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NUCLEAR ACCENT TYPES AND PROMINENCE: SOME PSYCHOLINGUISTIC EXPERIMENTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Gayle Marie Ayers, B.A.

* * * * *

The Ohio State University
1996

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ACKNOWLEDGMENTS

I gratefully acknowledge the guidance and advice of my committee members Mary Beckman, Julie Boland, and Keith Johnson, and other members of the linguistics community, especially Gösta Bruce, Julia Hirschberg, Bob Ladd, and Jacques Terken. I give my warmest thanks to my family and friends for their love and support during this process, and special thanks to Margaret Jelinek, Tim Elam, and Stan Dodds. The research for this dissertation was funded in part by The Ohio State University Department of Linguistics, The Ohio State University Graduate School through an Ohio State University Presidential Dissertation Fellowship, and the National Science Foundation through a National Science Foundation Graduate Fellowship and a grant to Mary Beckman for the project "Prosodically Transcribed Data and Transcription Tools for Linguistics Research".

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Ayers, Gayle M. (1994) Discourse functions of pitch range in spontaneous and read speech. Ohio State University Working Papers in Linguistics 44, 1-49, J. Venditti (ed.).

Ayers, Gayle M. (1995) Nuclear accent types and prominence: Some psycholinguistic experiments. In Proceedings of the International Congress of Phonetic Sciences 3, 660-663. Stockholm, August 1995. K. Elenius and P. Branderud (eds.).

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FIELDS OF STUDY

Major Field: Linguistics

Studies in Phonetics and Psycholinguistics

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ABSTRACT

This dissertation explores the prominence of words in simple English sentences produced with declarative intonation patterns. Four components of prominence are addressed: acoustic, structural, perceptual, and informational prominence. The prominence of three accent statuses (nuclear accented, prenuclear accented, and unaccented) and three types of nuclear accent (regular, downstepped, and expanded pitch range) are investigated. Compared to regular nuclear accents, downstepped accents have lower fundamental frequency peaks, and expanded pitch range accents have higher peaks. Sentences had nuclear accent placement in early, medial, or late sentence position ("normal sentence stress"). Three experimental tasks are used to test whether the three nuclear accent types have different degrees of prominence: phoneme monitoring, question-answering, and cross-modal naming.

The accent statuses and nuclear accent types had the predicted differences in acoustic prominence. Nuclear accented was the most prominent, followed by prenuclear accented and then unaccented. Within nuclear accented, expanded pitch range was the most prominent, followed by regular and then downstepped. Accent status had a significant effect on phoneme monitoring speeds in the direction predicted by the acoustic prominence relationships; nuclear accented targets were responded to more quickly than non-nuclear accented targets. However, reaction times to prenuclear accented and postnuclear unaccented targets were indistinguishable, suggesting that the primary perceptual split is between nuclear accented and not nuclear accented. Reaction times to regular and expanded pitch range nuclear accents were indistinguishable, but downstepped nuclear accents were responded to least quickly, suggesting that they are less perceptually prominent than non-downstepped accents. A question-answering experiment investigated the informational prominence of the accent statuses and accent types. Subjects answered faster when the relevant part of the sentence in the sentence-question pair was most informationally prominent and slower when another part of the sentence was most prominent. The differences between nuclear accent types were not significant. Accent status had little effect on the speed of lexical access of target words in the cross-modal naming experiments. The experiments showed that nuclear accent placement and accent type influence sentence processing, and that nuclear accent is not a uniform category in terms of prominence.

CHAPTER I

INTRODUCTION

1.1 Introduction

This dissertation explores the prominence of words in simple English sentences produced with specific intonation patterns. Prominence is a multi-faceted concept. Four components of prominence are addressed here: acoustic prominence, structural (or metrical) prominence, perceptual prominence, and informational prominence. Acoustic prominence refers to how distinctly a word or phonetic features of a word are produced -- specifically, here, the duration and acoustic clarity of the phonemes and syllables in a word. Structural prominence refers to the position of the word in the rhythm of the utterance -- specifically, here, in the rhythm defined by the alignment between the intonation contour and the text. Perceptual prominence refers to how listeners perceive a word. Informational prominence refers to discourse flow and highlighting new (and important) information. The simplest correspondence among the four aspects of prominence is one in which the speaker intends to emphasize a particular word in a sentence to indicate that it is informationally prominent so she arranges the intonational contour to position the word in a structurally prominent position and carefully articulates all of its constituent syllables to give it the greater acoustic prominence characteristic of newly introduced or contrasted words. Then, because the word is acoustically prominent and placed in an intonationally salient position, the listener perceives that the word is prominent and understands the word as informationally prominent. However, although the four components are closely related, they need not necessarily be correlated precisely. For example, a speaker may produce alternations in acoustic prominence that the listener does not treat as perceptually relevant to the metrical structuring of an utterance. Furthermore, syntactic constructions can mark words as informationally prominent, and the listener may understand that they are informationally prominent even if they are not acoustically or structurally prominent.

The goal of this study was to explore the structural prominence differences posited by phonological theories by relating structural

prominence to acoustic prominence, perceptual prominence, and informational prominence. The differences in structural prominence were carefully controlled to contrast the three accent statuses (nuclear accented, prenuclear accented, and postnuclear unaccented) and three different types of accent type (regular nuclear accented, downstepped nuclear accented, and expanded pitch range nuclear accented). The differences in structural prominence examined here have to do with phonological theories of "sentence stress" -- that is, of prominence differences among words in an utterance that can stand alone as a complete turn in a discourse. To be more than a fragment of a turn, an utterance must have a complete well-formed intonation contour, and one of the important differences among theories of structural prominence is the relationship posited between this "tune" for the sentence and the "stress" pattern across its component words. In the theory adopted here as a starting point for the exploration of structural prominence, the relationship between intonation and "sentence stress" is a particularly intimate one. Some of the "notes" in the intonational tune (the "pitch accents") are associated with specific words in the sentence, and that association marks the words as structurally more prominent (or "accented"). There must be at least one pitch accent in every well-formed intonation contour, and the word associated with the only pitch accent (or with the last pitch accent if there is more than one) has the greatest structural prominence. It bears the "nuclear accent" -- i.e. it has *the* sentence stress. The theory also posits a (somewhat lesser) structural prominence for any accented word before the nuclear-accented one, and least structural prominence for any unaccented words. The experiments reported here were designed first of all to test whether this theory of "three accent statuses" corresponds with our expectations about differences in acoustic prominence and informational prominence.

A second set of questions concerns the relationship between structural prominence and pitch accent type. These questions are closely tied up with how phonological theories deal with non-structural prominence differences, such as the "paralinguistic" prominence that can be given to an entire sentence by "speaking up" to convey greater emotional involvement. This overall "paralinguistic" difference seems to be mimicked in the contrast among some nuclear pitch accent shapes for some intonation contours. Specifically, in a "declarative intonation" which specifies a sharp fall in pitch within the nuclear accented word, there are at least three choices of contour shape before the fall. The pitch can stay fairly level up to the accented syllable and then sharply fall; it can rise steeply onto the accented syllable just before falling; or it can gradually slope downward onto the accented syllable before falling more sharply. The choice of shape makes for a dramatic difference in peak pitch level within the accented word, and these differences seem to be correlated with a difference in informational prominence. If we think of the first contour as a "neutral" adding of information to the common ground shared by speaker and hearer, the other two contours differ from neutral, in opposite directions. The contour with the sharp rise before the fall conveys a sense of "expanded pitch range" for local "emphasis" or "contrast" on the word with sentence stress, whereas the contour with the gradually sloping "downstep" onto the nuclear accented word conveys a sense of "expectedness" from an explicit link to "old information" already shared between the speaker and hearer. The first contour has a "regular nuclear accent", the second contour has an "expanded pitch range nuclear accent", and the third contour has a "downstepped" nuclear accent. Thus the three nuclear accent types addressed here have differences in meaning as well as differences in peak pitch level within the accented word.

Acoustic measurements of materials in the experiments investigated the acoustic prominence of the categories. The acoustic measurements confirmed the expected differences in acoustic prominence in accent status; from most to least prominent was nuclear accented, prenuclear accented, and unaccented. The measurements also showed that there were differences in acoustic prominence for the accent types; from most to least prominent was expanded pitch range nuclear accented, regular nuclear accented, and downstepped nuclear accented.

The experiments examined the perceptual prominence and informational prominence associated with the differences in structural prominence using three experimental tasks: phoneme monitoring, question-answering, and cross-modal naming. These tasks provided a way to observe the influence of sentence intonation on the behavior of listeners, which gives us a window into understanding the prominence relationships among categories such as nuclear accent versus prenuclear accent and the status of accent type with respect to structural prominence values. That is, the experiments allowed us to systematically test for differences in perceptual prominence without asking for explicit judgments of how prominent a word is. In addition, they helped inform us of the role of intonation in lexical access and sentence processing. The differences in perceptual prominence and informational prominence for the categories were not as large as the differences in acoustic prominence were. Nuclear accented was perceptually and informationally more prominent than prenuclear accented and unaccented, but prenuclear accented and unaccented were not significantly different. Within nuclear

accented, downstepped nuclear accented seemed to be less perceptually prominent than either expanded pitch range nuclear accented or regular nuclear accented.

1.2 Structural prominence and levels of stress

This study investigated structural prominence in terms of three accent statuses: nuclear accented, prenuclear accented, and unaccented (see e.g., Beckman 1986, Beckman & Edwards 1994, Shattuck-Hufnagel 1995, de Jong 1995). Figures 1 through 3 illustrate the three accent statuses unaccented, prenuclear accented, and nuclear accented, respectively, on the sentence medial word *canyon* in three versions of the sentence *The girl admired the canyon from a distance.* All three versions of the sentence have only one type of accent, a regular peak accent (transcribed H*), on the prenuclear and nuclear accented words, and all three end with low phrase accents and boundary tones (L-L%). These are all declarative intonation patterns. Three different locations of nuclear accent on the sentence provide the three accent statuses on the word *canyon*. Table 1 shows a summary of the accent statuses and intonational transcriptions for the three utterances. The ToBI transcription system is explained in more detail in Section 1.5. The word *canyon* is unaccented (U) when the nuclear accent is in early sentence position. The word *canyon* is prenuclear accented (P) when the nuclear accent is in late sentence position. The word *canyon* is nuclear accented (N) when the nuclear accent is in medial sentence position.

In Figure 1, the word *canyon* is unaccented. The nuclear accent occurs early in the sentence, on *girl*, and all following words are

Table 1. Accent statuses unaccented, prenuclear accented, and nuclear accented in medial sentence position (the word *canyon*).

		The		admired the		from a	
(U)	Unaccented	The	**GIRL**	admired the	canyon	from a	distance.
			Nuclear		Unaccented		Unaccented
			H*				L-L%
(P)	Prenuclear accented	The	GIRL	admired the	CANYON	from a	**DISTANCE**.
			Prenuclear		Prenuclear		Nuclear
			H*		H*		H* L-L%
(N)	Nuclear accented	The	GIRL	admired the	**CANYON**	from a	distance.
			Prenuclear		Nuclear		Unaccented
			H*		H*		L-L%

Notes. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent. The intonational transcriptions follow the ToBI conventions.

unaccented. In this version of the sentence, which is an appropriate answer to the question *Who admired the canyon from a distance?*, the word *canyon* is not very important to the message of the sentence because the questioner already knew that someone admired the canyon; that is, *canyon* is "old" information so the speaker does not have to emphasize it by placing an accent on it. In Figure 2, the word *canyon* is prenuclear accented. The nuclear accent occurs late in the sentence, on *distance*, and *girl* and *canyon* are prenuclear accented. In this version of the sentence, which is an appropriate answer to the question *What happened this afternoon?,* the word *canyon* is important to the message of the sentence because it is "new" information, as are the other accented words. However, *canyon* is not the most important or most informationally prominent word in the sentence; *distance* is the most informationally prominent word in the sentence. In Figure 3, the word *canyon* is nuclear accented. In this version of the sentence, which is an appropriate answer to the question *Did the girl admire the painting from a distance?*, the word *canyon* is very important to the meaning of the sentence. It is the word that needs the most emphasis in the sentence, and it is the informationally most prominent word in the sentence.

This study assumes that the three kinds of accent status correspond to three different levels of stress or (structural) prominence that are contributed by intonation, with unaccented being the lowest and nuclear accented being the highest. The three accent status theory was meant to reconcile discrepancies between the observations of phonological theory concerning structural or positional determinants of stress and the experimental literature on the acoustic correlates of stress.

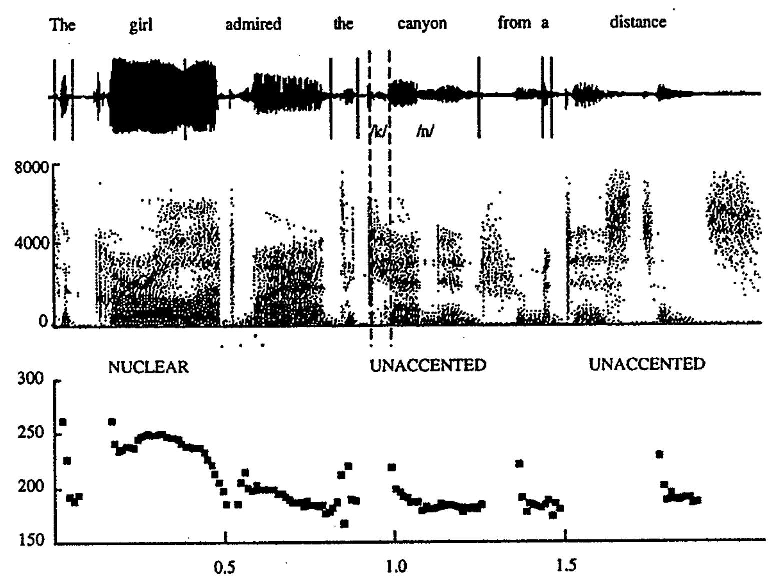


Figure 1. Unaccented *canyon* in medial sentence position -- early nuclear accent placement. Time aligned display (in seconds) of speech waveform, spectrogram (in Hz), and fundamental frequency contour (in Hz). The VOT of /k/ is between dashed lines.

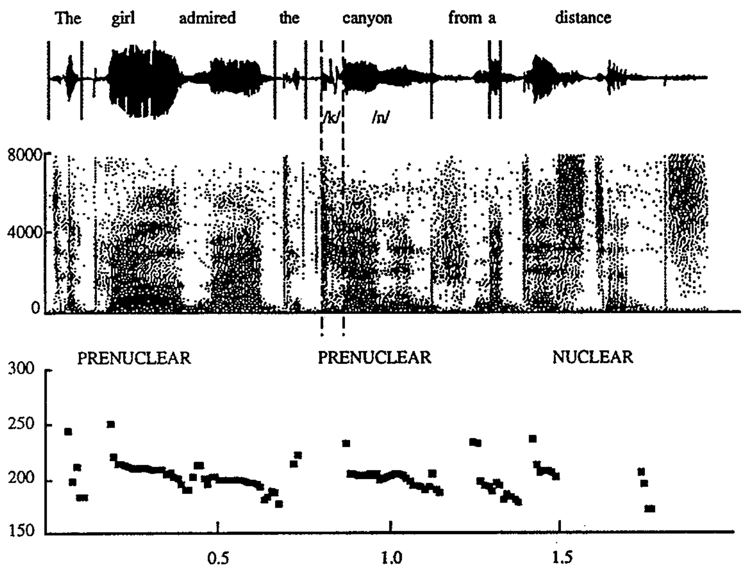


Figure 2. Prenuclear accented *canyon* in medial sentence position -- late nuclear accent placement. Time aligned display (in seconds) of speech waveform, spectrogram (in Hz), and fundamental frequency contour (in Hz). The VOT of /k/ is between dashed lines.

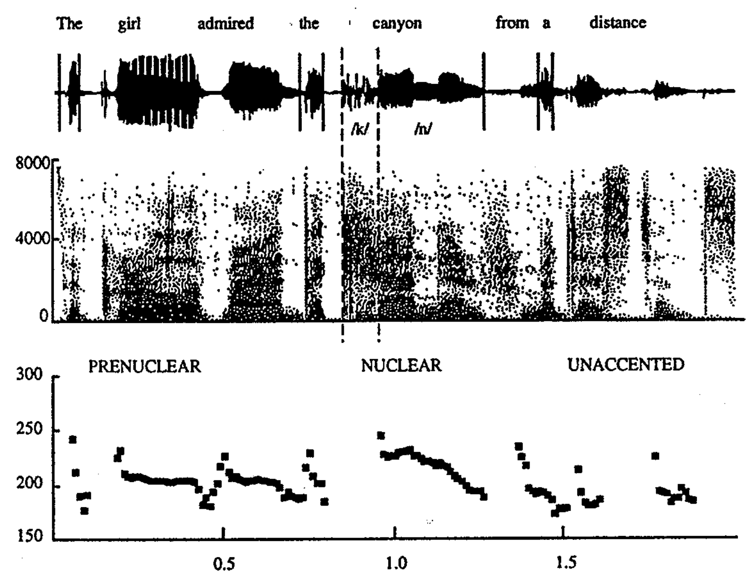


Figure 3. Nuclear accented *canyon* in medial sentence position -- medial nuclear accent placement. Time aligned display (in seconds) of speech waveform, spectrogram (in Hz), and fundamental frequency contour (in Hz). The VOT of /k/ is between dashed lines.

1.2.1 Phonological theory

The term "stress" refers to two different things in the literature. One usage of the term stress refers to a property of syllables in words. A stressed syllable is more (acoustically) prominent than an unstressed syllable, and each syllable in a word is either stressed or unstressed (e.g., Lehiste 1970, Vanderslice & Ladefoged 1972). For example, the noun *subject* and the verb *subject* are primarily distinguished by which syllable is stressed and which is unstressed. The noun *subject* is stressed on the first syllable *(SUBject)* and the verb *subject* is stressed on the second syllable *(subJECT)*. In this sense of the term stress, the intonational structure of a phrase is not relevant to the stress of syllables in a word. A second usage of the term treats stress as having "levels" of prominence. On top of the distinction between stressed and unstressed, more prominent syllables of words in a sentence have higher levels of stress. For example, stressed syllables in a word can have primary or secondary stress, and the most prominent word in a sentence has "nuclear stress" or "sentence stress" (e.g., Chomsky & Halle 1968).

The view of stress and prominence taken here is that there are "levels" of structural prominence that depend upon intonational structure and accent status, and these "levels" of structural prominence have acoustic correlates in the phonetic gradients of acoustic prominence. In addition, the levels of structural prominence are intimately connected to the degree of informational prominence; the greater the structural prominence, the greater the informational prominence. Not all researchers have treated "sentence stress" and prominence as having a connection to intonational accent, although many have treated "sentence stress" as expressing the focus and informational prominence of a sentence.

The American structuralist tradition going back to Trager & Smith (1951) posited four levels of stress, with the most prominent, primary stress, corresponding to "sentence stress" or "nuclear stress" in Chomsky & Halle's system, and the least prominent, weak stress, corresponding to unstressed or 0. Stress was assumed to be manifested by loudness, with each level being louder than the next lower level. In the typical American analysis, sentence stress was considered to be another "level of stress" as loudness. Pitch and stress were completely separate in their system, so that they had no conception of a connection between intonation and prominence, although they did transcribe pitch levels on an utterance. Because they consider stress and pitch to be unrelated, they had no explanation for the fact that what is perceived as the sentence stress often occurs at the highest pitch prominence of the intonation contour. Chomsky & Halle (1968), like Trager & Smith, called sentence stress a separate level of stress, but they say almost nothing about pitch. Liberman (1978) notes the connection between pitch changes and "strong" syllables, but for him, as for the rest of the Trager & Smith and Chomsky & Halle tradition, stress and pitch are independent phenomena.

In the British tradition, Kingdon (1958) used stress following the IPA convention of fully stressed, half-stressed, and unstressed, including a notation for emphatic stress. He described the pitch movements in sentences with "tonetic stress marks". The "nucleus" or most prominent syllable of a tone occurs at a fully stressed syllable, i.e., the sentence stress in the American descriptions. Halliday (1967) and Crystal (1969) also have a similar view of the connection between the nucleus ("tonic" for Halliday) and stress.

1.2.2 Acoustic correlates of stress and prominence

The experimental literature on stress in English point to four acoustic correlates of stress, in the sense of stress that includes "sentence stress": pitch, duration, intensity, and segment articulation. The general findings in this set of literature are that the greater the stress, the longer the duration, the higher the intensity, the more extreme the segment articulation, particularly the vowel formant structure, and often, the higher the fundamental frequency (e.g., Fry 1955, 1958, Lehiste 1970, Cooper et. al 1985, Fear et al. 1995, de Jong 1995). The story goes that all of these things taken together lead to a syllable and/or a word standing out and being more distinct in the acoustic signal. In other words, such syllables and words are prominent. For example, the classic perception experiments of Fry (1955, 1958) are generally interpreted as showing that duration, amplitude, and pitch movement are all important in the perception of word stress. He was able to switch listeners' perception of a word like *subject* from the noun with stress on the first syllable (SUBject) to the verb with stress on the second syllable (subJECT) by manipulating intensity, duration, and fundamental frequency change. Intensity was the weakest cue, while longer duration and fundamental frequency change on a syllable were effective cues for word stress, indicating higher prominence of syllables within words.

We can see these acoustic correlates of prominence in the example sentences given in Figures 1 to 3. The fundamental frequency contours show the expected relationship to acoustic prominence for the three accent statuses. For contours with only regular peak accents (H*) and with low phrase accents and boundary tones (L-L%), fundamental frequency is highest on the word with nuclear accent[1], relatively high on words with prenuclear accents, and low on unaccented words after the nuclear accent. That is, for peak accents, the higher the level of prominence, the higher the fundamental frequency. In Figure 1, the word *girl* has the highest F0 value of the whole sentence, and after that, the F0 is low and level on the remainder of the words in the sentence. The few high F0 points after the nuclear accented word are segmental perturbations due to voiceless consonants. In Figure 3, F0 is relatively high on the prenuclear accented word *girl*, the F0 is highest on the nuclear accented word *canyon*, and as in Figure 1, the F0 is low and level on the remaining words in the sentence, with the exception of segmental perturbations. In Figure 2, all three accented words have relatively high F0.

In addition, the duration of the word *canyon* in the three different accent statuses shows the expected relationship to prominence. The word duration is shortest for the unaccented version (330 ms), longer for the prenuclear accented version (358 ms), and longest for the nuclear accented version (429 ms). The intensity of the energy in the three instances of *canyon* also show the expected relationship to prominence for the three accent statuses. The speech waveforms and the spectrograms both show that the unaccented *canyon* has the lowest intensity, the prenuclear accented one has a greater intensity, and the nuclear accented one has the greatest intensity. This is especially clear in the spectrogram representation, where the formants are quite faint in the unaccented token, and darker and clearer in the prenuclear accented and nuclear accented tokens.

The final difference to note in the three tokens of *canyon* is the difference in the segment articulation. The more prominent the word, the more clearly the segments are articulated. De Jong (1995) describes this difference in segment articulation due to stress as a local shift toward hyperarticulate speech. In this view, stress entails changes in speech production which enhance the perceptual clarity of the speech, and all phonemically distinctive contrasts are affected by stress. This idea follows from the ideas of several researchers. Jones (1932) gives prominence the property of "distinctness". Öhman's (1967) model says that stress involves a greater amount of energy which reduces the amount of coarticulation in a stressed syllable, and therefore "[p]honetic distinctions would be sharper in these syllables" (p. 34). Lindblom (1990) and Lindblom & Engstrand (1989) suggest that all speech occurs on a continuum from hypoarticulate to hyperarticulate speech. Overall word duration and intensity in the different tokens already give some

indications that the higher the prominence, the more clearly a word is articulated. However, with respect to clarity of segmental articulation, notice in particular the difference in the duration of the aspiration noise of the /k/ in the three versions (shown between dashed lines), and the sharpness of the /n/ in the nuclear version as opposed to the other two (the light region in the spectrogram, at about 1.1 sec in the nuclear version, 1.0 sec in the prenuclear version, and 1.1 sec in the unaccented version).

However, there are problems with this simple view of stress as having acoustic correlates without respect to the phonological intonational structure of a phrase. For example, in sentences that have low tone accents and high tones at the phrase boundaries, such as canonical yes-no questions like *Were you mowing during the morning?*, it is low fundamental frequency that is associated with higher stress, not high fundamental frequency. Figure 4 shows the fundamental frequency contours for three versions of the question. First let's consider a version of the question in which *morning* is emphasized and the background assumption is "you were mowing sometime". In this version of the question (a), the word *morning* has the lowest fundamental frequency of the whole sentence, and the highest fundamental frequency of the whole sentence occurs at the end of the sentence, at the very end of the word *morning*. Notice also that the fundamental frequency is also quite low on *you*. Next let's consider a version of the question in which *mowing* is emphasized and the background assumption is "you were doing something during the morning". In this version of the question (b), the word *mowing* has the lowest fundamental frequency of the whole sentence, and again the highest fundamental frequency of the whole sentence occurs at the end of the word *morning*. Finally let's consider a version of the question in which *you* is emphasized and the background assumption is "someone was mowing during the morning". In this version of the question (c), the word *you* has the lowest fundamental frequency of the whole sentence, and once again the highest fundamental frequency of the whole sentence occurs at the end of the word *morning*.

An explanation of stress level based on fundamental frequency height alone is bound to fail since it makes exactly the wrong predictions, while an explanation that takes intonational structure into account does not have the same shortcoming. In each version of the sentence, the most emphasized word in the sentence had the lowest fundamental frequency, not the highest fundamental frequency.

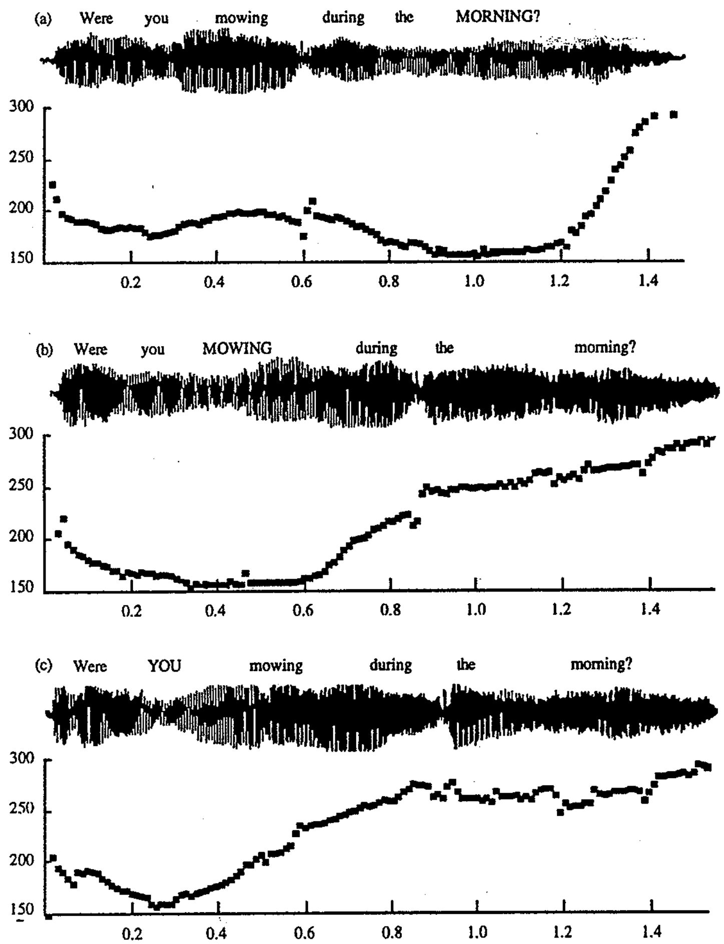


Figure 4. Three different locations of a low tone nuclear accented word in the sentence *Were you mowing during the morning?*. Time aligned display (in seconds) of speech waveform and fundamental frequency contour (in Hz).

(a) late nuclear accented *morning*
(b) medial nuclear accented *mowing*
(c) early nuclear accented *you*

1.2.3 Accent analyses of intonation and structural prominence

The example in Figure 4 shows that there can be a contradiction between the "usual" relationship of higher fundamental frequency and higher prominence. Note, however, that there is a parallel between the examples in Figures 1 - 3, in which the location of the most (informationally) prominent word corresponded with the highest pitch, and the examples in Figure 4, in which the location of the most (informationally) prominent word corresponded with the lowest pitch. In addition, when there was more than one prominent word in the sentence, with either high or low pitch, it was the final word that was most prominent.

Vanderslice & Ladefoged (1972), following Bolinger (1958), describe this prominence difference as a difference between accents that are nuclear (indicated with a feature [+/- intonation]) and accents that are not nuclear. Both Bolinger and Vanderslice & Ladefoged define "accent" in terms of pitch obtrusion on a prominent word. The pitch obtrusion can be up (as in our examples in Figures 1 - 3) or down (as in our examples in Figure 4). An upward pitch obtrusion is more common, which explains why the bulk of the experimental literature associates higher pitch with higher stress. Vanderslice & Ladefoged's account incorporates Chomsky & Halle's (1968) Nuclear Stress Rule and Liberman & Prince's (1977) Relative Prominence Projection Rule into an account of intonation that includes accents. The two rules together say that the nuclear stress is the highest level of stress and thereby the metrically strongest one. Continuing with Vanderslice & Ladefoged's synthesis of the approaches, unstressed syllables are the least prominent category (and may have reduced or full vowels). A stressed syllable may be unaccented or accented, with accented being more prominent. If a syllable is accented, it may be nuclear accented or not, with nuclear accented being the most prominent in this categorization. That is, a stressed syllable may be, from least to most prominent, unaccented, accented (but not nuclear accented), or nuclear accented.

Recent models have continued to describe intonation as having accents. They have described the fundamental frequency contours of English as being comprised of sequences of tonal elements: pitch accents, phrase accents, and boundary tones (e.g. Pierrehumbert 1980, Liberman & Pierrehumbert 1984, Beckman & Pierrehumbert 1986, Pierrehumbert & Hirschberg 1990, Silverman et al. 1992, Beckman & Hirschberg 1994, Beckman & Ayers 1994). In this system, all of the tonal phenomena of

English are described with only high tone (H) and low tone (L). Pitch accents are tonal markings associated with stressed syllables which mark prominences on words. Speakers place pitch accents on stressed syllables of specific words of a sentence. Words can be grouped into two levels of phrases in this system, intermediate phrases and intonational phrases. A phrase accent (L- or H-) follows the final accent in a intermediate phrase, and a boundary tone (L% or H%) marks the end of an intonational phrase. An intonational phrase contains at least one intermediate phrase.

In these recent models of intonation, which include the one that we are assuming here, the most basic distinction in accent status is between words that are accented and words that are unaccented. However, the final accent in a phrase is called the nuclear accent, and it has a special status. The nuclear accent is generally taken to be the most prominent accent within the phrase, or at least no other accent of the phrase is more prominent (Vanderslice & Ladefoged 1972, Pierrehumbert 1980). Because the nuclear accent is the final accent of a phrase, there are no accents following the nuclear accent of a phrase. Any words following the nuclear accented word of a phrase are necessarily unaccented, and their accent status is called postnuclear unaccented. Any accents before the nuclear accent are called prenuclear accents. This suggests a three-way contrast in accent status in English, the structural prominence that we are assuming here: nuclear accented (most prominent), prenuclear accented (second most prominent), and unaccented (least prominent).

Returning to our example sentences above, we can describe the difference in pitch levels between the declarative sentences in Figures 1 - 3 and the questions in Figure 4 as having different tonal targets for the accented words and the phrase boundaries. In the declarative sentences in Figures 1 - 3, the accented words had high tone accents (H*), and the sentence ended with phrase final low tone boundary tones (L-L%). In the questions in Figure 4, the accented words had low tone accents (L*), and the sentence ended with phrase final high tone boundary tones (H-H%). In the questions, the fact that the nuclear accented words were the most prominent words in the sentences even though they had the lowest fundamental frequency is explained by the fact that the nuclear accent type had a low tone target.

The relationship between prominence and fundamental frequency is different for peak (high tone) accents and low tone accents. In peak accents, fundamental frequency increases with amount of emphasis (informational prominence), while in low tone accents, fundamental frequency may even decrease with amount of emphasis. A very prominent peak accent is very high in the pitch range of the speaker (e.g., Liberman & Pierrehumbert 1984), and a very prominent low accent is very low in the pitch range of the speaker, as in our example (and see also Kori (1987) and Shih (1988) for the behavior of low tones in Osaka Japanese and Mandarin, respectively). Therefore, unless we specify that we are talking about peak accents, we cannot simply state that the greater the prominence of an accent, the higher the fundamental frequency will be. Conversely, we cannot simply state that the higher the fundamental frequency, the higher the prominence. The accent types L* and H* can be equally prominent despite great differences in fundamental frequency values. Fundamental frequency cues stress and prominence only indirectly, and it depends on where the accents are and what type they are.

To summarize briefly, the lexical and syntactic information were identical for all three versions of the sentence *The girl admired the canyon from a distance*, but each version of the sentence had a different intonational structure that conveyed the pattern of emphasis and its particular meaning. A word can be acoustically prominent because of acoustic/phonetic characteristics associated with accents, such as being articulated clearly and loudly, and (for these accents with high tone targets) with a large pitch movement. That is, an acoustically prominent word is distinct in the acoustic signal. A word that is informationally prominent can also be particularly important to the meaning of the sentence, as shown by the difference meanings of the different versions of the sentence. Acoustic prominence and informational prominence are not independent of one another but are related to the structural prominence of accent status. In addition, perceptual prominence of words in sentences also depend in part upon the structural prominence of accent status.

<u>1.3 The relationship between accent status and informational prominence</u>

One line of investigation in intonational theory is predicting what intonation pattern a sentence will be produced with and where the nuclear accent will fall. The location of the nuclear accent is closely linked to the informational prominence of words in the sentence. Some theorists believe that intonation patterns are fully predictable based on syntactic and/or semantic facts about sentences. These theorists believe that every sentence has a single word that "normally" receives nuclear accent (the "normal sentence stress") and any other location of nuclear accent is a deviation from that norm. Other theorists reject the notion that every sentence has a basic unmarked location for nuclear accent and believe instead that sentence context and what the speaker wants to emphasize determine the accent placement. Under either view, in specific contexts, such as the default out-of-the-blue context that theorists in the first group assume, certain intonation contours are less marked, more predictable, or more "normal" than other intonation contours. This relates to the contrast between early and late placement of nuclear accent in this study.

Many studies describe the principles determining accent placement within a sentence (e.g. Halliday 1967, Chomsky & Halle 1968, Bolinger 1972, Jackendoff 1972, Berman & Szamoxi 1972, Ladd 1980, Gussenhoven 1983, 1984, Wells & Local 1983, Selkirk 1984, Fuchs 1984, Horne 1985, Pierrehumbert & Hirschberg 1990, Hirschberg 1990, Horne 1991, Monaghan 1993). The majority of investigators discuss only the placement of nuclear accent (or "nuclear stress", "sentence accent", or "sentence stress" as it is variously called) and leave aside any discussion of prenuclear accents. Some investigators also mention the placement of prenuclear accents as well as nuclear accents (e.g. Gussenhoven 1983, 1984, Selkirk 1984, Pierrehumbert & Hirschberg 1990, Hirschberg 1990). A prenuclear accent may be on a word because of the phonological constraint to have a pitch target early in an utterance (e.g., Bolinger 1981, Shattuck-Hufnagel 1995) or because it genuinely contributes to the information being conveyed. None of these theories distinguish between accent types in their accounts. The theories try to account for accent placement in terms of syntactic principles, semantic/pragmatic principles, or a combination of the two. When the nuclear accent falls on the word in the sentence that it "should", then the sentence has "normal (or regular) sentence stress". Normal sentence stress generally falls on the last accentable lexical item of the sentence or phrase. For example, in our example sentence *The girl admired the canyon from a distance*, the "normal sentence stress" version of the sentence is the one illustrated in Figure 2 in which the word *distance* has the nuclear accent or "sentence stress". When the nuclear accent falls somewhere other than on the last accentable lexical item where it "should" fall, a word which "should" have been accented has been "deaccented", or another word has "contrastive stress" on it. For example, in the version of the sentence illustrated in Figure 3, *distance* is deaccented and *canyon* has the nuclear accent. This version could be an answer to the question *Did the girl admire the painting from a distance?*, thereby contrasting the correct answer *canyon* with the incorrect information *painting*.

One way of understanding the relationship between accent status and informational prominence of words in a sentence is related to what a speaker chooses to emphasize (focus) or de-emphasize in a particular

utterance of a sentence. The more a speaker emphasizes a word in a sentence using intonation (rather than, e.g., rewording by using different syntactic constructions to emphasize a word), the more prominent that word is acoustically, in the ways described above, and the more prominent it is informationally. Placing nuclear accent on a word emphasizes it, and omitting an accent de-emphasizes it.

In most of the descriptions, accent placement goes hand in hand with focus, which is in turn intimately related to "new" information (vs. "given" or "old" or "shared with the listener" information). Many researchers have used Chafe's (1974) working definitions of "given" and "new" information. According to Chafe, contextually "given" information has already been mentioned earlier in the same or preceding sentence. All other information is "new". This definition is equivalent to previous mention in a discourse, which not all researchers accept (see e.g. Fuchs 1984).

Researchers define focus in terms of emphasis or presuppositional sets, that is, what a listener already presupposes to be true. Halliday (1967: pp. 203-4) says that informational focus is one kind of emphasis. The speaker decides what part of the message the listener should interpret as informative and marks it with nuclear accent (Halliday's "tonic"). "What is focal is 'new' information, in the sense that the speaker presents it as not recoverable from the preceding discourse." (Halliday: p. 204) Unmarked focus (unmarked location of nuclear accent) comes from placing the nuclear accent on the final accentable lexical item; this assigns the function "new" to the constituent but leaves the status of the remainder unspecified. Marked focus is any other location of the nuclear accent; this assigns "new" to the focal constituent and "given" to the rest of the phrase, including the postnuclear unaccented section. Jackendoff (1972) and Enkvist (1979) discuss focus in terms of presuppositional sets. The speaker or listener presupposes that something is true (and hence "given"), for example, that someone admired the canyon from a distance. Then in answer to the question *Who admired the canyon from a distance?*; the sentence *The GIRL admired the canyon from a distance* marks *girl* as the focus and the new information. (This is the version of the sentence in Figure 1). The sentence is marked focally because *girl* is non-final; *distance* and *canyon* are also accentable lexical items. However, the sentence is not marked given the context because it is the answer to a question that presupposes someone admired the canyon from a distance. Enkvist (p. 142) says that the basic function of marked focus location is to "evoke a presuppositional set and present one of the set members as new information." In this case, then, only *girl* is new information, perhaps in contrast to the possibility that it was a boy who admired the canyon.

Halliday (1967: p. 207) gives an accent placement rule for nuclear accent (his "tonic") as a focus rule: "The tonic falls ... on the last accented syllable of the item under focus." Bolinger (1972) gives a semantic theory of accent placement which says that accent goes on the "point of information focus" in the sentence and highlights that information. Jackendoff (1972: p. 237), however, formulates the highest stress that comes from focus as being a syntactic rule in the set that assigns normal stress to a sentence: "If a phrase P is chosen as the focus of a sentence S, the highest stress in S will be on the syllable of P that is assigned highest stress by the regular stress rules."

Ladd (1980) says that "normal stress" is the accent placement that leaves focus broad, over a large domain, or unspecified as to how large a domain is focused. According to Ladd (1980: p. 77), "Accent -- in general -- goes on the rightmost accentable item *of the focus constituent* " [italics in original]. All other things being equal, nuclear accent comes late in a sentence and the sentence has "normal stress". However, if an early constituent of the sentence is focused, then it receives the nuclear accent, and the word which otherwise would have received the nuclear accent is "deaccented". For example, in *The GIRL admired the canyon from a distance*, *distance* is deaccented because *girl* receives the nuclear accent. Pierrehumbert & Hirschberg (1990: p. 286) say that the accenting or not accenting of items in general is associated with the speaker's desire to indicate the relative salience of accented items in a discourse. More salient items are more important in the informational structure of the discourse. According to them, accent placement gives a word phonological and informational salience (1990: pp. 288-289). Accented words are particularly important to the meaning of a sentence and/or discourse. Bolinger (e.g., 1965, 1981) and Horne (1985) view nuclear accent as adding prominence to the word stress and reject the notion of "deaccentuation" to describe a word that is not nuclear accented, even though in a "normal stress" production it would be nuclear accented. For them, nuclear accent location is assigned to a word in a sentence, not subtracted from a word in another production of the sentence.

In the "normal sentence stress" version of our example sentence, uttered perhaps as the answer to the out-of-the-blue question *What happened this afternoon?* , the speaker makes no effort to specifically emphasize or de-emphasize *girl, canyon*, or *distance* in the sentence. However, because they are accented, *girl, canyon*, and *distance* are informationally prominent, and *distance* is the most informationally

prominent because it has the nuclear accent. In addition, the word *distance* has "broad focus". In the answer to the question *What did the girl admire from a distance?; The girl admired the CANYON from a distance*, the speaker de-emphasizes *distance* by deaccenting it (*distance* is unaccented) and emphasizes *canyon* by placing the nuclear accent on it. In this case, the word *canyon* is more informationally prominent than in the "normal sentence stress" version, and the word *distance* is less informationally prominent.

To summarize briefly, this study posits a hierarchy of structural prominence for the three accent statuses. Nuclear accented words are structurally more prominent than prenuclear accented words, which are structurally more prominent than unaccented words. In addition, the three accent statuses seem have the same ordering in a hierarchy of informational prominence. The experiments test whether this theory of "three accent statuses" corresponds with our expectations about differences in acoustic prominence, perceptual prominence, and informational prominence.

1.4 Pitch range, pitch level, and prominence

Most theories of intonation are concerned in one way or another with modeling phrasal pitch range variations and pitch level targets on words within sentences. Many theories of intonation view pitch range as falling outside of the realm of phonology proper and within the realm of paralinguistic descriptions, pragmatics, and discourse analysis (for example, see Ayers (1994) for a review and discussion of the role of pitch range in mirroring discourse structure). Even so, many of these phonological theories address how specific intonation contours are affected by differences in pitch ranges. Of particular interest here is connection between pitch range and the non-structural prominence of "paralinguistic" prominence that can be given to an entire utterance, such as by "speaking up" to convey greater emotional involvement. Also of interest are the findings relating perceptual prominence of accents to their pitch levels. The relationship of pitch level to perceptual prominence and "paralinguistic" prominence relates to the question of the relationship between structural prominence and pitch accent type, as we will discuss further in Section 1.5.

1.4.1 Phonological theory

The height of the fundamental frequency peak (or valley) on an accented word in a phrase depends upon the overall pitch range of the phrase, the amount of emphasis on the accented word, and the target pitch level of the accent type. The prominence of an accented word depends upon the amount of local emphasis on the word and its structural prominence, i.e., whether it is a prenuclear or nuclear accent (e.g., Pierrehumbert 1980: pp. 19-20). Teasing apart the individual contributions to fundamental frequency heights and prominence values is not easy. One step in the process is measuring the fundamental frequency peaks on accented words and determining the phrasal pitch ranges. Prominence itself cannot be measured directly from the acoustic signal, although as we have seen, it is correlated with acoustic characteristics such as duration and intensity (and fundamental frequency level once accent type is accounted for). The fundamental frequency of an accented word can be measured at the midpoint of the vowel of the accented syllable. Such a measurement minimizes segmental perturbations and provides a consistent measurement criterion (Hirschberg 1990, Terken & Hirschberg 1994). An estimate of the pitch range of a phrase or utterance can be made by measuring the fundamental frequency of the peaks on accented words and the valleys at phrase boundaries. That is, in declarative utterances that have high tone peaks and low tone valleys, the difference between the accent peak maximum and the phrase boundary minimum is an estimate of the pitch range of a phrase.

Most recent theories of intonation view pitch range as independent of the phonological description of the intonation pattern of a phrase. However, descriptions such as Trager & Smith (1951) did not treat them as independent. They gave different numbers to different pitch level "phonemes", 1 for the lowest and 4 for the highest, which effectively phonemicized combinations of pitch range and intonation contours as part of the inventory of pitch movements that could appear within a phrase. Thus contours which had the same general shape but differed in how high the pitch was at the peak of the contour would be transcribed with different pitch levels, such as three different declarative falling intonation contours being transcribed as 41, 31, and 21. Other descriptions express the similarity between these three contours by saying that they have the same intonation contour but are realized in different overall pitch ranges (e.g. Bolinger 1951, Crystal 1969, Pierrehumbert 1980, Liberman & Pierrehumbert 1984, Ladd 1980, Ladd 1993a).

1.4.2 Experimental results

The overall shape of an intonation contour is generally preserved through changes in pitch range, and pitch range appears to be

continuously variable in expressing degrees of overall emphasis, involvement, and emotion, that is, in expressing the "paralinguistic" prominence of a sentence. Pierrehumbert (1980, Liberman & Pierrehumbert 1984) had speakers read sentences with different levels of "overall emphasis", "speaking up" from a mumble to a shout, and found that while the fundamental frequency range used expanded from least to most overall emphasis, the intonation contours maintained their overall shape. Bruce (1982a, 1984) found for Swedish that the pitch range used by the speaker also expanded when sentences were read in different levels of "involvement" (detached, neutral, and involved), but the overall shape of a contour remained constant. In studies looking at signals of emotion in German, fundamental frequency range had a continuous effect on judgments of scales involving arousal, such as e.g. "involved", "aroused", and "annoyed", with higher fundamental frequency signaling higher arousal (Scherer et al. 1984, Ladd et al. 1985). Traunmüller & Eriksson (1995) found for Swedish that listeners rated speech with larger fundamental frequency excursions to be more lively than ones with smaller movements. Hirschberg & Ward (1991) found that greater pitch range invoked an "incredulity" reading as opposed to an "uncertainty" reading for the L*+H pitch accent which they attribute to the greater pitch range from greater speaker involvement in the "incredulity" reading. These different involvement/emotional scales expressing "paralinguistic" prominence surely have a connection to acoustic prominence such that the greater the involvement and therefore the larger the pitch range, the more prominent the words in the utterance are relative to less involved utterances. However, studies such as these do not speak to the issue of relative prominence of different words in the same utterance.

Relative perceptual prominence of words within a phrase has been investigated in several studies with English and Dutch listeners. These studies had subjects specifically evaluate perceptual prominence of accents, and in general they found that the higher the fundamental frequency was, the more prominent the accent was perceived to be. The studies used the baseline of the contour (the fundamental frequency minima) or a more abstract reference line as the reference for prominence. They all used reiterant speech (i.e., repeated nonsense syllables) instead of sentences with real words. The sentences had intonation contours appropriate to signaling two accented words within the phrase, and the fundamental frequency peaks of the accented words were manipulated (the peak of the first accented word called P1, second P2). Listeners judged which of the two peaks was higher in frequency, adjusted the frequency of P2 so that the accent had equal perceptual prominence as the first accent peak, or rated the prominence of the second accent. Pierrehumbert (1979) synthesized two accented peaks on a declining baseline. In the first experiment, she asked English listeners to judge which of the two accented syllables was higher in pitch; there was a difference in amplitude of the two accented syllables. She found that when they sounded equal, P2 was actually lower. Taking into account the manipulation of amplitude she found that increasing amplitude gave impressions of higher pitch. In a second experiment, listeners were able to judge independently which was higher in pitch and which was higher in amplitude relatively successfully. Therefore, she interpreted the results of the first experiment as listeners judging prominence (as cued by pitch and amplitude) instead of judging pitch alone.

Based on these and the results of pitch range with speakers "speaking up", Liberman & Pierrehumbert (1984) developed an explicit model of prominence, pitch range, and downstep for English. For them, the prominence of an individual accent was determined with respect to the "reference level" of a pitch range and any expected phonological downstep relations. The amount an accent was downstepped was taken to be a multiplicative constant. The "reference level" was somewhere in the middle of the pitch range used by the speaker and was dependent upon the degree of overall emphasis, with higher reference levels for higher degrees of overall emphasis. Downstep was expressed as an exponential decay from one accent to the next once the "reference level" asymptote was subtracted. The downstep constant was taken to be independent of the overall pitch range of an utterance. The peak pitch height that represented equal prominence was compressed locally from one downstepped accent to the next as determined by the downstep constant. As long as the peaks of the accents followed the curve determined by the downstepping constant, the accents were assumed to be equally prominent.

In experiments with Dutch listeners, a 1.5 semitone difference in excursion size from baseline to peak (about 16 Hz at 125 Hz) was necessary to cause a perception of difference in prominence between the two peaks ('t Hart 1981, Rietveld & Gussenhoven 1985). Terken (1991) set out to test two theories of prominence dependence upon fundamental frequency (with Dutch listeners). In one, prominence was related to relative magnitude of fundamental frequency changes (as 't Hart and Rietveld & Gussenhoven), and in the other prominence was related to the relative frequencies of two f0 maxima. He used a declining baseline and a level baseline. Subjects adjusted P2 to be lower with the declining baseline than with the level baseline. He also found, as Pierrehumbert

(1979) did, that listeners had different strategies for judging prominence and pitch. When subjects were asked to adjust P2 to the same prominence they adjusted it to a lower frequency value than when they were asked to adjust it to the same pitch. Neither the excursion size relative to the baseline nor the relative height of the peaks proved to be a very accurate predictor of prominence. Recently Ladd and Terken have reanalyzed the results of the experiment to try to find a reference value that better accounts for prominence (Ladd 1993c, Terken 1993). Terken concluded that the role of reference for prominence is played by the bottom of the speaker's range and that the distance between the actual peaks and valleys also have to be incorporated into the equation to account for prominence. His decision to take the bottom of the range as the reference differed from that of Pierrehumbert and colleagues who use an abstract reference line in the middle of the range (e.g. Liberman & Pierrehumbert 1984). The connection between baseline declination and downstep is not very clear in these studies, however, so it is difficult to relate the results to predictions about the prominence of downstepped accents.

In another experiment with Dutch listeners, Gussenhoven & Rietveld (1988) found that increases in pitch range of P1 caused P2 to be perceived as more prominent even when P2 was unchanged. Ladd et al. (1994) replicated this effect with English listeners when the height of P2 was moderate or "normal" (our "regular nuclear accent"), but when the pitch range on P2 was high or "emphatic" (our "expanded pitch range nuclear accent") then increases in pitch range on F1 caused P2 to be perceived as less prominent. Ladd et al. interpreted this as an interaction between overall pitch range of an utterance and local prominence of an accent. In the case where P2 was non-emphatic, higher P1 made the overall pitch range higher and so P2 was judged more prominent. In the emphatic case, a low P1 set the scene for an even more emphatic P2 than did a high P1 which downplayed the emphasis on P2 since the whole phrase was in a high pitch range. Ladd et al. (1994, Ladd 1993a) described these differences by separating the overall pitch range of an utterance from the pitch range of an individual accent. An emphatic accent can then be realized with a "raised peak", similar to our "expanded pitch range" nuclear accent, in either a low overall pitch range or a high overall pitch range, and the degree of prominence of the emphatic accent depends upon overall pitch range of the other accents. The local prominence of an accent within a phrase and the pitch range (and resulting "paralinguistic" prominence) of the phrase are involved in a complex relationship, and it is difficult to separate one from the other.

1.5 Accent type and prominence

In theories such as the "three accent status" theory assumed here, all types of nuclear accent are considered to be equally structurally prominent. However, it does not necessarily follow that just because all types of nuclear accent are equally structurally prominent, i.e., that they are all nuclear accents, that they are also equally informationally prominent, perceptually prominent, and/or acoustically prominent. Therefore, the experiments in this study investigate the acoustic prominence, perceptual prominence, and informational prominence of three accent types[2]: regular nuclear accented, downstepped nuclear accented, and expanded pitch range nuclear accents. These three nuclear accent types are all "peak accents", meaning that the tonal target of the pitch accent is realized relatively high in the speaker's range, not low in the speaker's range. This study does not address the relative prominence of nuclear accents realized low in the speaker's range (recall the earlier discussion of nuclear accents realized low in the speaker's range).

Although the regular, downstepped, and expanded pitch range nuclear accents are all peak accents, each accent type has a unique, phonologically specified tonal target within the phrasal pitch range. Given the same overall pitch range for a phrase, downstepped nuclear accents have lower tonal targets than regular nuclear accents, and expanded pitch range nuclear accents have higher tonal targets than regular nuclear accents. We can see this in Figures 5 - 7 which illustrate the three types of nuclear accent on the sentence *The poet admired the canyon.*[3] These sentences were used as materials in Experiment 3. Figures 5, 6, and 7 have regular, downstepped, and expanded pitch range nuclear accents, respectively, in late sentence position. For comparison's sake, Figure 8 has a regular nuclear accent in early sentence position.

Figure 5 shows the sentence with regular nuclear accent in late sentence position, the "normal sentence stress" version of the sentence. Both *poet* and *canyon* are accented, but neither is specially emphasized or focused. As in Figure 2, which also has regular nuclear accent in late sentence position, the fundamental frequency is relatively high on the accented words. This sentence could be the answer to the out-of-the-blue question *What happened this afternoon?* or the answer to the yes-no question *Did the poet admire the canyon?* in which no part of the sentence requires special emphasis or focus. That it, there is broad focus on the sentence as a whole.

Figure 6 shows an example of the downstepped nuclear accented version of this sentence. Again, both *poet* and *canyon* are accented, and neither is specially emphasized or focused. The downstepped nuclear accent is downstepped in pitch relative to the preceding prenuclear accent. That is, the pitch peak on the nuclear accent is not as high as that of the preceding accent. As with the regular nuclear accent version of the sentence, this sentence could be the answer to the questions *What happened this afternoon?* and *Did the poet admire the canyon?* However, the meaning of the answer is not the same with the two different nuclear accent types. In contrast to the regular nuclear accent version, the downstepped nuclear accent version means something like 'You should know this already, because it happens every afternoon; the poet admired the canyon' or 'Of course, as usual, the poet admired the canyon. Why did you even bother to ask me?'. That is, the downstepped version conveys a sense of "expectedness" from an explicit link to "old information" already shared between the speaker and the hearer.

Figure 7 shows the sentence with expanded pitch range nuclear accent in late sentence position. An expanded pitch range nuclear accent occurs in a version of the sentence *The poet admired the canyon* in which *canyon* is specially emphasized or has "contrast" on it, for example as the answer the question *Did the poet admire the tree?*; *No. The poet admired the CANYON.* Notice that the fundamental frequency is much higher on the expanded pitch range nuclear accent than on the prenuclear accent, and that the fundamental frequency is low before the high of the accent. The expanded pitch range nuclear accent version of the sentence gives special informational prominence to the nuclear accented word, much more than does a regular nuclear accent.

For comparison's sake, Figure 8 shows a version of this sentence in which *canyon* is unaccented; the only word that is accented in the sentence is the early sentence position word *poet.* As in Figures 1 and 3, the fundamental frequency is low after the nuclear accent. This version of the sentence de-emphasizes (by deaccenting) the late sentence position word *canyon.* It could be the answer to the question *Did the baker admire the canyon?*, in which the questioner already knows that someone admired the canyon.

This study hypothesizes that expanded pitch range nuclear accents are more prominent than regular nuclear accents and downstepped nuclear accents are less prominent than regular nuclear accents. The expanded pitch range nuclear accents have a higher level of emphasis than the regular nuclear accents, and so by definition they are more informationally prominent than the regular nuclear accents. The downstepped nuclear accent type is less informationally prominent than the regular nuclear accent type because the downstepped nuclear accent type signals that it is "old" information, information that the speaker and listener already share. This study investigates whether the relationship that holds for informational prominence among the three accent types holds for acoustic prominence and perceptual prominence as well. Notice that the order of the fundamental frequency target levels for the three accent types parallels the informational prominence relationship. The results of the experiments investigating the relationship between fundamental frequency height and the perceptual prominence of accents, as well as the results of studies of paralinguistic prominence, also parallel the fundamental frequency heights in the three accent types. Notice also that the duration of the aspiration noise of the /p/ is longer for the early nuclear accent than the prenuclear accents, and that the duration of the aspiration noise of the /k/ is longest in the expanded pitch range nuclear accent and shortest in the unaccented token. The difference in aspiration duration hints that there is a difference in acoustic prominence for these accent types; we will give a more complete characterization of the acoustic properties of the accent types in Chapter 2.

Accent placement was how people like Vanderslice and Ladefoged (1972), Ladd (1980), Selkirk (1984), and Beckman (1986), etc. reconciled intonational description with such things as the Nuclear Stress Rule and the fact that L* accents can be prominent, not just H* accents. In these descriptions, all phrase final accents belong to the same category of nuclear accent and have the same level of (structural) prominence, independent of the type of accent. That is, there is no systematic correspondence between nuclear accent type and prominence; all nuclear accent types are assumed to be equally prominent. However, there is a puzzle in that nuclear accent alone done does not seem to adequately describe the prominence relationships in all sentences. Bolinger (1986), for example, says that although the unmarked sentence intonation has the most prominent accent last, the last accent need not be the most prominent or most important accent. He gives the example *I'm gonna hâve to get âfter that húsband of mine*, in which the "main" accent is the accent on *after*, and *husband* is also accented but downstepped relative to the main accent (p. 50). Horne (1991) also suggests that a downstepped accent is metrically weaker than a non-downstepped accent.

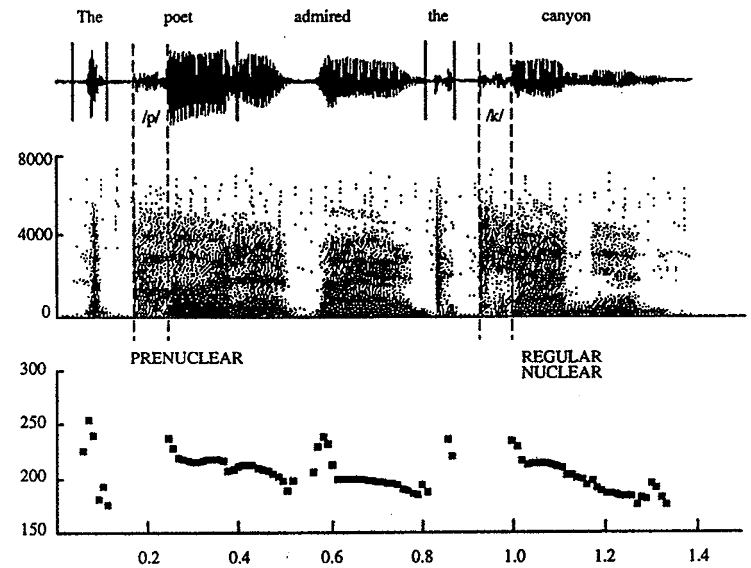


Figure 5. Late nuclear accent placement: regular nuclear accented and early prenuclear accented. Time aligned display (in seconds) of speech waveform, spectrogram (in Hz), and fundamental frequency contour (in Hz). The VOTs of word initial /p/ and /k/ are between dashed lines.

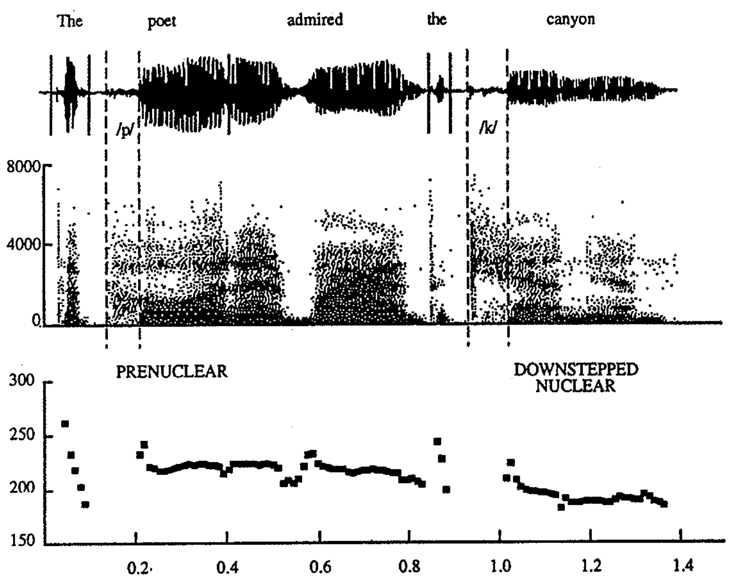


Figure 6. Late nuclear accent placement: downstepped nuclear accented and early prenuclear accented. Time aligned display (in seconds) of speech waveform, spectrogram (in Hz), and fundamental frequency contour (in Hz). The VOTs of word initial /p/ and /k/ are between dashed lines.

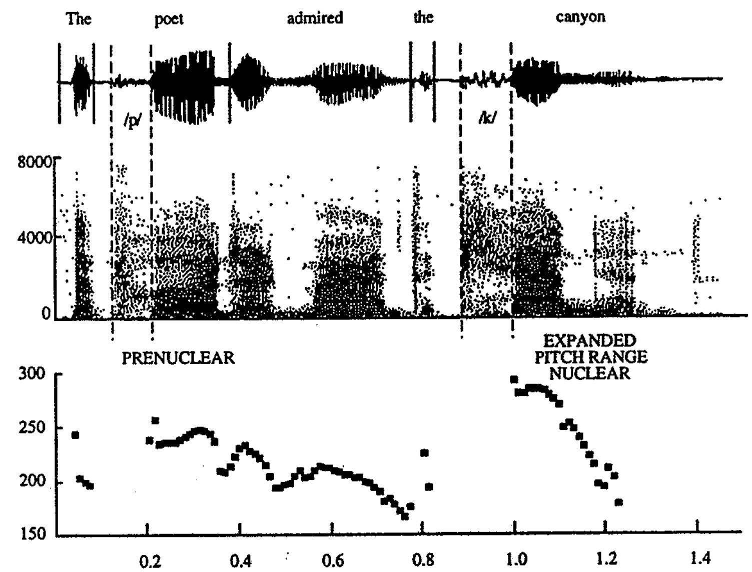


Figure 7. Late nuclear accent placement: expanded pitch range nuclear accented and early prenuclear accented. Time aligned display (in seconds) of speech waveform, spectrogram (in Hz), and fundamental frequency contour (in Hz). The VOTs of word initial /p/ and /k/ are between dashed lines.

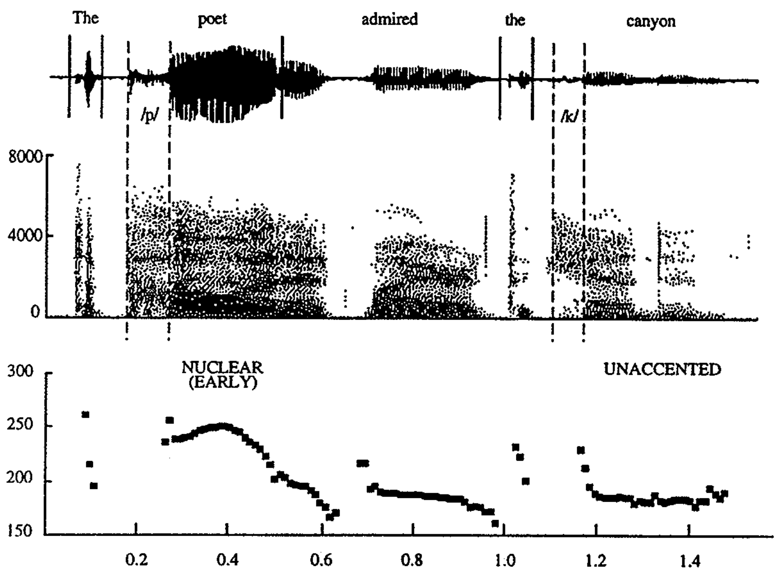


Figure 8. Early nuclear accent placement: regular nuclear accented and late unaccented. Time aligned display (in seconds) of speech waveform, spectrogram (in Hz), and fundamental frequency contour (in Hz). The VOTs of word initial /p/ and /k/ are between dashed lines.

Because the expanded pitch range nuclear accent involves a higher degree of "emphasis" or "focus" on the nuclear accented word than does the regular nuclear accent, the expanded pitch range nuclear accent is informationally more prominent than the regular nuclear accent. However, there is some disagreement about whether the expanded pitch range nuclear accent is a distinct type of nuclear accent from the regular nuclear accent. What we are calling expanded pitch range nuclear accent has been called "contrastive stress". The term contrastive stress, however, has been used to refer both to a difference in accent placement (what we are calling "early nuclear accent" placement) and to a local difference in degree of emphasis (what we are calling "expanded pitch range nuclear accent" in late sentence position). Trager and Smith (1951) used pitch level 4, an "Overhigh" tone, to represent a very high pitch level. Bolinger (1951), however, strongly criticized the idea of distinguishing a very high pitch level (4) from a regular high pitch level (3) and argued that because these pitch levels were pitch "phonemes", contours involved them such as two falling contours, for example 31 and 41, are phonemically distinct, and therefore they should not share any commonality in meaning, while in fact there are commonalities in meaning. Instead he argued for pitch "configurations" like "fall" and "rise" instead of pitch levels. Further, Bolinger (1961) said that contrastive stress is not phonetically definable, but rather is the same as highlighting a word with a pitch accent but to the more extreme end. Bolinger would presumably say that what we are calling regular nuclear accent and expanded pitch range nuclear accent are the same except for the degree of emphasis. Recently, Ladd (1994, Ladd et al. 1994) has suggested that the distinction between regular high pitch accents and "overhigh" or "emphatic" pitch peak accents should be treated similarly to how Trager & Smith treated them, as a difference in pitch range on the accented words. This study represented the differences between the two as a difference in accent type (H* vs. L+H*), as Pierrehumbert (1980) and the ToBI transcription system generally do (see references and description below).

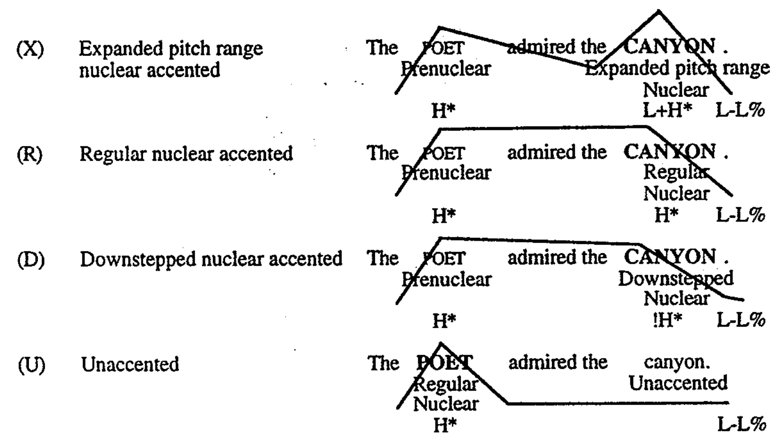
Cooper et al. (1985) found that in each position besides final, a word with contrastive stress had a higher f0 peak as compared to a neutral non-contrastive version of the sentence (where contrastive stress or "focus" was given by an answer to a question that specifically contrasted that word with an alternative; e.g. *Did Chuck like the letter or the present that Shirley sent to her sister? Chuck liked the PRESENT that Shirley sent to her sister.*) After the contrastive stress/focus f0 was low and level to the end of the sentence. By contrast, Couper-Kuhlen (1984) said that contrastive stress does not have a single phonetic realization and is not simply a pitch configuration on a single syllable.

Only a small subset of English intonation was considered in this study, and it was transcribed following the tonal component of the ToBI transcription conventions (Tones and Break Indices), the most recent version of Pierrehumbert and her colleagues' intonational system (Silverman et. al 1992, Beckman & Ayers 1994, Beckman & Hirschberg 1994, Pitrelli, Beckman, & Hirschberg 1994). All of the sentences used in the experiments were one phrase declaratives and ended with the low tone phrase accent-boundary tone combination L-L%. The three types of nuclear accents that this study addressed were all peak accents, which means that the tonal targets of the accents are relatively high in the speaker's range. The commonality of the high tonal target is indicated in the ToBI transcription symbols for these accent types (regular nuclear accent: H*, downstepped nuclear accent: !H*, expanded pitch range nuclear accent: L+H*). The high tone symbol H followed by * shows that it is a high tone which is associated with the stressed vowel of the accented word. The symbol '!' marks the downstepping of accents explicitly on the affected accents, as the feature system that Ladd (1983, 1993b) advances. The expanded pitch range nuclear accent was transcribed as L+H*, because in the materials used in these experiments, in addition to the associated high tone target of the accent there was also a low tone component to the accent just before the high tone component. Not all expanded pitch range accents have such clear low tone components, and those cases are transcribed in the ToBI system as H* in a higher than average pitch range. These two alternative transcriptions reflect a variation in the phonetic realization of expanded pitch range nuclear accents in English.

Table 2 shows a summary of the accent statuses, nuclear accent types, schematic intonation contours, and intonational transcriptions for the four intonation patterns used to compare the three types of nuclear accent in late sentence position with the early nuclear accent placement pattern. In late sentence position, the four accent status contrasts are expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and unaccented.

The categorical view of prominence predicts that the nuclear accented categories will be indistinguishable from one another on the different scales of prominence, and that these values will be well above those of the unaccented category (Pierrehumbert 1980, Selkirk 1984). This reflects the fact that the level of stress (structural prominence) associated with nuclear accented words is two levels above that of unaccented (but

Table 2. Accent status in early and late sentence position of four intonation patterns. The labels refer to the late sentence position accent status and accent type. The first three patterns have late nuclear accent placement, and the fourth pattern has early nuclear accent placement.



Notes. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent. The intonational transcriptions follow the ToBI conventions.

stressed) words and that each level of stress has a single structural prominence value.

The view of English intonation that Bolinger and Horne advance says that the prominence of the downstepped nuclear accent will be less than that of the regular nuclear accent, but it does not say how much less prominent it will be. The hypothesis advanced here is that these four categories have systematic prominence relationships with one another, and that from most to least prominent (acoustically, perceptually, and informationally) they are expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and post-nuclear unaccented. This leaves as an open question for investigation how close to one another in prominence the categories are. That is, are these four categories nearly equally spaced on some scale of prominence, for example, is downstepped nuclear accented midway between regular nuclear accent and unaccented, or do the nuclear accent types cluster closely together and have much higher prominence than the unaccented category?

In a description of sentence accents in German (the final accent in the sentence, similar to nuclear accent in English), Kohler (1992, 1994) proposed a categorization that is very similar to the hypothesis advanced here about the prominence levels of nuclear accented and postnuclear unaccented words. Kohler describes German as having four levels of sentence accent: reinforced, neutral, partially deaccented, and completely deaccented. His description is in terms of amount of emphasis or focus on the word with sentence accent, so his description is one of informational prominence. The default sentence accent is "neutral", similar to our regular nuclear accent. "Reinforced" is a sentence accent that provides special emphasis to a word, similar to our expanded pitch range nuclear accent. "Completely deaccented" is the same as our unaccented. Finally, "partially deaccented" is a sentence accent which provides some emphasis to a word, but not as much as the default neutral sentence accent. This description of partially deaccented is similar to Horne's (1991) description of downstepped nuclear accent. Kohler describes German as having four different levels of sentence accent, and this seems to predict four different levels of informational prominence, and following from that, differences in acoustic prominence and informational prominence as well. Furthermore, this categorization seems to imply that the prominence of the partially deaccented sentence accent falls midway between that of the neutral and completely deaccented levels of sentence accent. In the final chapter we will compare these predictions to the results for English.

Bruce (e.g. 1977, 1982a) described Swedish intonation as being comprised of a sequence of separately identifiable prominence-lending pitch movements: word accents, phrase accents, and boundary tones. This description of Swedish strongly influenced the Pierrehumbert-style description of English intonation. Word accents are located on specific words, and each accent is one of the two lexically specified kinds of accent, which differ in the alignment of high and low tones to the accented syllable. Words are grouped into phrases which are marked by boundary tones. The most prominent accent in a phrase is the focal accent. In standard Swedish, the focal accent is phonologically marked by a high tone (called the phrase accent) following the tones associated with the word accent. In the unmarked case, a neutral phrase has the phrase accent located in phrase final position, as a focus final sentence (Bruce 1977). However, focal accent may be located earlier in the phrase, and some phrases have no focal accent at all. That is, no word in the sentence is phonologically marked as being the focus, although this is much less common than marking a word a being the focus. When the focal accent is

not the final accent in a phrase, all accents following the focal accent are successively downstepped (e.g. Bruce 1977, 1982a, 1982b, 1984). Thus, in Swedish the final accent in a phrase has no special status in and of itself. The final accent in a phrase may be the focal accent, as it is in a neutral sentence or one with focus on the last accented word, or it may be a post-focal accent. The downstepping of accents after the focal accent conveys the pattern of emphasis of the phrase and the reduced prominence of post-focal words in a phrase. Downstep in English may convey something similar.

In summary, this study questions whether these three types of nuclear accents are equal with respect to prominence, as the cover term "nuclear accent" would suggest, or whether expanded pitch range and downstepped nuclear accents have systematically different levels of prominence from regular nuclear accents.

1.6 Preview of the experiments

As mentioned in the earlier sections of this chapter, the experiments in this study investigated the prominence of three levels of stress due to accentuation (nuclear accented, prenuclear accented, and unaccented) and three kinds of nuclear accent (regular, downstepped, and expanded pitch range). The goal of this study is to determine how the prominence values of the categories relate to one another. There are two aspects to this, production by a speaker and perception by a listener. The first aspect is addressed by the question, are there systematic acoustic/phonetic properties that a speaker produces to distinguish the categories? Earlier production studies have found that there are differences in syllable duration and the local articulatory prominence of segments. Chapter 2 presents a summary of the acoustic characterizations of the materials in the experiments to confirm that the materials conformed to my expectations given earlier production studies. The second aspect is addressed by the question, does a listener perceive differences in prominence in these categories? The experiments in Chapters 3 through 5 demonstrate what is perceptually important to a listener. The experiments show what affect the prominence differences of the categories have on different aspects of sentence processing, including lexical access, attention, and memory. Comparing what the speaker produces and what the listener perceives and treats as different gives a relatively complete picture of the different aspects of prominence associated with the theoretical intonational categories.

Tables 1 and 2 above summarized the intonation patterns of the sentence materials used in the experiments. Table 1 showed the three intonation patterns used in Experiment 1. In Experiment 1, the sentences had one, two, or three accents, depending upon the location of nuclear accent. This experiment contrasted the accent statuses nuclear, prenuclear, and unaccented in medial sentence position (with medial, late, and early nuclear accent placement, respectively). In the materials in this study, nuclear accent placement in early or medial sentence position was focally marked, and nuclear accent placement in late sentence position was focally unmarked, or "normal".

Table 2 showed the four intonation patterns used in the other five experiments. The sentences had either early or late nuclear accent placement. For early nuclear accent placement (a marked location for the nuclear accent), the sole accent was on the head noun of the subject noun phrase. For late nuclear accent placement (the unmarked location for the nuclear accent; normal sentence stress), the prenuclear accent was on the head noun of the subject noun phrase and the nuclear accent was on the head noun of the object noun phrase. The two different nuclear accent placements allowed for accent status contrasts in both early and late sentence position. In early position, the contrast was between prenuclear accented and nuclear accented. In late position, the contrast was between nuclear accented (of three different accent types) and postnuclear unaccented.

Natural productions of sentences were chosen over synthesized speech because the intonational categories themselves were under investigation. Sentences were produced by a speaker experienced in reading sentences with particular intonation patterns on demand (the author). This ensured that the sentences were typical examples of the patterns because it relied on human production and not the success of a synthesis system. It also provided the most natural sounding stimuli for use in perception experiments. The experiments were highly controlled, both in terms of the stimuli sentences used and the laboratory setting in which they were investigated. However, the results obtained from these controlled experiments should be relevant to speech produced outside the laboratory.

Three experimental tasks were used to test listeners' perception of sentences with the different prominence categories: phoneme monitoring, question-answering, and cross-modal naming. All three tasks are indirect measures of sentence processing. The data are measures of the time it takes for subjects to perform the tasks. In the phoneme monitoring task, reaction time is measured from when the target phoneme is articulated in the sentence to when the subject presses a button to indicate that the

phoneme was detected. In the question-answering task, reaction time is measured from the presentation of the question to when the subject presses a button to indicate a 'yes' or 'no' response. In the cross-modal naming task, reaction time is measured from when a target word is displayed on the screen to when the subject starts reading the word aloud.

Chapter 3 presents results of three phoneme monitoring experiments. The experiments asked whether the differences in structural prominence that affected acoustic prominence also affected the perceptual prominence as reflected by how quickly listeners could identify that a phoneme occurred in a target word in the sentence. Experiment 1 contrasted the accent statuses nuclear, prenuclear, and unaccented in medial sentence position, avoiding the non-comparability of the reaction times to the accent statuses in different sentence positions. Experiment 2 compared regular nuclear accented versus non-nuclear accented in early and late sentence position. The target words in the two sentence positions had one of three accent status categories: (regular) nuclear accented, prenuclear accented, or postnuclear unaccented. In early position the contrast was between nuclear and prenuclear accented, and in late position the contrast was between nuclear and postnuclear unaccented. Experiment 3 compared prenuclear accented and early nuclear accented in early sentence position and regular, downstepped, and expanded pitch range nuclear accents and unaccented in late sentence position. Specific comparisons were made to see if the predicted prominence relationships occurred, from most to least prominent: expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and unaccented.

Chapter 4 presents the results of a question-answering experiment. The experiment asked whether nuclear accent placement (early or late sentence position) and type of nuclear accent (regular, downstepped, and expanded pitch range) affected the relative attention paid to different parts of the sentence, a reflection of informational prominence. Yes-no questions were presented after the sentences. The questions were true, false because of subject mismatch, and false because of object mismatch with respect to the stimulus sentence. Any differences in the speed of answering the question were attributed to how the intonation patterns directed the listener's attention to different parts of the sentence.

Chapter 5 presents the results of two cross-modal naming experiments. The experiments asked whether accent status had an effect on lexical access of target words over and above that of the semantic relatedness effect. These experiments also touched secondarily on the issue of "normal" nuclear accent placement, in as far as the results showed differences between sentences with nuclear accents in early and late sentence position. The experiments compared regular nuclear accented versus non-nuclear accented in early and late sentence position, as in Experiment 2. The target words in the two sentence positions had one of three accent status categories: (regular) nuclear accented, prenuclear accented, or postnuclear unaccented. In early position the contrast was between nuclear and prenuclear accented, and in late position the contrast was between nuclear and postnuclear unaccented.

Chapter 6 discusses the main findings and presents some conclusions that can be drawn from the study.

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[1] Note, however, that "final lowering" sometimes makes a nuclear H* accent lower than a prenuclear H* accent.

[2] Although the accent types were only looked at in nuclear position in this study, Pierrehumbert's theory posits the same inventory of pitch accents for prenuclear position.

[3] Recall from Section 1.2 that the regular nuclear accent occurred in the example sentence *The girl admired the canyon from a distance*, and most clearly in Figure 3, the version in which *girl, canyon*, and *distance* were all accented but none were specially emphasized.

CHAPTER II

MATERIALS USED IN THE EXPERIMENTS:

AN INTONATIONAL AND ACOUSTIC CHARACTERIZATION

2.1 The accent status and accent type contrasts

The sentence materials used in the six experiments of this study contrasted accent status (nuclear accented, prenuclear accented, postnuclear unaccented) and nuclear accent type (expanded pitch range, "regular" pitch range, downstepped) in particular sentence positions. In total, seven intonation patterns were used to make the accent status and accent type contrasts. All of the sentences were single main clause declarative sentences, and they were read as single intermediate-intonational phrases with between one and three accents. Sentences had early nuclear accent placement (nuclear accent on the subject), late or "normal" nuclear accent placement (nuclear accent on the final content word), or sentence medial nuclear accent placement. The accent types used were a limited subset of the English pitch accent inventory; described using the ToBI scheme of transcription they were H*, !H*, and L+H*. The regular nuclear accents and all accents on the subject noun phrase (whether prenuclear accents or early nuclear accents) were H* accents. The downstepped nuclear accents were !H* accents, and the expanded pitch range nuclear accents were L+H* accents.

Experiment 1 compared the three accent statuses directly in the same sentence medial position. Table 3 shows an example of the nuclear accent location and the accent statuses of the words in early, medial, and late sentence positions in the three intonation patterns used to examine nuclear accented (N), prenuclear accented (P), and postnuclear unaccented (U) in medial sentence position. The primary difference between these three patterns is in the location of the nuclear accent, the final accent of the phrase. The nuclear accented words are indicated with bold capital letters in the table, and the prenuclear accented words are indicated with small capital letters. The intonation transcriptions follow the ToBI conventions. The sentence labeled as the nuclear accented version (N) has sentence medial nuclear accent placement; the nuclear accent is on the word

Table 3. Three intonation patterns, in order of decreasing prominence in medial sentence position. The three accent statuses in medial sentence position (the word *canyon*) are nuclear accented, prenuclear accented, and unaccented.

(N)	Nuclear accented	The	GIRL H*	admired the	**CANYON** H*	from a	distance. L-L%
(P)	Prenuclear accented	The	GIRL H*	admired the	CANYON H*	from a	**DISTANCE**. H* L-L%
(U)	Unaccented	The	**GIRL** H*	admired the	canyon	from a	distance. L-L%

Notes. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent. The intonational transcriptions follow the ToBI conventions.

canyon. The sentence labeled as the prenuclear accented version (P) has late nuclear accent placement; the nuclear accent comes after the word *canyon*, on *distance*. The sentence labeled as the unaccented version (U) has early nuclear accent placement; the nuclear accent comes before the word *canyon*, on *girl*. All three of these intonation patterns are considered examples of the "hat pattern", with regular high tone accents on the accented words (transcribed H* in ToBI) and with low tone at the end of the phrase (transcribed L-L% in ToBI). These three patterns were illustrated in Figures 1 - 3 of Chapter 1. Recall that the fundamental frequency was high on the prenuclear accented and nuclear accented words, and that it was low and level after the nuclear accent.

Experiments 2 - 6 compared the three accent statuses indirectly through comparisons of nuclear accented and non-nuclear accented in early and late sentence position. Sentences had early nuclear accent placement (nuclear accent on the subject) and late nuclear accent placement (nuclear accent on the final content word). In early sentence position, words were nuclear accented and prenuclear accented. In late sentence position, words were nuclear accented and postnuclear unaccented. In Experiments 2, 5, and 6, the nuclear accented words had regular nuclear accents in both early and late sentence position. In Experiments 3 and 4, the nuclear accented words in late sentence position were of three nuclear accent types: expanded pitch range, regular pitch range, and downstepped. The nuclear accented words in early sentence position had regular nuclear accents. Table 4 shows an example of the nuclear accent location, nuclear accent type, and the accent statuses of the words in early and late sentence position in the four intonation patterns which were used to examine the nuclear and non-nuclear contrasts in

Table 4. Four intonation patterns, in order of decreasing prominence in late sentence position. The labels refer to the late sentence position accent status and accent type. The first three patterns have late nuclear accent placement, and the fourth pattern has early nuclear accent placement.

(X)	Expanded pitch range nuclear accented	The	POET	admired the	**CANYON** .	
			H*		L+H*	L-L%
(R)	Regular nuclear accented	The	POET	admired the	**CANYON** .	
			H*		H*	L-L%
(D)	Downstepped nuclear accented	The	POET	admired the	**CANYON** .	
			H*		!H*	L-L%
(U)	Unaccented	The	**POET**	admired the	canyon.	
			H*			L-L%

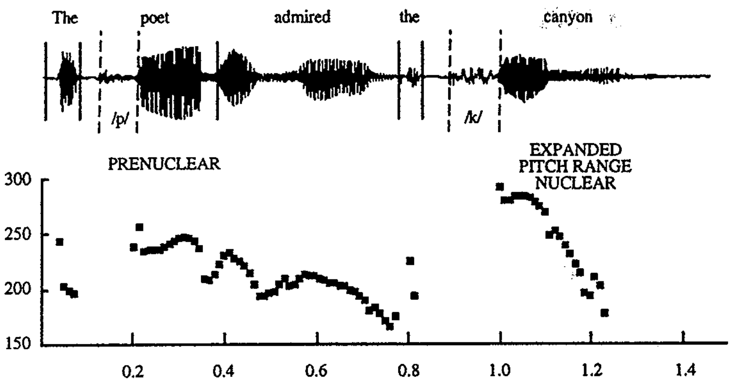
Notes. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent. The intonational transcriptions follow the ToBI conventions.

early and late sentence position and the three kinds of nuclear accent in late sentence position. The nuclear accented words are indicated with bold capital letters in the table, and the prenuclear accented words are indicated with small capital letters. The intonation transcriptions follow the ToBI conventions. The intonation patterns are illustrated in Figure 9.

The four intonation patterns are listed in order of decreasing prominence on the word in late sentence position, *canyon* in this example. The first three intonation patterns have late nuclear accent placement, with nuclear accent on *canyon*, and the fourth intonation pattern has early nuclear accent placement, on *poet*. The intonation patterns are labeled according to the accent status and accent type of the word in late sentence position. The first intonation pattern (X) has an expanded pitch range nuclear accent, transcribed as L+H*, in late sentence position. The second intonation pattern (R) has a regular nuclear accent, transcribed as H*, in late sentence position. The third intonation pattern (D) has a downstepped nuclear accent, transcribed as !H*, in late sentence position. The fourth intonation pattern (U) is unaccented in late sentence position.

Other things being equal (since we have to control for overall pitch range, length, etc., to get cross-utterance comparisons), the height of the fundamental frequency peak on an expanded pitch range nuclear accent is higher than that of a regular nuclear accent. In addition, in a sentence with an expanded pitch range nuclear accent, the height of the fundamental frequency peak on a nuclear accent is higher than that of earlier prenuclear accents in the sentence. In contrast to an expanded pitch range nuclear accent, the height of the peak on a downstepped nuclear accent is lower than that of earlier prenuclear accents in the sentence. We can easily see these fundamental frequency relationships between the accent types in the examples in Figure 9.

(X)



(R)

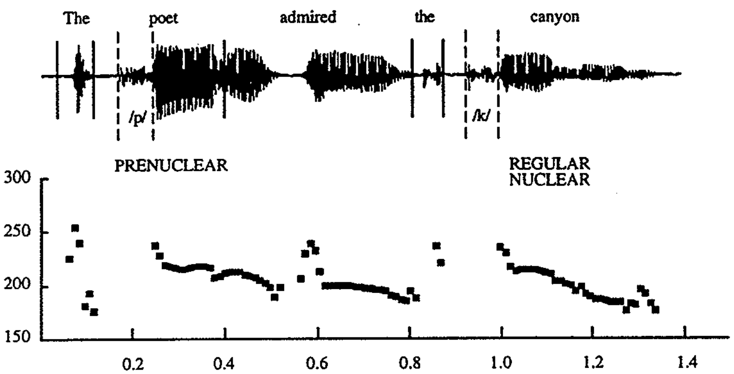
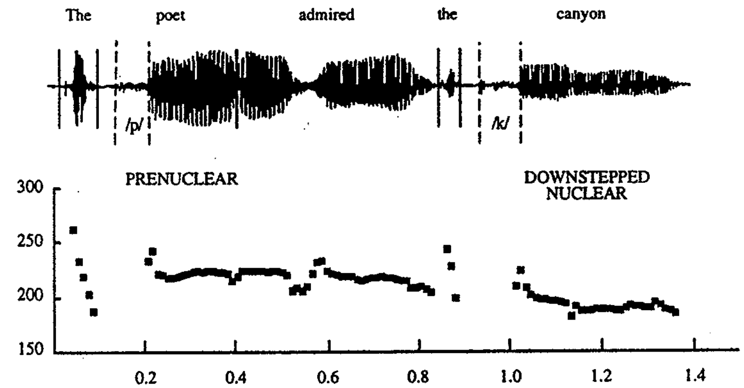


Figure 9. Four intonation patterns, in order of decreasing prominence in late sentence position. Time aligned display (in seconds) of speech waveform and fundamental frequency contour (in Hz). The VOTs of word initial /p/ and /k/ are between dashed lines.

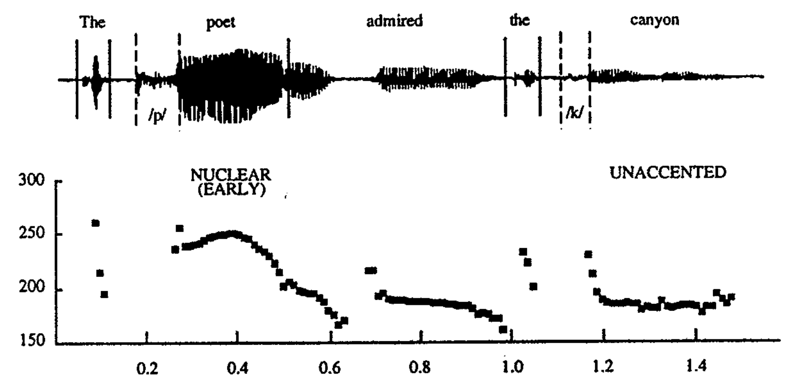
(X) Late expanded pitch range nuclear accented.
(R) Late regular nuclear accented.
(D) Late downstepped nuclear accented.
(U) Late postnuclear unaccented -- early regular nuclear accent placement.

Figure 9. (continued)

(D)



(U)



2.2 Acoustic characterization of the materials

A subset of the experimental materials, which were representative of the complete set of materials used in the experiments, were characterized acoustically in terms of fundamental frequency, vowel onset time (VOT), and syllable duration for two reasons. The first reason was to confirm that the intonation patterns were produced consistently, and as intended, on the different sentences in the experiments. The second reason was to confirm that these materials had the same kinds of effects of articulatory/acoustic prominence that, e.g., de Jong (1995) found. The acoustic characterization of the materials presented here was not intended as a full-fledged production experiment, but rather as a study to insure that the intonation was as intended and that the materials did in fact yield the same kinds of local segmental differences associated with accent status that others have found.

2.2.1 Materials

The test sentences from Experiments 1 and 3 were analyzed acoustically. See Appendix A for the list of sentences in Experiment 1 and Appendix C for the list of sentences in Experiment 3. The materials in Experiment 1 contained the three-way contrast of accent status (nuclear accented, prenuclear accented, unaccented) in medial sentence position. The materials in Experiment 3 contained the four intonation patterns contrasting early and late nuclear accent placement and three types of nuclear accent (expanded pitch range, regular, downstepped).

In Experiment 1, 60 critical sentences were recorded with the three intonation patterns described in the previous section, for a total of 180 utterances. The medial sentence position words of these utterances were nuclear accented, prenuclear accented, and postnuclear unaccented. In Experiment 3, 96 critical sentences were recorded with the four intonation patterns described in the previous section, for a total of 384 utterances. The early sentence position words of these utterances were (regular) nuclear accented and prenuclear accented, and the late sentence position words of these utterances were expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and postnuclear unaccented.

The materials in Experiment 3 were representative of the materials used in Experiments 2 - 6. The sentence materials in Experiments 2, 5 and 6 contained only two of the four intonation patterns considered in Experiment 3, and the materials in Experiment 4 were identical to those

of Experiment 3. In addition, the sentences in experiments other than Experiments 1 and 3 were not as segmentally constrained, making it impossible, for example, to make the VOT measurements.

2.2.2 Recording the materials

The recordings of the sentence materials were made in a sound-damped booth, using a SHURE head-mounted microphone and a TEAC V-427C stereo cassette deck. The microphone was adjusted to be approximately two inches from the corner of the speaker's mouth.

The author, a woman in her late twenties, was the speaker who produced all of the sentence materials. She read the sentences four times with all of the intonation patterns of interest for a particular experiment. The third of the four recordings of each sentence was chosen for use in the experiments unless there was something wrong with that utterance (e.g., a disfluency or noise during the recording). In those cases, one of the other three recordings was usually acceptable and was chosen. However, a few sentences had to be completely rerecorded. The author read the sentences in a fixed order, producing all of the sentences using one intonation pattern before continuing on to read the sentences using the next intonation pattern.

The Entropic Research Laboratory, Inc. speech processing package ESPS/waves+ 5.0 was used on a SUN SparcStation 10 to digitize the sentences, record the stimulus tapes, and make the acoustic measurements. The utterances were digitized at 16 bits using a sampling rate of 16 kHz and stored to disk. Details of recording the stimulus tapes are described in the Methods sections of the experiment chapters.

2.2.3 Fundamental frequency

The fundamental frequency measurements were made to characterize the fundamental frequency targets on nuclear accented, prenuclear accented and unaccented words in early, medial, and late sentence position in the intonation patterns. They were also to confirm that the different sentences were produced with comparable fundamental frequency targets in similar pitch ranges.

Method

The fundamental frequency contour of each sentence was computed using the RAPT (Robust Algorithm for Pitch Tracking) algorithm implemented in the ESPS/waves+ speech processing package's program "get_f0" (Talkin 1995). The program implements a fundamental frequency (F0) estimation algorithm using the normalized cross correlation function and dynamic programming. The output of the algorithm is a sequence of fundamental frequency estimate values (in Hz), one value every 10 ms, plus values indicating probability of voicing, RMS energy value, and peak value of cross correlation.

F0 measurements were made at the midpoint of the stressed syllable of target words which occurred in three sentence positions in Experiment 1 and in two sentence positions in Experiment 3. For the materials in Experiment 1, F0 measurements were made for the head content words in early and late sentence position and for the target words in medial sentence position. For the materials in Experiment 3, F0 measurements were for the target words in early and late sentence position.

Results

Figure 10 shows the average F0 values for early, medial, and late position words for the three intonation patterns used in Experiment 1, and the average F0 values for the early and late target words in the four intonation patterns used in Experiment 3. (The error bars show the 95% confidence intervals for each average value.) These measurements give a rough schematic F0 contour for the intonation patterns.

As we see in the top of the figure for the three locations of nuclear accent, the nuclear accented words on average had higher F0 peaks than the prenuclear accented words. In addition, the prenuclear accented words had higher F0 values than the unaccented words. These schematic F0 contours summarize the F0 targets of the actual F0 contours shown in Chapter 1, Figures 1 - 3. Notice that the F0 values on words after the nuclear accent (i.e., the unaccented words) were the lowest values, as expected from the phonological transcription of the intonation pattern.

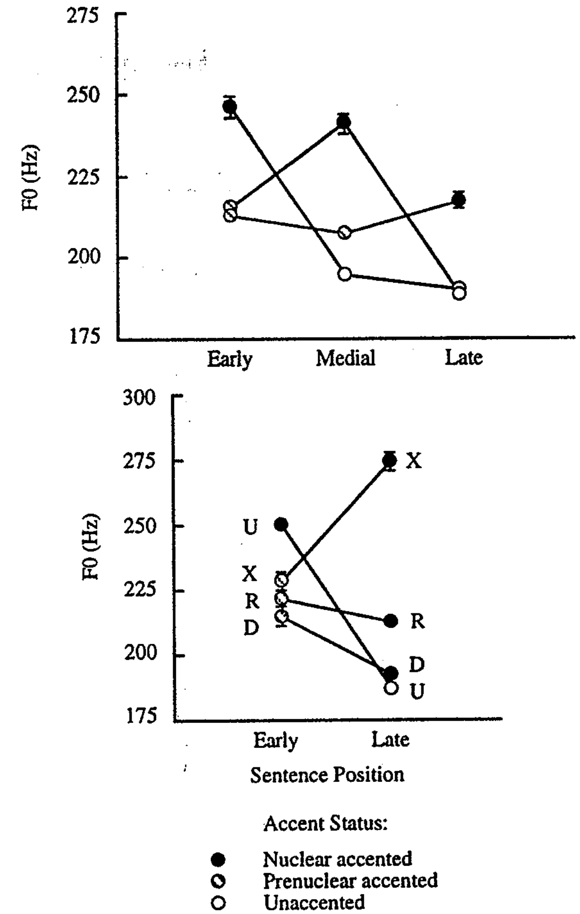


Figure 10. Mean fundamental frequency values (in Hz) at stressed syllable midpoints by sentence position and intonation contour type.
(top) Early, medial, and late nuclear accent placement. The medial sentence position contrasts nuclear accented, prenuclear accented, and unaccented. Measurements from Experiment 1 materials.
(bottom) Three types of accent for late nuclear accent placement (X: expanded pitch range, R: regular, D: downstepped) and early nuclear accent placement (U: unaccented in late position). Measurements from Experiment 3 materials.

The bottom of the figure shows the F0 values for the four intonation contours contrasting nuclear accent type and nuclear accent placement. The early nuclear accent placement contour (U) had a high F0 peak on the early sentence position nuclear accented word and a low F0 value on the late sentence position unaccented word. The F0 value for the early nuclear accent peak was significantly higher than the F0 values of the prenuclear accents in the other three intonation patterns. The three late nuclear accent placement patterns were characterized by the difference in F0 level on the nuclear accented words. The regular nuclear accent (R) had a pitch level similar to that of the preceding prenuclear accent, although it was slightly lower due to final lowering (e.g. Liberman & Pierrehumbert 1984). The expanded pitch range nuclear accent (X) had a very high F0 value on the nuclear accented word, much higher than the preceding prenuclear accent and also much higher than a regular nuclear accent ($t = 34.1$, $p < 0.01$). The downstepped nuclear accent (D) was substantially lower than the preceding prenuclear accent, and much lower than a regular nuclear accent. The average F0 on the downstepped nuclear accent was significantly higher than it was on the late position unaccented words ($t = 6.33$, $p < 0.01$).

2.2.4 Voice onset time (VOT)

The voice onset time was measured as a way of characterizing acoustic prominence as reflected by articulatory enhancement. That is, the longer the vowel onset time, the more the phoneme was articulatorily enhanced.

Method

The voice onset time of the initial /p/ or /k/ consonant of each target word (medial sentence position for Experiment 1 and early and late sentence position for Experiment 3) was determined visually from inspection of the speech waveform using the waves+ program. The VOT was measured from the acoustic release of the stop consonant to the start of voicing for the following vowel. The acoustic release of the stop consonant was measured at the release burst after the end of the closure interval associated with the /p/ or /k/. This time point for the release of the stop was also used as the reference point for the occurrence of the phoneme in the phoneme monitoring experiments (see Chapter 3). The start of voicing of the vowel was taken to be the time point of the maximum of the peak during the first voicing cycle in the vowel. VOT was measured in a display window which showed 200 ms of the

waveform containing this portion of the signal. The durations were accurate to within 5 ms.

Results

The left side of Figure 11 shows the VOTs for Experiment 1: nuclear accented, prenuclear accented, and unaccented in medial sentence position. A two-way ANOVA was performed with VOT as the dependent variable and consonant type (/p/ or /k/) and accent status (nuclear, prenuclear, or unaccented) as the independent variables. There were significant main effects of consonant type and accent status, but no significant interaction of consonant type x accent status ($F(2, 116) = 1.35$, $p > 0.1$). The lack of interaction between consonant type and accent status means that /p/ and /k/ behaved similarly with respect to the effect of accent status. As has been found before (Lehiste 1970), the VOT of /k/ was longer than the VOT of /p/ (71 ms vs. 59 ms; $F(1, 58) = 22.2$, $p < 0.01$), the phonetic result that velar consonants have longer VOT than labials. Because the main effect of accent status was significant ($F(2, 116) = 71.74$, $p < 0.01$), as expected, post-hoc comparisons of the accent status means were performed.

The average VOT of the initial consonant in the target words was 76 ms for the nuclear accented words, 64 ms for the prenuclear accented words, and 56 ms for the unaccented words. Each of these means was significantly different from the others. That is, the VOT duration of the initial consonant was longer in nuclear accented words (N) than in prenuclear accented words (P) ($F(1, 116) = 52.4$, $p < 0.01$), and the VOT duration of the initial consonant was longer in prenuclear accented words (P) than in unaccented words (U) ($F(1, 116) = 21.6$, $p < 0.01$).

The right side of Figure 11 shows the VOT durations for Experiment 3: nuclear and non-nuclear in early and late sentence position. A three-way ANOVA was performed with VOT duration as the dependent variable and consonant type (/p/ and /k/), sentence position (early and late), and intonation pattern (X, R, D, U) as the independent variables. There were significant main effects of consonant type, sentence position, and intonation pattern, as well as a significant interaction between sentence position and intonation pattern. There were, however, no significant interactions of consonant type and intonation pattern ($F(3, 567) = 1.3$, $p > 0.1$) or of consonant type and sentence position ($F(1, 189) = 1.5$, $p > 0.1$). The lack of interaction between consonant type and either intonation pattern or sentence position means that /p/ and /k/ behaved similarly with respect to the effect of accent status, as in Experiment 1.

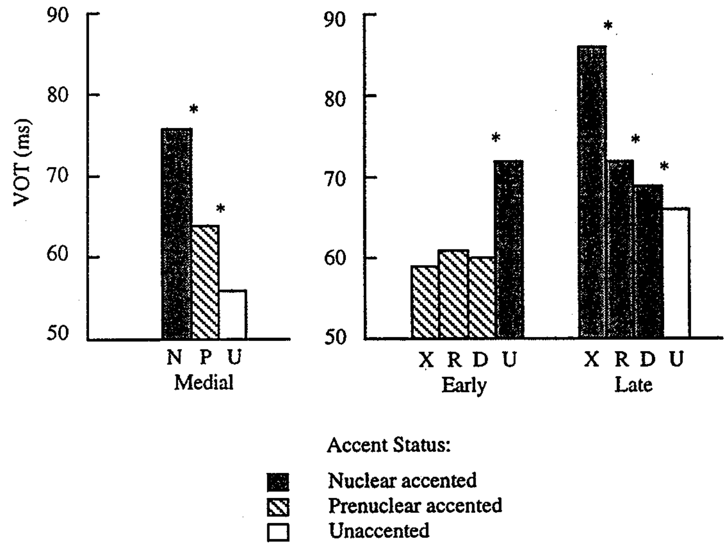


Figure 11. Mean VOT (in ms) by sentence position and intonation contour type. Asterisks mark significant differences between categories ($p < 0.05$).
(left) Nuclear accented, prenuclear accented, and unaccented in medial sentence position. Measurements from Experiment 1 materials.
(right) Three types of accent for late nuclear accent placement (X: expanded pitch range, R: regular, D: downstepped) and early nuclear accent placement (U: unaccented in late position). Measurements from Experiment 3 materials.

As in the materials for Experiment 1, the VOT of /k/ was longer than the VOT of /p/ (73 ms vs. 63 ms; $F(1, 189) = 82.7$, $p < 0.01$), matching the standard phonetic result that velar consonants have longer VOT than labial consonants. The main effect of position was significant, with VOT being longer in late sentence position than in early sentence position ($F(1, 189) = 59.5$, $p < 0.01$). Because the interaction of intonation pattern and sentence position was significant ($F(3, 567) = 105.2$, $p < 0.01$), as expected, post-hoc comparisons of the means were performed at early and late sentence position, collapsing over consonant type.

In early sentence position, the average VOT duration for the nuclear accented words (Early-U) was 72 ms, and the average VOT duration for the prenuclear accented words was 59 ms for Early-X, 61 ms for Early-R, and 60 ms for Early-D. The VOT of the nuclear accented words was significantly longer than the VOT of the prenuclear accented words ($F(1, 285) = 133$, $p < 0.01$), as we might have expected from the difference in level of stress. The VOT of the prenuclear accented words in the three different intonation pattern types were not significantly different. This is what we expected, because they all have the same accent status and level of stress.

In late sentence position, the average VOT duration for the nuclear accented words was 86 ms for Late-X, 72 ms for Late-R, and 69 ms for Late-D, and the average VOT duration for the unaccented words (Late-U) was 66 ms. All four of these VOT durations were significantly different from each other. That is, the three types of nuclear accent had different VOT durations, as well as each being longer than the unaccented words. Furthermore, the expanded pitch range nuclear accent VOT duration was longer than the regular nuclear accent VOT duration, which in turn was longer than the downstepped nuclear accent VOT duration (X vs. R: $F(1, 285) = 141.0$, $p < 0.01$; R vs. D: $F(1, 285) = 5.8$, $p < 0.02$; D vs. U: $F(1, 285) = 4.2$, $p < 0.05$).

2.2.5 Syllable duration

Syllable duration was measured because other studies have looked at how it corresponds to levels of stress and accent status.

Method

The syllable duration of the stressed syllable of each target word (medial sentence position for Experiment 1 and early and late sentence position for Experiment 3) was determined visually from inspection of the speech waveform using the waves+ program. The syllable duration was measured from the acoustic release of the stop consonant to the end of voicing for the following vowel in open syllables and to the end of the consonant following the vowel in closed syllables. The acoustic release of the stop consonant was measured at the release burst after the end of the closure interval associated with the /p/ or /k/. The syllable duration was measured in a display window which showed 200 ms of the waveform containing this portion of the signal. The durations were accurate to within 5 ms.

Results

The left side of Figure 12 shows the syllable durations for Experiment 1: nuclear accented, prenuclear accented, and unaccented in medial sentence position. A one-way ANOVA was performed with syllable duration as the dependent variable and accent status (nuclear, prenuclear, or unaccented) as the independent variable. There was a significant effect of accent status, as expected ($F(2, 118) = 87.5$, $p < 0.01$). Therefore, post-hoc comparisons of the accent status means were performed.

The average syllable duration of the stressed syllable in the target words was 185 ms for the nuclear accented words, 146 ms for the prenuclear accented words, and 145 ms for the unaccented words. The syllable duration was longer in the nuclear accented words (N) than in prenuclear accented words (P) ($F(1, 118) = 136.1$, $p < 0.01$), but the syllable duration was not significantly different in the prenuclear accented words (P) and the unaccented words (U) ($F(1, 118) = 0.19$, $p > 0.1$).

The right side of Figure 12 shows the syllable durations for Experiment 3: nuclear and non-nuclear in early and late sentence position. A two-way ANOVA was performed with syllable duration as the dependent variable and sentence position (early and late), and intonation pattern (X, R, D, U) as the independent variables. The main effect of position was significant, with syllable duration being longer in late sentence position than in early sentence position ($F(1, 95) = 39.6$, $p < 0.01$). There was also a significant two-way interaction of sentence position and intonation pattern, as expected ($F(3, 285) = 103.4$, $p < 0.01$). Therefore, post-hoc comparisons of the means were performed at early and late sentence position.

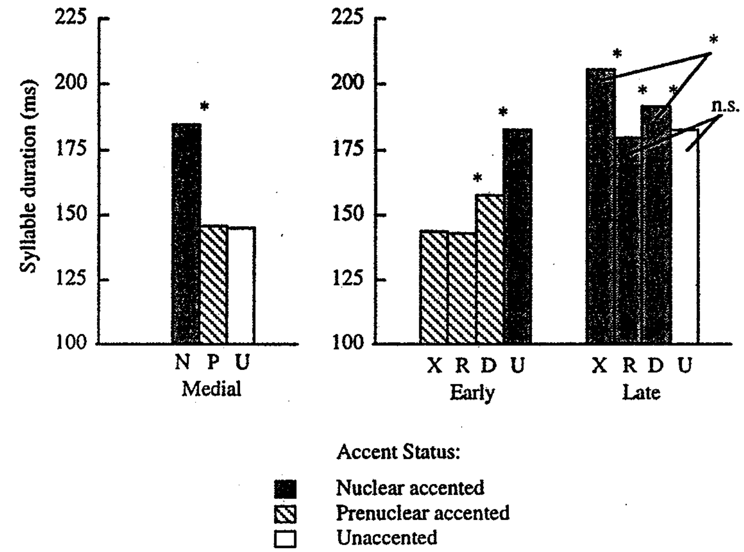


Figure 12. Mean syllable durations (in ms) by sentence position and intonation contour type. Asterisks mark significant differences between categories ($p < 0.05$).
(left) Nuclear accented, prenuclear accented, and unaccented in medial sentence position. Measurements from Experiment 1 materials.
(right) Three types of accent for late nuclear accent placement (X: expanded pitch range, R: regular, D: downstepped) and early nuclear accent placement (U: unaccented in late position). Measurements from Experiment 3 materials.

In early sentence position, the average syllable duration for the nuclear accented words (Early-U) was 183 ms, and the average VOT for the prenuclear accented words was 145 ms for Early-X, 143 ms for Early-R, and 158 ms for Early-D. The syllable duration of the nuclear accented words was significantly longer than the syllable duration of the prenuclear accented words ($F(1, 285) = 285.6$, $p < 0.01$), as we might have expected from the difference in level of stress and the VOT results. However, while the VOT results showed that the VOT of the prenuclear accented words in the three different intonation pattern types were not significantly different, the syllable durations were not all the same for the prenuclear accented words. The prenuclear accented words in the expanded pitch range and the regular patterns were not significantly different ($F(1, 285) = 0.68$, $p > 0.1$), but the prenuclear accented words in the downstepped pattern were longer than those in the regular contour

(F(1, 285) = 40.1, $p < 0.01$). This is somewhat unexpected, because all the prenuclear accented words have the same accent status and level of stress.

In late sentence position, the average syllable duration for the nuclear accented words was 206 ms for Late-X, 180 ms for Late-R, and 192 ms for Late-D, and the average syllable duration for the unaccented words (Late-U) was 183 ms. Surprisingly, the syllable durations of the regular nuclear accented words and the unaccented words were not significantly different (F(1, 285) = 1.2, $p > 0.1$). However, the expanded pitch range nuclear accent was longer than the regular nuclear accent (F(1, 285) = 108.5, $p < 0.01$) and the downstepped nuclear accent, and the downstepped nuclear accent was longer than the unaccented (F(1, 285) = 14.3, $p < 0.01$). That is, except for the regular nuclear accented words, the syllable durations showed the expected pattern, with the nuclear accented words longer than the unaccented, and the expanded pitch range longer than the regular and downstepped nuclear accents.

2.2.6 Discussion

The fundamental frequency measurements showed that the different sentences were produced quite consistently and with the intended intonation patterns. In late sentence position, the fundamental frequency on the words from highest to lowest was expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and postnuclear unaccented, as expected. In early sentence position, the fundamental frequency for the early nuclear accent peak was significantly higher than the fundamental frequency values of the prenuclear accents in the other three intonation patterns. The prenuclear accents in the three late nuclear accent patterns had similar fundamental frequency peaks, although the one in the expanded pitch range pattern had a higher fundamental frequency than the one in the regular pattern, and the one in the downstepped pattern had a lower fundamental frequency than the one in the regular pattern. Greater overall involvement (as in Bruce 1982a, 1984, Scherer et al. 1984, Ladd et al. 1985, Hirschberg & Ward 1991) may explain why the expanded pitch range prenuclear had a higher fundamental frequency than the regular prenuclear, and likewise lesser overall involvement in downstepped patterns may explain why the prenuclear accented word had lower pitch level than regular prenuclear. In particular, Ladd et al (1994) found exactly this sort of pitch range relationship in their materials contrasting expanded and regular pitch range.

The VOT durations showed that accent status and accent type had a significant and systematic effect on the realization of initial consonant segments in stressed syllables. The higher the level of stress -- from unaccented, to prenuclear accented, to prenuclear accented -- the longer the VOT, at a given position in the sentence. Furthermore, the higher the predicted prominence of the nuclear accent type -- from downstepped to regular to expanded pitch range -- the longer the VOT. These differences in VOT can be viewed as a strengthening or enhancement of the stop consonant phonemes as suggested by Pierrehumbert & Talkin (1992) and Jun (1993). Thus, VOT showed differences that exactly matched the predicted prominence orderings, for accent status and accent type. The difference in VOT of nuclear accent types suggests that there is a progressive increase in acoustic prominence accompanying the segmental enhancement.

The results of the syllable duration measurements were similar to those of the VOT measurements, although slightly less clear. In general, the higher the predicted prominence of the word, the longer the syllable duration was. However, there were a few exceptions to this prediction. For example, in early sentence position, the prenuclear accented words in the downstepped pattern had longer syllable durations than the prenuclear accented words in the expanded pitch range and regular patterns. In late sentence position, the syllable durations were in the predicted direction except for the fact that the regular nuclear accented words were not significantly longer than the postnuclear unaccented words. We cannot explain these exceptions to the predictions because we do not know enough about syllable duration and how to tease apart local rate effects such as "final lengthening" from prominence effects (Harris 1978, Summers 1987, Edwards, Beckman & Fletcher 1991).

The VOT and fundamental frequency measurements suggest that there are certain commonalities between early nuclear accent versus prenuclear accents and between expanded pitch range nuclear accents (X) versus regular nuclear accents (R). The largest difference in VOT in late sentence position was between the expanded pitch range nuclear accent (X) and the others, mirroring the large difference in early sentence position between the early nuclear accent placement (U) and the prenuclear accents of the other intonation patterns. In addition, not only was the fundamental frequency peak on the early nuclear accents on average higher than the prenuclear accents in early sentence position, it was much higher than on the late regular nuclear accents (although it was lower than on the late expanded pitch range nuclear accents). The F0 measurements do not make it entirely clear that the early nuclear accents were regular nuclear accents rather than expanded pitch range nuclear accents. However, early nuclear accent placement signals narrow focus in terms of contrast and emphasis much as does the difference between expanded pitch range nuclear accent (X) and regular nuclear accent (R) in late sentence position. If we consider that narrow focus is expressed in early sentence position by a difference in accent status (nuclear vs. prenuclear accented) and in late sentence position by a difference in accent type (expanded pitch range nuclear accent vs. regular nuclear accent), this reinforces our motivation for considering late nuclear accent type as functionally similar to nuclear accent placement.

From the acoustic measurements, we know that the materials showed effects of accent status suggested by earlier researchers on production, so while this was not a production study per se, the acoustic measurements give further support to the hypothesis that accent status and accent type influence acoustic prominence. The acoustic measures, particularly VOT duration, suggest that the higher the stress, the greater the acoustic prominence. In addition, these measures showed that there were differences in the way the nuclear accent types were produced which are seemingly inconsistent with a categorization that treats all types of nuclear accents as identical except for how they are realized tonally. Chapters 3 - 6 investigated whether they were perceived similarly. That is, they investigated whether there were differences in perceptual prominence and informational prominence. Because the materials had reliable articulatory/acoustic differences between the accent statuses and nuclear accent types, the results of the phoneme monitoring, question-answering, and cross-modal naming experiments can be interpreted in a way that ties together the articulatory/acoustic prominence literature and the perception literature.

CHAPTER III

ACCENT AND PERCEPTUAL PROMINENCE: THREE PHONEME MONITORING EXPERIMENTS

This chapter presents the results of three experiments which examined the relative prominence of the three accent statuses (nuclear accented, prenuclear accented, and postnuclear unaccented) and three nuclear accent types (expanded pitch range, regular, and downstepped) using the phoneme monitoring paradigm. The experiments explored the question of whether differences in intonational structure influence the time it takes to notice that a phoneme was present in a sentence. In the phoneme monitoring task, sentences are presented auditorily, and subjects press a response button as soon as they detect the target phoneme in the sentence. The reaction time measured in this task is the delay between when the phoneme occurs in the sentence and when the subject presses the button indicating that the phoneme occurred. The task allows the investigator to probe the complexity of sentence processing and focus of attention on-line. In this study we were particularly interested in using phoneme monitoring to investigate focus of attention as it relates to perceptual prominence. We can assume that the reaction time to a phoneme target is influenced by both how distinctly the phoneme is produced in the sentence (acoustic prominence) and by where the intonation pattern directs the listener's attention in the sentence (informational prominence).

3.1 Background

The phoneme monitoring task was first developed by Foss and associates (Foss 1969, Foss & Lynch 1969) as a way of judging the complexity of sentence processing at certain points in a sentence. They found that reaction times were slower after the occurrence of a low frequency as opposed to a high frequency word (Foss 1969) and in structurally complex as opposed to structurally simple sentences (Foss & Lynch 1969). They explained these results in terms of a limited-capacity central processing mechanism which handles the demands of all tasks that a listener is concurrently performing. Therefore, the more difficult the

sentence processing task is, the greater the demand the sentence processing task makes on the central processing mechanism, and consequently the slower the reaction time to the phoneme monitoring task. Experiments that manipulate the sentence context prior to the word containing the target phoneme have found that reaction time is slowed by preceding the target phoneme by a low frequency word (Foss 1969), a syntactically complex structure (Foss & Lynch 1969), or a phonetically similar phoneme (Newman & Dell 1978). These kinds of things in the prior context take attention to process, and in the case of phonetically similar phonemes, to distinguish from the target phoneme. Therefore, they limit the attention that is available to process the word containing the target phoneme and respond to the target phoneme. In addition, sentence position has been found to influence the time that it takes to respond to the target phoneme, such that targets in early sentence position are responded to more slowly than targets in late sentence position (Mehta & Cutler 1988).

A second group of experiments using the phoneme monitoring task are of more direct interest to this study. These experiments manipulate focus of attention directly on the word or syllable containing the target phoneme by manipulating stress level. Target phonemes are responded to more quickly in stressed words than unstressed words, where stressed means that the word has sentence stress (Shields, McHugh & Martin 1974, Cutler 1976, Cutler & Foss 1977), and more quickly in accented than in unaccented words (Mehta & Cutler 1988). The acoustic correlates of stress and accent, such as segmental enhancement, are partly responsible for these results, but they are not completely responsible. Cutler (1976) spliced acoustically identical words with neutral stress into sentences which had high stress or low stress on the target word when they were intact. She found that the target phonemes were responded to more quickly in the high stress condition than the low stress condition, even though the targets themselves were identical. Cutler & Darwin (1981) found that even when the fundamental frequency cues to high and low stress were removed by resynthesizing a sentence with a monotone fundamental frequency, the phoneme targets were still responded to more quickly in the high stress condition than in the low stress condition. Pitt & Samuel (1990) also found that phoneme monitoring times were faster on syllables that the listener expected to be stressed, even if the local acoustic correlates of stress were missing. In further experiments, Cutler & Fodor (1979) showed that varying the focus of a sentence by means of preposing questions also resulted in focused targets having consistently faster reaction times than did nonfocused targets, despite the fact that the sentences themselves were acoustically identical and only the preceding questions were different. These experiments suggest that intonation patterns and semantic focus expectations direct attention during sentence comprehension to the points where high stress will fall. High stress or the expectation of high stress may speed reaction time because of the connection to focus of attention.

Theories describe two competing ways that listeners can recognize that a phoneme is present in a sentence: top-down, from identification of the word to recognizing that the word begins with the target phoneme, and bottom-up, from an acoustic analysis of the signal (Dell & Newman 1980). These two ways of detecting the phoneme are considered to be in competition with each other, and the fastest one wins. Cutler & Norris (1979) describe the top-down lexical strategy involved in phoneme monitoring. The listener determines that the target phoneme is present by reference to the stored phonological knowledge of the word involved. When this strategy is used, reaction time is related to the timing of word identification, since the phonological representation of the word in memory cannot be consulted until the listener knows what word is being heard. The results that target phonemes are responded to more quickly in stressed words than unstressed words (Shields, McHugh & Martin 1974, Cutler 1976, Cutler & Foss 1977), and more quickly in locations with predicted focus (Cutler & Fodor 1979) suggest that more attention is being paid to such words and that lexical access is faster for them. Alternatively, when the acoustic correlates of stress are present, such as segmental enhancement, the bottom-up mechanism might receive the advantage.

Cutler (1984) says that in production, sentence accent expresses the information structure of the sentence, and the speaker assigns accent according to what he considers more or less important. In perception, the listener finds it important to identify the location of the sentence accent and uses all available cues to do so. Cutler says that the reason accent is so keenly sought (even if the sentence accent does not occur in the expected location) is because it expresses focus, and thus the percept of accent is intimately connected with the information structure of the sentence.

In summary, the phoneme monitoring task is sensitive to differences in stress and acoustic/phonetic prominence and also to focus of attention, what the listener is paying special attention to. The three experiments in this chapter begin from this starting place, but they also control the intonational pattern more carefully than previous experiments have done. They explore not only the effect of "sentence stress", but also the effects

of the three accent statuses (nuclear accented, prenuclear accented, unaccented) and of three different types of nuclear accent (expanded pitch range, regular, and downstepped).

3.2 Hypotheses

The experiments examined a total of seven intonation patterns using phoneme monitoring. Experiment 1 examined the accent statuses directly by targeting nuclear accented, prenuclear accented, and postnuclear unaccented words in the same sentence medial position. That is, each sentence had medial, late, or early nuclear accent placement, so that the target word fell at, before, or after the nucleus, respectively, and all nuclear accents were regular nuclear accents. Experiment 2 used shorter sentences to examine the interaction between accent status and early versus late sentence position. Sentences had early or late nuclear accent placement, and all nuclear accents were regular nuclear accents. Words containing the target phoneme in early sentence position were nuclear accented or prenuclear accented, and words containing the target phoneme in late sentence position were nuclear accented or unaccented. That is, the three-way distinction in accent status (nuclear accented, prenuclear accented, and postnuclear unaccented) was represented between the two sentence positions. Experiment 3 examined the two intonation patterns used in Experiment 2 and two additional ones with late nuclear accent placement in order to compare three types of nuclear accent: expanded pitch range, regular, and downstepped. The sentences were presented auditorily, and subjects pressed a button as quickly as possible to indicate that they had heard the target phoneme.

The basic hypothesis is that the more prominent a word is due to its accent status and accent type, the more quickly listeners will respond to the target phoneme. Both phoneme enhancement and focus of attention are expected to contribute to the faster response times to phonemes in prominent words. Paralleling the acoustic production data and the stress hierarchy, target phonemes are expected to be responded to more quickly in nuclear accented words than in non-nuclear accented words (prenuclear accented and unaccented), and target phonemes in prenuclear accented words are expected to be responded to more quickly than in unaccented words. Paralleling the acoustic production data and the predicted prominence relationships between nuclear accent types, target phonemes are expected to be responded to more quickly in expanded pitch range nuclear accented words than in regular nuclear accented words, which in turn are expected to be responded to more quickly than in downstepped nuclear accented words.

Besides the predictions of phoneme monitoring times as they relate to accent status and accent type, phoneme monitoring times are predicted to be influenced by sentence position. Phoneme monitoring times are predicted to be shorter in words in late sentence position than in early sentence position, as has been previously found in the literature.

Experiment 1 directly compares nuclear accented, prenuclear accented, and unaccented in the same sentence position (medial sentence position). Experiments 2 and 3 compare nuclear accented and prenuclear accented in early sentence position and nuclear accented and unaccented in late sentence position. Because Experiments 2 and 3 do not directly compare prenuclear accented and unaccented accent statuses in the same sentence positions, sentence position effects may obscure any effects of accent status which would otherwise distinguish prenuclear accented from unaccented. However, the shorter sentences are more natural than those with the excessively long tails necessary to vary accent status only and allow for a more natural manipulation of accent type. Experiment 3 has three different types of nuclear accents in late sentence position (expanded pitch range, regular, downstepped).

3.3 Experiment 1: Nuclear accented, prenuclear accented, and unaccented in medial sentence position

This experiment examined three accent statuses using phoneme monitoring. Words in medial sentence position were nuclear accented, prenuclear accented, or unaccented. Sentences had early, medial, and late nuclear accent placement, and all nuclear accents were regular nuclear accents. The sentences were presented auditorily, and subjects pressed the 'yes' response button when they detected the target phoneme. The target phoneme was specified at the beginning of each trial by a capital letter, either 'P' for /p/ or 'K' for /k/. The ordering of the reaction times was predicted to be, from fastest to slowest, nuclear accented, prenuclear accented, and postnuclear unaccented.

3.3.1 Method

Subjects

32 undergraduate volunteers from The Ohio State University participated in the experiment for course credit in introductory

psychology and linguistics classes. All subjects were native speakers of English and had normal or corrected-to-normal vision. No subjects reported any hearing loss. Two subjects failed to meet the accuracy criterion of at least 90% correct on the critical trials, leaving 30 subjects for the final data analysis. Ten subjects were assigned to each of the three lists.

Materials

There were 166 sentences with target phonemes specified for the experimental trials and 20 sentences with phoneme targets specified for the practice trials. 60 of the experimental trials were critical sentences. The critical sentences all contained a word in medial sentence position beginning with a target phoneme, and they were produced with the word containing the target phoneme in one of three accent statuses (nuclear accented, prenuclear accented, or unaccented).

Critical materials. Sixty sentences were constructed so as to be suitable for use in the phoneme monitoring task as critical trials. The sentences in this experiment were longer than the sentences in the rest of the experiments, and they had content words in early, medial, and late sentence position, not just in early and late sentence position as the other experiments did. Each sentence had a word containing one of the two target phonemes in medial sentence position. The target phonemes were the voiceless stop consonants /p/ and /k/. The target phoneme was always the initial phoneme of the word it appeared in, and it was always followed by a vowel. A sentence contained only one of the two target phonemes, and that phoneme occurred only once during the sentence. See Appendix A for the complete list of all the sentences used in the experiment.

The 60 sentences were read by the author with three different intonation patterns, yielding a total of 180 utterances overall. Depending upon the location of nuclear accent within the sentence, the words in medial sentence position were nuclear accented (N), prenuclear accented (P), or unaccented (U). The nuclear accents in early, medial, and late sentence position were regular nuclear accents. (See Chapter 2 for further details about the three intonation patterns and their effects on F0, duration, and VOT of the target syllable and stop phoneme.) Table 5 shows an example of the three intonation patterns for a sentence. The words containing the target phonemes are underlined. Nuclear accented words are shown in bold capital letters, and prenuclear accented words are shown in small capital letters. For this sentence, the target phoneme is the /k/ in *canyon*.

Table 5. Sample materials used in Experiment 1, phoneme monitoring (target phonemes cued visually). Accent statuses, in decreasing order of prominence, nuclear accented (N), prenuclear accented (P), and unaccented (U) in medial sentence position.

					Medial /k/ Target		
(N)	Nuclear	The	GIRL	admired the	**CANYON**	from a	distance.
(P)	Prenuclear	The	GIRL	admired the	CANYON	from a	**DISTANCE** .
(U)	Unaccented	The	**GIRL**	admired the	canyon	from a	distance.

Notes. The phoneme monitoring targets were the initial consonant phonemes of words in medial sentence position, shown underlined. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent.

Additional materials. In addition to the 60 critical sentences, there were 66 filler sentences and 40 catch sentences, for a total of 166 experimental sentences. There were also 20 practice sentences used in the experiment. In the filler sentences, the target phoneme was also a word initial /p/ or /k/ phoneme (followed by a vowel or sonorant consonant) which occurred nowhere else in the sentence. The word containing the target phoneme in a filler sentence could be any word in the sentence, not just a word in medial sentence position. In the catch sentences, the target phoneme occurred nowhere at all in the sentence.

The filler and catch sentences were constructed to accomplish several purposes. First, the words containing the target phonemes for the filler sentences were placed in various locations within the sentences to balance for the fact that in the critical trial sentences the words containing the target phonemes always were in sentence medial position. Also, the words containing the target phonemes in the filler sentences consisted of various parts of speech to balance for the fact that in the critical sentences they were almost always nouns. Finally, the catch sentences were included to ensure that subjects were only responding that they had heard the target phoneme when it was in fact present, instead of adopting the strategy of responding 'yes' at the end of the sentence.

Design

The overall design for an ANOVA by subjects for this experiment was a 3 x 3 mixed factorial, with one between- and one within-subjects variable. The between-subjects variable was list (3 stimuli lists), and the within-subjects variable was accent status (N, P, U). The design for an ANOVA by items was a 3 x 3 mixed factorial with one between- and one within-items variable. The between-items variable was item group (3 groups), and the within-items variable was accent status (N, P, U).

The 60 critical sentences containing the words with target phonemes were recorded with three intonation patterns, yielding a total of 180 recorded sentences for the critical trials. In addition to the critical trials, the 66 filler and 40 catch sentences occurred with early nuclear accent placement (U) or late nuclear accent placement (R). The filler and catch trials occurred equally often in the two intonation patterns.

The 180 recorded sentences for the critical trials, and the sentences for the filler and catch trials, were digitized on a SUN SparcStation 10 at 16 kHz, 16 bit resolution. For each utterance, a two-channel audio file was made. One channel of the file contained the recorded sentence, and the other channel of the file contained a 10 ms long 1000-Hz tone placed one second before the sentence was played on the other channel. The tone marked the beginning of the time interval between the presentation of the prompt specifying the target phoneme and the occurrence of the target phoneme itself. For the critical trials, the time point taken as the occurrence of the target phoneme (/p/ and /k/) was the acoustic release of the stop, measured as described in Chapter 2.

An initial list containing 166 trials (60 critical trials, 66 filler trials, and 40 catch trials) was created according to the following randomization scheme. For each of the 60 critical sentences, the list contained the sentence recorded in one of the three intonation patterns, so that 20 sentences occurred with each intonation pattern. Therefore, 20 critical trials occurred in each of the three experimental conditions. The list also contained the 66 filler sentences and the 40 catch sentences.

The additional two lists were created from the first list by replacing each of the 60 critical trial sentences with one of the other two intonation patterns for that sentence. The three lists had the trials in the same pseudo-random order, differing only by the intonation pattern on each critical sentence. For each list, an equal number of the critical sentences occurred in each intonation pattern, with each sentence only appearing once per list. Across the three lists, each sentence occurred in all three of the accent status conditions.

A tape was made for each list. The tapes were made by playing back the audio files in the predetermined pseudo-random order and recording them to stereo metal audio tapes with the speech on one channel and the tones on the other.

Procedure

Subjects were tested individually in a quiet room. They were seated in front of a 386SX-16 computer and a SONY Stereo Cassette Deck TC-FX25, and they wore headphones. The stimulus sentences were played binaurally through the headphones at a comfortable listening level that was the same for all subjects.

On each trial, subjects saw a symbol on the computer screen specifying the target phoneme they were to listen for , e.g. 'K', and heard a trial sentence (a critical, filler, or catch sentence). 'P' indicated that they were to listen for the sound /p/ as in the word *page*, and 'K' indicated that they were to listen for the sound /k/ as in *car*. Subjects pressed the 'yes' response button when they detected the target phoneme, and they pressed the 'no' response button if they did not hear the target phoneme in the sentence. Subjects were instructed that if the phoneme occurred in the sentence, it would always be the first consonant sound in a word. In addition, it was the first sound of the word, not the first letter in the spelling of the word, which was important (for example *car* begins with the phoneme /k/ although it is spelled with a 'c').

Timing tones on the second channel of the tape (which were not heard by subjects) were fed into a relay which was interfaced with the computer. When a tone activated the relay, the computer displayed the target phoneme prompt ('P' or 'K') and started a millisecond timer. The subject's button press response stopped the timer, recorded the reaction time, and cleared the screen. The reaction time that the computer recorded was the time interval between the timing tone (the presentation of the prompt specifying the target phoneme) and the subject's button press response. The subject's true reaction time to the target phoneme was calculated by subtracting the time delay between the timing tone and the occurrence of the phoneme target from the reaction time collected by the computer. The acoustic release of the stop was the time point used for the occurrence of the phoneme. There was a 4 second interval between the end of a sentence presentation and the start of the next trial.

A sentence comprehension task was interspersed with the phoneme monitoring task to ensure that the subjects were attending to and comprehending the sentences instead of merely listening for individual consonants. Questions that could be answered 'yes' or 'no' were displayed on the screen at random intervals after phoneme monitoring trials. There were a total of 34 comprehension questions, half of which were answered 'yes', and half of which were answered 'no'. As with the phoneme monitoring response, the yes/no button response stopped the timer and

cleared the computer screen. After a sentence was presented on the screen, there was a 4 second interval before the start of the next trial.

In total, subjects were given 12 phoneme monitoring trials and 4 sentence comprehension trials during the practice session and 166 phoneme monitoring trials and 34 sentence comprehension trials during the experimental session.

3.3.2 Results

The effects of outliers were curtailed by cutoffs established at ± 2.5 standard deviations from the mean for each subject. Values more than 2.5 standard deviations from the mean were replaced with the cutoff values. The data were discarded from the trials in which a subject responded incorrectly ('no' instead of 'yes'), failed to respond, or responded in less than 100 ms. These types of error accounted for fewer than 0.5% of the data, and outliers accounted for less than 0.5% of the data. With these adjustments, the mean response latency was computed for each of the experimental conditions for each subject (collapsed across items) and for each item (collapsed across subjects).

The results were analyzed in two separate mixed factorial ANOVAs to match the designs described above, one by subjects (reported as F1) and one by items (reported as F2). These two analyses taken together treat both subjects and items as random factors, allowing significant results to be generalizable beyond the particular samples of each used in the study (Clark 1973). In the subject analysis, the data consist of each subject's mean response times to the three experimental conditions (20 items contributed to the mean per condition). In the item analysis, the data consist of the mean response time to the three experimental conditions (10 subjects contributed to the mean per condition).

Figure 13 shows the overall mean reaction times in the three accent status conditions. The analyses by subjects and items showed that the main effect of accent status was significant ($F1(2, 54) = 4.2$, $p < 0.05$; $F2(2, 114) = 5.4$, $p < 0.01$). To further explore the main effect of accent status, post-hoc comparisons of the accent status means were carried out. Pairwise comparisons of nuclear accented and prenuclear accented showed that the reaction times to the two accent statuses were significantly different ($F1(1,54) = 3.9$, $p < 0.05$; $F2(1, 114) = 5.4$, $p < 0.05$). The reaction time to phoneme targets in words that were nuclear accented (415 ms) was faster than for words that were prenuclear accented (435 ms). However, pairwise comparisons of prenuclear accented and unaccented showed that the reaction times to the two accent statuses were not significantly different ($F1(1,54) = 0.68$, $p > 0.1$; $F2(1, 114) = 0.71$, $p > 0.1$), although the reaction time to phoneme targets was on average faster in prenuclear accented (435 ms) words than in unaccented (443 ms) words. Finally, as expected, pairwise comparisons of nuclear accented and unaccented showed that the reaction time to phoneme targets was faster in nuclear accented words than in unaccented words ($F1(1,54) = 7.9$, $p < 0.01$; $F2(1, 114) = 10.1$, $p < 0.01$).

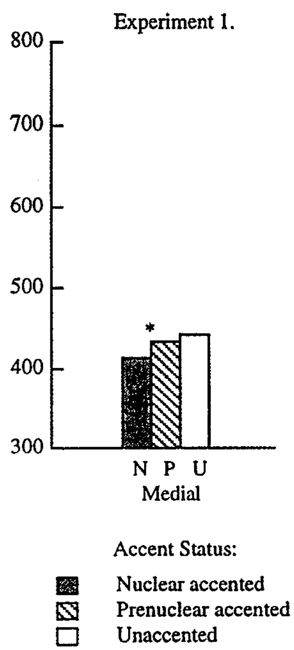


Figure 13. Experiment 1. Reaction times (in ms) to phoneme monitoring targets. Phoneme targets occurred in medial sentence position in three accent statuses: nuclear accented (N), prenuclear accented (P), and unaccented (U). Target consonants /p/ and /k/ were cued visually. Asterisks mark significant differences between categories ($p < 0.05$).

3.3.3 Discussion

The reaction time to phoneme targets in nuclear accented words was significantly faster than the reaction time to phoneme targets in prenuclear accented and unaccented words, as expected. However, the reaction time to phoneme targets in prenuclear accented words was not significantly faster than the reaction time to phoneme targets in unaccented words, although the prenuclear ones were on average faster than the unaccented ones. These results had the same pattern of significant differences as the syllable duration results, in which nuclear accented syllable rhyme was significantly longer than prenuclear accented and unaccented, but prenuclear accented and unaccented were not significantly different from one another. However, the reaction times to the target phonemes, which we take as a reflection of perceptual prominence and focus of attention, were not simply a consequence of the local acoustic strength of the target consonant itself, since consonant VOT measures would lead us to expect a significant difference between the two non-nuclear accent statuses.

The results of this experiment favor an interpretation in which nuclear accented words are perceptually distinguished from the other two accent statuses. In this interpretation, what is perceptually important to a listener in the phoneme monitoring task is whether the word is nuclear accented or not; prenuclear accented and unaccented are treated the same. Thus, the primary perceptual split in these data was between nuclear accented and non-nuclear accented, not between accented and unaccented.

3.4 Experiment 2: Early and late nuclear accent placement with regular nuclear accents

This experiment examined two intonation patterns using phoneme monitoring. Sentences had early and late nuclear accent placement, and all nuclear accents were regular nuclear accents. Words in early sentence position were nuclear accented or prenuclear accented, and words in late sentence position were nuclear accented or unaccented. The sentences were presented auditorily, and subjects pressed the 'yes' response button when they detected the target phoneme. The target phoneme was specified at the beginning of each trial by an auditorily presented phrase of the form, e.g., "Listen for /k/ as in *car*." The reaction time was predicted to be faster for nuclear accented than prenuclear accented in early sentence position and faster for nuclear accented than unaccented in late sentence position. In addition, reaction times were predicted to be faster in late sentence position than in early sentence position.

3.4.1 Method

Subjects

25 undergraduate volunteers from The Ohio State University participated in the experiment for course credit in introductory psychology classes. All subjects were native speakers of English and had normal or corrected-to-normal vision. No subjects reported any hearing loss. Five of the subjects failed to meet the accuracy criterion of at least 90% correct on the critical trials, leaving 20 subjects for the final data analysis. Ten subjects were assigned to each of the two lists.

Materials

There were 100 sentences with target phonemes specified for the experimental trials and 20 sentences with phoneme targets specified for the practice trials. Of the experimental trials, 40 of them were critical sentences. The critical sentences all contained one word beginning with a target phoneme, and they were all produced with two intonation patterns (early and late nuclear accent placement).

Critical materials. 40 sentences for the critical trials were developed from a list of 40 words which contained a target phoneme as the initial consonant of the word and a vowel as the second phoneme in the word. In all critical sentences, the word containing the target phoneme was a noun in either early or late sentence position. The target phoneme of the word was a bilabial or velar stop consonant (/p/, /b/, /k/, or /g/), and the target phoneme occurred nowhere else in the sentence. See Appendix B for the complete list of all the sentences and target phonemes used.

Twenty sentences had the word containing the target phoneme in early sentence position (as the head noun of the subject noun phrase), and twenty had the word containing the target phoneme in late sentence position (as the head noun of the object noun phrase). The sentences were read by the author with both early nuclear accent placement (U) and late nuclear accent placement (R), yielding a total of 80 utterances overall. (See Chapter 2 for further details about the two intonation patterns and their effects on F0, duration, and VOT of the target syllable and stop phoneme.) The words containing the target phonemes were either nuclear accented or non-nuclear accented, depending upon the placement

Table 6. Sample materials used in Experiment 2, phoneme monitoring (target phonemes cued auditorily). Nuclear vs. non-nuclear accent status in early and late sentence positions. The intonation patterns are characterized by late position accent status: regular nuclear accented (R) and unaccented (U) (early nuclear accent placement).

	Auditorily Presented Sentences	Phoneme Targets
Early Sentence Position:		
(R)	A <u>BOAT</u> was near the **TOWER**	/b/
(U)	A **<u>BOAT</u>** was near the tower.	/b/
Late Sentence Position:		
(R)	The BABY saw the **<u>CAT</u>**.	/k/
(U)	The **BABY** saw the <u>cat</u>.	/k/

Notes. The phoneme monitoring targets were the initial consonant phonemes of words in early and late sentence positions, shown underlined. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent.

of nuclear accent. Table 6 shows examples of the two different nuclear accent placements for a sentence with the word containing the target phoneme in early sentence position and for a sentence with the word containing the target phoneme in late sentence position. The words containing the target phonemes are underlined. Nuclear accented words are shown in bold capital letters, and prenuclear accented words are shown in small capital letters. In these examples, the early sentence position target phoneme is the /b/ in *boat*, and the late sentence position target phoneme is the /k/ in *cat*.

Additional materials. In addition to the 40 critical sentences, there were 40 filler sentences and 20 catch sentences, for a total of 100 experimental sentences. There were also 20 practice sentences used in the experiment. In the filler sentences, the target phoneme was also a word initial phoneme (followed by a vowel or sonorant consonant) which occurred nowhere else in the sentence. However, instead of being restricted to the target phonemes /p/, /b/, /k/, and /g/ which were used in the critical sentences, the target phoneme could also be one of the phonemes /w/, /f/, /s/, or /h/. The word containing the target phoneme in a filler sentence could be any word in the sentence, not just a noun in early or late sentence position. In the catch sentences, the target phoneme occurred nowhere at all in the sentence.

Design

Two lists resulted from nesting sentence position (early and late) within accent status (nuclear and non-nuclear). Both sentence position and accent status were within-subjects variables. List (2 stimuli lists) was a between-subjects variable. Therefore, the overall design for an ANOVA by subjects for this experiment was a 2 x 2 x 2 mixed factorial, with one between- and two within-subjects variables. The design for an ANOVA by items was a 2 x 2 x 2 mixed factorial with two between- and one within-items variables. The between-items variables were item group (2 groups) and sentence position (early and late). The within-items variable was accent status.

The 40 words containing target phonemes for the critical trials were randomly assigned to the two sentence positions, giving 20 words in early sentence position and 20 words in late sentence position. The 40 critical sentences containing the words with target phonemes were recorded with two intonation patterns, one with the word containing the target phoneme nuclear accented, and one with the word containing the target phoneme non-nuclear accented, yielding a total of 80 recorded sentences for the critical trials. In addition to the critical trials, the 40 filler and 20 catch sentences occurred with one of the two intonation patterns. The filler and catch trials occurred equally often in the two intonation patterns.

The 80 recorded sentences for the critical trials, and the sentences for the filler and catch trials, were digitized on a SUN SparcStation 10 at 16 kHz, 16 bit resolution. For each utterance, a two-channel audio file was made. One channel of the file contained the auditory prompt phrase for the target phoneme, 400 ms of silence, and then the recorded sentence. The other channel of the file contained a 10 ms long 1000-Hz tone placed at the end of the auditory prompt for the target phoneme. The tone marked the beginning of the time interval between presentation of the prompt specifying the target phoneme and the occurrence of the target phoneme itself. For the critical trials, the time point of the occurrence of the target phoneme (/p/, /b/, /k/, /g/) was the acoustic release of the stop, measured as described in Chapter 2.

An initial list containing 100 trials (40 critical trials, 40 filler trials, and 20 catch trials) was created according to the following randomization scheme. For each of the 40 critical sentences, the list contained either the version in which the word containing the target phoneme was nuclear accented or the version in which it was non-nuclear accented (prenuclear accented in early sentence position and unaccented in late sentence position). Twenty of the sentences had the word containing the target phoneme in early sentence position, and twenty had it in late sentence position. Ten critical trials occurred in each of the four experimental conditions. The list also contained the 40 filler sentences and the 20 catch sentences.

A second list was created from the first list by replacing the 40 critical trial sentences with the opposite accent status version of each sentence. Sentences which occurred in the nuclear accent status condition in the first list occurred in the non-nuclear accent status condition in the second list, and vice versa. Between the two lists, each word containing a target phoneme appeared in both accent status conditions (i.e., in early sentence position both nuclear accented and prenuclear accented, and in late sentence position both nuclear accented and unaccented).

A tape was made for each list. The sentences occurred in the same order on both tapes, but the location of nuclear accent within the critical trial sentences (and hence the accent status of the word containing the target phoneme) differed. The tapes were made by playing back the audio files in the predetermined pseudo-random order and recording them to stereo metal audio tapes with the speech on one channel and the tones on the other.

Procedure

Subjects were tested individually in a quiet room with the same experimental setup as in Experiment 1. In this experiment, however, the phoneme target for each trial was presented auditorily over the tape instead of being displayed visually on the computer screen. On each trial, subjects heard a phrase specifying the target phoneme they were to listen for, e.g. "Listen for /k/ as in *car* ", and a trial sentence (a critical, filler, or catch sentence). Subjects pressed the 'yes' response button when they detected the target phoneme, and they pressed the 'no' response button if they did not hear the target phoneme in the sentence. As in the first experiment, subjects were instructed that if the phoneme occurred in the sentence, it would always be the first consonant sound in a word, and that it was the phoneme and not the spelling that was important.

After the phoneme prompt, a timing tone on the second channel of the tape (which was not heard by subjects) was fed into a relay which was interfaced with the computer. When the tone activated the relay, the computer displayed a "ready" signal on the screen and started a millisecond timer. The button press response stopped the timer, recorded the reaction time, and cleared the screen. The true reaction time to the critical target phonemes (/p/, /b/, /k/, and /g/) was calculated by subtracting the time delay between the timing tone and the acoustic release of the stop (the release burst after the end of the closure interval) from the reaction time collected by the computer. There was a 4 second interval between the end of a sentence presentation and the start of the next trial.

A sentence recognition task was interspersed with the phoneme monitoring task to ensure that the subjects were attending to and comprehending the sentences instead of merely listening for individual consonants. Every ten phoneme monitoring trials were followed by three sentence recognition trials, for a total of 30 recognition trials during the experiment. Written sentences were displayed on the screen, and subjects pressed either the 'yes' or 'no' button on the response box to indicate whether they had heard the sentence during the experiment. Half of the sentences had occurred in the previous ten phoneme monitoring trials, and half were new sentences which did not occur during the experiment. As with the phoneme monitoring response, the yes/no button response stopped the timer and cleared the computer screen. After a sentence was presented on the screen, there was a 4 second interval before the start of the next trial.

In total, subjects were given 20 phoneme monitoring trials and 6 sentence recognition trials during the practice session and 100 phoneme monitoring trials and 30 sentence recognition trials during the experimental session.

3.4.2 Results

The mean response latency for each of the experimental conditions for each subject was computed with the same adjustments described in Experiment 1. The results were analyzed in two separate mixed factorial ANOVAs, one by subjects and one by items to match the designs described above. In the subject analysis, the data consisted of each subject's mean response times to the four experimental conditions (10 items contributed to the mean per condition). In the item analysis, the data consisted of the mean response time to the two experimental conditions that a sentence appeared in (10 subjects contributed to the mean per condition).

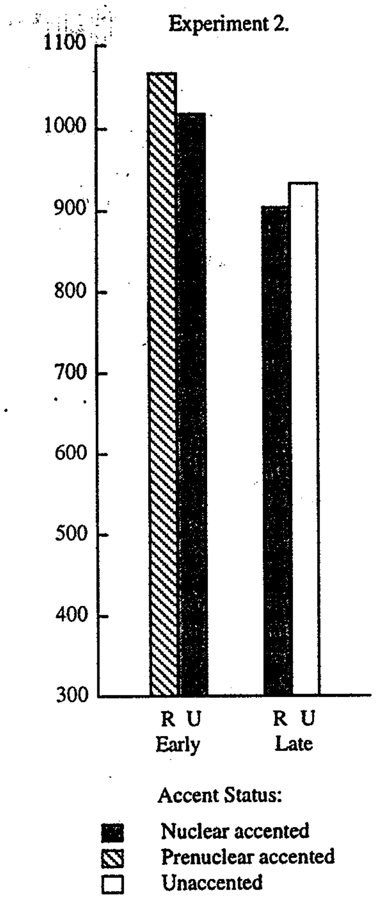


Figure 14. Experiment 2. Reaction times (in ms) to phoneme monitoring targets. Phoneme targets occurred in early and late sentence position of sentences with late regular nuclear accent placement (R) and early nuclear accent placement (U: unaccented in late position). Target consonants were cued orally from a set of eight possible consonants.

The overall mean reaction times are shown in Figure 14. The main effects of sentence position (early and late) and accent status (nuclear accented and non-nuclear accented) were significant by both subjects and items, but the two-way interaction of sentence position x accent status was not significant. Phoneme targets in late sentence position were responded to more quickly than phoneme targets in early sentence position ($F1(1, 18) = 22.4$, $p < 0.01$; $F2(1, 37) = 23.8$, $p < 0.01$). This is in line with Foss (1969) who found that phoneme monitoring response latencies are faster later in a sentence than they are early in a sentence. Phoneme targets in nuclear accented words were responded to more quickly than those in non-nuclear accented words ($F1(1, 18) = 5.8$, $p < 0.05$; $F2(1, 37) = 44.6$, $p < 0.01$). Recall that in early sentence position the non-nuclear condition corresponded to a prenuclear accented word, while in late sentence position the non-nuclear condition corresponded to an unaccented word. Because of the stress level differences in the two sentence positions, we might expect to see a sentence position x accent status interaction such that there is a larger reaction time difference between the nuclear and non-nuclear accented conditions in late sentence position than in early sentence position. However, again, this interaction was not significant ($F1(1, 18) = 0.23$, $p > 0.1$; $F2(1, 37) = 0.41$, $p > 0.1$).

3.4.3 Discussion

The result that phoneme monitoring responses were faster when the words containing the target phoneme were nuclear accented rather than non-nuclear accented was expected. Studies by Cutler and colleagues found phoneme monitoring in words with high stress (the word had contrastive stress) to be faster than in words with low stress (the word occurred after the contrastive stress) (e.g., Cutler 1976, Cutler & Foss 1977), and this result is similar to those. It is the late sentence position conditions of this experiment which most closely replicate Cutler's experiments, which apparently compared nuclear accented and unaccented in late sentence position. The current experiment also contrasted nuclear accented and prenuclear accented and found the same advantage for the phoneme targets in words with nuclear accent. This was documented by the existence of a significant main effect of accent status together with the lack of a significant interaction between sentence position and accent status.

The design of this experiment only allowed indirect comparison of prenuclear accented and unaccented because these accent statuses did not occur in the same sentence position. Only through a sentence position and accent status interaction could we say anything about the relative status of

prominence in prenuclear accented and unaccented words. Because there was no interaction between sentence position and accent status, we could not make a direct comparison. Given the results of the first experiment, which did contrast the three accent statuses in the same sentence position, it is not surprising that we saw no sentence position and accent status interaction.

The reaction times in Experiment 2 were very slow compared to previous phoneme monitoring experiments reported in the literature, which had reaction time means in the 300 to 600 ms range (e.g., Morton & Long, 1976; Cutler, 1976; Newman & Dell, 1978; Dell & Newman, 1980; Cutler, 1981; Foss & Gernsbacher, 1983). It is not clear why the reaction times were so much slower in this experiment than in earlier studies, including Experiment 1. One difference between Experiment 2 and previous studies is that subjects were monitoring for eight different targets in this experiments and not just one or two phonemes, as is more usual. However, Morton & Long (1976) used ten phoneme targets and also had quite fast reaction times. Although the reaction times in this study were so much slower than earlier studies, the pattern of results with respect to accent status is the same.[1]

3.5 Experiment 3: Early and late nuclear accent placement with three types of nuclear accents (expanded pitch range, regular, and downstepped)

This experiment examined four intonation patterns using phoneme monitoring. Sentences had early and late nuclear accent placement, and nuclear accents in late sentence position were of three types. Words in early sentence position were regular nuclear accented or prenuclear accented, and words in late sentence position were expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, or unaccented. The sentences were presented auditorily, and subjects pressed the 'yes' response button when they detected the target phoneme. The target phoneme was specified at the beginning of each trial by a capital letter, either 'P' for /p/ or 'K' for /k/. The reaction time was predicted to be faster for nuclear accented than prenuclear accented in early sentence position. In late sentence position, the reaction times were predicted to be, from fastest to slowest, expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and unaccented. In addition, the reaction times were predicted to be faster in late sentence position than in early sentence position.

3.5.1 Method

Subjects

80 undergraduate volunteers from The Ohio State University participated in the experiment for course credit in introductory psychology and linguistics classes. All subjects were native speakers of English and had normal or corrected-to-normal vision. No subjects reported any hearing loss. Ten subjects were assigned to each of the eight lists.

Materials

There were 176 sentences with target phonemes specified for the experimental trials and 20 sentences with phoneme targets specified for the practice trials. Of the experimental trials, 96 of them were critical sentences. The critical sentences contained two words beginning with potential target phonemes (one in early sentence position and one in late sentence position), and sentences were produced with four intonation patterns (early and late nuclear accent placement, and three types of nuclear accent in late sentence position).

Critical materials. Ninety-six sentences, distinct from those used in the first two experiments, were constructed so as to be suitable for use in the phoneme monitoring task. The initial phoneme of each word containing a target phoneme was a voiceless stop consonant (/p/ or /k/) which was followed by a vowel. Each sentence contained a word beginning with /p/ and a word beginning with /k/, one in early sentence position and one in late sentence position. 48 sentences had the word containing the /p/ target phoneme in early sentence position, and 48 sentence had the word containing the /k/ target phoneme in early sentence position. Those target phonemes occurred nowhere else in the sentence. Although the sentences had potential phoneme targets (either /p/ or /k/) in both early and late sentence position, an individual subject was to monitoring for only one of the phonemes in each sentence, as prompted at the beginning of a trial. See Appendix C for the complete list of all the sentences used in the experiment.

The 96 sentences were read by the author with four different intonation patterns, yielding a total of 384 utterances overall. As in Experiment 2, words in early sentence position were either prenuclear accented or nuclear accented, and words in late sentence position were either nuclear accented or unaccented. The nuclear accents in late sentence position were one of three types: expanded pitch range (X),

Table 7. Sample materials used in Experiment 3, phoneme monitoring (target phonemes cued visually). Accent status in early and late sentence position of four intonation patterns. The intonation patterns are characterized by late position accent status, in decreasing order of prominence: expanded pitch range (X), regular (R), and downstepped (D) nuclear accented, and unaccented (U) (early nuclear accent placement).

		Early /p/ Target	Late /k/ Target
(X)	Expanded pitch range nuclear accented	The POET admired the	**CANYON**.
(R)	Regular nuclear accented	The POET admired the	**CANYON**.
(D)	Downstepped nuclear accented	The POET admired the	**CANYON**.
(U)	Unaccented	The **POET** admired the	canyon.

Notes. The phoneme monitoring targets were the initial consonant phonemes of words in early and late sentence positions, shown underlined. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent.

regular (R), and downstepped (D). The nuclear accents in early sentence position were regular nuclear accents. Two of the intonation patterns are the same as those used in Experiment 2: early regular nuclear accent placement (U) and late regular nuclear accent placement (R). The other two intonation patterns have the other two types of nuclear accent in late sentence position: expanded pitch range nuclear accent (X) and downstepped nuclear accent (D) (See Chapter 2 for further details about the four intonation patterns and their effects on F0, duration, and VOT of the target syllable and stop phoneme.) Table 7 shows an example of the nuclear accent locations and accent types of the four intonation patterns for a sentence. The words containing the target phonemes are underlined. Nuclear accented words are shown in bold capital letters, and prenuclear accented words are shown in small capital letters. In this sentence, the early sentence position target phoneme is the /p/ in *poet*, and the late sentence position target phoneme is the /k/ in *canyon.*

Additional materials. In addition to the 96 experimental sentences, there were 20 filler sentences and 60 catch sentences, for a total of 176 experimental sentences. There were also 20 practice sentences used in the experiment. In the filler sentences, the target phoneme was also a word initial /p/ or /k/ phoneme which occurred nowhere else in the sentence. The word containing the target phoneme in a filler sentence could be any word in the sentence, not just a noun in early or late sentence position. In the catch sentences, the target phoneme occurred nowhere at all in the sentence.

Design

Eight lists resulted from crossing the two within-subjects variables sentence position (early and late) and intonation pattern (X, R, D, U). List (8 stimuli lists) was a between-subjects variable. Therefore, the overall design for an ANOVA by subjects for this experiment was an 8 x 2 x 4 mixed factorial, with one between- and two within-subjects variables. The design for an ANOVA by items was an 8 x 2 x 4 mixed factorial with one between- and two within-items variables. The between-items variable was item group (8 groups), and the within-items variables were sentence position (early and late) and intonation pattern (X, R, D, U).

The 96 critical sentences containing the words with target phonemes were recorded with four intonation patterns, yielding a total of 384 recorded sentences for the critical trials. In addition to the critical trials, the 20 filler and 60 catch sentences occurred with one of the two intonation patterns R or U. The filler and catch trials occurred equally often in the two intonation patterns.

The 384 recorded sentences for the critical trials, and the sentences for the filler and catch trials, were digitized on a SUN SparcStation 10 at 16 kHz, 16 bit resolution. For each utterance, a two-channel audio file of the type described in Experiment 1 was made. One channel of the file contained the recorded sentence, and the other channel of the file contained a 10 ms long 1000-Hz tone placed one second before the sentence was played on the other channel.

An initial list containing 176 trials (96 critical trials, 20 filler trials, and 60 catch trials) was created according to the following randomization scheme. For each of the 96 critical sentences, the list contained the sentence recorded in one of the four different intonation patterns, so that 24 sentences occurred with each intonation pattern. 48 of the sentences had the word containing the target phoneme in early sentence position, and 48 had it in late sentence position. Twelve critical trials occurred in each of the eight experimental conditions. The list also contained the 20 filler sentences and the 60 catch sentences.

The additional seven lists were created from the first list by replacing the 96 critical trial sentences with the other combinations of intonation pattern and target word position for each sentence. The eight lists had the trials in the same pseudo-random order, differing only by the intonation pattern that the critical sentences were read with. For each list, an equal

number of the critical sentences occurred in each intonation pattern, with each sentence only appearing once per list. Across the eight lists, each sentence occurred in all eight of the sentence position and intonation pattern conditions.

Four tapes were made for the eight lists. A tape served for two lists; where one list had the /p/ target for a critical item, the other had the /k/ target, and vice versa. The four tapes had the trials in the same pseudo-random order, differing only by the intonation pattern that the critical items were read with. The tapes were made by playing back the audio files in the predetermined pseudo-random order and recording them to stereo metal audio tapes with the speech on one channel and the tones on the other.

Procedure

Subjects were tested individually in a quiet room with the same experimental setup as in Experiment 1. The phoneme target for each trial ('P' for /p/, 'K' for /k/) was displayed visually on the computer screen. The same kind of sentence recognition task as in Experiment 2 was used. Every eleven phoneme monitoring trials were followed by two sentence recognition trials, for a total of 32 recognition trials during the experiment. Half of the sentences had occurred in the previous eleven phoneme monitoring trials, and half were new sentences which did not occur during the experiment.

In total, subjects were given 22 phoneme monitoring trials and 4 sentence recognition trials during the practice session and 176 phoneme monitoring trials and 32 sentence recognition trials during the experimental session.

3.5.2 Results

The mean response latency for the experimental conditions for each subject were computed with the same adjustments described in Experiment 1. The results were analyzed in two separate mixed factorial ANOVAs, one by subjects and one by items to match the designs described above. In the subject analysis, the data consisted of each subject's mean response times to the eight experimental conditions (12 items contributed to the mean per condition). In the item analysis, the data consisted of the mean response time to the eight experimental conditions (10 subjects contributed to the mean per condition).

Figure 15 shows the overall mean reaction times in the eight conditions. The analyses by subjects and items showed that the two-way interaction of intonation pattern and sentence position was significant (F1(3, 216) = 17.4, $p < 0.01$; F2(3, 264)= 15.3, $p < 0.01$), as were the main effects of sentence position (early and late) (F1(1, 72) = 39.6, $p < 0.01$; F2(1, 88) = 43.3, $p < 0.01$) and intonation pattern (X, R, D, U) (F1(3, 216) = 3.2, $p < 0.02$; F2(3, 264) = 2.5, $p = 0.06$). As in Experiment 2, phoneme targets in late sentence position were responded to more quickly than phoneme targets in early sentence position (early: 637 ms, late: 562 ms).

To further explore the two-way interaction of intonation pattern and sentence position, post-hoc comparisons of the intonation pattern means were carried out for early and late sentence positions. In both early and late sentence positions, the reaction time to phoneme targets in words with nuclear accent (averaging over all three types) was faster than those with non-nuclear accent. In early sentence position, the reaction time to phoneme targets in words with nuclear accent was on average 34 ms faster than those with prenuclear accent (nuclear: 611 ms, prenuclear: 645 ms) (F1(1, 216) = 19.2, $p < 0.01$; F2(1, 264) = 15.4, $p < 0.01$). In late sentence position, the reaction time to phoneme targets in words with nuclear accent was on average 45 ms faster than those which were unaccented (nuclear: 551 ms, unaccented: 596 ms) (F1(1, 216) = 32.7, $p < 0.01$; F2(1, 264)= 31.1, $p < 0.01$).

Comparing the reaction times in the prenuclear accented words (early sentence position of X, R, and D), we find that these reaction times were basically identical in the three intonation patterns with late nuclear accent placement. The only significant difference when making pairwise comparisons was that mean reaction time for the prenuclear accent in the regular nuclear accent pattern (R) was faster by subjects than that for the downstepped nuclear accent pattern (D) (F1(1, 216) = 4.9, $p < 0.05$; F2(1, 264) = 2.7, $p = 0.1$). The reaction times were not significantly different for expanded pitch range and regular, nor for expanded pitch range and downstepped (all $F < 1$, $p > 0.1$). The similarity of the reaction times within the prenuclear accented accent status was in contrast to the significant difference between the prenuclear accent in the regular nuclear accent pattern and the nuclear accent in the early nuclear accent placement pattern. As was found in Experiment 2, the nuclear accented case (611 ms) was faster than the prenuclear accented case (633 ms) (F1(1, 216) = 5.2, $p = 0.02$; F2(1, 264) = 5.1, $p = 0.02$).

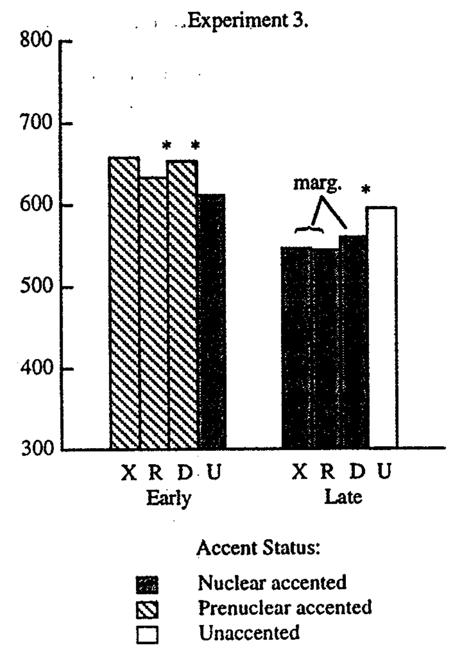


Figure 15. Experiment 3. Reaction times (in ms) to phoneme monitoring targets. Phoneme targets occurred in early and late sentence position of sentences of four intonation contour types: late nuclear accent placement (X: expanded pitch range, R: regular, D: downstepped) and early nuclear accent placement (U: unaccented in late position). Target consonants /p/ and /k/ were cued visually. Both /p/ and /k/ occurred in the critical sentences, while only one was the specified target for a given trial. Asterisks mark significant differences between categories ($p < 0.05$).

Comparing the reaction times in the nuclear accented words in the late nuclear accented intonation patterns (late sentence position of X, R, and D), we found that these reaction times were very similar, as were the prenuclear accent reaction times in the three intonation patterns. None of the reaction times for the three nuclear accent types were significantly different when making pairwise comparisons. The reaction times were essentially identical for expanded pitch range (547 ms) and regular nuclear accents (545 ms) ($F1(1, 216) = 0.02$, $p > 0.1$; $F2(1, 264) = 8 \times 10^{-6}$, $p > 0.1$). The reaction time differences approached significance for regular (545 ms) versus downstepped (561 ms) nuclear accents ($F1(1, 216) = 2.9$, $p = 0.09$; $F2(1, 264) = 2.1$, $p > 0.1$). However, when expanded pitch range and regular nuclear accents were taken together and compared with downstepped nuclear accents, the reaction time to phonemes in words with downstepped nuclear accents was marginally slower than the other two types of nuclear accent ($F1(1, 216) = 3.5$, $p = 0.06$; $F2(1, 264) = 2.8$, $p = 0.09$). The similarity of the reaction times within the nuclear accented accent status was in contrast to the significant difference between the downstepped nuclear accent and the unaccented accent statuses, where the downstepped nuclear accent had the slowest reaction time of the three nuclear accent types. The reaction time to phoneme targets in words with downstepped nuclear accents (561 ms) was significantly faster than for the unaccented words (596 ms) ($F1(1, 216) = 12.9$, $p < 0.01$; $F2(1, 264) = 12.9$, $p < 0.01$), as was the general result mentioned above for nuclear accented versus unaccented without distinguishing accent type.

3.5.3 Discussion

As in Experiment 2, the reaction time to phoneme targets in nuclear accented words was faster than in non-nuclear accented words, in both early and late sentence position. This was true for the two patterns investigated in Experiment 2, regular nuclear accents in early and late sentence position, and for the patterns with expanded pitch range and downstepped nuclear accents in late sentence position as well. These results were expected given the difference in accent status between nuclear accented and prenuclear accented and between nuclear accented and unaccented.

The reaction time to the phoneme targets in the nuclear accented words in late sentence position was very similar for all three types of nuclear accent. However, the reaction time was marginally slower for the downstepped nuclear accents than for the expanded pitch range and regular nuclear accents. This is consistent with the difference in phonetic

prominence as reflected by the VOTs. However, the expanded pitch range and the regular nuclear accents had equally large differences in VOT, but they showed no differences in the phoneme monitoring task.

The prenuclear accented words in the three intonation patterns with late nuclear accent placement were also quite similar to each other. The reaction times to the phoneme targets in the prenuclear accented words were not significantly different for the intonation patterns with expanded pitch range and the regular nuclear accents, although the expanded pitch range pattern had longer reaction times on average. However, the reaction time to the phoneme targets in the prenuclear accented words was significantly longer in the downstepped than in the regular nuclear accented pattern. This was an unexpected result because the accent status was identical (prenuclear accented), and the VOT for both cases was also identical.

3.6 General discussion

In summary, the phoneme monitoring results showed that a target phoneme was responded to more quickly when the word containing it was nuclear accented rather than non-nuclear accented, and that the three types of nuclear accented had nearly identical reaction times, with the exception that the downstepped nuclear accent was somewhat slower than the expanded pitch range and regular nuclear accents. The results of all three phoneme monitoring experiments suggest that the difference between nuclear accented and non-nuclear accented is what is perceptually important in the phonological three-way accent status distinction of nuclear accented, prenuclear accented, and unaccented. Grouping prenuclear accented and postnuclear unaccented together as non-nuclear accented in contrast to nuclear accented explains the results of the experiments better than either the three-way accent status distinction or a distinction between accented (prenuclear and nuclear) and unaccented. In addition, the experiments suggest that the accent status of a nuclear accented word is perceptually more important for focusing attention on it than the accent type, although accent type does influence the results somewhat.

The reaction times were significantly faster for both the prenuclear accented and nuclear accented words in the regular nuclear accented pattern than in the downstepped pattern. The difference in the prenuclear accents was unexpected, while the difference in the nuclear accents was expected. The difference for the prenuclear accents was unexpected because they had the same accent status in both intonation patterns. The acoustic information gave conflicting information about whether the prenuclear accented words were produced the same way in the two patterns; the VOTs were identical, but the syllable durations were longer in the downstepped nuclear accented pattern than in the regular nuclear accented pattern. For the nuclear accented words in the two patterns, the difference in the reaction times was expected because the downstepped nuclear accent was predicted to be less perceptually prominent than the regular nuclear accent, and the VOTs suggest that the target phonemes were produced more distinctly in the regular nuclear accented words than in the downstepped nuclear accented words. One possible explanation for why the reaction time was slower for the prenuclear accented words in the downstepped pattern than in the regular pattern has to do with the intonation pattern itself. For example, listeners may be able to tell from the beginning of the sentence that the sentence is in the downstepped pattern, which is anomalous in this out-of-the-blue context, given the contours meaning as suggested by Pierrehumbert and Hirschberg (1990) and Bolinger's various observations. That is, the downstepped intonation pattern would be much more natural as the second sentence of a story. For example, imagine a joke that starts "A poet, a hitman, and a lawyer were standing in a group of tourists at the Grand Canyon. The poet admired the canyon, the hitman considered pushing his victim over the edge, and the lawyer thought of suing the parks division for having no restraining fence ..." In the story context, the downstepped intonation pattern would be relatively natural, whereas it is somewhat odd in the out-of-the-blue context, and that oddness may account for the extra reaction time delay for the prenuclear accent. Comparing the reaction times to phoneme targets in downstepped sentences between sentences in an appropriate context and in isolation might address this issue. We would predict that the sentences in context would not show the extra reaction time delay.

The reaction time was on average faster, but not significantly faster, for the prenuclear accented words in the regular nuclear accented pattern than in the expanded pitch range pattern, and the reaction times were identical in the nuclear accented words. It is somewhat surprising that there was no difference in the phoneme monitoring times for the nuclear accents in these two patterns given the clear difference in acoustic prominence that the acoustic measures showed. The expanded pitch range nuclear accent had a much longer VOT than the regular nuclear accent (86 vs. 72 ms) and longer syllable duration (206 vs. 180 ms). It seems that there is no advantage in phoneme monitoring for the expanded pitch range nuclear accent over regular nuclear accent, even though the

acoustic measure suggests that the phoneme itself was produced more distinctly in the expanded pitch range nuclear accent, at least in these materials.

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[1] Experiment 2 was conducted before Experiments 1 and 3. In order to try to keep down the reaction times and improve their reliability in Experiments 1 and 3, the number of phoneme targets was reduced to two (the target phonemes were /p/ and /k/). In addition, the prompts which indicated which phoneme to monitor for during a trial were visual instead of auditory. The prompts stayed on the screen as a constant reminder of what phoneme to listen for, thereby simplifying the task by reducing the memory load on the subject. This combination of changes to the implementation of the task did indeed speed the reaction times.

CHAPTER IV

ACCENT AND INFORMATIONAL FOCUS:

A QUESTION-ANSWERING EXPERIMENT

This chapter presents the results of a question-answering experiment used to explore the informational focus and of the four intonation patterns used in Experiment 3. The experiment investigated the relationship between informational prominence and accent status (nuclear accented, prenuclear accented, and postnuclear unaccented) and nuclear accent type (expanded pitch range, regular, and downstepped). The experiment explored the question of whether differences in intonational structure influence the time it takes to answer a question about a sentence. The time it takes to answer a question about a sentence is influenced by what the listener is paying attention to in the sentence and what she thinks is important.

4.1 Background

In the question answering task, the subject hears an auditory sentence, sees a question, and presses a response button 'yes' or 'no' as quickly as possible to answer the question. The reaction time data measured in this task is the time delay between when the question is displayed on the screen and when the subject presses the response button.

Experiments with other conceptually related tasks show that intonation patterns influence the amount of attention that listeners pay to different parts of a sentence. Placing nuclear accent on a word emphasizes it, and omitting an accent de-emphasizes it. The location of nuclear accent is therefore important to the meaning of a sentence, and listeners are sensitive to such differences. For example, Terken & Nooteboom (1988) found that the intonation pattern of a sentence describing a simple scene influenced how quickly listeners could verify that the description of the scene was true or false. The accent status of the words in the sentences which referred to items in the scene interacted with the given/new status of the objects in the scene. An object in the scene which could be considered new information was verified faster when the word expressing

it was accented. That is, a listener was able to verify the description more quickly when the accent status drew attention to the new item. An object in the scene which could be considered given or old information was verified faster when the word expressing it was unaccented. That is, a listener was able to verify the description more quickly when the intonation pattern did not draw attention to the old information. In the experiment presented in this chapter, we investigated whether the intonation pattern of a sentence influenced the amount of time it took listeners to answer 'yes' or 'no' correctly to a question based on the sentence they just heard. The information gained from Experiment 3 and this experiment together can tell us about the informational prominence of the different types of nuclear accent.

4.2 Hypotheses

The basic hypothesis is that the more prominent a speaker makes a word by choice of its accent status, the greater the informational focus on the word, and the more attention listeners will pay to the word. Therefore, if a sentence has an intonation pattern that focuses the information which is relevant to answering a yes-no question, the subject should be able to answer the question more quickly. Thus, if there are differences in the time that it takes subjects to answer 'yes' or 'no' to a question after sentences with different intonation patterns, we can assume that the differences are due to the way the intonation pattern expresses the information structure and guides the listener's attention.

Consider what this general hypothesis predicts for the simple sentences used in Experiments 2 and 3 in the previous chapter. The specific predictions will depend upon where the intonational focus is placed (either early on the subject or late on the object) and on what information needs to be foregrounded in order to arrive at the correct 'yes' or 'no' response. It is easiest to determine what information needs to be foregrounded when the correct answer is 'no'.

For questions which should be answered 'no' because the subject noun phrase contains false information, the intonation pattern with early nuclear accent should lead to the fastest 'no' response. This is because the early nuclear accent falls on the word which is most important to answering the question correctly, the one that does not match. The intonation pattern with early nuclear accent on the subject noun phrase brings the subject noun phrase to the foreground as the "new" information or informational focus. The deaccenting of the object noun phrase relegates the object noun phrase to the background, which is appropriate for this kind of question because the object noun phrase is not particularly important to answering the question correctly. The intonation pattern with expanded pitch range nuclear accent in late sentence position should lead to the slowest response, because that intonation pattern emphasizes the object noun phrase and places narrow focus on the object noun phrase. This is misleading from the point of view of being able to answer the question quickly because the object noun phrase is the same in the sentence and the question, and as such should be backgrounded rather than foregrounded. No specific predictions are made for the intonation patterns with regular and downstepped nuclear accents in late sentence position because there is broad focus on the entire sentence. However, the results of the comparison may be informative.

For questions which should be answered 'no' because the object noun phrase contains false information, the predictions are just the opposite from the questions which should be answered 'no' because of the subject noun phrase. The intonation pattern with expanded pitch range in late sentence position should lead to the fastest 'no' response because the expanded pitch range nuclear accent on the object noun phrase brings the object noun phrase to the foreground as the "new" information or informational focus. The narrow focus on the object should draw attention to the object noun phrase, which is the information most important for answering 'no' correctly. The early nuclear accent placement pattern should lead to the slowest response because the nuclear accent is on the subject, leaving the information most important to answering the question unaccented. The deaccenting of the object noun phrase relegates the object noun phrase to the background, which is misleading because the information which is most important to answering the question should be foregrounded rather than backgrounded. Again, the results of the experiment may be informative for the intonation patterns with regular and downstepped nuclear accents in late sentence position.

The predictions are not as clear for questions that should be answered 'yes' since in these questions both the subject and the object contain information that is important to answering the question correctly. The expanded pitch range pattern may be slightly faster than the other patterns because of the emphasis on the last part of the sentence which remains to be verified when reading the question. However, any of the intonation patterns may be equally suitable or unsuitable for the 'yes' question.

4.3 Method

Subjects

48 undergraduate volunteers from The Ohio State University participated in the experiment for course credit in introductory psychology classes. All subjects were native speakers of English and had normal or corrected-to-normal vision. No subjects reported any hearing loss. Twelve subjects were assigned to each of the four lists.

Materials

There were 168 sentence-question pairs for the experimental trials and 10 sentence-question pairs for the practice trials. Of the experimental trials, 96 of them were critical sentences. The critical sentences were all produced with four intonation patterns (early and late nuclear accent placement, and three types of nuclear accent in late sentence position).

Critical materials. The ninety-six critical sentences and the four intonation patterns (X, R, D, U) used in Experiment 3 were used in this experiment. The words in early sentence position were either prenuclear accented or nuclear accented, and words in late sentence position were either nuclear accented or unaccented. The nuclear accents in late sentence position were of three types: expanded pitch range (X), regular (R), and downstepped (D). The nuclear accents in early sentence position were regular nuclear accents. (See Chapter 2 for further details about the four intonation patterns and their effects on F0, duration, and VOT of the target syllable and stop phoneme.)

Three different kinds of yes/no questions were written for the sentences. One kind of question was answered 'no' because of the subject noun phrase ((a) in Table 8), one was answered 'no' because of the object noun phrase ((b) in Table 8), and one was answered 'yes' ((c) in Table 8). Thus, the 'no' questions can be distinguished by whether the listener knew that the answer was 'no' early in the sentence (because of subject mismatch, called early 'no') or late in the sentence (because of object mismatch, called late 'no'). Table 8 shows an example of the nuclear accent locations and accent types of the four intonation patterns for a sentence and the three kinds of yes/no questions that were used in the experiment. Nuclear accented words are shown in bold capital letters, and prenuclear accented words are shown in small capital letters. See Appendix D for the complete list of all the sentences and questions used in the experiment.

Table 8. Sample materials used in Experiment 4, question answering. Accent status in early and late sentence position of four intonation patterns. The intonation patterns are characterized by late position accent status, in decreasing order of prominence: expanded pitch range (X), regular (R), and downstepped (D) nuclear accented, and unaccented (U) (early nuclear accent placement).

(X)	Expanded pitch range nuclear accented	The POET admired the **CANYON** .
(R)	Regular nuclear accented	The POET admired the **CANYON** .
(D)	Downstepped nuclear accented	The POET admired the **CANYON** .
(U)	Unaccented	The **POET** admired the canyon.

Question Types		Sample sentence and question pairs
(a) 'No' because of subject mismatch (Early 'no')	(U)	The **POET** admired the canyon. Did the doctor admire the canyon?
(b) 'No' because of object mismatch (Late 'no')	(M)	The PARCEL held a **KEY**. Did the parcel hold a donut?
(c) 'Yes'	(R)	The CATCHER missed the **PASS**. Did the catcher miss the pass?

Notes. Each sentence was associated with only one of the three different questions types. Across the four lists, all four versions of a sentence were paired with the appropriate question. Sentences were presented auditorily, and questions were presented visually. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent.

The questions were direct syntactic transformations of the sentences into questions, with the substitution of one word in the subject or object noun phrase for the 'no' questions, and no change other than the interrogative reordering in the 'yes' questions. There were two constraints in writing the questions. The first constraint involved making sure that the substituted noun in a question was not semantically related to any of the words in the sentence. This was so that the questions would be clearly false and not require a great deal of effort in making that decision, as might be required if words were semantically related. The second constraint involved making sure that the substituted noun in a question began with a different phoneme from the original noun in the sentence so that the words were phonologically distinct from the beginning of the word, so that the subject could make the decision as early as possible upon

reading the word. Further, this eliminated any complication from phonological interference effects.

Additional materials. In addition to the 96 critical sentence-question pairs, there were 72 filler sentence-question pairs, for a total of 168 experimental sentence-question pairs. There were also 16 practice sentence-question pairs used in the practice session. In the filler trials, 20 of the questions were answered 'no' and 52 were answered 'yes'. One purpose of the filler trials was to balance the number of 'yes' and 'no' responses. Another purpose of the filler trials was to disguise the fact that in all of the critical trials, the questions were direct syntactic transformations of the sentences into questions, with the substitution of at most one word in the subject or object noun phrase. Therefore, the filler questions involved rewording the subject matter of the sentences or required the subject to make inferences in order to answer the questions.

Design

Four lists resulted from nesting question type (early 'no', late 'no', and 'yes') within intonation pattern (X, R, D, U). Both variables were within-subjects variables. Question type was nested within intonation pattern because a fully factorial design in which every version of every sentence was paired with every question type would require many subjects in order to have adequate statistical power. Each sentence was randomly assigned to one of the three yes/no question types, for 32 sentences in each question type condition. List (4 stimuli lists) was a between-subjects variable. Therefore, the overall design for an ANOVA by subjects for this experiment was a 4 x 4 x 3 mixed factorial, with one between- and two within-subjects variables. The design for an ANOVA by items was a 4 x 4 x 3 mixed factorial with two between- and one within-items variables. The between-items variables were item group (4 groups) and question type (early 'no', late 'no', and 'yes'), and the within-items variable was intonation pattern (X, R, D, U).

The recorded sentences for the critical and filler trials were previously digitized on a SUN Sparc 10 at 16 kHz, 16 bit resolution as they were used in Experiment 3. For each utterance, a two-channel audio file was made. One channel of the file contained the recorded sentence, and the other channel of the file contained a 10 ms long 1000-Hz tone placed at the acoustic offset of the sentence. The tone marked the time when the question was to be displayed on the computer screen.

An initial list containing 176 trials (96 critical trials and 72 filler trials (52 'yes' questions and 20 'no' questions)) was created according to the following randomization scheme. For each of the 96 critical sentences, the list contained the sentence recorded in one of the four different intonation patterns, so that 24 sentences occurred with each intonation pattern. 32 of the sentences had early 'no' (subject mismatch) questions, 32 had late 'no' (object mismatch) questions, and 32 had 'yes' questions. Twelve critical trials occurred in each of the eight experimental conditions. The list also contained the 72 filler sentences.

The additional three lists were created from the first list by replacing the 96 critical trial sentences with the other intonation patterns for each sentence. The four lists had the trials in the same pseudo-random order, differing only by the intonation pattern that the critical sentences were read with. For each list, an equal number of the critical sentences occurred in each intonation pattern, with each sentence appearing only once per list. Across the four lists, each sentence occurred in all four intonation patterns, but because each sentence was paired with only one of the question types, each sentence occurred in only four of the twelve intonation pattern x question type conditions.

A tape was made for each list. The four tapes had the trials in the same pseudo-random order, differing only by the intonation pattern that the critical items were read with. The tapes were made by playing back the audio files in the predetermined pseudo-random order and recording them to stereo metal audio tapes with the speech on one channel and the tones on the other.

Procedure

Subjects were tested individually in a quiet room with the same experimental setup as in the phoneme monitoring experiments. The sentences were played binaurally through the headphones at a comfortable listening level that was the same for all subjects. On each trial subjects heard a trial sentence, either a filler or a critical sentence. The question for each trial was displayed visually on the computer screen. A tone on the second channel of the tape synchronized with the acoustic offset of the sentence activated a voice-activated relay which displayed the question on the screen and started a millisecond timer. The subject responded 'yes' or 'no' by pressing the appropriately labeled button. The button press response stopped the timer, recorded the reaction time, and cleared the question from the screen.

In total, subjects were given 10 question-answering trials during the practice session and 168 question-answering trials during the experimental session.

4.4 Results

The effects of outliers were curtailed by cutoffs established at ± 2.5 standard deviations from the mean for each subject. Values greater than 2.5 standard deviations from the mean were replaced with the cutoff values. Trials in which the subject failed to answer the question and trials in which the subject responded in less than 100 ms were omitted from the reaction time data. These types of error accounted for fewer than 0.5% of the data, and outliers accounted for fewer than 0.5% of the data. With these adjustments, the mean response latency was computed for each of the experimental conditions for each subject (collapsed across items) and for each item (collapsed across subjects).

The results were analyzed in two separate mixed factorial ANOVAs, one by subjects (reported as F1) and one by items (reported as F2) to match the designs described above. In the subject analysis, the data consisted of each subject's mean response times to the 12 experimental conditions (8 items contributed to the mean per condition). In the item analysis, the data consisted of the mean response time to an item for each of the 4 experimental conditions that it appeared in, collapsed across the 12 subjects who received the item in each condition. 32 items contributed to the means for each of the 12 experimental conditions.

Figure 16 (top) shows the reaction times in the 12 conditions. The analyses by subjects and items showed that the two-way interaction of intonation pattern and question type was significant ($F1(6, 264) = 3.7$, $p < 0.01$; $F2(6, 252) = 3.1$, $p < 0.01$), as were the main effects of intonation pattern ($F1(3, 132) = 4.6$, $p < 0.01$; $F2(3, 252) = 3.4$, $p = 0.02$) and question type ($F1(2, 88) = 56.3$, $p < 0.01$; $F2(2, 84) = 21.8$, $p < 0.01$). The main effect of question type was that 'yes' questions had much faster response times than the 'no' questions ('yes': 1335 ms, early 'no': 1561 ms, late 'no': 1566 ms); there was no significant difference in the response times to the early 'no' and the late 'no' questions ($F(1, 88) < 1$, $p > 0.1$).

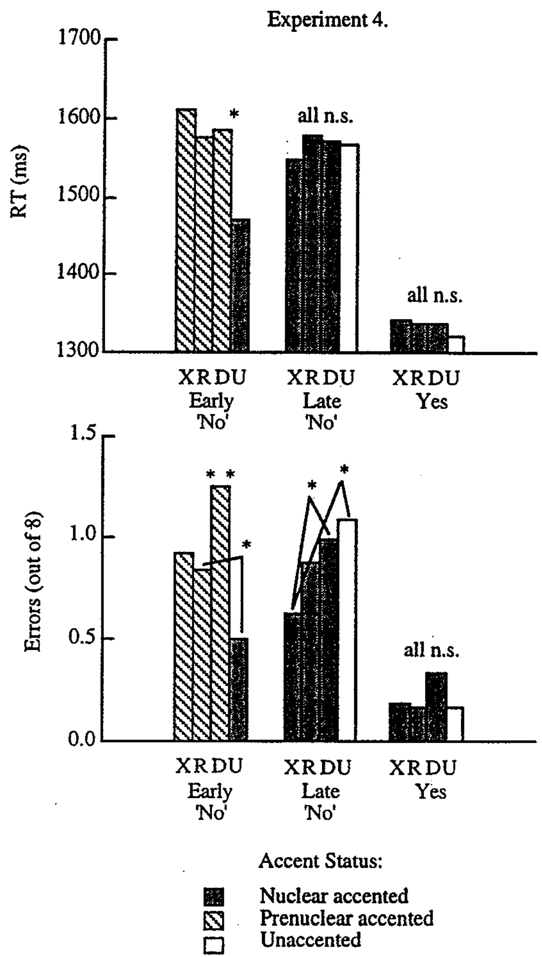

Figure 16. Experiment 4.
(top) Reaction times (in ms) to answer questions 'yes' or 'no'.
(bottom) Number of errors (out of 8) in answering questions 'yes' or 'no'.
Noun phrases critical to answering the questions correctly occurred in early and late sentence position in sentences with late nuclear accent placement (X: expanded pitch range, R: regular, D: downstepped) and early nuclear accent placement (U: unaccented in late position). Asterisks mark significant differences between categories ($p < 0.05$).

To further explore the two-way interaction of intonation pattern and question type, post-hoc comparisons of the intonation pattern means were carried out for each question type. The intonation pattern made significant differences in the reaction time only in the early 'no' questions. Intonation pattern had no significant influence on reaction time for the late 'no' and 'yes' question types. That is, the reaction times were not significantly different for any of the pairs of intonation patterns in the late 'no' and the 'yes' questions. In the early 'no' questions the three patterns with late nuclear accent placement (X, R, and D) were not significantly different from one other, but the reaction time was significantly faster for the early nuclear accent placement pattern (U) than for the downstepped pattern (D), the fastest of the late nuclear accent placement contours, and hence it was faster than all three patterns with late nuclear accent placement (X, R, D) ($F1(1, 264) = 20.1$, $p < 0.01$; $F2(1, 252) = 7.6$, $p < 0.01$).

Because the subjects and items analyses of the reaction times did not indicate many differences between the intonation patterns, an error analysis was also conducted, with the same design as the subjects design described above. Figure 16 (bottom) shows the errors (out of 8) in the 12 conditions. In the errors analysis, the data consisted of the number of errors (i.e., the questions answered incorrectly or not answered at all) that each subject made in each of the 12 experimental conditions (8 items contributed to the mean per condition). As in the subjects and items analyses, the analysis showed that the two-way interaction of intonation pattern and question type was significant ($F1(6, 264) = 3.9$, $p < 0.01$), as were the main effects of intonation pattern ($F1(3, 132) = 4.6$, $p < 0.01$; $F2(3, 252) = 5.1$, $p < 0.01$) and question type ($F1(2, 88) = 26.7$, $p < 0.01$). The main effect of question type was that 'yes' questions had fewer errors than the 'no' questions ('yes': 0.214, early 'no': 0.875, late 'no': 0.891); there was no significant difference in the number of errors in the early 'no' and the late 'no' questions ($F(1, 88) < 1$, $p > 0.1$).

To further explore the two-way interaction of intonation pattern and question type in the error analysis, post-hoc comparisons of the intonation pattern means were carried out for each question type. The intonation pattern made significant differences in the reaction time in both the early 'no' and late 'no' questions, but not in the 'yes' questions. That is, the reaction times were not significantly different for any of the pairs of intonation patterns in the 'yes' questions.

In the early 'no' questions there were significantly fewer errors for the early nuclear accent placement pattern (U) than for the late regular nuclear accent placement pattern (R) ($F1(1, 264) = 5.0$, $p < 0.05$) and the downstepped nuclear accent pattern (D) ($F1(1, 264) = 25.1$, $p < 0.01$). The expanded pitch range and regular nuclear accented patterns had the same number of errors ($F1(1, 264) <1$, $p > 0.1$). The downstepped pattern had significantly more errors than the regular nuclear accent pattern ($F1(1, 264) = 7.7$, $p < 0.01$) and the early nuclear accented pattern, as reported above.

In the late 'no' questions, the number of errors increased as the prominence of the late sentence word decreased. Although none of the adjacent pairs were significantly different from one another (i.e., X vs. R, R vs. D, D vs. U), pairs two and three away from each other in the posited prominence hierarchy were significantly different (X vs. D: $F1(1, 264) = 5.6$, $p = 0.02$; X vs. U: $F1(1, 264) = 9.4$, $p < 0.01$). This is evidence that the trend is significant, even though not all of the individual steps are statistically different.

4.5 Discussion

The overall results of the experiment show that intonation pattern does influence the way that listeners attend to sentences and answer simple yes/no questions about them. However, the influence of intonation pattern was only present for the 'no' questions and not the 'yes' questions. For the 'yes' questions, the type of intonation pattern did not influence the time that it took for the subjects to answer the questions, nor did it influence the number of errors that subjects made when answering the questions. Subjects were much faster answering the 'yes' questions than the 'no' questions, and they were much more accurate as well. The result that 'yes' questions were answered an average of 229 ms faster than the 'no' questions (1335 ms vs. 1564 ms) agrees with the general psycholinguistic result that 'no' responses take longer than 'yes' responses.

For the 'no' questions, however, the type of intonation pattern did influence the time that it took subjects to answer the questions in the early 'no' condition, and it also influenced the number of errors that subjects made when answering the questions in both 'no' conditions. Furthermore, although the average time that it took to answer the 'no' questions was the same whether the word that made the question false was early in the sentence or late in the sentence, the influence of intonation pattern on reaction time and errors was different for the two kinds of 'no' questions.

In the questions that were answered 'no' because the false information was early in the sentence, the reaction times matched the predictions. The intonation pattern with the early nuclear accent led to the fastest

responses, and it also had the least number of errors. This intonation pattern had nuclear accent on the information which was most important to answering the question correctly, and the subject's responses showed that it was easier to answer the question correctly than for the other intonation patterns. The other specific prediction, that the intonation pattern with expanded pitch range nuclear accent in late sentence position would lead to the slowest responses, was borne out by the qualitative trend but not by any significant statistical differences. Statistically there were no significant differences between the response times for the three contours with late nuclear accent placement. It seems that the location of nuclear accent, no matter what type, made the most influence on whether subjects were able to answer the question quickly. When the nuclear accent was on subject noun phrase, which was most important to answering the question correctly, rather than on the object noun phrase, the responses were on average 114 ms faster. The results for this kind of sentence-question pair support the interpretation that nuclear accent influences what part of the sentence the listener pays most attention to, and what they remember best when questioned about it.

In the questions which were answered 'no' because the false information was late in the sentence, the reaction times did not match the predictions as well as they did for the early 'no' questions. The prediction that the intonation pattern with expanded pitch range nuclear accent in late sentence position would lead to the fastest responses was borne out qualitatively but not statistically; although the reaction time for the expanded pitch range nuclear accent pattern (X) was shortest there were no significant differences between the response times for any of the four intonation patterns. Differences between the reaction times in the four intonation patterns may have been obscured by the effect of reprocessing right at the end of the sentence, because the late 'no' questions look exactly like 'yes' questions until the final word of the question.

Although the response times showed no significant differences for the four intonation patterns, the error data did show significant differences, and in the predicted direction. The intonation pattern with expanded pitch range nuclear accent in late sentence position had the fewest errors, and the pattern with early nuclear accent placement had the most errors. Furthermore, there were fewer errors as the prominence of the accent type increased. That is, of the three nuclear accent types in late sentence position, there were most errors for the downstepped nuclear accent, slightly fewer errors for the regular nuclear accent, and least errors for the expanded pitch range nuclear accent. Furthermore, early nuclear accented intonation pattern which was unaccented in late sentence position had the most errors of all, almost twice as many errors as the expanded pitch range pattern. Therefore, the error data suggest that accent status and accent type do influence the amount of attention that listeners pay to words in sentences and how they remember them when asked questions about them.

CHAPTER V

ACCENT AND PRIMING:

TWO CROSS-MODAL NAMING EXPERIMENTS

This chapter presents the results of two experiments which examined the relative prominence of the three types of accent status (nuclear accented, prenuclear accented, and postnuclear unaccented) using the cross-modal naming paradigm. The experiments explore the question of whether differences in intonational structure influence word recognition, lexical access, and sentence processing, above and beyond what can be accounted for by the lexical content of sentences. Specifically, it investigates whether the accent status (nuclear accented, prenuclear accented, unaccented) of a priming word in a sentence affects the naming time of a target word, and thus the speed of lexical access of the target word. Further, the study investigates whether intonational structure influences the time course of activation of priming in a sentence because of a connection to the attentional state of the listener.

5.1 Background

In the cross-modal naming task, the subject hears an auditory priming context (a word, phrase, or sentence), sees a visual target word, and then names the target word (reads the target word aloud) as quickly as possible. Cross-modal refers to the difference in modality (auditory and visual) of the stimuli that are presented to the subject. The reaction time data measured in this task is the time delay between when the target word is displayed and when the subject begins naming the target word. In the lexical decision task, the subject decides as quickly as possible whether a visual target is a valid word. Both tasks tap on-line aspects of the role of the lexicon in sentence processing. They measure the speed of word recognition and lexical access, and they allow the effects of lexical priming to be observed. The naming task is a reasonably natural task which is relatively free from decision effects unrelated to the process of lexical access (Forster 1981: p. 472).

Previous studies using these two tasks have shown that words are

recognized more quickly when they are preceded by a semantically related word (e.g., Meyer & Schvaneveldt 1971, Collins & Loftus 1975, Neely 1977). This result generally holds true for words following sentences which contain related words as well as for single word contexts, for both visually and auditorily presented words and sentences (Forster 1981, Peterson & Simpson 1989, Simpson et al. 1989, O'Seaghda 1991, among many others). The general result is that a word which is related to a word in the sentence is recognized faster than one which is not related to any word in the sentence context. For example, after a sentence such as *A boat was near the tower*, the word *ship* is recognized more quickly than a word such as *shop* which is not semantically related to any word in the sentence. However, this priming effect is not always observed and may be due to differences in the mode of presentation (e.g., auditory vs. visual, see Sharkey & Sharkey 1992). Other factors besides the presence of a related priming word which influence the naming times of the target word are word frequency (faster naming when the word prior to the naming target word is a high frequency rather than a low frequency word and also when the naming target word is a high frequency word) and sentence position (target words are named faster when they are presented later in the sentence rather than early in the sentence).

Collins & Loftus (1975:411) proposed a spreading-activation theory to account for the semantic priming result. According to this model, a word spreads activation throughout the semantic network that it is a part of, and words that are connected to it will be activated to a certain extent. They assumed that (a) the semantic network is organized by semantic similarity, (b) the longer that the concept is in continuous processing (via reading, hearing, rehearsing, etc.) the longer activation is released, and (c) activation decreases over time and/or intervening activity. Neely (1977) proposed that in addition to fast automatic inhibitionless spreading-activation from a word, that there is also a slow limited-capacity conscious-attention mechanism that comes into play when processing words. He assumed that the limited-capacity attentional mechanism is (a) slow acting, (b) cannot operate without intention and conscious awareness, and (c) inhibits retrieval of information stored in semantically unrelated logogens upon which it is not focused (1977:228, and see Morton 1969 about the logogen model).

For the most part, priming effects due to intonation and/or focus have not been systematically explored previously, even in the experiments which have used the cross-modal naming task. Most of those experiments did not control the intonation pattern or the pattern of emphasis over the auditory priming context sentences. In view of the difference that intonational structure makes to the meaning of a sentence, and the degree to which it differentially emphasizes words within sentences, it is interesting to investigate whether the intonational structure of a sentence also affects lexical priming.

The experiments examined two intonation patterns using cross-modal naming. Experiment 5 used semantic associate priming, and Experiment 6 used identity priming. Sentences had early and late nuclear accent placement, and all nuclear accents were regular nuclear accents. Priming words in early sentence position were nuclear accented or prenuclear accented, and priming words in late sentence position were nuclear accented or unaccented. That is, the three-way distinction in accent status (nuclear accented, prenuclear accented, and postnuclear unaccented) was represented between the two sentence positions. The sentences were presented auditorily as the priming context, and subjects named the target words as quickly as possible. Target words were presented visually at three delay conditions.

5.2 Hypotheses

There are two accounts that predict different possible outcomes of the effects of accent status on naming time, a spreading-activation theory and a focus-of-attention theory. The spreading-activation theory can be interpreted as predicting differences in semantic priming of related target words which depend upon accent status of the priming words (following Collins & Loftus 1975). Related target words are named faster than unrelated target words, and because of short-term activation dying off, target words are named more slowly at longer time delays. However, because nuclear accent makes a word perceptually as well as informationally highly prominent, the activation from a nuclear accented word will be stronger and longer lasting than the activation produced by a word without nuclear accent. Therefore, target words related to nuclear accented priming words should be responded to more quickly than those related to priming words that are not nuclear accented (i.e. are prenuclear accented or are postnuclear unaccented). At longer time delays, also related target words should be responded to more quickly when the priming word is nuclear accented than when it is not, since the semantic activation stays present in memory longer and continues to prime related concepts. This account also predicts that the priming differences between nuclear accented and unaccented priming words should be greater than the priming differences between nuclear accented and prenuclear accented

priming words. Thus, this account predict differences that accrue from the effects of accent status on the naming times of related targets.

The focus-of-attention theory (following Neely 1977) predicts inhibition of unrelated concepts which depend upon accent status of the priming word. As with the first theory, related target words are predicted to be named faster than unrelated target words. Again, nuclear accent draws attention to the nuclear accented word. Attention is focused on the nuclear accented word and its related concepts, which inhibits retrieval of information stored in semantically unrelated logogens upon which attention is not focused. Because the focus-of-attention mechanism is slow acting, target words are named faster at longer time delays. Therefore, target words unrelated to nuclear accented priming words are responded to more slowly than target words unrelated to non-nuclear accented priming words because a greater shift of attention is needed in the nuclear accented case. By the same token, the nuclear accented priming word should cause the related target word to be responded to more quickly than a priming word without nuclear accent, unless there are ceiling effects of attention on related target words. At longer time delays, unrelated target words are responded to more slowly when the priming word is nuclear accented than when it is not, because the listener's attention is focused more strongly in the nuclear accented case. The argument of strength of attention from accent also predicts that the priming differences between nuclear accented and unaccented priming words should be greater than the priming differences between nuclear accented and prenuclear accented priming words. Thus, by contrast to the first account, the focus of attention theory predicts the clearest differences in the naming times for the targets which are not primed by a preceding semantically related word.

In addition to the standard relatedness effects (related target words are named more quickly than unrelated target words) and the predictions made by the two theories for accent status, early sentence position target words should be named more slowly than late sentence position target words. Early sentence position target words are presented while the sentence is still being heard, and late sentence position target words are always presented after the completion of the sentence. This means that subjects must both continue to listen to the sentence and name the target word in the early sentence position trials but only name the target word in the late sentence position trials since the sentence is completed when the target word is presented. Having to perform two tasks at once makes it almost certain that the naming task will not be performed as quickly for the early sentence position trials.

5.3 Experiment 5: Semantic associate priming

5.3.1 Method

Subjects

48 undergraduate volunteers from The Ohio State University participated in the experiment for course credit in introductory psychology and linguistics classes. All subjects were native speakers of English and had normal or corrected-to-normal vision. No subjects reported any hearing loss. Six of the 48 participants failed to meet the speed criterion, described in Procedure below, leaving 42 subjects whose data was used in the analysis. Seven subjects were assigned to each of the six lists.

Materials

There were 192 sentence and target word pairs for the experimental trials and 25 sentence and target word pairs for the practice trials. 96 critical sentences were used, each containing one priming word and each produced with two intonation patterns (early and late nuclear accent placement).

Critical materials. Materials for the experimental trials were developed from 96 word triples. All words in the triples were nouns. One word of each triple was the priming word and occurred in an auditorily presented sentence, and the other two words were visually presented target words. One of the target words was semantically related to the priming word, and the other target word was unrelated to the priming word. See Appendix E for the complete list of all the sentences and target words used.

Ninety-six sentences were constructed using the priming words of the word triples. Forty-eight sentences had the priming word in early sentence position (as the head noun of the subject noun phrase), and forty-eight had the priming word in late sentence position (as the head noun of the object noun phrase). All of the sentences were read by the author with both early nuclear accent placement (U) and late nuclear accent placement (R), yielding a total of 192 utterances overall. (See Chapter 2 for further details about the two intonation patterns and their effects on F0, duration, and VOT of the target syllable and stop phoneme.) The priming words were either nuclear accented or non-nuclear accented depending upon the placement of nuclear accent. Table 9 shows examples

of the two different nuclear accent placements for a sentence with the priming word in early sentence position and for a sentence with the priming word in late sentence position. Nuclear accented words are shown in bold capital letters, and prenuclear accented words are shown in small capital letters.

The two words of the word triples which were semantically related (the priming word and the related target word) belong to the same semantic category, as given in the Battig & Montague (1969) category norms. The semantically related words were intended to be bidirectional semantic associates (see Peterson & Simpson 1989 for a discussion of the difference between bidirectional and unidirectional associates and the implications for priming effects). Sets of association norms were used, where possible, to verify these association relations and to supplement the category information obtained from Battig & Montague (Palermo & Jenkins 1964, Shapiro & Palermo 1968, Postman & Keppel 1970). As judged by the experimenter and a colleague, the unrelated target word bore no relation to the priming word or to the general meaning of the sentence containing the priming word.

The two target words of a word triple (the related and unrelated target words) were matched for printed word frequency and had the same or

Table 9. Sample materials used in Experiments 5 and 6, cross-modal naming. Nuclear vs. non-nuclear accent status in early and late sentence positions. The intonation patterns are characterized by late position accent status: regular nuclear accented (R) and unaccented (U) (early nuclear accent placement).

	Auditorily Presented Sentences	Visually Presented Naming Targets: Experiment 5 Semantic Priming	Visually Presented Naming Targets: Experiment 6 Identity Priming
Early Sentence Position:			
(R)	A <u>BOAT</u> was near the **TOWER**.	Related: SHIP	Identical: BOAT
(U)	A <u>**BOAT**</u> was near the tower.	Unrelated: SHOP	Unrelated: BOX
Late Sentence Position:			
(R)	The BABY saw the <u>**CAT**</u>.	Related: DOG	Identical: CAT
(U)	The **BABY** saw the <u>cat</u>.	Unrelated: DUST	Unrelated: CLOCK

Notes. The naming targets were presented visually after the acoustic offset of the priming words in early and late sentence positions, shown underlined. Small capital letters indicate prenuclear accent, and bold capital letters indicate nuclear accent.

acoustically similar word onsets (initial phonemes). In addition, when possible, the nouns had high concreteness ratings (at least 500). Noun candidates with suitable word frequencies, onsets, and concreteness ratings were selected with the help of an on-line psycholinguistics database (Coltheart 1981, Wilson 1987, Kučera & Francis 1967). Table 9 shows a few examples of the priming relationships used in the experiment. The word triple BOAT - SHIP - SHOP occurred in the early sentence position condition, and the word triple CAT - DOG - DUST occurred in the late sentence position condition. CAT and DOG, for example, are bidirectional associates with an association existing from CAT to DOG, as well as from DOG to CAT. The unrelated target word DUST begins with /d/ as the related target word DOG does and bears no relation to the general meaning of the sentence *The baby saw the cat.*

Twenty-seven of the sentences used in Experiment 2 (phoneme monitoring) were also used in the naming experiments. In fifteen of the sentences, the word containing the target phoneme was also the priming word in Experiment 2.

Each of the 192 recorded sentences were paired with a target word and a delay time for the target word to be shown. The target words were shown on the screen at three interstimulus interval delays after the priming word in the sentence: 0 ms, 400 ms, and 800 ms.

Additional materials. In addition to the experimental trials, there were 25 practice trials. Thirteen of the practice trial had related target words, and 12 had unrelated target words. There were nine 0 ms, eight 400 ms, and eight 800 ms delay trials, with a mix of nuclear and non-nuclear accented priming words in early and late sentence position.

Design

Six lists resulted from crossing the within-subjects variables accent status (nuclear and non-nuclear) and delay (0 ms, 400 ms, 800 ms delay). The within-subjects variable target relatedness (related and unrelated) occurred in both target relatedness conditions for each item of each list. The fourth within-subjects variable, sentence position (early and late), was nested within the other variables rather than being completely crossed with them. Therefore, the overall design for an ANOVA by subjects for this experiment was a 6 x 2 x 3 x 2 x 2 mixed factorial, with one between- and four within-subjects variables. The design for an ANOVA by items was a 6 x 2 x 3 x 2 x 2 mixed factorial with two between- and three within-items variables. The between-items factors were item group (6 groups) and sentence position (early and late). The within-items variables were delay, target relatedness, and accent status.

The 96 word triples (described in Materials above) were randomly assigned to the two sentence positions for the location of the priming word, which gave 48 in early sentence position and 48 in late sentence position. The 96 sentences associated with the priming words were recorded with two intonation patterns, one with the priming word nuclear accented, and one with the priming word non-nuclear accented, yielding a total of 192 recorded sentences.

The 192 recorded sentences were digitized on a SUN Sparc 10 at 16 kHz, 16 bit resolution. The acoustic offset of the priming words was determined by visual inspection of the waveform and interactive playback of the signal. For each utterance, three two-channel audio files were made, each with a 10 ms long 1000-Hz tone placed on a separate data channel at either 0 ms, 400 ms, or 800 ms from the offset of the priming word. These tones marked the time delay between the priming words and the target words.

An initial list containing 192 trials was created according to the following randomization scheme. The list contained all 192 recorded sentences, both the nuclear accented and the non-nuclear accented versions of each sentence. Half of the sentences occurred on the list first in the nuclear accented version, and half occurred first in the non-nuclear accented version. Each priming word was randomly paired with one of the three delays between the priming words and the target words. The two versions of a sentence occurred with the same delay time for the target words. One version of the sentence was paired with the related target word, and the other version was paired with the unrelated target word. For example, if a sentence occurred in the list in the early, 0 ms, related, nuclear accented condition, it also occurred on the list in the early, 0 ms, unrelated, non-nuclear accented condition. Eight trials occurred in each of the 24 experimental conditions.

Five additional lists were created from the first list by reassigning priming words to a different delay x relatedness combination, so that across the six lists, all priming words, which were either early or late in the sentence, were paired with all twelve possible combinations of delay x relatedness x accent status. That is, between the six lists, each target word appeared in all 12 of the conditions resulting from crossing accent status, relatedness, and delay for the two sentence positions.

All 192 recorded sentences (with both early and late nuclear accent placement in the 96 sentences) were used in each experimental list, and they occurred in the same pseudo-random order on all six lists. However, the actual experimental trials varied across lists according to relatedness and delay. That is, only the delay x target relatedness combinations for each sentence differed between identical trial numbers on the six lists. Of the experimental trials on each of the six lists, half were in the nuclear accented condition and half were in the non-nuclear accented condition. Half were in early sentence position, and half were in late sentence position. Half were related, and half were unrelated. There were also equal numbers of the three delay conditions. Although each sentence occurred with both early and late nuclear accent placement (nuclear and non-nuclear accent status), one version appeared with the related target word and one appeared with the unrelated target word. Therefore, each target word appeared only once per list.

For the six lists, three tapes were made, and each tape was paired with the two different possible combinations of related and unrelated target words. The recorded sentences occurred in the same order on all three tapes, but the location of the tones marking the delay after the offset of the priming words differed. That is, each tape had a different playback order for the three two-channel audio files associated with each recorded sentence. The tapes were made by playing back the audio files in the predetermined pseudo-random order and recording them to stereo metal audio tapes with the speech on one channel and the tones on the other. The three tapes together with two different combinations of the related and unrelated target words comprised the six lists used in the experiment.

Procedure

Subjects were tested individually in a quiet room. They were seated in front of a 386SX-16 computer and a SONY Stereo Cassette Deck TC-FX25, and they wore headphones with an ATR 35 omnidirectional microphone mounted to the headset. On each trial they heard a priming sentence played binaurally through the headphones at a comfortable listening level which was the same for each subject. At a predetermined interval after the acoustic offset of the priming word (either 0 ms, 400 ms, or 800 ms), a tone from the second channel of the tape deck (which was not heard by subjects) was fed into a voice-activated relay, which was interfaced with the computer. When the tone activated the relay, the computer displayed the appropriate visual target word on the screen and started a millisecond timer. Subjects were asked to name (read aloud) the target word as rapidly as possible. The sound of the subject's voice was picked up by the microphone. That triggered the voiced-activated relay, which stopped the millisecond timer and cleared the computer screen. In

the sentences with the priming word in late sentence position, there was a 3 second interval between the presentation of the target word and the start of the next trial. In the sentences with the priming word in early sentence position, the 3 second interval before the start of the next trial was timed from the end of the priming sentence or the presentation of the target word, whichever came later.

To ensure that subjects were attending to the sentences that they heard and not just naming the target words that they saw on the screen, they were also given a comprehension task in a randomly selected one-third of the trials. In these trials, immediately after the subject named the target word and the screen cleared, a comprehension question which was related to the sentence which had just been heard appeared on the computer screen. All questions could be answered yes or no, and subjects indicated their response by pressing the appropriately labeled button on the response box. As with the naming response, the yes/no button response stopped the timer and cleared the computer screen. In the trials with comprehension questions, an additional 3 seconds was included in the interval before the start of the next trial to allow for time to answer the comprehension question.

In total, subjects were given 25 naming trials and 8 comprehension questions during the practice session and 192 naming trials and 64 comprehension questions during the experimental session.

To encourage subjects to respond as quickly and accurately as possible, there was a $10 bonus award given to the subject with the fastest and most accurate responses. Even with this incentive, six of the 48 participants failed to meet the speed criterion, an overall mean reaction time of 625 ms. Subjects with longer mean reaction times waited until the end of the sentence before naming the target word, even when the naming target word was presented well before the end of the sentence. The analysis is based on the data from the 42 subjects who met the speed criterion.

5.3.2 Results

The effects of outliers were curtailed by cutoffs established at ± 2.5 standard deviations from the mean for each subject. Values greater than 2.5 standard deviations from the mean were replaced with the cutoff values. Trials in which the subject failed to name the target word and trials in which the subject responded in less than 100 ms were omitted from the reaction time data. These types of error accounted for fewer than 0.5% of the data, and outliers accounted for fewer than 0.5% of the data. With these adjustments, the mean response latency was computed for each of the experimental conditions for each subject (collapsed across items) and for each item (collapsed across subjects).

The results were analyzed in two separate mixed factorial ANOVAs, one by subjects (reported as F1) and one by items (reported as F2). In the subject analysis, the data were analyzed in a 6 x 2 x 3 x 2 x 2 mixed factorial ANOVA, with list (6 lists) as a between-subjects variable and sentence position (early, late), delay (0, 400, 800 ms), target relatedness (related, unrelated), and accent status (nuclear, non-nuclear) as within-subjects variables. The subject data consisted of each subject's mean response times for each of the 24 experimental conditions, collapsed across items. Eight trials contributed to the means for each of the 24 experimental conditions per subject. In the item analysis, the data were analyzed in a 6 x 2 x 3 x 2 x 2 mixed factorial ANOVA, with item group (6 groups) and sentence position (early, late) as between-items variables and delay (0, 400, 800 ms), target relatedness (related, unrelated), and accent status (nuclear, non-nuclear) as within-items variables. The item data consisted of the mean response time to an item for each of the 12 experimental conditions that it appeared in, collapsed across subjects. The response times for all 42 subjects contributed to the means for each of the 12 experimental conditions per item.

The results of the overall ANOVA including all four experimental factors (sentence position, target relatedness, delay, and accent status) are discussed in more detail in Appendix F. In brief, all four factors were significant, as was the interaction of sentence position and delay. The effect of accent status, the primary variable of interest, on reaction time was strongest at the 0 ms delay condition and non-existent at the 800 ms delay. The 0 ms delay condition results will be presented here. Appendix F includes a graph of the mean reaction times for all 24 conditions, including all three delay conditions.

Considering only the reaction time data from the 0 ms delay conditions gives the following results. The mean reaction times for each condition are plotted in the left-hand side of Figure 17. The main effects of sentence position (early and late) and target relatedness were highly significant, as expected based on the results in the literature. These results confirm that there was an effect of semantic associate priming in these materials. Target words were named faster in late sentence position (469 ms) than in early sentence position (570 ms) ($F1(1, 36) = 47.5$, $p < 0.01$; $F2(1, 84) = 195$, $p < 0.01$). Related target words (509 ms) were named faster than unrelated target words (531 ms) ($F1(1, 36) = 22.1$, $p < 0.01$; $F2(1, 84) = 51.4$, $p < 0.01$).

Accent status (nuclear and non-nuclear), however, was only marginally significant, with target words following nuclear accented priming words (524 ms) being named more slowly than those following non-nuclear accented priming words (516 ms) ($F1(1, 36) = 3.8$, $p = 0.06$; $F2(1, 84) = 3.0$, $p = 0.09$). The two-way interaction of accent status x sentence position, which distinguishes the three-way accent status distinction of nuclear accented, prenuclear accented, and unaccented, was not significant ($F1(1, 36) = 1.0$, $p > 0.1$; $F2(1, 84) = 0.5$, $p > 0.1$). Target words following nuclear accented words were named more slowly than those following non-nuclear accented words in both early and late sentence position (early nuclear: 576 ms, early prenuclear: 564 ms, late nuclear: 472 ms, late unaccented: 467 ms).

The two-way interaction of accent status x relatedness, in which the unrelated target words showed a larger effect of accent status than the related target words, was marginally significant by subjects ($F1(1, 36) = 3.2$, $p = 0.08$) and significant by items ($F2(1, 84) = 4.1$, $p < 0.05$).

In post-hoc comparisons of the nuclear accented and non-nuclear accented condition means at each combination of sentence position and relatedness, only the pair of nuclear accented and prenuclear accented in the unrelated, early sentence position condition were significantly different ($F1(1, 36) = 8.4$, $p < 0.01$).

The results of the comprehension question task indicate that the subjects were indeed paying attention to the auditory priming sentences and not just naming the words on the screen. Overall, 87 percent of the comprehension questions were answered correctly.

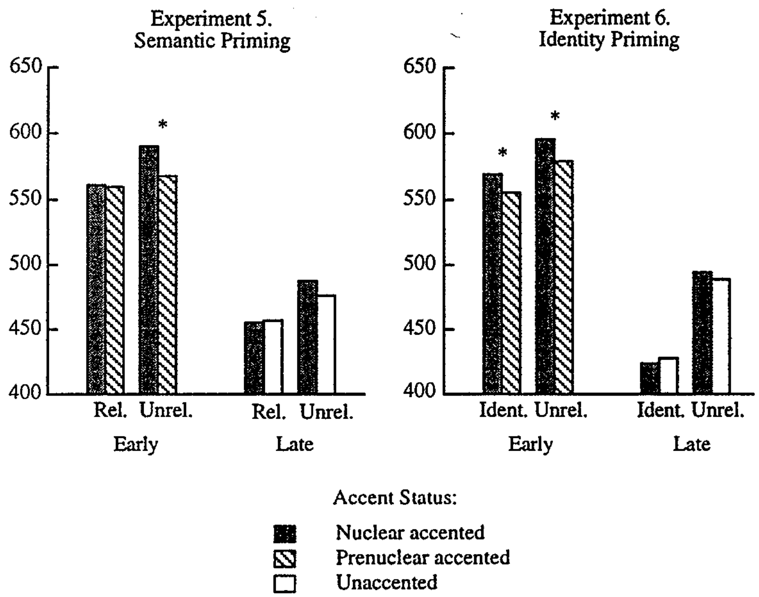

Figure 17. Experiments 5 and 6. Reaction times (in ms) to cross-modal naming target words. Target words occurred in early and late sentence position of sentences with early nuclear accent placement and late regular nuclear accent placement. Asterisks mark significant differences between categories ($p < 0.05$).
(left) Experiment 5, semantic priming. Related and unrelated target words.
(right) Experiment 6, identity priming. Identical and unrelated target words.

5.4 Experiment 6: Identity priming

Semantic associate priming did not show strong effects of accent status differences. Identity priming may show more robust effects of accent status differences because it does not have to rely on the intermediary step of semantic priming of related target words.

5.4.1 Method

Subjects

43 undergraduate volunteers from The Ohio State University participated in the experiment for course credit in introductory psychology and linguistics classes. All subjects were native speakers of English and had normal or corrected-to-normal vision. No subjects reported any hearing loss. One of the 43 participants failed to meet the speed criterion, leaving 42 subjects whose data was used in the analysis. Seven subjects were assigned to each of the six lists.

Materials

The materials for this experiment were nearly identical to the materials for Experiment 5. Instead of using semantically related target words as in Experiment 5, the priming word was repeated as an identical target word. That is, one of the target words was identical to the priming word and the other target word was unrelated to the priming word. As in Experiment 5, the two target words of a word triple (the identical and unrelated target words) were matched for printed word frequency and had the same or acoustically similar word onsets (initial phonemes). See Appendix E for the complete list of all the sentences and target words used. Table 9 shows a few examples of the priming relationships which were used in the experiment, as well as examples of the recorded sentences, which are the same as those in Experiment 5. As in Experiment 5, there were 192 experimental trials and 25 practice trials.

Design

The experimental design is the same as in Experiment 5, with the one difference that the levels of the target relatedness condition were identical and unrelated instead of related and unrelated. The experiment used the same three tapes as used in Experiment 5. Each tape was paired with the two different combinations of identical and unrelated target words to comprise the six lists.

Procedure

The same testing procedure was used in this experiment as in Experiment 5. In total, subjects were given 25 naming trials and 8 comprehension questions during the practice session and 192 naming trials and 64 comprehension questions during the experimental session. The analysis is based on the data from the 42 subjects who met the speed criterion, an overall mean reaction time of 625 ms.

5.4.2 Results

The results of the overall ANOVA including all four experimental factors (sentence position, target relatedness, delay, and accent status) are discussed in more detail in Appendix F. In brief, sentence position, target relatedness, and delay were significant, as were the three-way interaction of sentence position x target relatedness x delay and all three of the possible two-way interactions. Accent status, however, was not significant. As in Experiment 5, what effect there was of accent status on reaction time was strongest at the 0 ms delay condition, and those results will be presented here. Appendix F includes a graph of the mean reaction times for all 24 conditions, including the three delay conditions.

Considering only the reaction time data from the 0 ms delay conditions gives the following results. The mean reaction times for each condition are plotted in the right-hand side of Figure 17 above. As in Experiment 5, the main effects of sentence position (early and late) and target relatedness were highly significant. Target words were named faster in late sentence position (459 ms) than in early sentence position (575 ms) ($F1(1, 36) = 105.5$, $p < 0.01$; $F2(1, 84) = 266.3$, $p < 0.01$). Identical target words (495 ms) were named faster than unrelated target words (540 ms) ($F1(1, 36) = 63.5$, $p < 0.01$; $F2(1, 84) = 78.5$, $p < 0.01$).

Accent status (nuclear versus non-nuclear), however, was not significant, although target words following nuclear accented words were named on average slower than those following non-nuclear accented words, but there were not statistically different (521 ms versus 514 ms) ($F1(1, 36) = 2.4$, $p > 0.1$; $F2(1, 84) = 2.0$, $p > 0.1$). The two-way interaction of accent status x sentence position, which distinguishes the three-way accent status distinction of nuclear accented, prenuclear accented, and unaccented, was not significant either ($F1(1, 36) = 2.8$, $p > 0.1$; $F2(1, 84) = 1.8$, $p > 0.1$). Target words following nuclear accented words were named on average more slowly than those following non-nuclear accented words in early sentence position (early nuclear: 583 ms, early prenuclear: 568 ms), but they were essentially identical in late sentence position (late nuclear: 460 ms, late unaccented: 459 ms).

The two-way interaction of sentence position x relatedness, in which the late sentence position target words showed a larger effect of relatedness than the early sentence position target words, was highly significant ($F1(1, 36) = 20.8$, $p < 0.01$; $F2(1, 84) = 15.5$, $p < 0.01$).

Post-hoc comparisons of the nuclear accented and non-nuclear accented condition means were made at each combination of sentence position and relatedness. Target words following nuclear accented words were named significantly more slowly than those following prenuclear accented words in early sentence position for both the identical target words and the unrelated target words (identical: $F1(1, 36) = 4.5$, $p < 0.05$, unrelated: $F1(1, 36) = 6.6$, $p < 0.02$).

As in Experiment 5, 87 percent of the comprehension questions were answered correctly. The subjects were indeed paying attention to the auditory priming sentences and not just naming the words on the screen.

Considering the 0 ms delay conditions of Experiments 5 and 6 together, experiment (5 and 6) was not significant, which means that the overall reaction times for the two different types of priming relationships in the two experiments were comparable.[1] Furthermore, as expected based on the results for the experiments individually, sentence position and relatedness were significant main effects. In addition, the two-way interaction of sentence position x relatedness was significant, with greater differences of relatedness in early sentence position than in late sentence position, contrary to what was predicted based on the greater accent status differences in late sentence position (nuclear versus unaccented) than in early sentence position (prenuclear versus nuclear).

More important to this study, there were some significant effects involving accent status. Accent status was significant, with target words following nuclear accented words (523 ms) being named more slowly than those following non-nuclear accented words (514 ms) ($F1(1, 72) = 6.0$, $p = 0.02$; $F2(1, 84) = 4.1$, $p < 0.05$). The two-way interaction of accent status x position, which distinguishes the three-way accent status distinction of nuclear accented, prenuclear accented, and unaccented, was marginally significant by subjects ($F1(1, 72) = 3.8$, $p = 0.06$; $F2(1, 84) = 1.8$, $p > 0.1$). However, contrary to the predictions made by the degree of prominence due to the differences in accent status, the difference in early position between nuclear accented and prenuclear accented was greater than the difference in late sentence position between nuclear accented and unaccented was. In early position, target words following nuclear accented words were named relatively more slowly than those following prenuclear accented words (580 ms and 566 ms), while in late position, target words following nuclear accented words were named essentially equally quickly as those following unaccented words (465 ms vs. 463 ms). Accent status x relatedness was marginally significant ($F1(1, 72) = 3.3$, $p = 0.07$; $F2(1, 84) = 3.3$, $p = 0.07$), with unrelated target words showing a greater difference between nuclear accented and non-nuclear accented (543 ms vs. 529 ms) than related target words did (503 ms vs. 500 ms).

One additional result is that the three-way interaction of experiment x relatedness x sentence position was highly significant ($F1(1, 72) = 8.7$, $p < 0.01$; $F2(1, 84) = 9.0$, $p < 0.01$), as was the two-way interaction of experiment x relatedness ($F1(1, 72) = 9.5$, $p < 0.01$; $F2(1, 84) = 14.2$, $p < 0.01$) (and so was the sentence position x relatedness interaction mentioned above). These results show that there was a greater priming effect for identity priming than for semantic associate priming, and that the effect was greater in late sentence position than in early sentence position.

5.5 Discussion

The results of these experiments showed that the cross-modal naming task was not particularly sensitive to differences in accent status, although it was very sensitive to the relatedness of the target word to the priming word, the sentence position, and the delay between the occurrence of the priming word and the target word.

Related and identical target words were named faster than unrelated target words, as predicted by both the spreading-activation and the focus-of-attention theories, and as demonstrated many times before. Related and identical target words were named faster than unrelated target words at both sentence positions (early and late) and for the accent statuses nuclear accented and non-nuclear accented. The results of the two experiments taken together showed that identical target words were named fastest, followed by related target words. Unrelated target words in the semantic associate priming experiment (Experiment 5) were named slightly faster than unrelated target words in the identity priming experiment (Experiment 6). This difference in the naming times of unrelated target words in the two experiments probably reflects a strategic response difference in the two experiments. In the identity priming experiment, subjects saw target words which either occurred in

the sentences or did not occur in the sentences, while in the semantic associate priming experiment, no target words were identical with words in the sentences. Subjects could adopt the strategy of expecting a word from the sentence to appear as a target word in Experiment 6, and therefore new words would be named even more slowly than in Experiment 5, in which all words were new words and subjects could not form equally strong expectations about what the target words might be.

Early sentence position target words were named more slowly than late target words, the standard sentence position result. In these experiments, the sentence position effect was mediated by an interaction of sentence position and target delay. At the longer delay intervals, early target words were named approximately equally as fast as late sentence position target words. Predictions of neither the spreading-activation theory nor the focus-of-attention theory predictions for delay of the naming target word were borne out. At longer delays (400 ms and 800 ms), there was no difference between the naming times of nuclear accented and non-nuclear accented target words, for neither related target words nor unrelated target words. (See Appendix F for more information about the effects of delay.)

The accent status of the priming word in the sentence context (nuclear accented, prenuclear accented, and unaccented) did have some influence on time that it took to name the target word, but it was not a reliable effect. That is, accent status of the priming words did not strongly affect lexical access of the target words. Experiment 5 had a significant main effect of accent status, while Experiment 6 had no main effect of accent status. With the two experiments taken together, there was a main effect of accent status. Target words primed by nuclear accented words were named more slowly than those primed by non-nuclear accented words (prenuclear accented and postnuclear unaccented). These results support an interpretation that nuclear accents are special and can be contrasted with the non-nuclear accent status of prenuclear accents and postnuclear unaccented words.

In both Experiments 5 and 6, it was the early sentence position that showed the greatest difference between the nuclear and non-nuclear accented conditions. In early sentence position, the nuclear accented conditions were named more slowly than the prenuclear accented conditions. That is, target words that were primed by words with early nuclear accents were named somewhat more slowly than those with prenuclear accents. Early placement of nuclear accent in a sentence led to slower naming times, for both related and unrelated target words. This suggests that there may be something "not normal" about early nuclear accent placement, at least in the null context that the sentences were presented in here. One possible explanation is that it takes extra time and attention for the listener to process such an intonation pattern (and pattern of emphasis) than the more "normal" one with late nuclear accent placement (the prenuclear accented data in the early sentence position). The difference in reaction time may be explained by the listener's placing greater attention on the early nuclear accented word when it occurs, which subsequently slows down the naming task.

Greater differences in stress level predicted a greater difference in priming between nuclear accented and unaccented pairs than between nuclear accented and prenuclear accented pairs. In these experiments, the comparison between nuclear accented and unaccented occurred in late sentence position, and the comparison between nuclear accented and prenuclear accented occurred in early sentence position. Therefore, a significant sentence position x accent status interaction would have given statistical weight to this prediction. However, no such support was found. In fact, as discussed in the previous paragraph, when the sentence position x accent status interaction was significant, the results were in the opposite direction, with a greater difference between the early nuclear accented and the prenuclear accented conditions. In addition to the explanation of "normal" location of nuclear accent, the lack of strong effects between nuclear accented and unaccented in late position may be explained by sentence position effects. Because the effect of sentence position was so much stronger than that of accent status, the faster naming time due to being in late sentence position may have completely obscured any differences due to accent status. A task which is more sensitive to differences in accent status is needed in order to distinguish differences between the three accent statuses, and particularly between prenuclear accented and postnuclear unaccented.

The effects of accent status on naming time that were present were not amenable to explanations from either the spreading-activation theory or the focus-of-attention theory. The presence of nuclear accent on a priming word did not speed target word naming times relative to prenuclear accented or unaccented priming words, for either related or unrelated. On the contrary, the most reliable effect of nuclear accent status on naming time was to increase the naming time when the nuclear accented word was in early sentence position. Birch & Garnsey (1995) found similar weak effects of focus (invoked syntactically, not intonational) on semantic priming. They also found large effects of semantic priming, but only small effects of focus. They expected focus to

lead to greater priming, but instead they got weak evidence that non-focus lead to greater priming.

A facilitation effect for related trials could perhaps have been found using the same paradigm with low frequency words as target words. Because the words used in this study were so common, the naming response may have had ceiling effects. By making the task harder, i.e. by naming low frequency target words, the semantic associates may be facilitated.

A possible explanation for the pattern of results that were found is that not only did the nuclear accent draw the listener's attention to the word, but also that the relatively unexpected location of nuclear accent early in a sentence momentarily distracted the listener from the naming task as she parsed the marked intonation contour, thereby slowing the naming response. In this view, the early location of nuclear accent in a sentence is not the "normal" location for nuclear accent in a context like the list of sentences that listeners were presented with. One way to see if this sort of "startle" effect of early nuclear accent placement can be removed is to place the sentence in a context where early nuclear accent is the expected intonation pattern. If the effect disappears in such a context, then we could say that early nuclear accent placement is not exactly a not "normal" location for nuclear accent, but rather that it is perfectly normal in the right context.

In summary, for lexical priming, basically a word was a word, no matter whether it was nuclear accented, prenuclear accented, or completely unaccented. The occurrence of an identical or semantically related word in a sentence before a target word speeded the naming time relative to an unrelated target word, and in general, accent status had very little influence on naming times.

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[1] Note, however, that six subjects were discarded as too slow in Experiment 5, with semantic priming, while only one subject was discarded as too slow in Experiment 6, with identity priming. This difference is most likely due to individual differences in subjects rather than any inherent differences in difficulty of the two types of priming.

CHAPTER VI

CONCLUSIONS

This study provided mixed support for the three accent status theory of stress level due to intonation. The sentence materials were carefully controlled to contrast the three accent statuses (nuclear accented, prenuclear accented, and unaccented) and three types of nuclear accent (expanded pitch range nuclear accented, regular nuclear accented, and downstepped nuclear accented). Although this was not a production study per se, the materials showed distinctions due to accent status that earlier production studies have found. The acoustic measurements, especially the reliable differences in voice onset time of word initial stops, showed evidence of the phonological distinction between nuclear accented, prenuclear accented, and unaccented as advanced by e.g., Beckman (1986), Beckman & Edwards (1994), and de Jong (1995). Voice onset time increased as the stress level increased, from postnuclear unaccented to prenuclear accented to nuclear accented, exactly as the stress hierarchy predicts and as some articulatory patterns have shown. That is, there was evidence for distinctions in articulatory prominence that matched the distinction in structural prominence.

In addition, the acoustic characterization of the materials used in this study suggested that the nuclear accent types of expanded pitch range nuclear accent, regular nuclear accent, and downstepped nuclear accent also had systematic differences in acoustic prominence, evidenced in part by the acoustic production data of voice onset time. The voice onset time of downstepped nuclear accents was shorter than that of regular nuclear accents, and the voice onset time of expanded pitch range nuclear accents was longer than that of regular nuclear accents. These voice onset times provide some evidence for an interpretation that within the accent status of nuclear accented that there are differences in acoustic prominence, such that expanded pitch range nuclear accents are more prominent than regular nuclear accents, which are more prominent than downstepped nuclear accents.

A series of perceptual tests investigated how listeners perceived the accent statuses (nuclear accented, prenuclear accented, postnuclear

unaccented) and the three accent types (expanded pitch range, regular, downstepped). The results of the experiments showed that while listeners did perceive differences between the intonational categories and that intonation did influence their behavior in certain tasks, that not as many of the categories were reliably distinguished in perception (as reflected in psycholinguistic behaviors) as in speech production. That is, the effects on perception were less fine grained than the distinctions that the speaker produced.

All three tasks point to the fact that nuclear accents have a special status. In the phoneme monitoring task, target phonemes were recognized faster in words that were nuclear accented than in words that were non-nuclear accented. In contrast, the reaction time to target phonemes was not reliably different in prenuclear accented and postnuclear accented words. Therefore, the primary perceptual split seemed to be between nuclear accents on the one hand and prenuclear accents and unaccented on the other. In the question-answering task, again nuclear accent was important for predicting listeners' behavior. In questions that were false because information in the subject noun phrase was untrue, listeners were able to answer 'no' much more quickly when the subject noun phrase of the sentence was nuclear accented than when it was prenuclear accented. Nuclear accent drew attention to the information that was most important to answering the question correctly; there was an effect of informational prominence. In the cross-modal naming task, there was also a small effect of nuclear accent status of the priming word on the naming time of the target word. When the target word was shown after an early sentence position priming word, the target word was named more slowly when the priming word was nuclear accented than when it was prenuclear accented. However, when the target word was shown after a late sentence position priming word, there was essentially no effect of nuclear accent status.

Of the three tasks, the results of the cross-modal naming task were perhaps the most surprising. The general conception of the effect of nuclear accent is to draw the listener's attention to the nuclear accented word in favor of other words in the sentence that do not have nuclear accent. The informationally most prominent words should be the ones that listeners pay the most attention to. Therefore, it would have seemed reasonable for nuclear accent to have speeded the naming time of a target word rather than slowing the naming time when the target word was related to the nuclear accented priming word. The semantic concepts associated with the nuclear accented word should have been in stronger focus, thereby facilitating the naming of the related target word. Instead, the pattern of results was just the opposite, with an early nuclear accented word slowing the naming response of both related and unrelated target words. Early placement of nuclear accent in a sentence led to slower naming times, for both related and unrelated target words. This suggests that there may be something "not normal" about early nuclear accent placement, at least in the context like the list of sentences that listeners were presented with here.

The phoneme monitoring and question answering experiments, however, did not give any suggestions that early nuclear accent placement is a marked intonation pattern. If anything, the question-answering experiment suggested that early nuclear accent placement was the appropriate intonation pattern for expressing certain information, because it speeded the reaction time to the appropriate 'no' question, and that particular intonation pattern had the fewest errors in the responses as well. Cutler & Foss (1977) manipulated what they called the "normality of the stress pattern" in the phoneme monitoring task and they found no effect of "normal" versus "non-normal" stress. As long as the item containing the phoneme target was stressed (our nuclear accented) it was faster than if it were unstressed (our unaccented). The results of these experiments match their results.

By contrast, the results of the phoneme monitoring experiments hint that if any of the four intonation patterns was treated as a marked intonation pattern for this context it was the downstepped nuclear accent pattern. The reaction time to phoneme targets in the prenuclear accented words of the downstepped nuclear accent pattern was longer than the reaction time to phoneme targets in the prenuclear accented words of the regular nuclear accent pattern. Given that the words were prenuclear accented in both patterns, and that the vowel onset time was the same for the prenuclear accents in both patterns, this is a bit of an unexplained result. It may be that listeners could tell from the beginning of the sentence that the intonation pattern was the downstepped pattern and that that somehow affected how they quickly they responded to the phoneme target.

The phoneme monitoring and the question answering task suggested that listeners did make some distinction between the three types of nuclear accent, although the most important distinction is whether or not a word was nuclear accented. In the question-answering task, subjects made the fewest number of errors when answering 'no' to questions that were false because of information late in the sentence when the word in late sentence position was most informationally prominent (expanded pitch range nuclear accented) and the most number of errors when it was least informationally prominent (postnuclear unaccented). In the phoneme

monitoring task, the reaction time was slightly longer for target phonemes in words with downstepped nuclear accents than with expanded pitch range nuclear accents or regular nuclear accents.

In view of the fact that phoneme monitoring responses have been shown to be speeded both from segmental enhancement due to different levels of stress and due to manipulation of focus of attention where there were no acoustic differences between the words containing the target phoneme, it would be beneficial to have a control condition for these phoneme monitoring experiments in which the test words were excised from their sentence contexts and presented in isolation. Such a control condition would address the question of whether the reaction time differences due to accent status and accent types persist in the absence of the full intonational context. If the differences persisted in the absence of the well-formed intonational context, the differences in the phoneme monitoring reaction times in the experiments may be due to more local segmental changes which covary with accent status and accent type, i.e., the differences in acoustic prominence alone. For example, the relationships could be attributed to the different VOTs. If the differences did not persist in the absence of the complete intonational context, the differences in the phoneme monitoring reaction times in the experiments could be attributed to the way that the intonation pattern as a whole focuses the listener's attention, separate from any local segmental enhancement due to accent status and accent type. In that case, we could say that intonation influences informational prominence and perceptual prominence above and beyond the acoustic prominence provided by accent status.

In summary, these experiments have provided some evidence for perceptual differences between the accent types expanded pitch range nuclear accented, regular nuclear accented, and downstepped nuclear accented. However, all three of these accent types behaved more similarly to each other, as members of the accent status category nuclear accented, than they did to being truly different levels of stress, as Kohler describes German. Recall that he describes German as having four different levels of sentence accent: reinforced (similar to our expanded pitch range nuclear accented), neutral (similar to our regular nuclear accented), partially deaccented (similar to our downstepped nuclear accented), and completely deaccented (our unaccented). That is, a downstepped nuclear accent behaved much more like a nuclear accent than something that was halfway between being nuclear accented and unaccented in the way that it influenced a listener's behavior. Acoustically, however, it did have some characteristics of being part way between being regular nuclear accented and unaccented, such as the intermediate VOT. Similarly, an expanded pitch range nuclear accent behaved very much like a regular nuclear accent in terms of the way that it influenced a listener's behavior. Acoustically, however, it did seem to be more prominent than a regular nuclear accent, both in terms of the expanded pitch range itself and the longer VOT.

APPENDIX A

MATERIALS USED IN EXPERIMENT 1

The sentences were presented auditorily, and subjects pressed the 'yes' response button when they detected the target phoneme, which was presented visually before each trial sentence. In all trials, the target phoneme occurred only once in the sentence, as the initial phoneme of a word (the underlined words of the sentences listed below). The target phoneme was either the bilabial or velar voiceless stop /p/ or /k/ and was followed by a vowel. The target word in the critical trials was the second noun in the sentence.

Each sentence was produced with three different intonation contours. The nuclear accent fell on the head noun of the subject noun phrase (early nuclear accent placement), on the head noun of the second noun phrase, or on the final word in the sentence (late nuclear accent placement). The intonation contour types are referred to by the accent status of the target word. Early nuclear accent placement sentences are referred to as 'unaccented', and late nuclear accent placement sentences are referred to as 'prenuclear', and mid-sentence nuclear accent placement sentences are referred to as 'nuclear'.

All two-syllable target words have lexical stress on the first syllable. Early and late position targets are matched for target word frequency.

	Auditory sentences	Target phonemes
	Critical trials:	
1.	The girl held a candle in her hand.	k
2.	The boy ate candy for lunch.	k
3.	The design adorned the canvas and the frame.	k
4.	The girl admired the canyon from a distance.	k
5.	His arm was in a cast to the elbow.	k
6.	A ghost haunted the castle for years.	k
7.	The snake ate the catfish for dinner.	k
8.	The tree was near the cave by the river.	k
9.	The story amused the coach and the manager.	k
10.	The waiter ruined her coffee with salt.	k
11.	The string wound in a coil was frayed.	k
12.	The bird hid the coin in the nest.	k
13.	His love was a comfort and a joy.	k
14.	The rules of the contest were violated.	k
15.	The tire had a core made of rubber.	k
16.	The statue was in the corner by the altar.	k
17.	The toy was stuffed with cotton and foam.	k
18.	The photo over the couch has a story.	k
19.	The widow left the country after the war.	k
20.	The lawyer asked the court for a witness.	k
21.	The woman lifted the cover of the box.	k
22.	The rain bothered the cats and the dogs.	k
23.	The student was late for curfew at midnight.	k
24.	The road followed the curve of the hill.	k
25.	The beggar sold a kettle to the woman.	k
26.	The drawer held a key to the safe.	k
27.	His friend wore a kilt to the fair.	k
28.	The dust irritated the king during the morning.	k
29.	The door to the kitchen was broken.	k
30.	The adult saw the kite in the tree.	k
31.	The horse drained the pail in one swallow.	p
32.	The hunter chased a panther through the jungle.	p
33.	The girl in the pantry was hiding.	p
34.	The shades in the parlor were drawn.	p
35.	The woman ate the parsley and the tomato.	p
36.	The riot disturbed the pastor before the sermon.	p
37.	The kids loved pastry after school.	p
38.	The chemist had several patents and inventions.	p
39.	The singer had a paunch and was bald.	p
40.	The manager voided the payment from the register.	p
41.	The girl wanted peanuts at the movie.	p
42.	The gang stole a pearl and an emerald.	p
43.	The man lost his pension during the buy-out.	p
44.	The woman in the penthouse was famous.	p
45.	A dove and a pigeon were on the roof.	p
46.	The man was a pilot and a teacher.	p
47.	The man used a pistol in the robbery.	p
48.	The boy delivered the piston to the store.	p
49.	The writer read the poem to the audience.	p
50.	The symbol was a point inside a diamond.	p
51.	The man wearing a poncho was freezing.	p
52.	The shot startled the pony and its rider.	p
53.	The neighbor watched the poodle for a month.	p
54.	The children near the pool were shivering.	p
55.	The bay sheltered the port during the storm.	p
56.	The wagon hit the post and the sign.	p
57.	The marbles were in a pouch during school.	p
58.	The drugs slowed her pulse for the surgery.	p
59.	The buyer dreaded the purchase of the house.	p
60.	The mirror from her purse was missing.	p

Filler trials:

1.	The cancer devastated his grandfather.	k
2.	The cargo weighed several tons.	k
3.	The catcher missed the ball.	k
4.	The coast astonished the sailor.	k
5.	The collie ran through the hole in the fence.	k
6.	The colt was not a winner.	k
7.	His comment influenced her decision.	k
8.	The costume fit the model.	k
9.	The cotton was lost in the move.	k
10.	The cow mooed through the night.	k
11.	The current frightened the swimmer.	k
12.	The custard was almost a failure.	k
13.	The kitten snoozed on the rug.	k
14.	The pain affected his driving.	p
15.	The password had a number in it.	p
16.	Her patience lasted through the afternoon.	p
17.	The penance allayed her fears.	p
18.	The Pisces loved the gag gift.	p
19.	The poet was near the city.	p
20.	The pole reached to the swimmer.	p
21.	The poor dreamed about going on a tour.	p
22.	The portrait suited the chief.	p
23.	The potatoes are in the oven.	p
24.	The potter enjoyed the feel of the glaze.	p
25.	The ant was on his calf.	k
26.	The dentist ate a carrot.	k
27.	The stew bubbled in the cauldron.	k
28.	A charm hung at her collar.	k
29.	Her anger disturbed her colleague.	k
30.	The bread was eaten in the convent.	k
31.	A man served the coffee.	k
32.	The bluejay flew through the corn.	k
33.	The child walked around the courtyard.	k
34.	Her fury amazed the coward.	k
35.	Some dirt fell onto the pad.	p
36.	The chauffeur drove to the palace.	p
37.	The tints were on the palette.	p
38.	The answer astonished the parish.	p
39.	The boy watched the path.	p
40.	The shawl was made of pelts.	p
41.	The billing amount was more than his pension.	p
42.	Her nephew was in great peril.	p
43.	The buzzer frustrated the pest.	p
44.	The habit had its pitfalls.	p
45.	The family sat on the porch.	p
46.	A football hit the post.	p
47.	A student coughed during the film.	k
48.	The boy cuddled his rabbit.	k
49.	The knife cut through the bone.	k
50.	The lover kept his promise.	k

51.	The mailman carried the letter.	k
52.	The message confused the woman.	k
53.	The player captured the flag.	k
54.	The rain covered the path.	k
55.	The repairman came at a bad time.	k
56.	The zebra cooled off in the shade.	k
57.	A girl pushed her brother.	p
58.	A journal published the work.	p
59.	An eye peeked through the hole.	p
60.	His finger got pinched in the door.	p
61.	The accountant purged all the records.	p
62.	The kid pounded on the table.	p
63.	The kid pulled the wagon.	p
64.	The man polled all the customers.	p
65.	The water poured out of the faucet.	p
66.	The woman picked a tomato.	p

Catch trials:

1.	A ball flew over the fence.	k
2.	A boat was near the tower.	k
3.	A lion rested in the shade.	k
4.	A man found a mouse.	k
5.	A rose was near the door.	k
6.	A waiter brought the salt.	k
7.	The baby ate a banana.	k
8.	The bed is by the window.	k
9.	The boy followed his brother.	k
10.	The bread was on the table.	k
11.	The day held a surprise.	k
12.	The driver hated the hail.	k
13.	The foyer had a mirror.	k
14.	The hotel was near the road.	k
15.	The husband went to the store.	k
16.	The lobster was in a box.	k
17.	The salesman approached the house.	k
18.	The statue was on a hill.	k
19.	The wind blew the sand.	k
20.	The woman smiled at her daughter.	k
21.	A duck walked on the shore.	p
22.	A gun scared the man.	p
23.	A nickel lay on the sidewalk.	p
24.	An adult eats with a fork.	p
25.	An oak grew in the yard.	p
26.	The attic had a draft.	p
27.	The scouts took the train.	p
28.	The woman went to the doctor.	p
29.	A glove lay in the grass.	p
30.	A lemon was in the mixture.	p
31.	The child hurt her finger.	p
32.	The children fed the goat.	p
33.	The girl used a drill.	p

34.	The girl visited her aunt.	p
35.	The hunting amused the men.	p
36.	The niece made a gift.	p
37.	The radio fell to the ground.	p
38.	The salmon went around the log.	p
39.	The silver gleamed in the light.	p
40.	The swing was made of iron.	p

APPENDIX B

MATERIALS USED IN EXPERIMENT 2

The sentences were presented auditorily, and subjects pressed the 'yes' response button when they detected the target phoneme. The target phoneme was specified at the beginning of each trial by an auditorily presented phrase of the form, e.g., "Listen for /k/ as in 'car'." In all trials, the target phoneme occurred only once in the sentence, as the initial phoneme of a word. In the critical trials, the target phoneme was one of the bilabial or velar stop consonants /p, b, k, g/ and was followed by a vowel. In the filler trials, the consonants /h, w, f, s/ were also included as target phonemes. The complete list of phoneme prompts is as follows:

Listen for /p/ as in 'page'.	Listen for /f/ as in 'fin'.
Listen for /b/ as in 'boy'.	Listen for /s/ as in 'Sam'.
Listen for /k/ as in 'car'.	Listen for /h/ as in 'hair'.
Listen for /g/ as in 'game'.	Listen for /w/ as in 'wheel'.

The word containing the target phoneme in the critical trials was either the head noun of the subject noun phrase (early sentence position) or the head noun of the object noun phrase (late sentence position). Each sentence was produced with two different intonation contours. Either the nuclear accent fell on the head noun of the subject noun phrase (early nuclear accent placement) or on the head noun of the object noun phrase (late nuclear accent placement). (15 out of the 40 words containing the target phonemes were the priming words in the naming experiments, and 27 out of the 40 sentences also used in the priming experiments.)

All two-syllable words had lexical stress on the first syllable. Early and late position words were roughly matched for word length and vowel type, but not particularly well matched for word frequencies.

In the following listing of critical trials, those numbered 1 to 20 have the phoneme targets in early sentence position, and 21 to 40 have them in late sentence position.

Auditory sentences	Target phonemes
Critical trials:	
1. A pot was on the counter.	p
2. The painter worked for a week.	p
3. The poet was near the city.	p
4. The pole reached to the swimmer.	p
5. The pad was covered with sketches.	p
6. A ball flew over the fence.	b
7. The beer spilled on the mat.	b
8. A boat was near the tower.	b
9. The boy watched the horse.	b
10. The buckle fastens on the side.	b
11. The ketchup is in a bottle.	k
12. The kid pulled the wagon.	k
13. The cargo weighed several tons.	k
14. The cotton was lost in the move.	k
15. The cow mooed through the night.	k
16. The gas leaked from the container.	g
17. A gun scared the man.	g
18. The guys played the blues.	g
19. The girl visited her aunt.	g
20. The garbage smelled like socks.	g
21. The family sat on the porch.	p
22. A football hit the post.	p
23. The stream went under the path.	p
24. Her knee hit the pavement.	p
25. The nun walked to the park.	p
26. A novel lay on the bench.	b
27. A shoe was under the basket.	b
28. The knife cut through the bone.	b
29. The animal cracked the bowl.	b
30. The dog licked his body.	b
31. The dentist ate a carrot.	k
32. The baby saw the cat.	k
33. A man served the coffee.	k
34. The vase is made of copper.	k
35. The guest sat on the couch.	k
36. The boy smelled the garlic.	g
37. The children fed the goat.	g
38. The niece made a gift.	g
39. The woman opened the gate.	g
40. The model wore the gown.	g
Filler trials:	
1. A journal published the work.	p
2. An eye peeked through the hole.	p
3. The woman picked a tomato.	p
4. A daisy grew by the gate.	b
5. A dollar buys an ice cream.	b
6. A noun begins the story.	b

7. A waiter brought the salt.	b
8. The child broke his arm.	b
9. The wind blew the sand.	b
10. The rain covered the path.	k
11. The team crossed the ocean.	k
12. An oak grew in the yard.	g
13. The silver gleamed in the light.	g
14. A duck walked on the shore.	w
15. An adult eats with a fork.	w
16. The bed is by the window.	w
17. The family went to church.	w
18. The flu weakened the boy.	w
19. The husband went to the store.	w
20. The milk was on the table.	w
21. A man found a mouse.	f
22. The boy followed his brother.	f
23. The child hurt her finger.	f
24. The foyer had a mirror.	f
25. The prince found the slipper.	f
26. The radio fell to the ground.	f
27. A nickel lay on the sidewalk.	s
28. A piano stood in the corner.	s
29. The crack was in the ceiling.	s
30. The salmon went around the log.	s
31. The swing was made of iron.	s
32. The woman smiled at her daughter.	s
33. A child had the mumps.	h
34. A hammer was on the bench.	h
35. The attic had a draft.	h
36. The day held a surprise.	h
37. The feather tickled his lips.	h
38. The king called his mother.	h
39. The plate had a crack.	h
40. The statue was on a hill.	h
Catch trials:	
1. A rabbi visited the school.	p
2. The girl grew an inch.	p
3. A rose was near the door.	k
4. The baby ate a banana.	k
5. A lemon was in the mixture.	g
6. The hook ripped his shirt.	g
7. The salesman approached the house.	g
8. The child rubbed her hand.	w
9. The kid killed the fly.	w
10. The prof left for a minute.	w
11. A lion rested in the shade.	f
12. The hunting amused the men.	f
13. The kids went to the lake.	f
14. The lobster was in a box.	f
15. The boy dropped an apple.	s

16. The driver hated the hail. s
17. The hotel was near the road. s
18. A car came around the curve. h
19. A glove lay in the grass. h
20. The woman went to the doctor. h

APPENDIX C

MATERIALS USED IN EXPERIMENT 3

The sentences were presented auditorily, and subjects pressed the 'yes' response button when they detected the target phoneme, which was presented visually before each trial sentence. In all trials, the target phoneme occurred only once in the sentence, as the initial phoneme of a word (the underlined words of the sentences listed below). The target phoneme was either the bilabial or velar voiceless stop /p/ or /k/ and was followed by a vowel. The target word in the critical trials was either the head noun of the subject noun phrase (early sentence position) or the head noun of the object noun phrase (late sentence position). Each sentence contained both a /p/ target and a /k/ target (half each in early and late sentence position), but each subject was to monitor for only one of the targets on any given trial.

The sentences were all produced with the four intonation patterns characterized by the accent status of the final noun: expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and unaccented.

All two-syllable target words had lexical stress on the first syllable. Early and late position targets were matched for target word frequency.

In the following listing of critical trials, those numbered 1 to 48 have /p/ targets in early sentence position and /k/ targets in late sentence position. Critical trials numbered 49 to 96 have /k/ targets in early sentence position and /p/ targets in late sentence position.

Auditory sentences	Target phonemes
Critical trials:	
1. The pain hurt his colon.	p, k
2. His pal wore a kilt.	p, k
3. The panda always ate candy.	p, k
4. The panther hunted a cobra.	p, k
5. The parcel held a key.	p, k
6. The parchment was shown in court.	p, k
7. The pardon amazed the coward.	p, k
8. The parent saw the kite.	p, k
9. The parrot hid the coin.	p, k
10. The parson walked around the courtyard.	p, k
11. His passion was a comfort.	p, k
12. The password had a comma.	p, k
13. The past haunted the castle.	p, k
14. The patch was on his calf.	p, k
15. Her patience lasted through the concert.	p, k
16. The patriot returned to his country.	p, k
17. The patron lifted the cover.	p, k
18. The pattern adorned the canvas.	p, k
19. The pavement went around the curve.	p, k
20. The peach was eaten in the convent.	p, k
21. The pearl was owned by a cult.	p, k
22. The peasant held a candle.	p, k
23. The peddler sold a kettle.	p, k
24. His pelvis was in a cast.	p, k
25. The penance soothed her conscience.	p, k
26. The pencil had a soft core.	p, k
27. A pendant hung at her collar.	p, k
28. The permit authorized the contest.	p, k
29. The pillar was in the corner.	p, k
30. The pillow was stuffed with cotton.	p, k
31. The pilot was late for curfew.	p, k
32. The pine was near the cave.	p, k
33. The Pisces loved the kiss.	p, k
34. The pitcher was in front of the couch.	p, k
35. Her pity disturbed her colleague.	p, k
36. The poet admired the canyon.	p, k
37. The poison ruined her coffee.	p, k
38. The pollen irritated the king.	p, k
39. The poor dreamed about the cash.	p, k
40. The porch was near the kitchen.	p, k
41. The porridge bubbled in the cauldron.	p, k
42. The portrait suited the cowboy.	p, k
43. The possum waddled through the corn.	p, k
44. The poster amused the coach.	p, k
45. The potter enjoyed the kindness.	p, k
46. The puddle bothered the cow.	p, k
47. The pulley was wound in a coil.	p, k
48. The python devoured the catfish.	p, k

49. The caddie watched the path.	k, p
50. The cage held a pigeon.	k, p
51. The Cajun was wearing a poncho.	k, p
52. The camel drained the pail.	k, p
53. The cancer devastated his patient.	k, p
54. The canine had a paunch.	k, p
55. The cannon fired at the penthouse.	k, p
56. The car drove to the palace.	k, p
57. The cart ran into the post.	k, p
58. The cat ate the parsley.	k, p
59. The catcher missed the pass.	k, p
60. The cattle were near the pool.	k, p
61. His caution delayed the purchase.	k, p
62. The Celt was a pagan.	k, p
63. The chaos overwhelmed the pastor.	k, p
64. The chorus loved the pastry.	k, p
65. Some coal fell onto the pad.	k, p
66. The coast astonished the pilgrim.	k, p
67. The code frustrated the pest.	k, p
68. The codeine slowed her pulse.	k, p
69. The college had several patents.	k, p
70. The collie ran through the pasture.	k, p
71. The colonel read the poem.	k, p
72. The colors were on the palette.	k, p
73. The colt was not a pet.	k, p
74. The comb was in her purse.	k, p
75. The comet astonished the parish.	k, p
76. His comment influenced her posture.	k, p
77. The convict hid in the pantry.	k, p
78. The coolant was sold in pints.	k, p
79. The cord was stored in a pouch.	k, p
80. The cost was more than his pension.	k, p
81. The costume fit the painter.	k, p
82. The council voided the payment.	k, p
83. The courier delivered the piston.	k, p
84. Her cousin was in great peril.	k, p
85. The cove sheltered the port.	k, p
86. The current frightened the puma.	k, p
87. The curse startled the pony.	k, p
88. The cursor was only a point.	k, p
89. The curtains were drawn in the parlor.	k, p
90. The cushion was made of pelts.	k, p
91. The custard was almost a paste.	k, p
92. The custom had its pitfalls.	k, p
93. The kennel watched the poodle.	k, p
94. The kid wanted a peanut.	k, p
95. The killer used a pistol.	k, p
96. The kitten rested on the pier.	k, p

Filler trials:

1. A girl pushed her brother. p
2. A journal published the work. p
3. An eye peeked through the hole. p
4. His finger got pinched in the door. p
5. The accountant purged all the records. p
6. The kid pounded on the table. p
7. The kid pulled the wagon. p
8. The man polled all the customers. p
9. The water poured out of the faucet. p
10. The woman picked a tomato. p
11. A student coughed during the film. k
12. The boy cuddled his rabbit. k
13. The knife cut through the bone. k
14. The lover kept his promise. k
15. The mailman carried the letter. k
16. The message confused the woman. k
17. The player captured the flag. k
18. The rain covered the path. k
19. The repairman came at a bad time. k
20. The zebra cooled off in the shade. k

Catch trials:

1. A car came around the curve. p
2. A duck walked on the shore. p
3. A glove lay in the grass. p
4. A gun scared the man. p
5. A lemon was in the mixture. p
6. A man served the coffee. p
7. A nickel lay on the sidewalk. p
8. An adult eats with a fork. p
9. An oak grew in the yard. p
10. The attic had a draft. p
11. The cargo weighed several tons. p
12. The child hurt her finger. p
13. The children fed the goat. p
14. The cotton was lost in the move. p
15. The cow mooed through the night. p
16. The crack was in the ceiling. p
17. The dentist ate a carrot. p
18. The gas leaked from the container. p
19. The girl used a drill. p
20. The girl visited her aunt. p
21. The hunting amused the men. p
22. The king called his mother. p
23. The niece made a gift. p
24. The radio fell to the ground. p
25. The salmon went around the log. p
26. The scouts took the train. p
27. The silver gleamed in the light. p
28. The swing was made of iron. p

29. The team crossed the ocean. p
30. The woman went to the doctor. p
31. A ball flew over the fence. k
32. A boat was near the tower. k
33. A football hit the post. k
34. A lion rested in the shade. k
35. A man found a mouse. k
36. A rose was near the door. k
37. A waiter brought the salt. k
38. The baby ate a banana. k
39. The bed is by the window. k
40. The beer spilled on the mat. k
41. The boy dropped an apple. k
42. The boy followed his brother. k
43. The bread was on the table. k
44. The day held a surprise. k
45. The driver hated the hail. k
46. The family sat on the porch. k
47. The foyer had a mirror. k
48. The hotel was near the road. k
49. The husband went to the store. k
50. The lobster was in a box. k
51. The poet was near the city. k
52. The pole reached to the swimmer. k
53. The potatoes are in the oven. k
54. The prince found the slipper. k
55. The prof left for a minute. k
56. The salesman approached the house. k
57. The statue was on a hill. k
58. The stream went under the path. k
59. The wind blew the sand. k
60. The woman smiled at her daughter. k

APPENDIX D

MATERIALS USED IN EXPERIMENT 4

The auditory stimuli sentence for this experiment are exactly the same sentences that were used in Experiment 3. The sentences were all produced with the four intonation patterns characterized by the accent status of the final noun: expanded pitch range nuclear accented, regular nuclear accented, downstepped nuclear accented, and unaccented. The three categories of questions are 'no' because of a mismatch with the subject, 'no' because of a mismatch with the object, and 'yes'.

Auditory sentences	Questions
<u>'No' because of subject mismatch critical trials:</u>	
1. The caddie watched the path.	Did the judge watch the path?
2. His caution delayed the purchase.	Did his mother delay the purchase?
3. The colt was not a pet.	Wasn't the bird a pet?
4. The cove sheltered the port.	Did the hill shelter the port?
5. The pain hurt his colon.	Did the food hurt his colon?
6. The past haunted the castle.	Did the news haunt the castle?
7. The penance soothed her conscience.	Did the gift soothe her conscience?
8. The poison ruined her coffee.	Did the waiter ruin her coffee?
9. The cage held a pigeon.	Did the trainer hold a pigeon?
10. The Celt was a pagan.	Was the German a pagan?
11. The comb was in her purse.	Was the photo in her purse?
12. The current frightened the puma.	Did the lights frighten the puma?
13. His pal wore a kilt.	Did his brother wear a kilt?
14. The patch was on his calf.	Was the fly on his calf?
15. The pencil had a soft core.	Did the tire have a soft core?
16. The pollen irritated the king.	Did the game irritate the king?
17. The Cajun was wearing a poncho.	Was the Swede wearing a poncho?
18. The chaos overwhelmed the pastor.	Did the movie overwhelm the pastor?
19. The comet astonished the parish.	Did the fire astonish the parish?
20. The curse startled the pony.	Did the shot startle the pony?
21. The panda always ate candy.	Did the kid always eat candy?
22. Her patience lasted through the concert.	Did her gum last through the concert?
23. A pendant hung at her collar.	Did a bow hang at her collar?
24. The poor dreamed about the cash.	Did the gardener dream about the cash?
25. The camel drained the pail.	Did the boy drain the pail?
26. The chorus loved the pastry.	Did the dentist love the pastry?
27. His comment influenced her posture.	Did his glance influence her posture?
28. The cursor was only a point.	Was the shadow only a point?
29. The panther hunted a cobra.	Did the girl hunt a cobra?

30. The patriot returned to his country.	Did the monkey return to his country?
31. The permit authorized the contest.	Did the mayor authorize the contest?
32. The poet admired the canyon.	Did the doctor admire the canyon?
<u>'No' because of object mismatch critical trials:</u>	
33. The cancer devastated his patient.	Did the cancer devastate his father?
34. Some coal fell onto the pad.	Did some coal fall onto the grate?
35. The convict hid in the pantry.	Did the convict hide in the hallway?
36. The curtains were drawn in the parlor.	Were the curtains drawn in the bedroom?
37. The parcel held a key.	Did the parcel hold a donut?
38. The patron lifted the cover.	Did the patron lift the spoon?
39. The pillar was in the corner.	Was the pillar in the pond?
40. The porridge bubbled in the cauldron.	Did the porridge bubble in the freezer?
41. The canine had a paunch.	Did the canine have a headache?
42. The coast astonished the pilgrim.	Did the coast astonish the captain?
43. The coolant was sold in pints.	Was the coolant sold in gallons?
44. The cushion was made of pelts.	Was the cushion made of foam?
45. The parson walked around the courtyard.	Did the parson walk around the block?
46. The pattern adorned the canvas.	Did the pattern adorn the placemat?
47. The pillow was stuffed with cotton.	Was the pillow stuffed with feathers?
48. The portrait suited the cowboy.	Did the portrait suit the merchant?
49. The cannon fired at the penthouse.	Did the cannon fire at the library?
50. The code frustrated the pest.	Did the code frustrate the manager?
51. The cord was stored in a pouch.	Was the cord stored in a box?
52. The custard was almost a paste.	Was the custard almost a liquid?
53. The pardon amazed the coward.	Did the pardon amaze the jury?
54. The pavement went around the curve.	Did the pavement go around the tree?
55. The pilot was late for curfew.	Was the pilot late for practice?
56. The possum waddled through the corn.	Did the possum waddle through the tar?
57. The car drove to the palace.	Did the car drive to the store?
58. The codeine slowed her pulse.	Did the codeine slow her speech?
59. The cost was more than his pension.	Was the cost more than his estimate?
60. The kitten rested on the pier.	Did the kitten rest on the chair?
61. The parent saw the kite.	Did the parent see the pie?
62. The peach was eaten in the convent.	Was the peach eaten in the station?
63. The pine was near the cave.	Was the pine near the river?
64. The poster amused the coach.	Did the poster amuse the bowler?
<u>'Yes' critical trials:</u>	
65. The cart ran into the post.	Did the cart run into the post?
66. The college had several patents.	Did the college have several patents?
67. The costume fit the painter.	Did the costume fit the painter?
68. The kennel watched the poodle.	Did the kennel watch the poodle?
69. The parrot hid the coin.	Did the parrot hide the coin?
70. The pearl was owned by a cult.	Was the pearl owned by a cult?
71. The Pisces loved the kiss.	Did the Pisces love the kiss?
72. The potter enjoyed the kindness.	Did the potter enjoy the kindness?
73. The cat ate the parsley.	Did the cat eat the parsley?
74. The collie ran through the pasture.	Did the collie run through the pasture?
75. The council voided the payment.	Did the council void the payment?
76. The kid wanted a peanut.	Did the kid want a peanut?

77.	The parchment was shown in court.	Was the parchment shown in court?
78.	The peasant held a candle.	Did the peasant hold a candle?
79.	The pitcher was in front of the couch.	Was the pitcher in front of the couch?
80.	The puddle bothered the cow.	Did the puddle bother the cow?
81.	The catcher missed the pass.	Did the catcher miss the pass?
82.	The colonel read the poem.	Did the colonel read the poem?
83.	The courier delivered the piston.	Did the courier deliver the piston?
84.	The killer used a pistol.	Did the killer use a pistol?
85.	His passion was a comfort.	Was his passion a comfort?
86.	The peddler sold a kettle.	Did the peddler sell a kettle?
87.	Her pity disturbed her colleague.	Did her pity disturb her colleague?
88.	The pulley was wound in a coil.	Was the pulley wound in a coil?
89.	The cattle were near the pool.	Were the cattle near the pool?
90.	The colors were on the palette.	Were the colors on the palette?
91.	Her cousin was in great peril.	Was her cousin in great peril?
92.	The custom had its pitfalls.	Did the custom have its pitfalls?
93.	The password had a comma.	Did the password have a comma?
94.	His pelvis was in a cast.	Was his pelvis in a cast?
95.	The porch was near the kitchen.	Was the porch near the kitchen?
96.	The python devoured the catfish.	Did the python devour the catfish?

'No' filler trials:

1.	The repairman came at a bad time.	Was the repairman's visit convenient?
2.	The message confused the woman.	Did the woman understand perfectly?
3.	The zebra cooled off in the shade.	Was the zebra in full sun?
4.	The cotton was lost in the move.	Do they know where the cotton is?
5.	The king called his mother.	Did the king forget about his mother?
6.	A lion rested in the shade.	Was the lion out hunting?
7.	A ball flew over the fence.	Did the ball stop at the fence?
8.	The beer spilled on the mat.	Was the mat perfectly dry?
9.	A football hit the post.	Did the football miss the post?
10.	A journal published the work.	Was the article rejected?
11.	The lobster was in a box.	Was the lobster swimming freely?
12.	The lover kept his promise.	Was the man untrustworthy?
13.	A man served the coffee.	Did a woman serve the coffee?
14.	The potatoes are in the oven.	Were the potatoes already served?
15.	The boy followed his brother.	Did the boy leave his brother alone?
16.	The prof left for a minute.	Was the prof always in the room?
17.	The kid pulled the wagon.	Did the kid ride in the wagon?
18.	The kid pounded on the table.	Did the kid sit quietly at the table?
19.	The accountant purged all the records.	Did the man save all the records?
20.	A girl pushed her brother.	Was the girl nice to her brother?

'Yes' filler trials:

1.	The player captured the flag.	Did the player get the flag?
2.	The mailman carried the letter.	Did someone carry a letter?
3.	The bed is by the window.	Is the bed near the window?
4.	A car came around the curve.	Did a car drive around the curve?
5.	The day held a surprise.	Was there a surprise during the day?
6.	An eye peeked through the hole.	Was someone looking through the hole?
7.	The foyer had a mirror.	Did the entrance have a mirror?

8.	A glove lay in the grass.	Was there a glove in the grass?
9.	The husband went to the store.	Did the man go shopping?
10.	A nickel lay on the sidewalk.	Was there a nickel on the sidewalk?
11.	An oak grew in the yard.	Was there an oak in the yard?
12.	The pole reached to the swimmer.	Was the pole long enough?
13.	The rain covered the path.	Was it wet outside?
14.	The salmon went around the log.	Did the fish swim around the log?
15.	The stream went under the path.	Was there a stream close to the path?
16.	The bread was on the table.	Was there bread in the house?
17.	The cargo weighed several tons.	Was the cargo heavy?
18.	The cow mooed through the night.	Did the cow make noise all night?
19.	A duck walked on the shore.	Was the duck near the water?
20.	The gas leaked from the container.	Was the gas leaking?
21.	A gun scared the man.	Was the man frightened?
22.	The hunting amused the men.	Were the men happy?
23.	The niece made a gift.	Did the niece have a gift?
24.	The poet was near the city.	Was the poet close to the city?
25.	The radio fell to the ground.	Did the radio fall?
26.	A rose was near the door.	Was there a rose near the door?
27.	The silver gleamed in the light.	Did the silver shine?
28.	The girl visited her aunt.	Did the girl see her aunt?
29.	The knife cut through the bone.	Was the knife sharp?
30.	The dentist ate a carrot.	Did someone eat a carrot?
31.	The woman went to the doctor.	Did the woman go somewhere?
32.	The child hurt her finger.	Did the child hurt herself?
33.	The children fed the goat.	Did the goat get fed?
34.	The statue was on a hill.	Was there a statue somewhere?
35.	The swing was made of iron.	Was it a metal swing?
36.	A man found a mouse.	Did the man find a rodent?
37.	A waiter brought the salt.	Did the customer end up getting salt?
38.	The prince found the slipper.	Had the slipper been missing?
39.	The scouts took the train.	Did the scouts ride on a train?
40.	The baby ate a banana.	Did the baby have something to eat?
41.	The crack was in the ceiling.	Was there a problem with the ceiling?
42.	The woman smiled at her daughter.	Was the woman happy to see her child?
43.	The girl used a drill.	Did the girl make a hole in something?
44.	An adult eats with a fork.	Do adults use forks?
45.	The driver hated the hail.	Was the woman driving in bad weather?
46.	The salesman approached the house.	Did the man want to sell something?
47.	The team crossed the ocean.	Was the team going somewhere?
48.	The family sat on the porch.	Was the family outside?
49.	The wind blew the sand.	Was the sand moving?
50.	His finger got pinched in the door.	Did the boy hurt himself?
51.	The man polled all the customers.	Did they care what the people thought?
52.	The water poured out of the faucet.	Was water coming out of the faucet?

APPENDIX E

MATERIALS USED IN EXPERIMENTS 5 AND 6

In these two cross-modal naming experiments the sentences were presented auditorily and the target words were presented visually. The auditory priming word in each sentence is underlined. The priming word was either the head noun of the subject noun phrase (early sentence position) or the head noun of the object noun phrase (late sentence position). The visual target words appeared on the screen either 0 ms, 400 ms, or 800 ms after the acoustic offset of the priming words. Only the 0 ms delay condition results are presented in Chapter 5. Appendix F shows all three delay conditions. Experiment 5 used semantic priming; the related target words are semantic associates of the priming words, and the unrelated target words are matched for word frequency and initial phoneme with the corresponding related target words. Experiment 6 used identity priming; the identity target words are the priming words from the sentences, and the unrelated target words are matched for word frequency and initial phoneme with the corresponding identity target words.

Each sentence was produced with two different intonation patterns. Either the nuclear accent fell on the head noun of the subject noun phrase (early nuclear accent placement) or on the head noun of the object noun phrase (late nuclear accent placement).

		Identity priming (Exp. 6)		Semantic priming (Exp. 5)	
	Auditory sentences	Identical Target	Unrelated Target	Related Target	Unrelated Target
Early sentence position trials:					
1.	The attic had a draft.	attic	arrow	basement	blanket
2.	A ball flew over the fence.	ball	blood	bat	brick
3.	The bed is by the window.	bed	bill	pillow	pearl
4.	The beer spilled on the mat.	beer	bomb	wine	wind
5.	A boat was near the tower.	boat	box	ship	shop
6.	The bread was on the table.	bread	brush	butter	bullet
7.	A car came around the curve.	car	court	bus	bone
8.	A daisy grew by the gate.	daisy	dresser	pansy	piston
9.	The day held a surprise.	day	door	night	note
10.	A dollar buys an ice cream.	dollar	driver	cent	cell
11.	A duck walked on the shore.	duck	doll	swan	sash
12.	An eye peeked through the hole.	eye	earth	nose	net
13.	The flu weakened the boy.	flu	frost	cold	club
14.	A football hit the post.	football	flower	baseball	bagpipe
15.	The foyer had a mirror.	foyer	fielder	hall	heart
16.	The gas leaked from the container.	gas	grass	oil	owl
17.	A glove lay in the grass.	glove	graph	mitten	mammal
18.	A gun scared the man.	gun	ground	pistol	penny
19.	A hammer was on the bench.	hammer	hymn	nail	noose
20.	The hotel was near the road.	hotel	human	motel	movie
21.	The hunting amused the men.	hunting	highway	fishing	flower
22.	The husband went to the store.	husband	hair	wife	wall
23.	A journal published the work.	journal	jury	article	artist
24.	The ketchup is in a bottle.	ketchup	kennel	mustard	merchant
25.	The king called his mother.	king	key	queen	quarter
26.	Her knee hit the pavement.	knee	net	elbow	eagle
27.	A lemon was in the mixture.	lemon	lobby	lime	leaf
28.	A lion rested in the shade.	lion	lung	tiger	trumpet
29.	The lobster was in a box.	lobster	leaflet	shrimp	shawl
30.	The milk was on the table.	milk	mail	water	weapon
31.	A nickel lay on the sidewalk.	nickel	nutmeg	dime	dove
32.	The niece made a gift.	niece	nail	nephew	needle
33.	A noun begins the story.	noun	noose	verb	vest
34.	A novel lay on the bench.	novel	nose	fiction	fellow
35.	The nun walked to the park.	nun	napkin	monk	mare
36.	An oak grew in the yard.	oak	opium	pine	purse
37.	A piano stood in the corner.	piano	palace	violin	velvet
38.	The plate had a crack.	plate	plug	bowl	boss
39.	A pot was on the counter.	pot	pile	pan	pin
40.	A rabbi visited the school.	rabbi	ribbon	priest	python
41.	The radio fell to the ground.	radio	rifle	stereo	shower
42.	The rain covered the path.	rain	ring	snow	seat
43.	A rose was near the door.	rose	rock	tulip	trolley
44.	The salmon went around the log.	salmon	soccer	tuna	tailor
45.	A shoe was under the basket.	shoe	soup	sock	spice

Auditory sentences	Identity priming (Exp. 6)		Semantic priming (Exp. 5)	
	Identical Target	Unrelated Target	Related Target	Unrelated Target
46. The silver gleamed in the light.	silver	sugar	gold	guard
47. The stream went under the path.	stream	spot	creek	cake
48. The table was in the corner.	table	town	chair	chain
Late sentence position trials:				
1. The boy dropped an apple.	apple	ankle	orange	outfit
2. The child broke his arm.	arm	artist	leg	lane
3. The girl visited her aunt.	aunt	arch	uncle	ulcer
4. The baby ate a banana.	banana	bouquet	pear	pig
5. A bird chased the bee.	bee	bolt	wasp	wig
6. The guys played the blues.	blues	boar	jazz	judge
7. The boy followed his brother.	brother	bridge	sister	supper
8. The dentist ate a carrot.	carrot	cavern	corn	coal
9. The baby saw the cat.	cat	clock	dog	dust
10. The crack was in the ceiling.	ceiling	stable	floor	food
11. The family went to church.	church	chief	chapel	channel
12. A man served the coffee.	coffee	cover	tea	trail
13. The vase is made of copper.	copper	creature	bronze	bolt
14. The girl liked the cotton.	cotton	cousin	wool	waist
15. The guest sat on the couch.	couch	cone	sofa	spear
16. The woman smiled at her daughter.	daughter	disease	son	square
17. The woman went to the doctor.	doctor	dinner	nurse	nest
18. The girl used a drill.	drill	dawn	saw	street
19. The child hurt her finger.	finger	frame	thumb	thunder
20. The kid killed the fly.	fly	fog	ant	axe
21. An adult eats with a fork.	fork	fur	spoon	sword
22. The boy smelled the garlic.	garlic	garment	onion	organ
23. The children fed the goat.	goat	gown	sheep	shell
24. The driver hated the hail.	hail	hawk	sleet	skate
25. The child rubbed her hand.	hand	hall	foot	frame
26. The statue was on a hill.	hill	hat	valley	village
27. The boy watched the horse.	horse	heart	cow	cloud
28. The salesman approached the house.	house	head	home	head
29. The girl grew an inch.	inch	ice	mile	mail
30. The swing was made of iron.	iron	Indian	steel	skin
31. The kids went to the lake.	lake	leg	pond	pile
32. The feather tickled his lips.	lips	lark	mouth	machine
33. The prof left for a minute.	minute	motor	hour	army
34. A man found a mouse.	mouse	moss	rat	ramp
35. A child had the mumps.	mumps	moth	measles	mixer
36. The team crossed the ocean.	ocean	orange	sea	sign
37. The potatoes are in the oven.	oven	organ	stove	straw
38. The family sat on the porch.	porch	pope	patio	prune
39. The girl tripped on the rug.	rug	rope	carpet	candy
40. A waiter brought the salt.	salt	suit	pepper	pasture
41. The wind blew the sand.	sand	slave	beach	block

Auditory sentences	Identity priming (Exp. 6)		Semantic priming (Exp. 5)	
	Identical Target	Unrelated Target	Related Target	Unrelated Target
42. The hook ripped his shirt.	shirt	star	pants	pork
43. The shopper chose the silk.	silk	sail	satin	sunburn
44. The prince found the slipper.	slipper	seaweed	boot	blade
45. The woman picked a tomato.	tomato	trolley	lettuce	laundry
46. The scouts took the train.	train	test	plane	plant
47. The kid pulled the wagon.	wagon	weapon	bike	broom
48. The painter worked for a week.	week	wife	month	market

APPENDIX F

EXPERIMENTS 5 AND 6 ADDITIONAL RESULTS:

REACTION TIMES IN THREE DELAY CONDITIONS

Figure 18 in this appendix presents the reaction time data for all three delay conditions (0 ms, 400 ms, 800 ms) used in Experiments 5 and 6. In Chapter 5, only the 0 ms delay condition means were presented because the most substantial effects of accent status on naming reaction time occurred at the 0 ms delay, and the differences between nuclear accented and non-nuclear accented became progressively less at the longer reaction times.

The closer the target word presentation was to the end of the auditory sentence, the faster the naming time. The target words in the early prime position with the 800 ms delay appeared sometime near the end of the sentence, either just before the end or just after the end. In general, these naming times were not significantly different from the late prime position 0 ms delay naming times.

Early placement of nuclear accent led to slower naming times for both related and unrelated target words at the two shortest delays. Note that nuclear and non-nuclear target words are named equally quickly at the 800 ms delay, suggesting that after a sufficient amount of time (or by the end of the sentence) the listener has dealt with the 'not normal' accent placement.

The differences that showed up in naming latencies at the different target delays match the prediction of early sentence position target words being named more slowly than late sentence position target words because the subject has to perform two tasks at once. The fact that the naming latency for the early sentence position 800 ms delay (in which the target word appeared near the end of the sentence) was not significantly different from the late sentence position 0 ms delay can be taken as evidence to support this conclusion. The late sentence position target words always appeared after the completion of the sentence, so in those cases there was no complication of the subject having to perform two tasks at once. Those condition means were for the most part not significantly different for the different delays. The only significant differences between the delay conditions was that the nuclear unrelated

target words were faster at 400 ms than at 0 ms. This suggests that neither the spreading-activation nor the focus-of-attention explanations given above give the true picture of what happens over time in the processing of the sentences. The spreading-activation dying off at longer time intervals is not confirmed, nor is the prediction that the focus-of-attention difference at longer time intervals should be stronger.

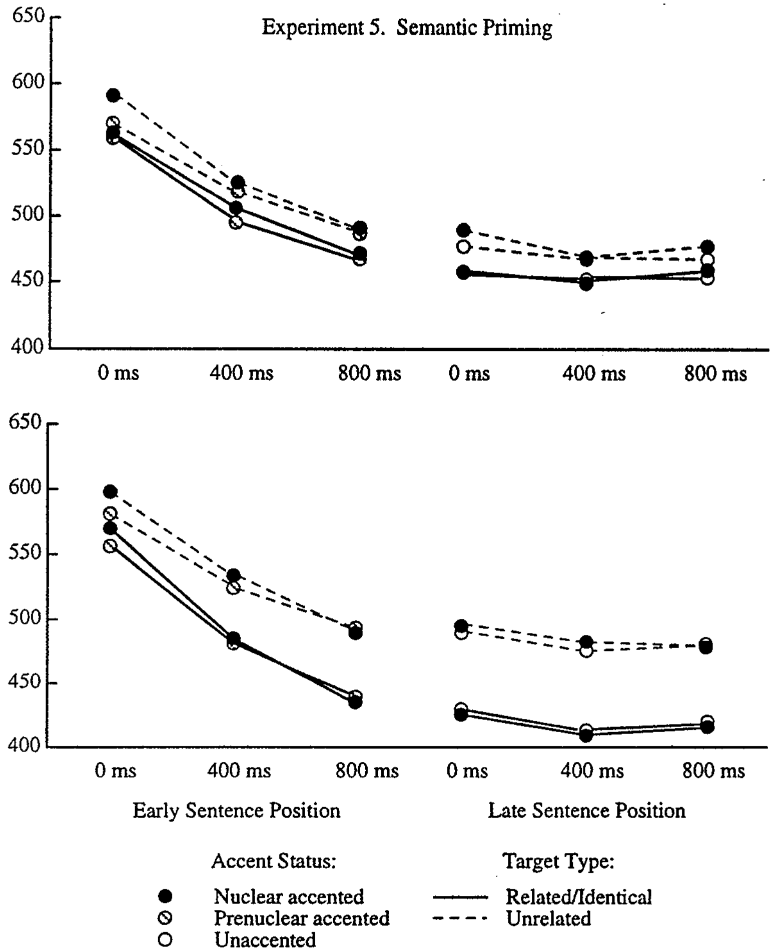

Figure 18. Experiments 5 and 6. Reaction times (in ms) to cross-modal naming targets at three delay conditions: 0 ms, 400 ms, and 800 ms. Target words occurred in early and late sentence position of sentences with early nuclear accent placement and late regular nuclear accent placement.
(top) Experiment 5, semantic priming. Related and unrelated target words.
(bottom) Experiment 6, identity priming. Identical and unrelated target words.

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