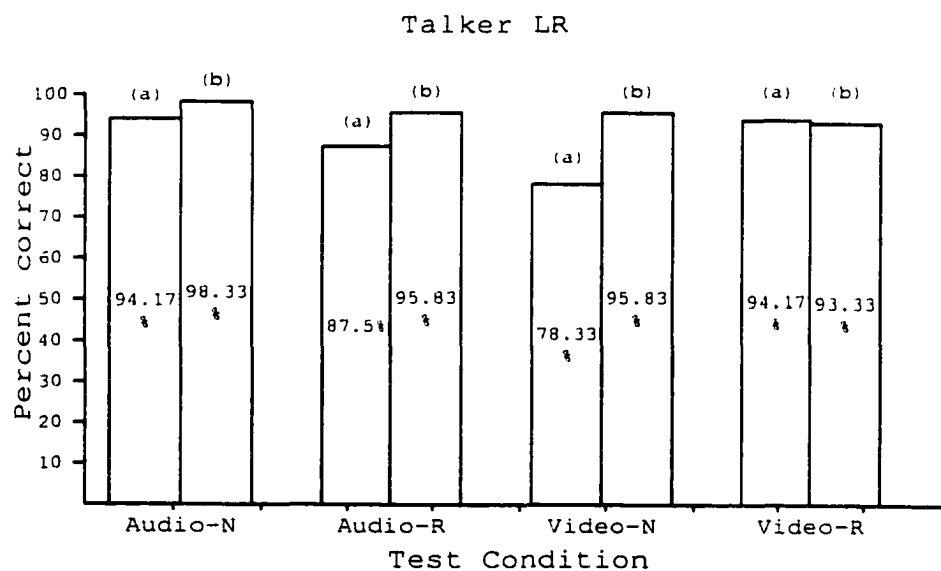
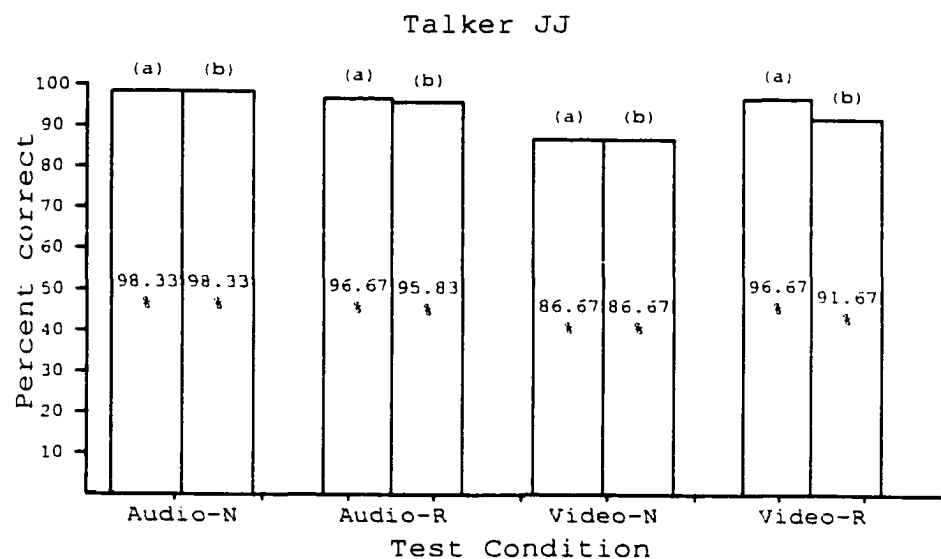


Figure 19.5 Sentence 4. Per cent correct identification of version by test condition in ambiguous sentence JOHN DOESN'T KNOW HOW [GOOD] [MEAT] TASTES.

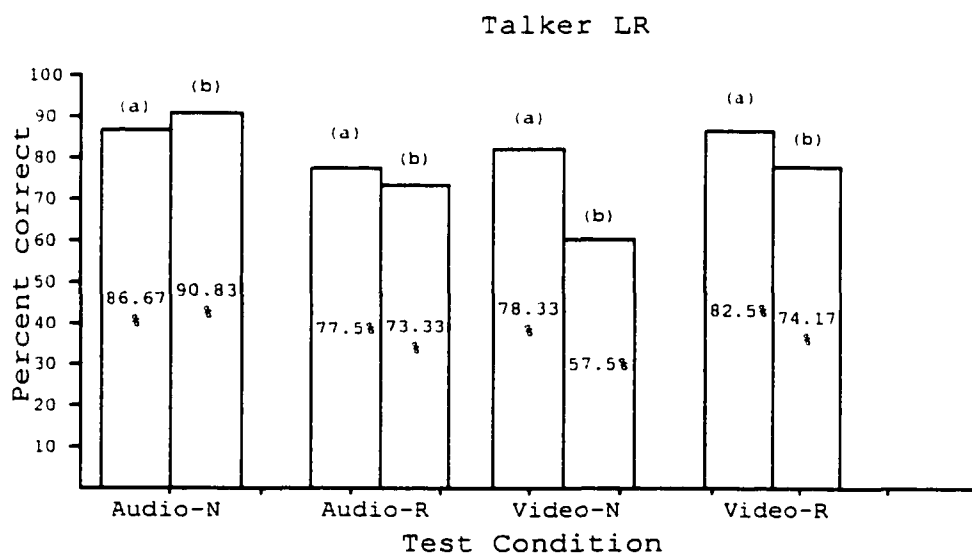
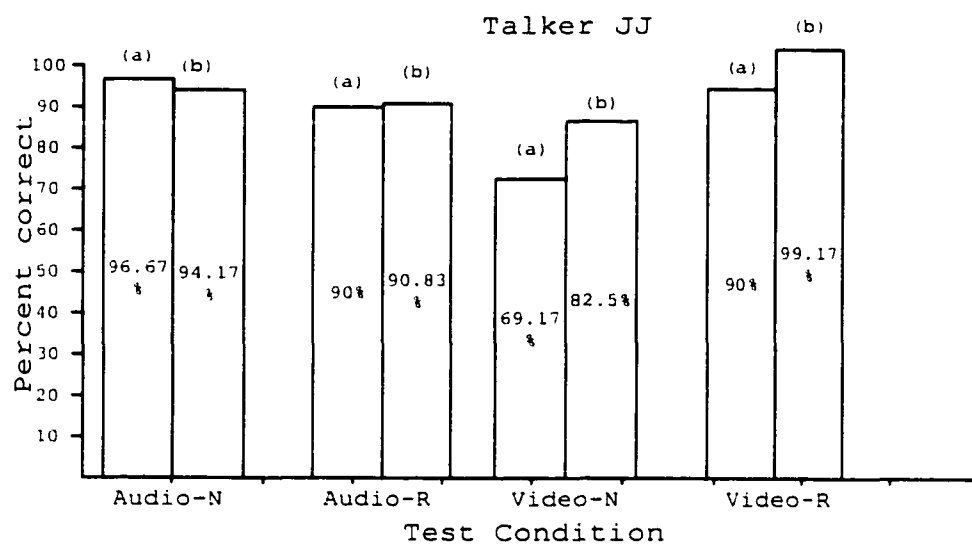


Figure 20.5 Sentence 5. Per cent correct identification of version by test condition in ambiguous sentence LT. BAKER INSTRUCTED HIS [TROO]P [NA]TURALLY.

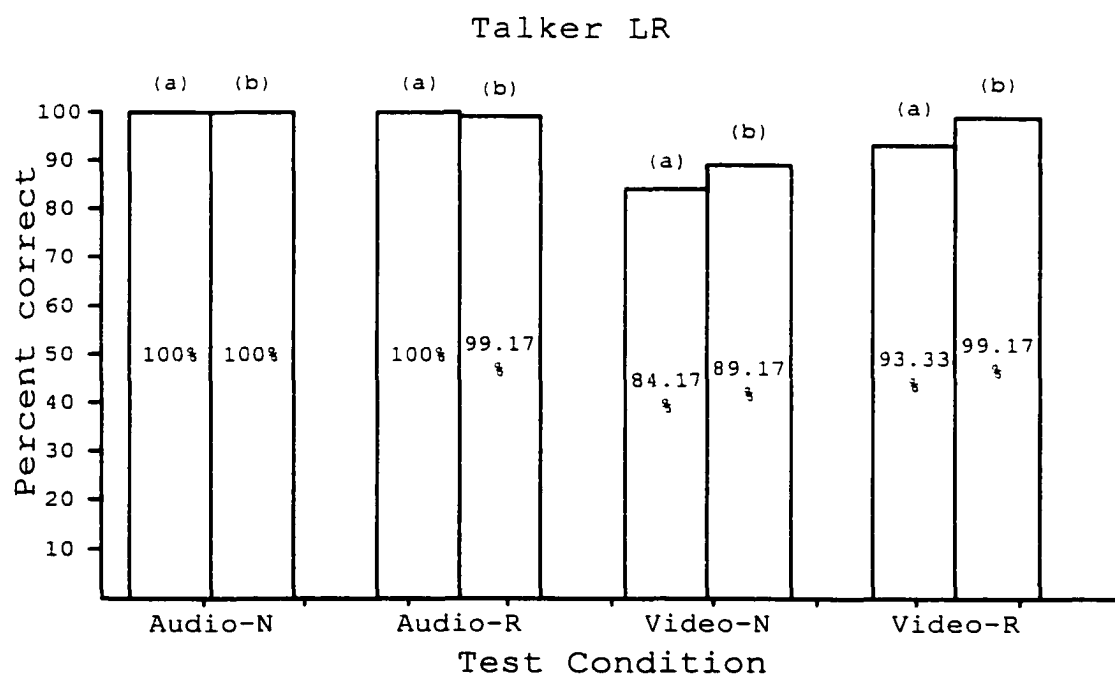
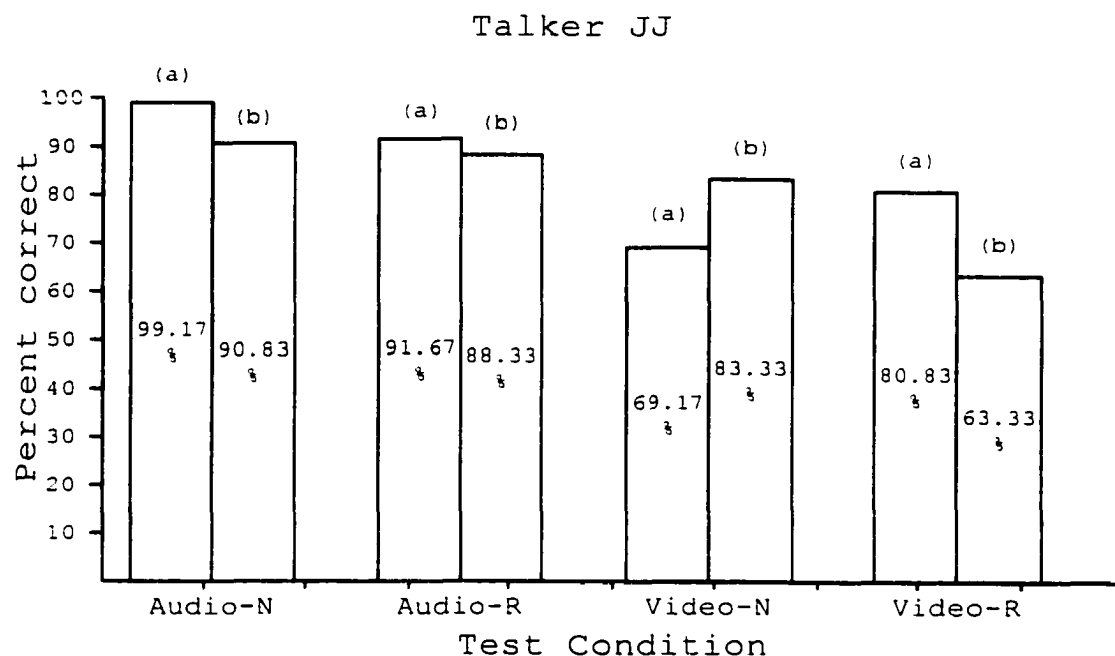


Figure 21.5 Sentence 6. Per cent correct identification of version by test condition in ambiguous sentence JEFFREY [HIT] THE [COP] WITH A STICK.

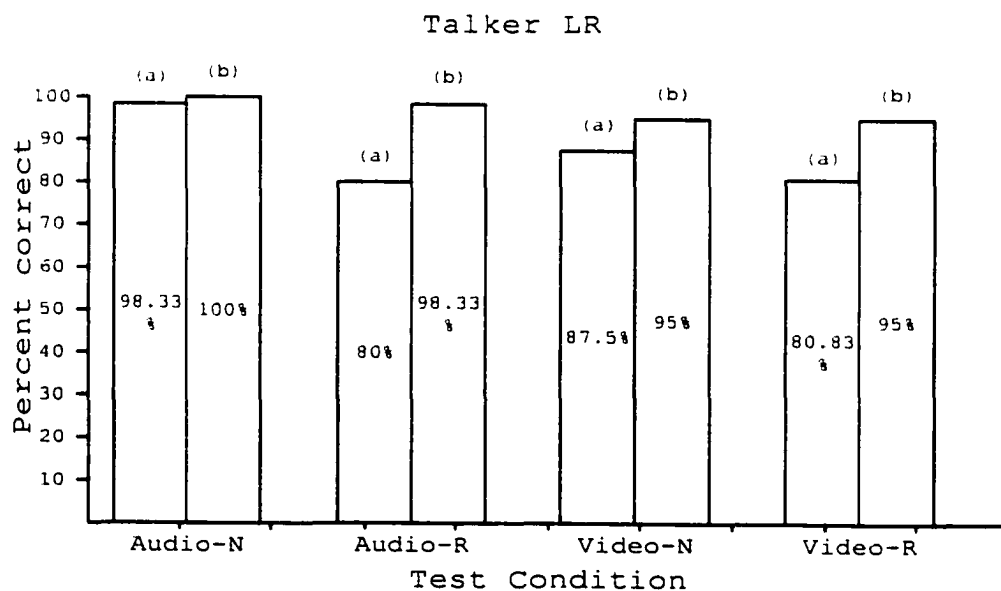
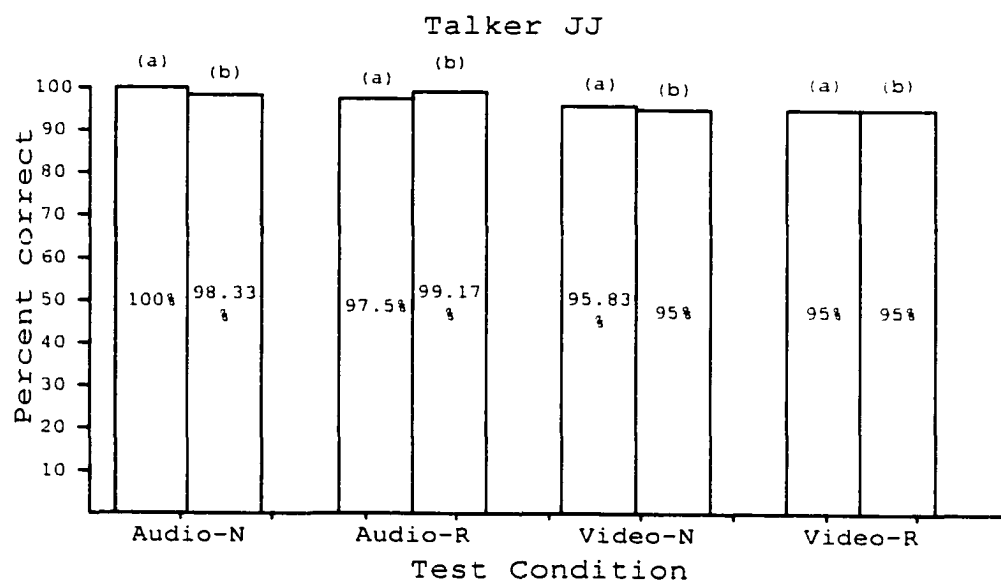


Figure 22.5 Sentence 7. Per cent correct identification of version by test condition in ambiguous sentence SHE [IS] UNHAPPILY [MAR]RIED.

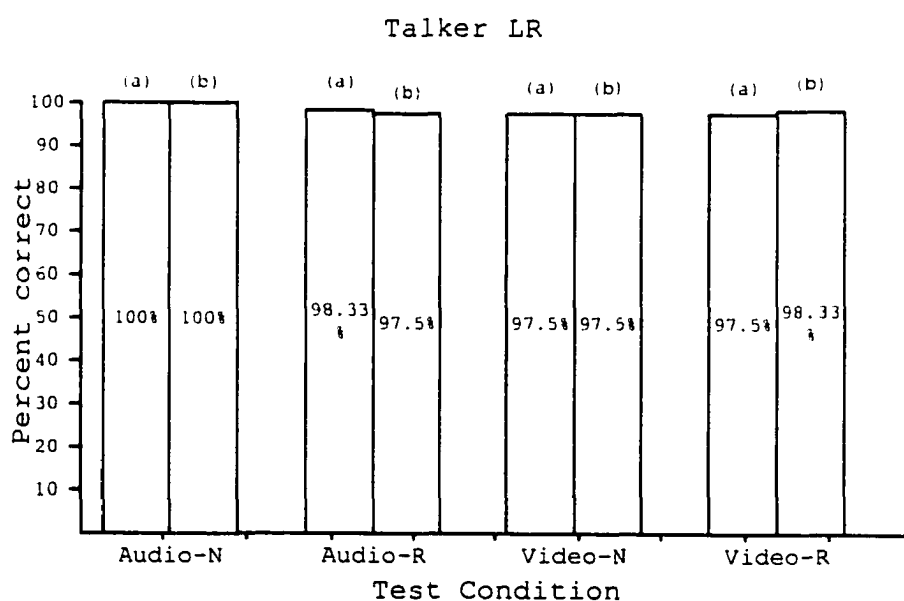
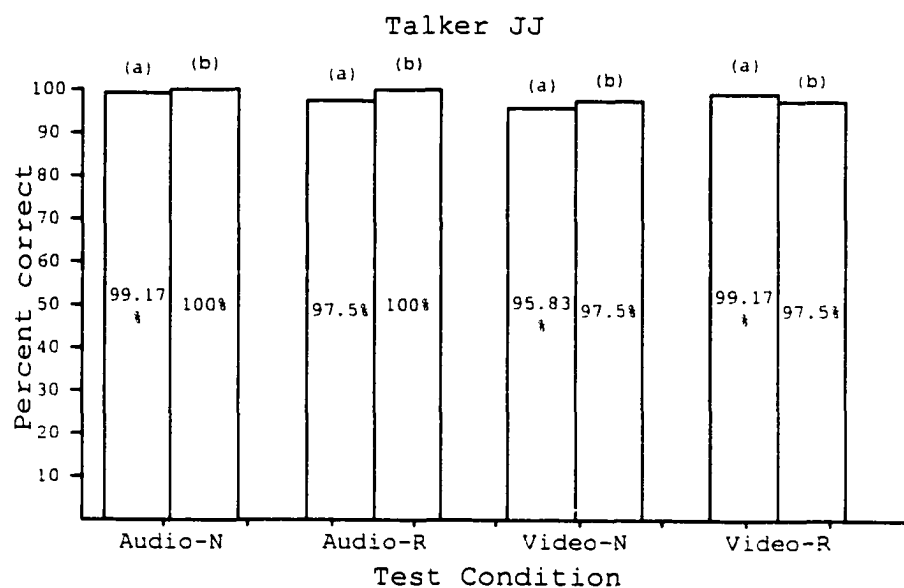
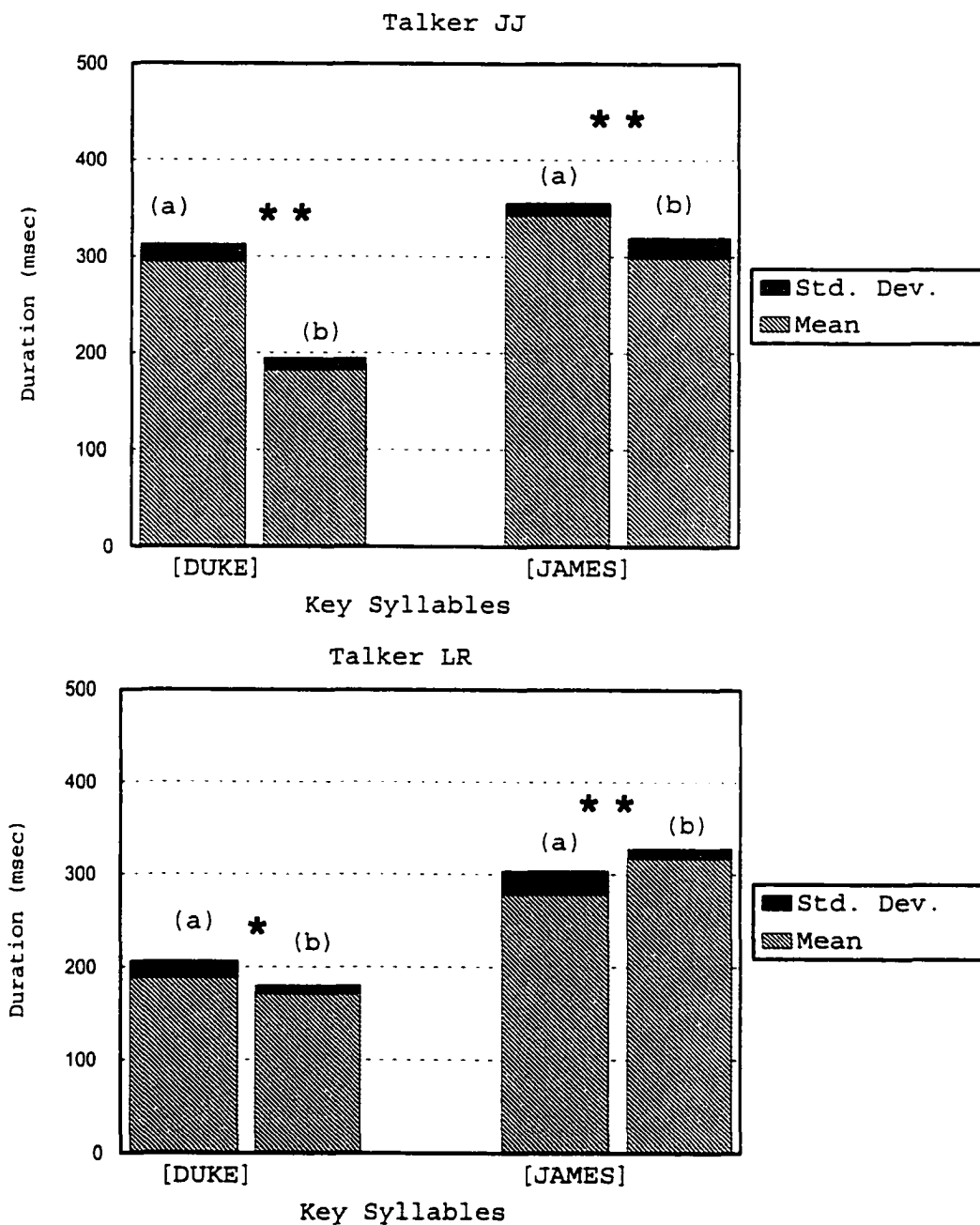


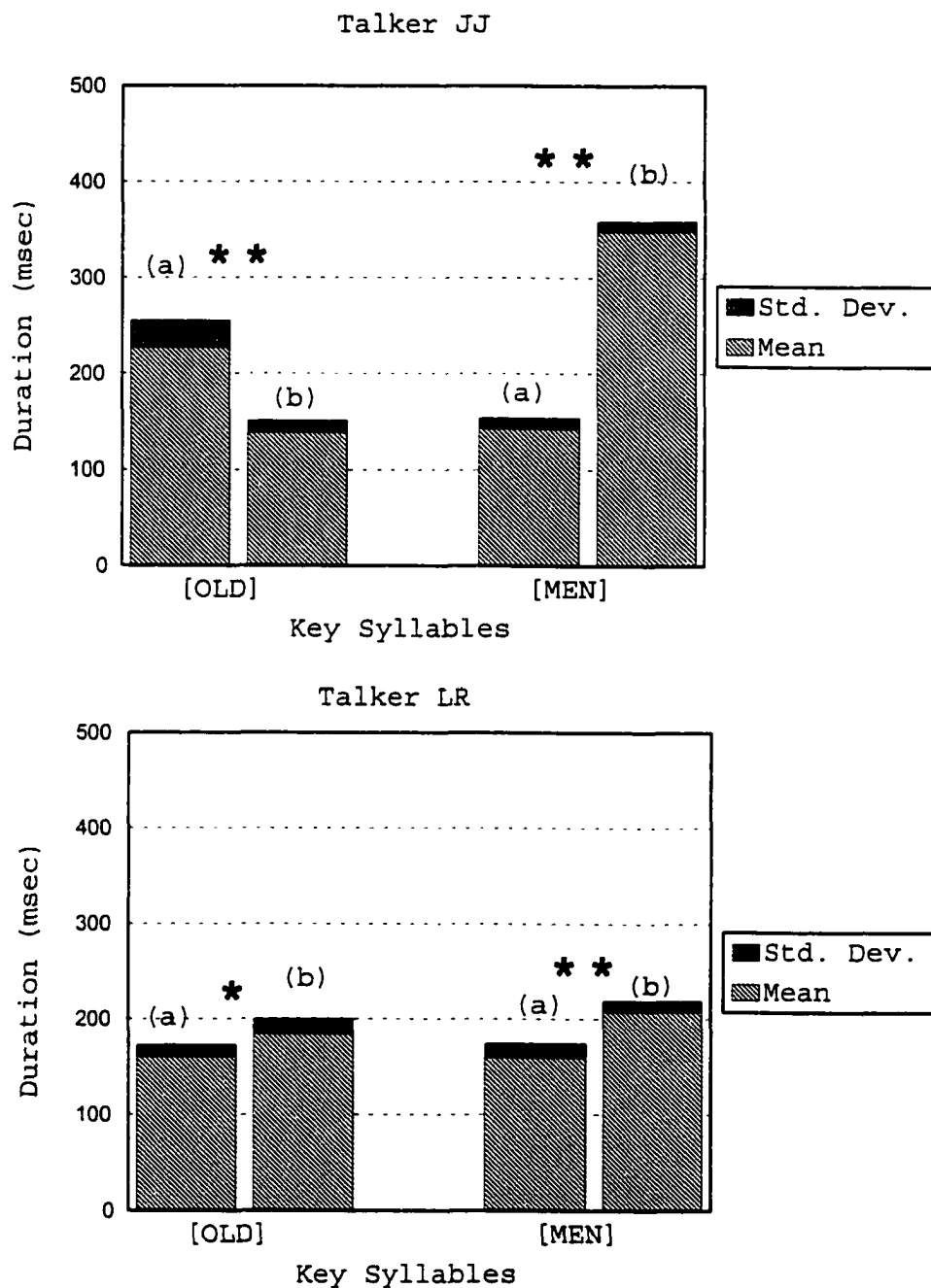
Figure 23.6
Sentence 1. Acoustic means and standard deviations for reiterant productions of the segment /a/ in ambiguous sentence HERE IS THE FAMOUS [DUKE] [JAMES].



* indicates one level of significance from ANOVA
** indicates two levels of significance from ANOVA

Figure 24.6

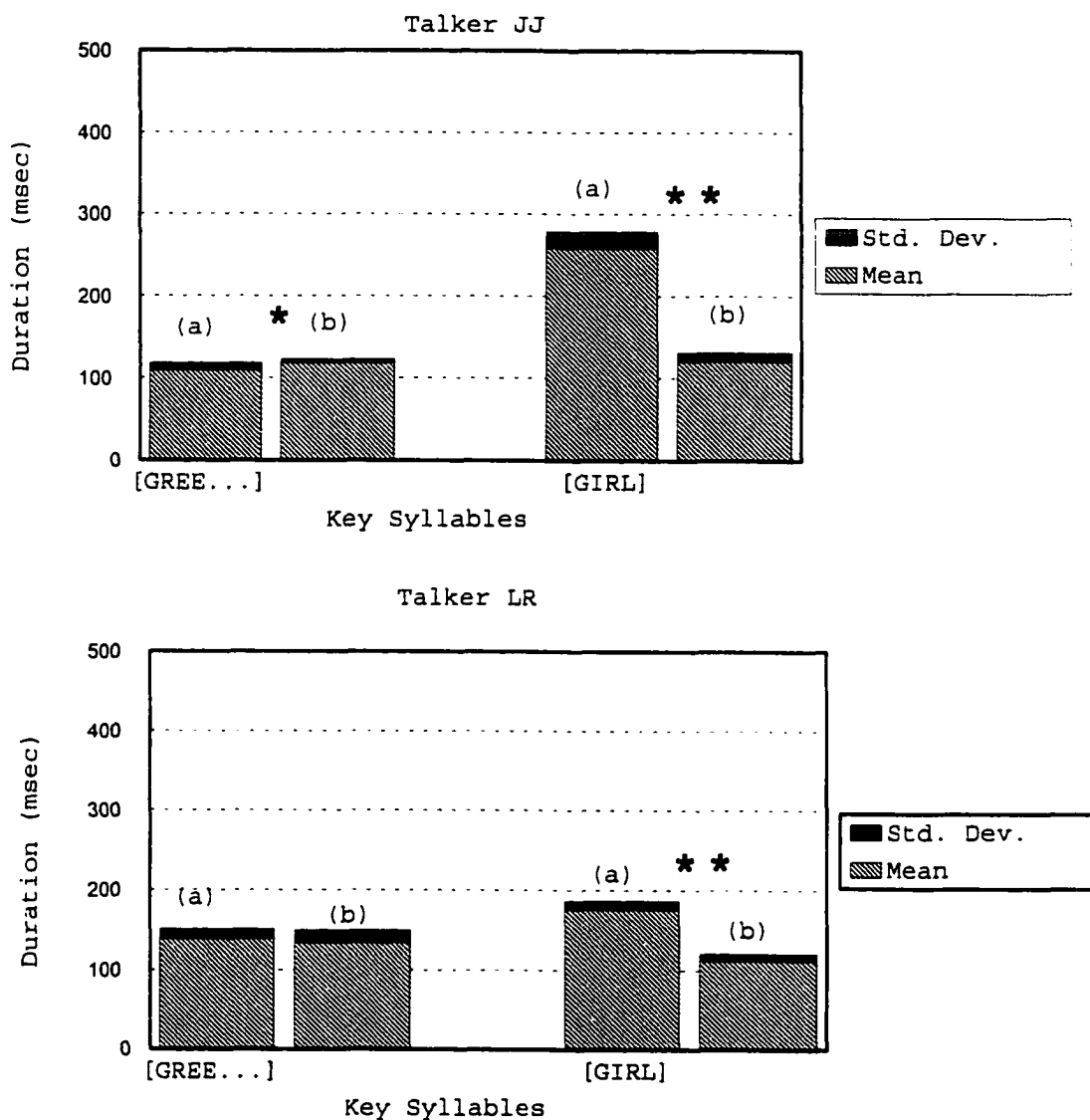
Sentence 2. Acoustic means and standard deviations for reiterant productions of the segment /a/ in ambiguous sentence THE [OLD] [MEN] AND WOMEN STAYED AT HOME.



* indicates one level of significance from ANOVA

** indicates two levels of significance from ANOVA

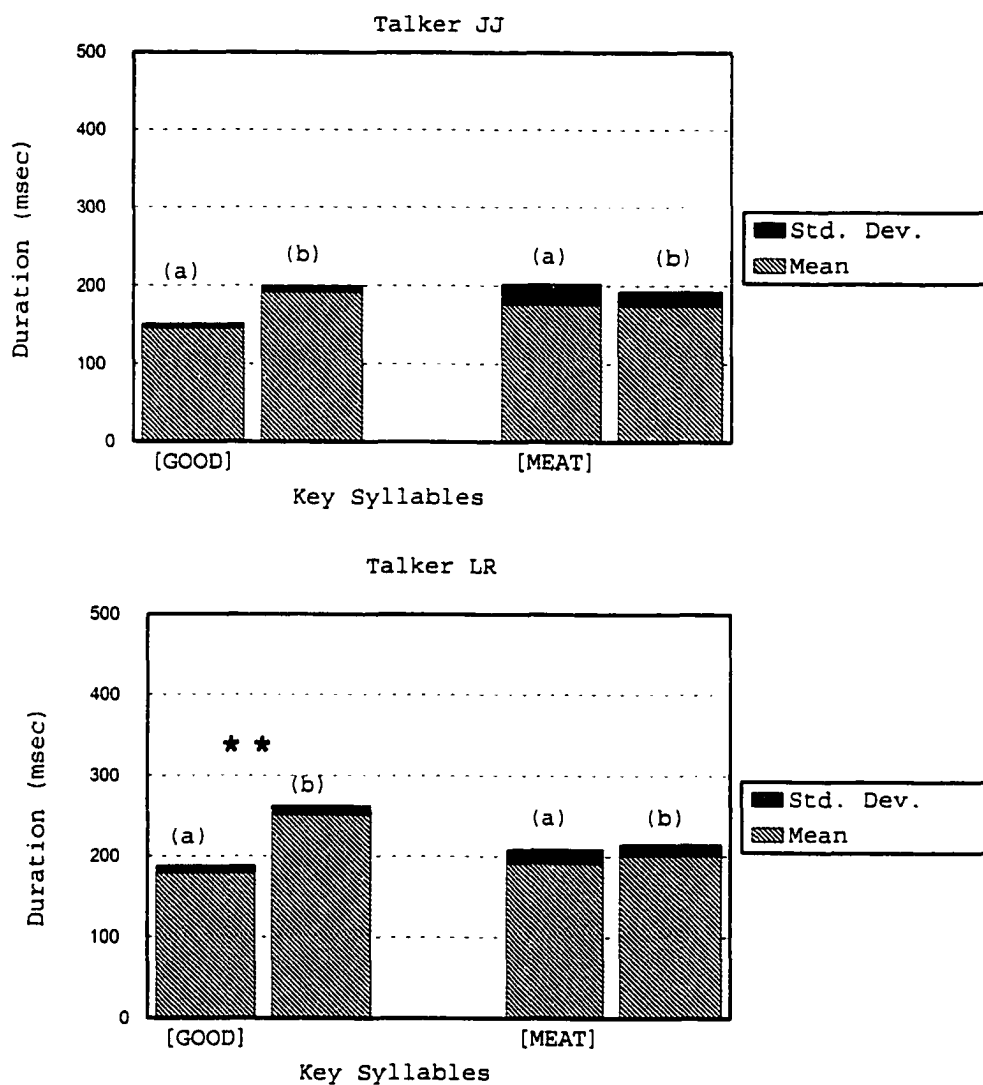
Figure 25.6
Sentence 3. Acoustic means and standard deviations
for reiterant productions of the segment /a/ in
ambiguous sentence THE HOSTESS [GREE]TED THE [GIRL]
WITH A SMILE.



* indicates one level of significance from ANOVA

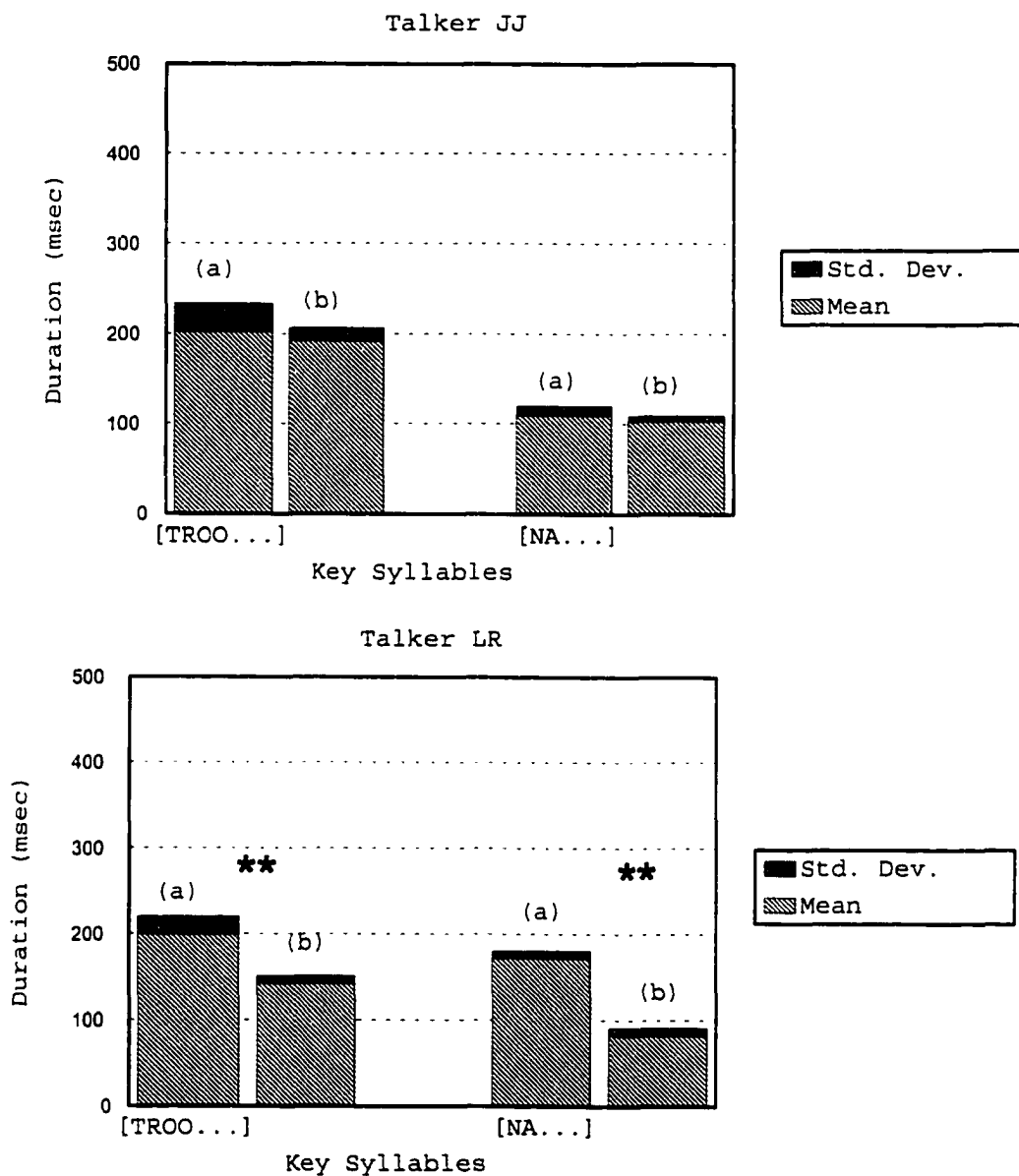
** indicates two levels of significance from ANOVA

Figure 26.6
Sentence 4. Acoustic means and standard deviations
for reiterant productions of the segment /a/ in
ambiguous sentence JOHN DOESN'T KNOW HOW [GOOD]
[MEAT] TASTES.



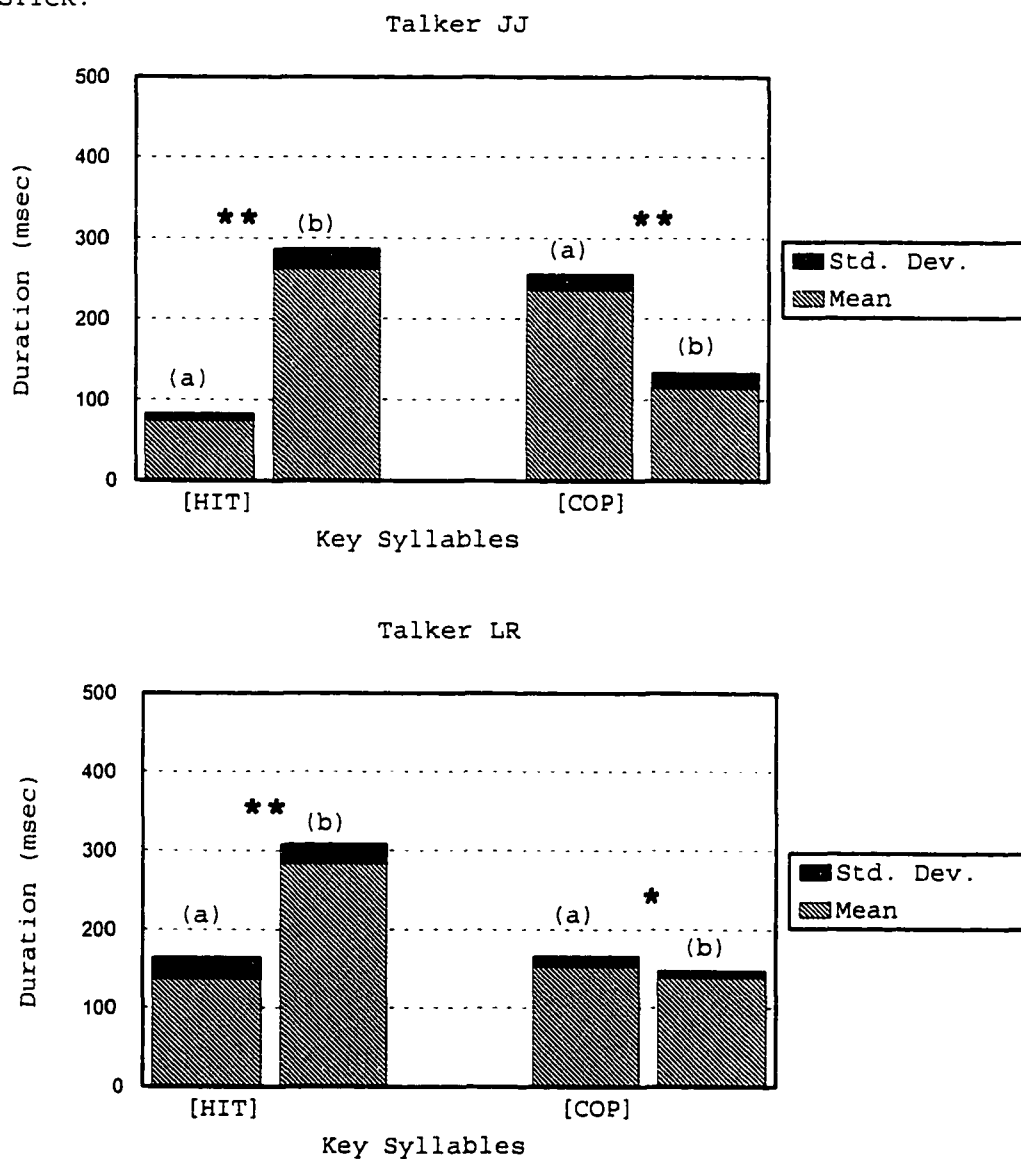
- * indicates one level of significance from ANOVA
- ** indicates two levels of significance from ANOVA

Figure 27.6
Sentence 5. Acoustic means and standard deviations
for reiterant productions of the segment /a/ in
ambiguous sentence LT. BAKER INSTRUCTED HIS [TROO]P
[NA]TURALLY.



* indicates one level of significance from ANOVA
** indicates two levels of significance from ANOVA

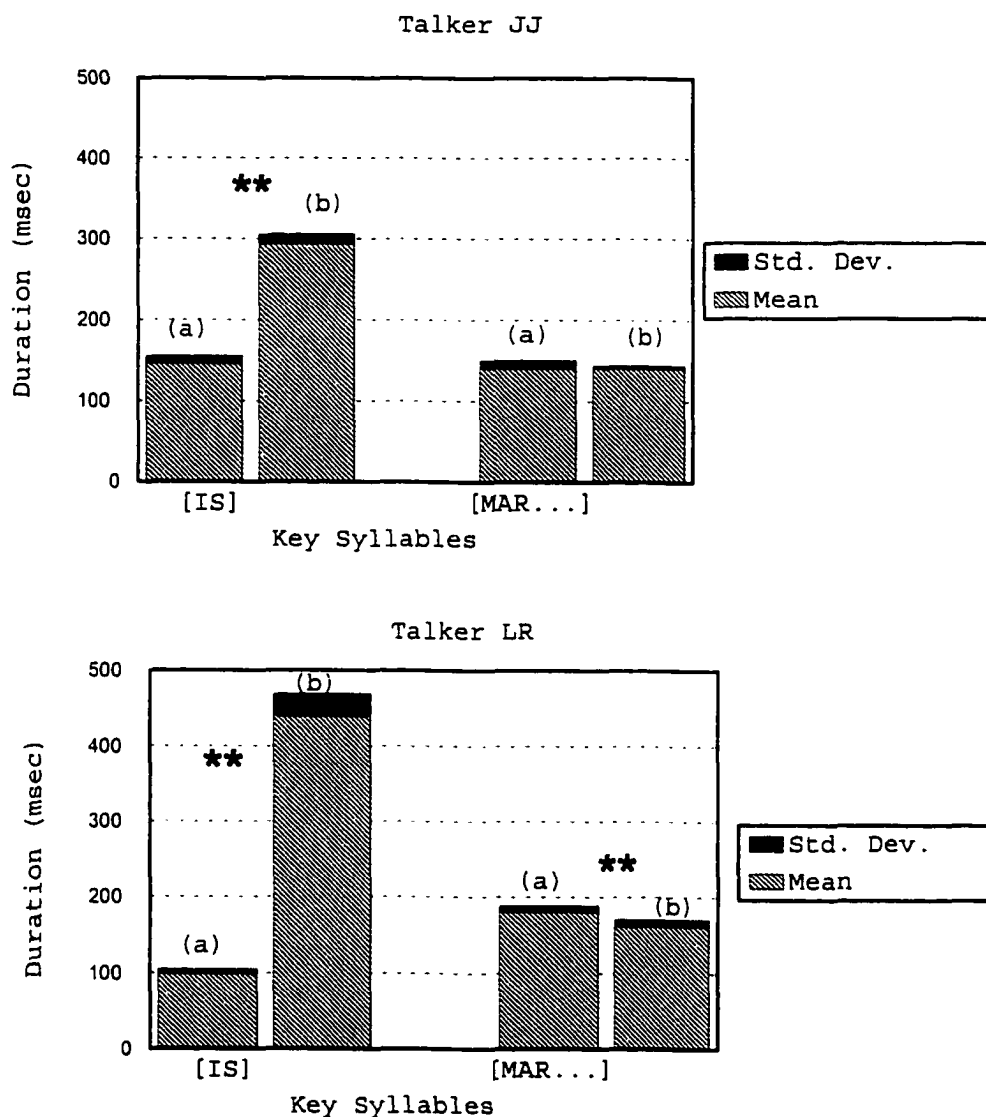
Figure 28.6
Sentence 6. Acoustic means and standard deviations
for reiterant productions of the segment /a/ in
ambiguous sentence JEFFREY [HIT] THE [COP] WITH A
STICK.



* indicates level of significance from ANOVA

** indicates two levels of significance from ANOVA

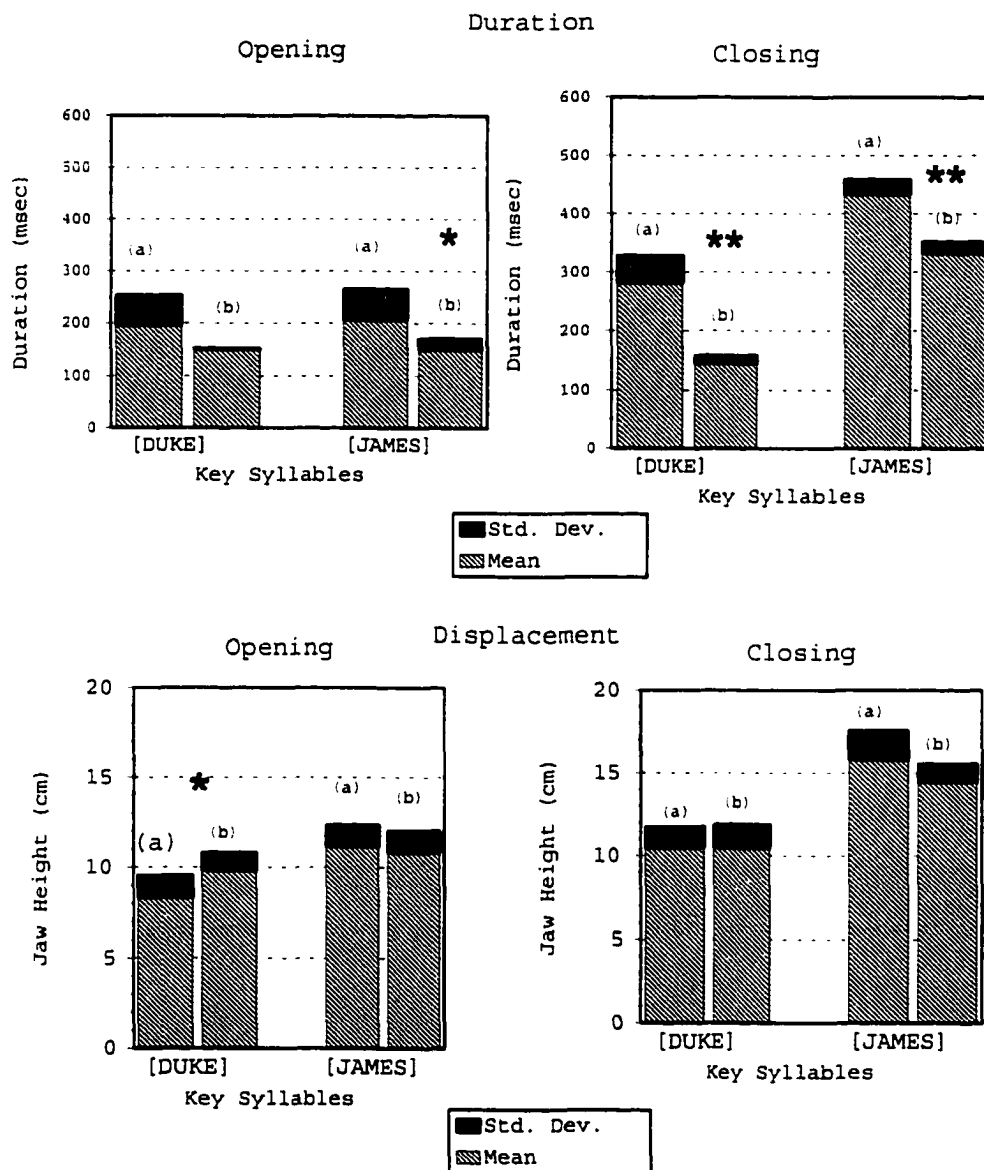
Figure 29.6
Sentence 7. Acoustic means and standard deviations
for reiterant productions of the segment /a/ in
ambiguous sentence SHE [IS] UNHAPPILY [MAR]RIED.



- * indicates one level of significance from ANOVA
- ** indicates two levels of significance from ANOVA

Figure 30.7

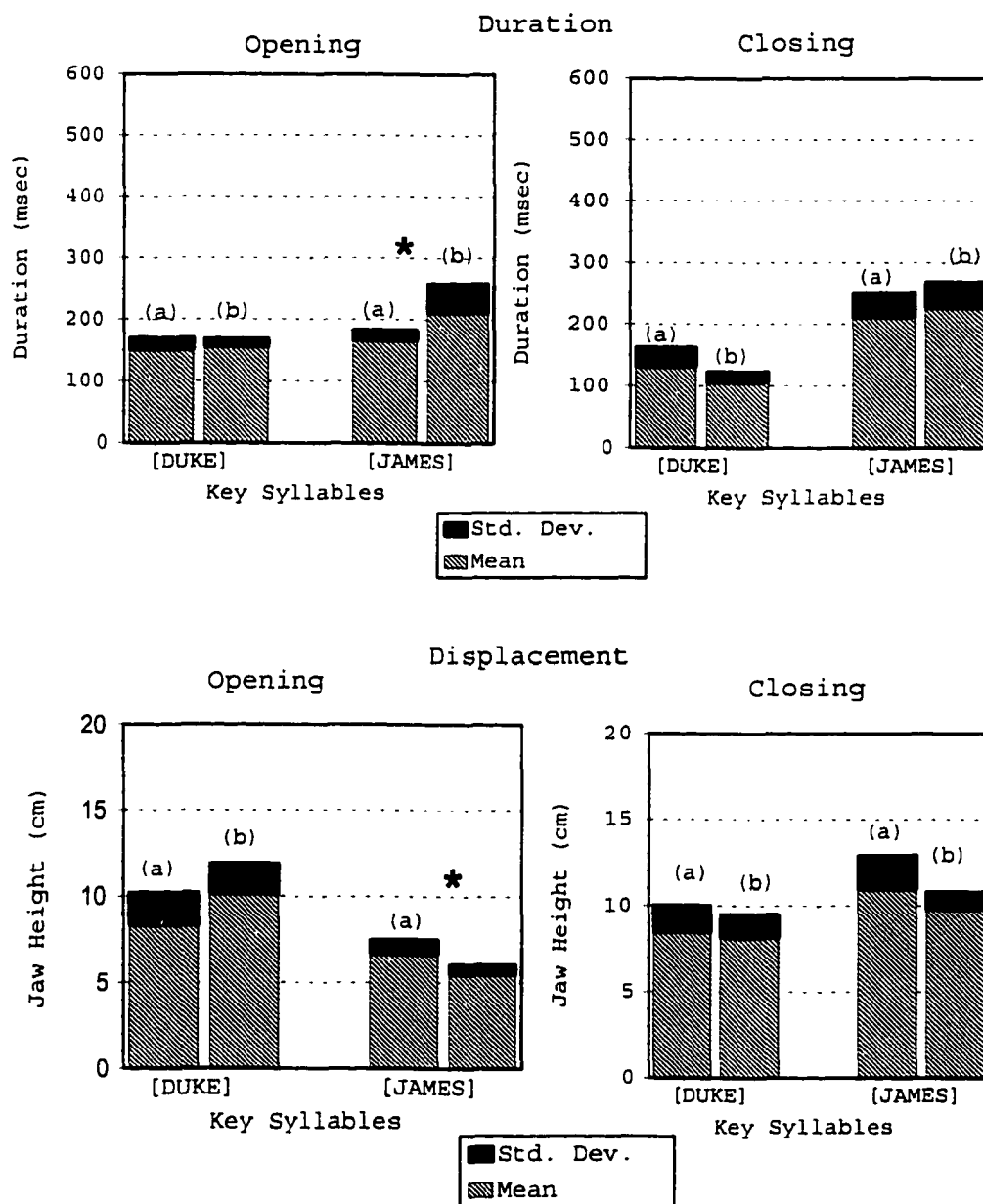
Sentence 1. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the jaw opening and closing phase of the segment /a/ in ambiguous sentence HERE IS THE FAMOUS [DUKE] [JAMES] as spoken by Talker JJ.



* one level of significance from univariate ANOVA
 ** two levels of significance from univariate ANOVA

Figure 31.7

Sentence 1. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence HERE IS THE FAMOUS [DUKE] [JAMES] as spoken by Talker LR.

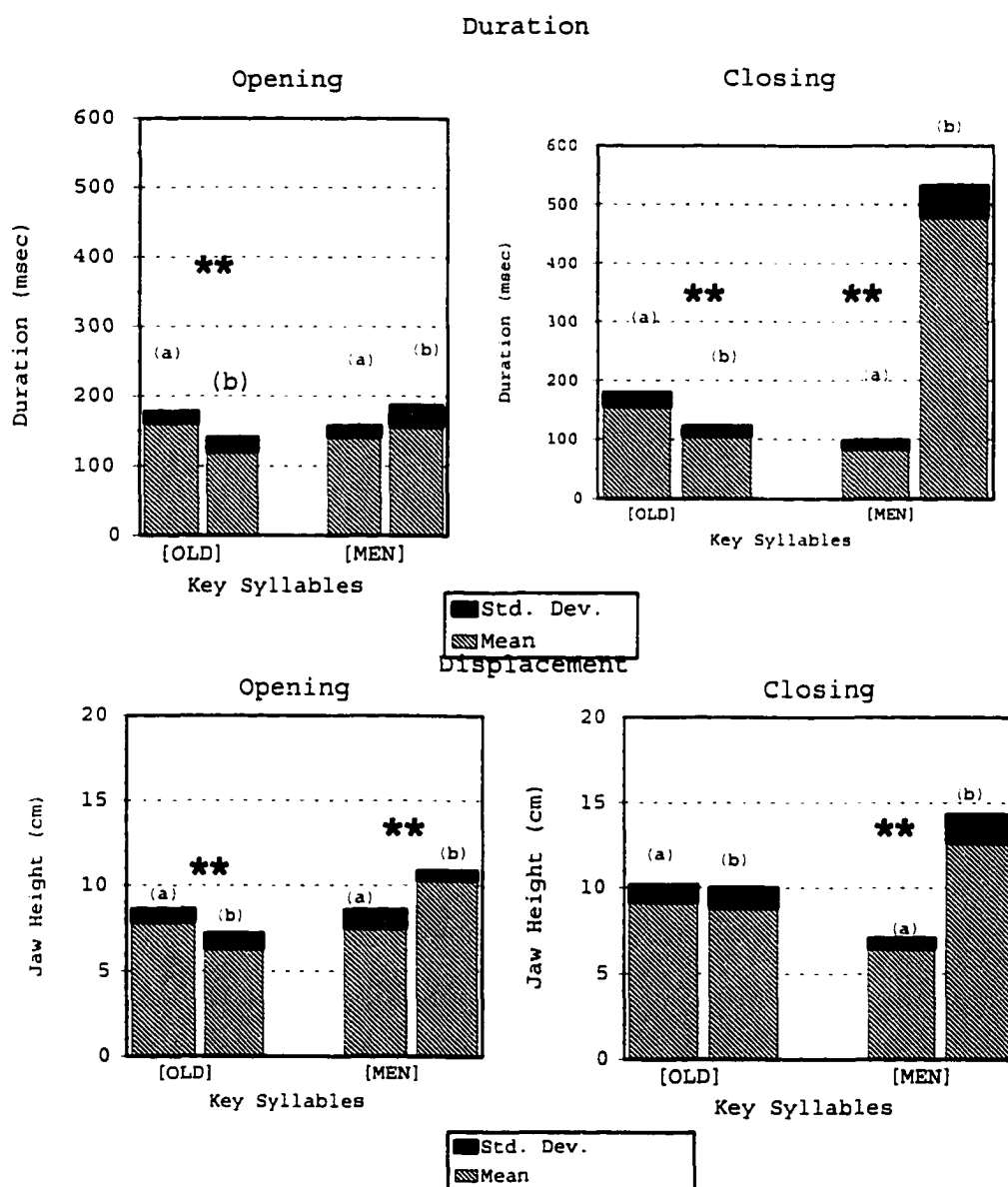


* one level of significance from univariate ANOVA

** two levels of significance from univariate ANOVA one

Figure 32.7

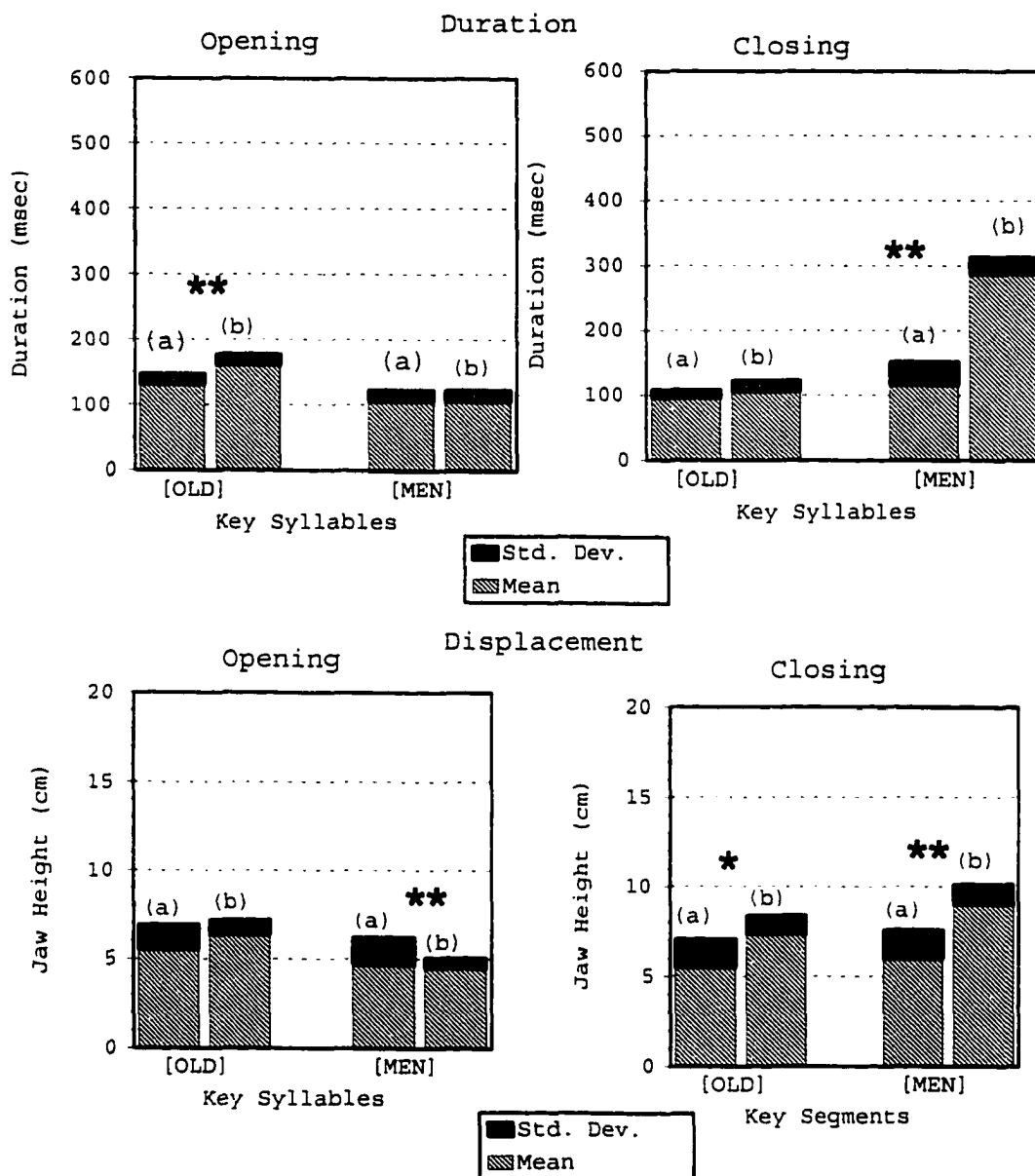
Sentence 2. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the jaw opening and closing phase of the segment /a/ in ambiguous sentence THE [OLD] [MEN] AND WOMEN STAYED AT HOME as spoken by Talker JJ.



- * one level of significance from univariate ANOVA
- ** two levels of significance from univariate ANOVA

Figure 33.7

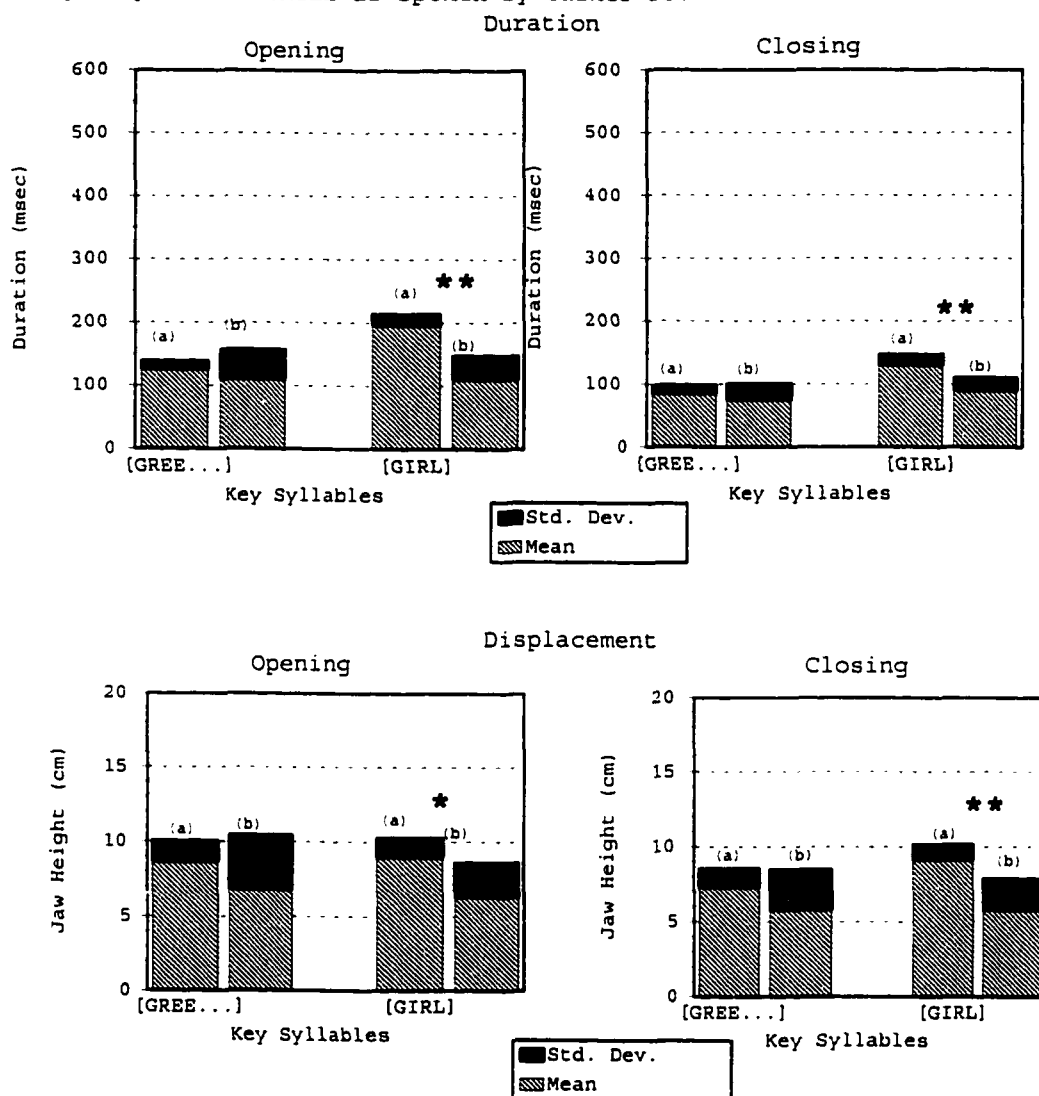
Sentence 2. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence THE [OLD] [MEN] AND WOMEN STAYED AT HOME as spoken by Talker LR.



- * one level of significance from univariate ANOVA
- ** two levels of significance from univariate ANOVA

Figure 34.7

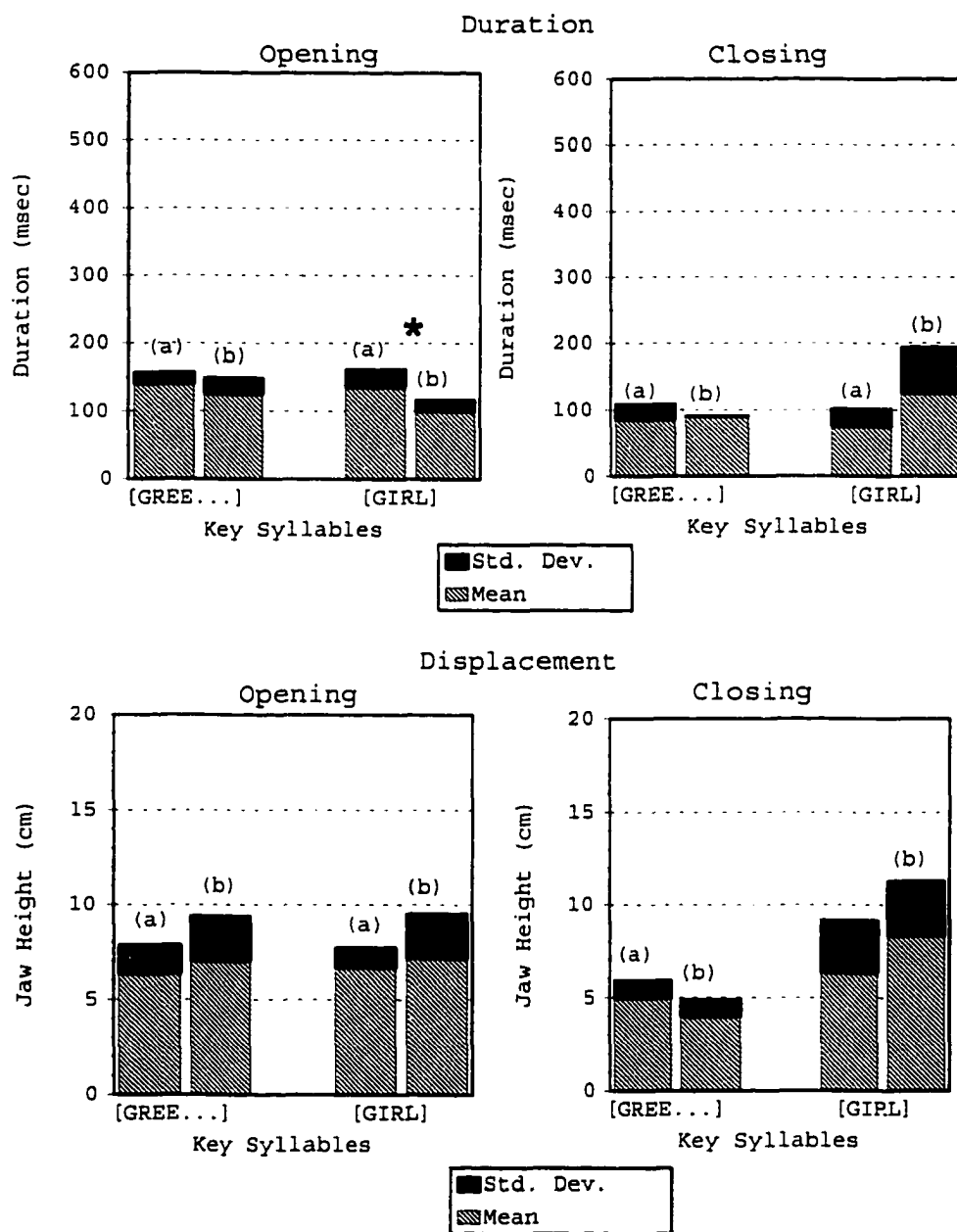
Sentence 3. Mean duration (msec) and mean jaw displacement with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence THE HOSTESS [GREE]TED THE [GIRL] WITH A SMILE as spoken by Talker JJ.



- * one level of significance from univariate ANOVA
- ** two levels of significance from univariate ANOVA

Figure 35.7

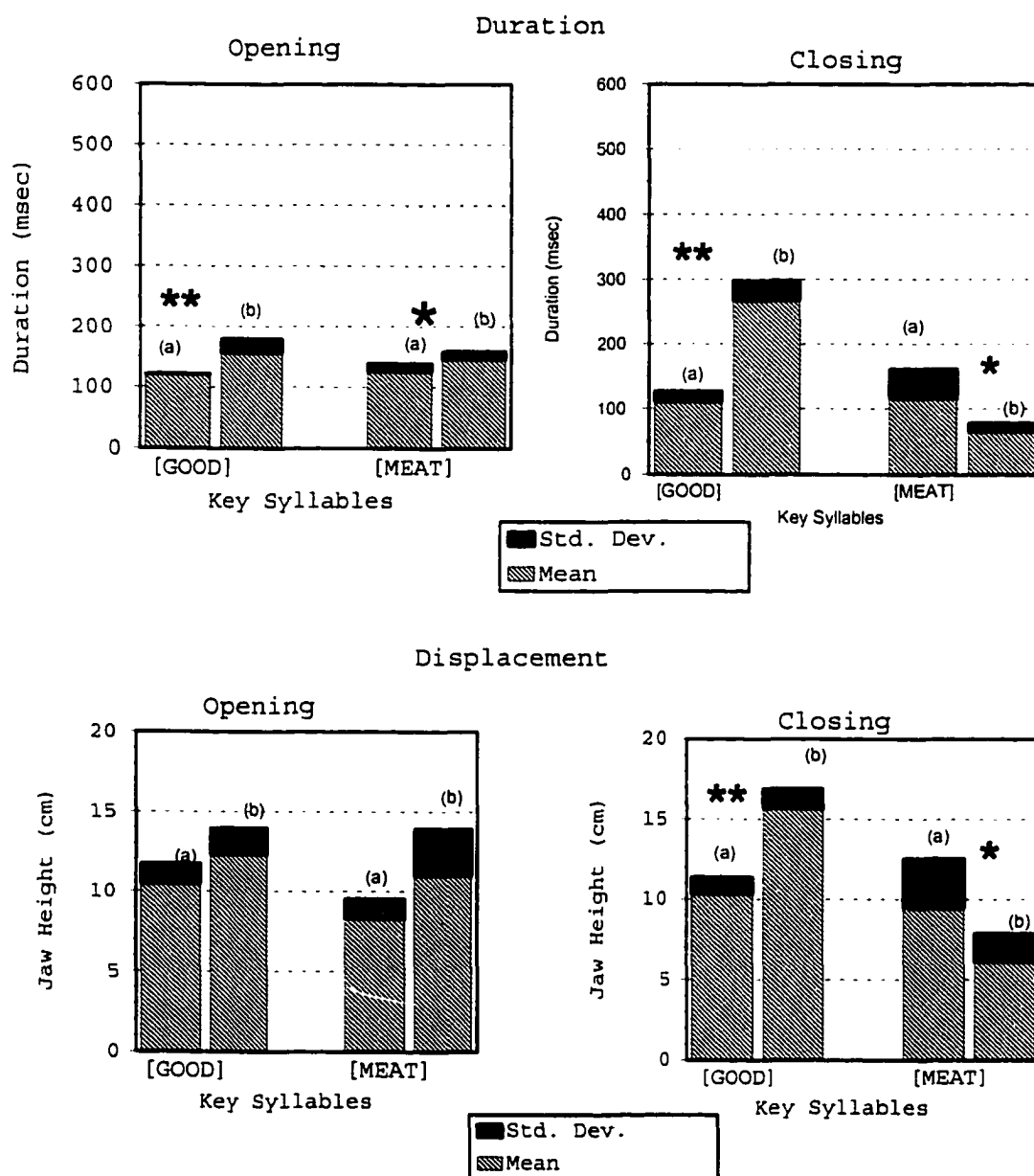
Sentence 3. Mean duration (msec) and mean jaw displacement with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence THE HOSTESS [GREE]TED THE [GIRL] WITH A SMILE as spoken by Talker LR.



* one level of significance from univariate ANOVA

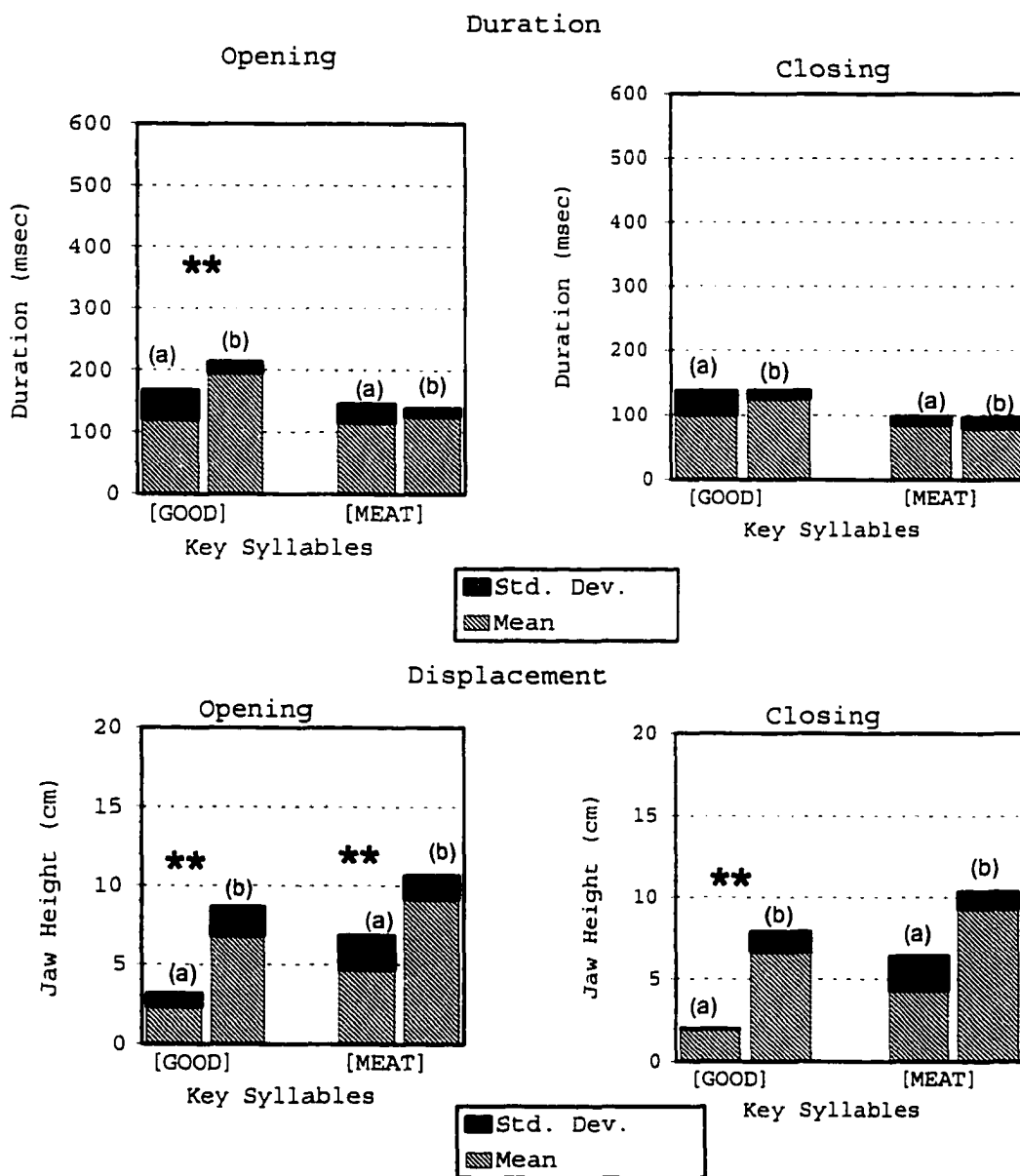
** two levels of significance from univariate ANOVA

Figure 36.7
Sentence 4. Mean duration (msec) and jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence JOHN DOESN'T KNOW HOW [GOOD] [MEAT] TASTES as spoken by Talker JJ.



- * one level of significance from univariate ANOVA
- ** two levels of significance from univariate ANOVA

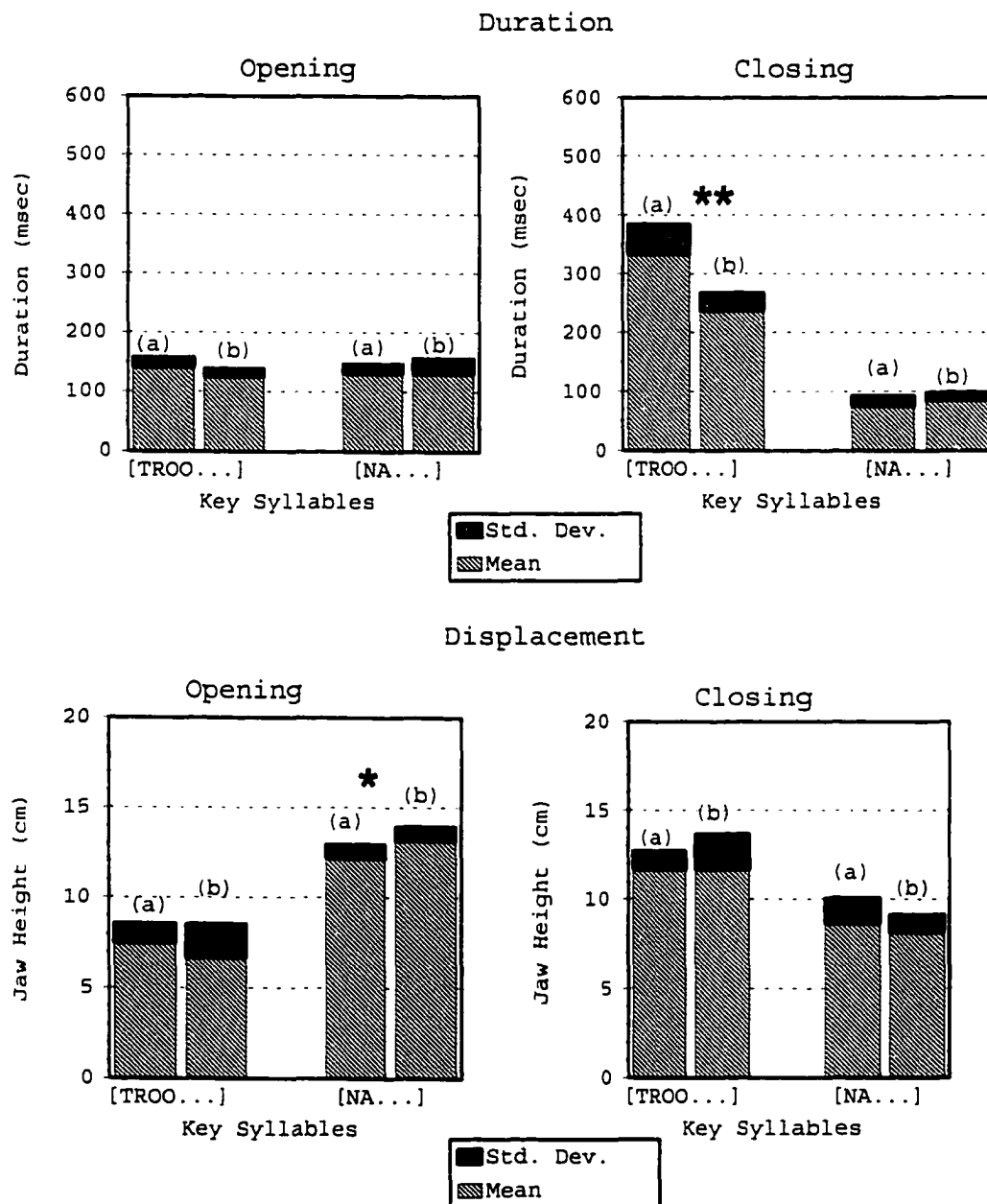
Figure 37.7
Sentence 4. Mean duration (msec) and jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence JOHN DOESN'T KNOW HOW [GOOD] [MEAT] TASTES as spoken by Talker LR.



- * one level of significance from univariate ANOVA
- ** two levels of significance from univariate ANOVA

Figure 38.7

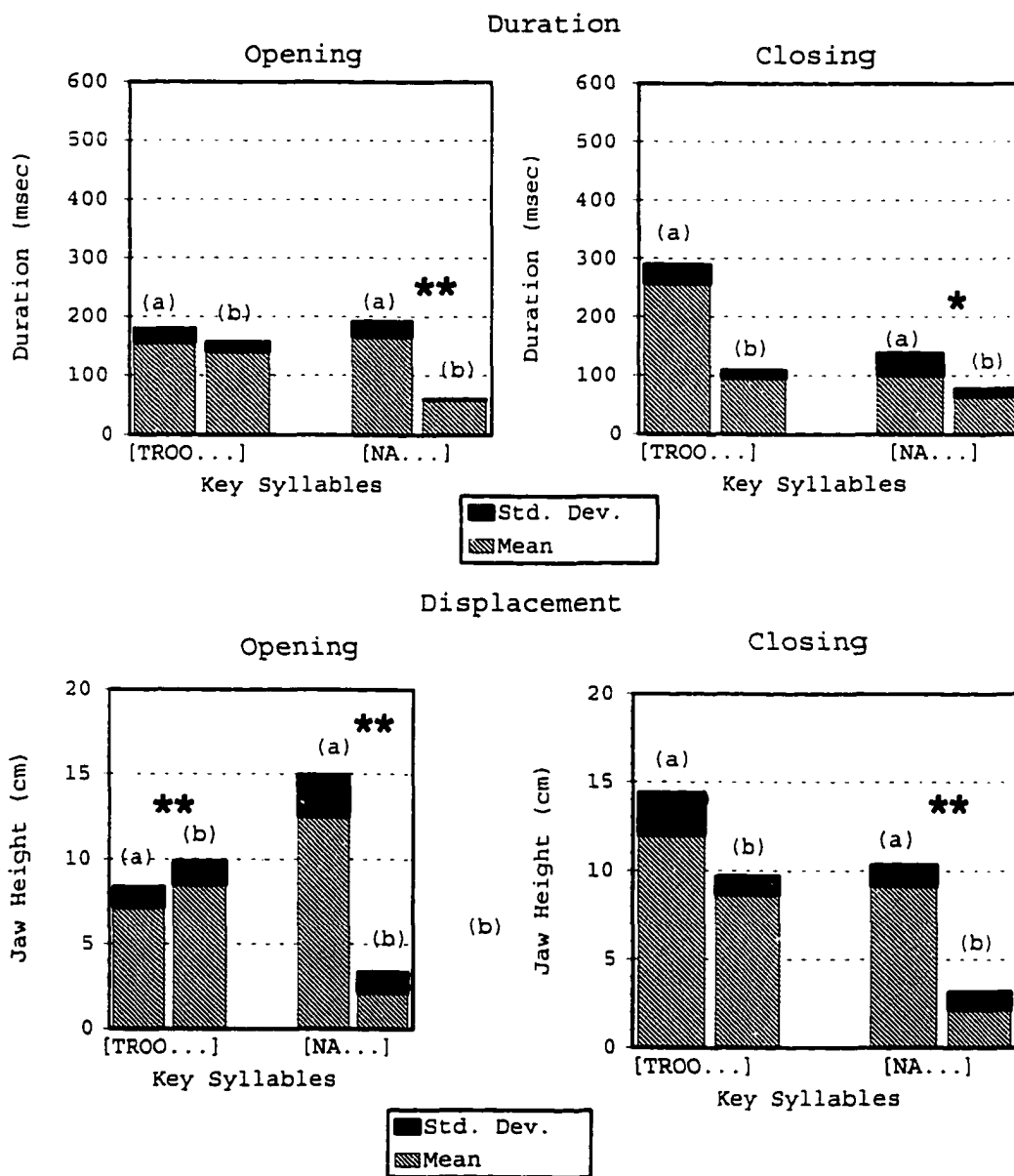
Sentence 5. Mean duration (msec) and jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence LT. BAKER INSTRUCTED HIS [TROO]P [NA]TURALLY as spoken by Talker JJ.



* one level of significance from univariate ANOVA
 ** two levels of significance from univariate ANOVA

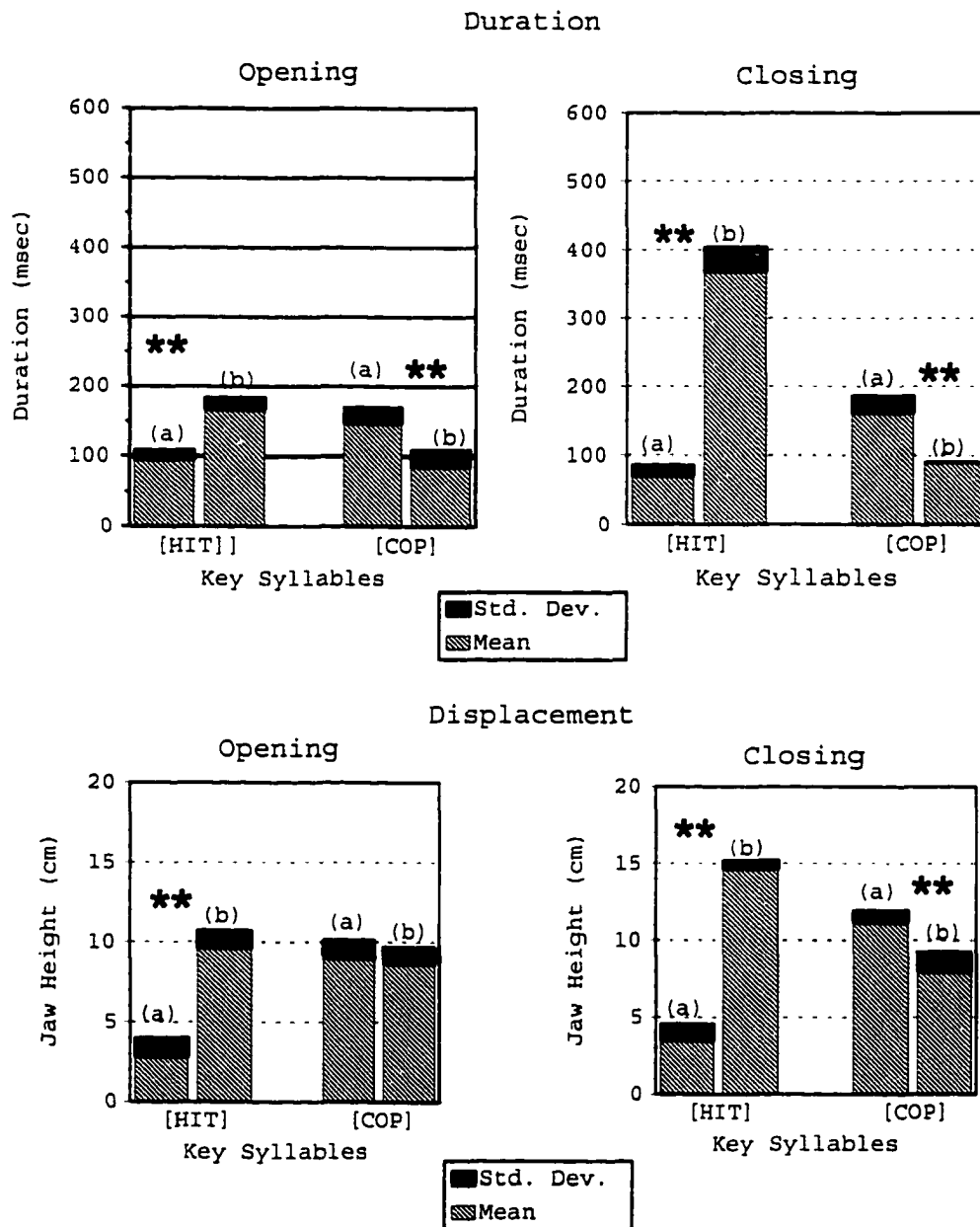
Figure 39.7

Sentence 5. Mean duration (msec) and jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence LT. BAKER INSTRUCTED HIS [TROO]P [NA]TURALLY as spoken by Talker LR.



* one level of significance from univariates
 ** two levels of significance from univariates

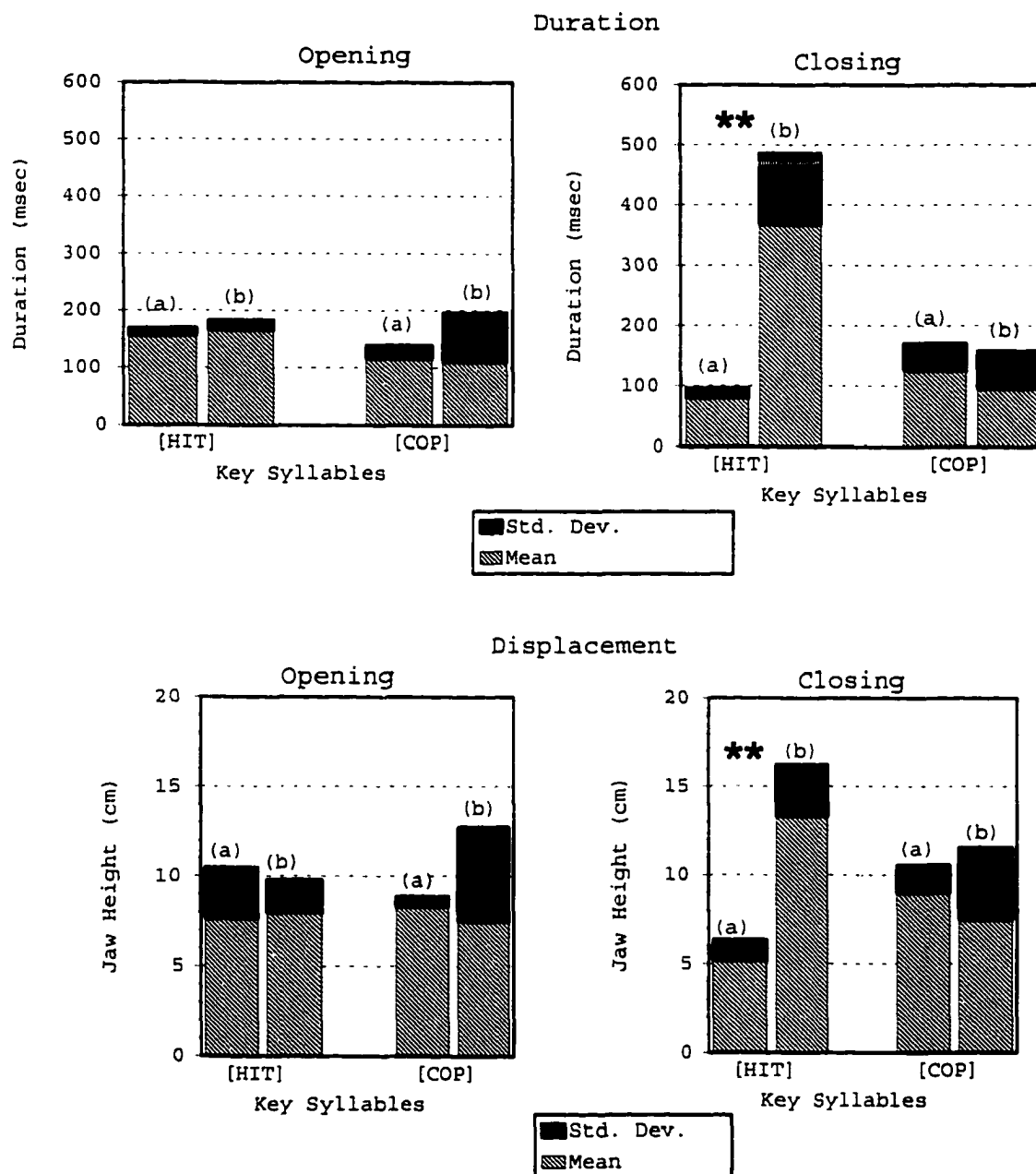
Figure 40.7
Sentence 6. Mean duration (msec) and mean displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence JEFFREY [HIT] THE [COP] WITH A STICK as spoken by Talker JJ.



- * one level of significance from univariate ANOVA
- ** two levels of significance from univariate ANOVA

Figure 41.7

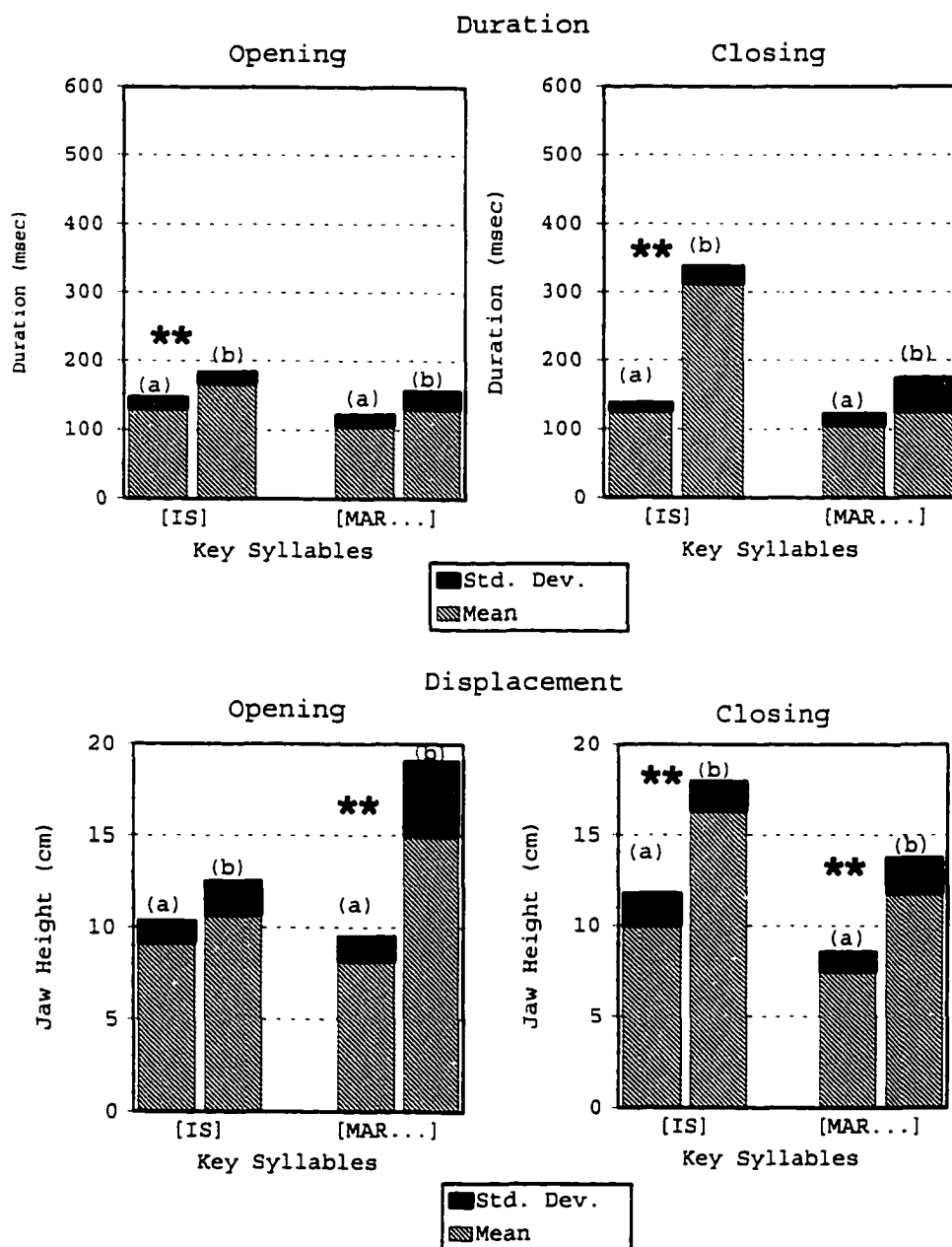
Sentence 6. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence JEFFREY [HIT] THE [COP] WITH A STICK as spoken by Talker LR.



- * one level of significance from univariate ANOVA
- ** two levels of significance from univariate ANOVA

Figure 42.7

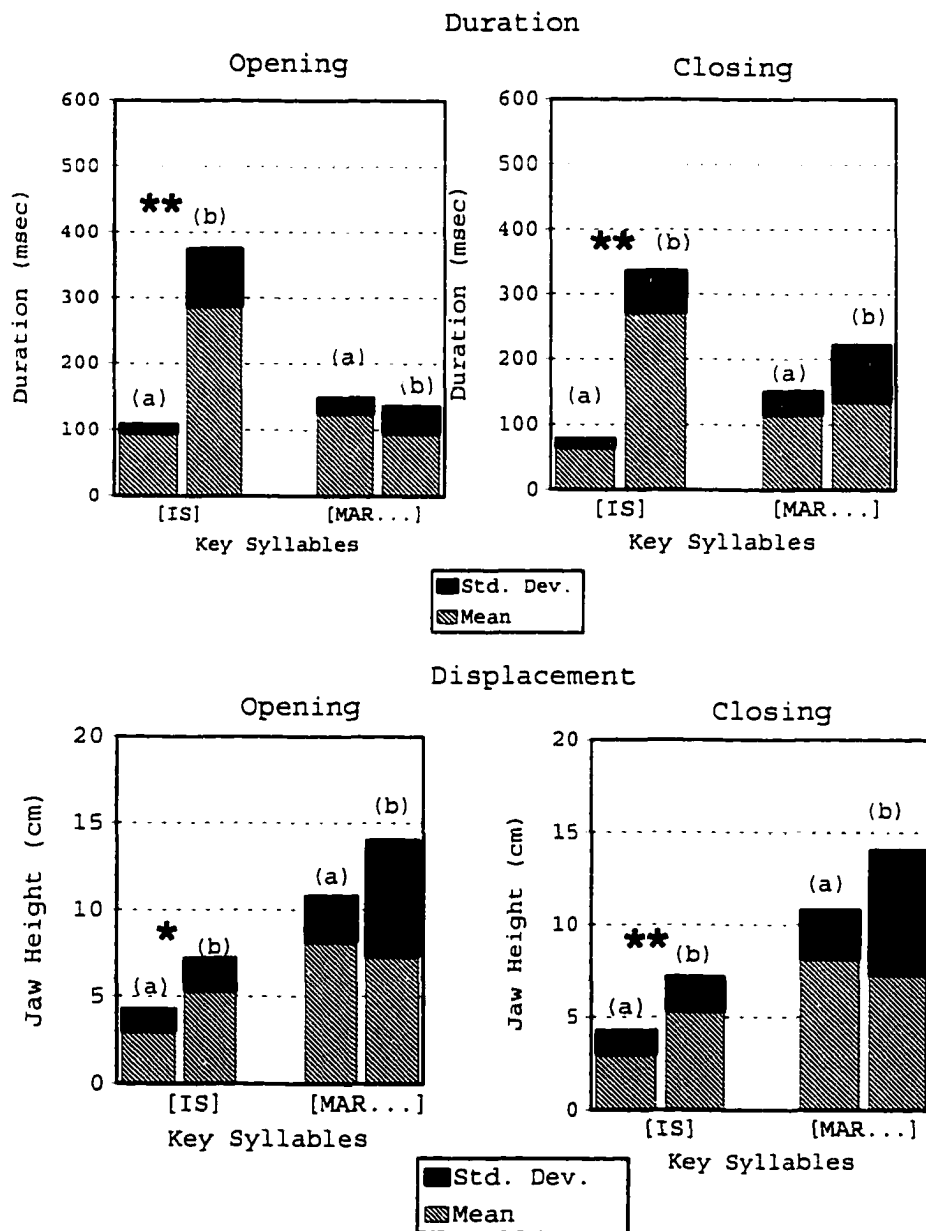
Sentence 7. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence SHE [IS] UNHAPPILY [MAR]RIED as spoken by Talker JJ.



- * one level of significance from univariate ANOVA
 ** two levels of significance from univariate ANOVA

Figure 43.7

Sentence 7. Mean duration (msec) and mean jaw displacement (cm) with standard deviations during the jaw opening and closing phase of key segment /a/ in ambiguous sentence SHE [IS] UNHAPPILY [MAR]RIED as spoken by Talker LR.



- * one level of significance from univariate ANOVA
 ** two levels of significance from univariate ANOVA

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