PHONETIC CUES IDENTIFYING ENGLISH COMPOUNDS

Tuuli Morrill Adams

New York University
tuuli.adams@nyu.edu

ABSTRACT

This study investigates the acoustic correlates of stress in English compounds by measuring the interaction of stress cues with different intonational environments. Effects on vowel duration, intensity, and pitch changes are compared in contrasting compounds and phrases. The results of an experiment in which participants pronounced compounds and phrases in controlled prosodic and intonational environments provide new evidence that the phonetic indicators of stress interact with these environments in a systematic way.

Keywords: compounds, stress, pitch, intonation

1. INTRODUCTION

The stress pattern in English compounds such as *greenhouse* (for plants) is distinct from that of the phrases like *green house* (house that is green). Most analyses assume that the first member of a compound is stressed and exhibits the same stress cues found in other words and phrases [7],[8]. However, no empirical study has shown that the structural difference between compounds and phrases is represented in their phonetic realization. If compounds and phrases are distinguished by a stress pattern, the acoustic signal should indicate this information. Previous work provides evidence that prosodic structure and intonational patterns both interact with stress [1],[4] necessitating a well-controlled experiment in which these effects can be investigated in compounds.

The cues of stress in English are generally considered duration, pitch and intensity. The relative contribution of these cues varies according to the level of stress, whether it is word-level or phrasal stress. Beckman and Edwards [1] found that when word-level stress is not accented, unreduced vowels and longer duration are consistent stress cues. However, at the phrasal level, with pitch accents, duration is not a consistent correlate of stress and pitch movement is. Results of another experiment [9] show that children's ability to use prosodic information may develop slowly, and this could account for their errors in distinguishing compounds from phrases. However, the adults also made errors, despite perceptual cues such as durational differences in stressed syllables. This suggests that the cues to stress in compounds are not invariant. The general claim that pitch changes, higher intensity, and longer duration are all consistent correlates of stress does not seem to hold true, as previous work has also acknowledged [5],[7]. Instead, the phonetic realization of a distinctive compound stress pattern may vary according to the intonational environment.

The current study undertakes a wider investigation of the acoustic correlates of stress in the contrasting prosodic environments of compounds and phrases. Stimuli were read in four different sentence types, with compounds and phrases in each of the intonational environments. In this way, any consistent phonetic cues identifying compound stress could be uncovered.

2. EXPERIMENT

2.1. Stimuli

The stimuli were 19 pairs of compounds and phrases consisting of an adjective and a noun, such as *greenhouse* (for plants) and *green house* (residence). All of the compounds were bi-syllabic. The compound and phrase were each placed in four sentences in the following positions: (1) subject of the sentence, (2) end of a clause, eliciting the continuation rise, (3) end of a statement, for falling intonation (4) end of a "yes-no" question, eliciting rising intonation. The pairs of compounds and phrases were always preceded by the same word and syntactic structure, as show in the examples in Table 1.

The 19 sets of sentences, a total of 152 stimulus sentences, were interspersed with 124 filler sentences, which were read by each participant. There were four different randomly ordered lists containing all of the stimuli and fillers. The large number of filler sentences worked to inhibit any tendency to place contrastive stress on the stimuli.

Table 1: Sample Test Sentences

Subject	Compound	The ***whitecaps*** were caused by the strong wind.
	Phrase	The ***white caps*** were knitted by the knitting club.
Question	Compound	When the wind was strong on the shore yesterday, did you *see the **whitecaps**?*
	Phrase	When you went to the craft fair, did you *see the **white caps***?
Clause-Final	Compound	If you were on the water and you didn't *see the **whitecaps,*** the strong wind could take you by surprise.
	Phrase	If you were at the craft fair and you didn't *see the **white caps,*** you probably weren't looking
Statement-Final	Compound	I thought the wind was strong at the beach yesterday, but I didn't *see the **whitecaps.***
	Phrase	I looked at all the knitting displays, but I didn't *see the **white caps.***

2.2. Participants

The participants were 12 adults, ages 18 to 24, 8 females and 4 males, who were recruited from the university community. All of the participants were native speakers of American English, and none had any known speech disorders.

2.3. Procedure

Participants were seated in a sound-proof booth and given a list of stimulus and filler sentences. They were not told of the specific purposes of the experiment, but were asked to read the sentences at a comfortable pace. Recordings were made using a Marantz PMD-680 Digital Audio Recorder.

2.4. Data Analysis

The recordings were analyzed using Praat[3]. Any token containing reading errors such as a word replacement was eliminated, and its compound or phrasal counterpart read by the same participant was also removed. This resulted in a total of 1696 sentences included in the analysis.

Duration was measured for both vowel intervals in each compound and phrase. Since all of the compounds and phrases consisted of two syllables, the vowels will be referred to as V1 and V2. Measurements of maximum intensity (dB) were extracted from each vowel. The difference from the maximum intensity of V1 to the maximum intensity of V2 was calculated, in order to measure the relative intensity of the first to the second syllable. Measurements were also taken for the maximum and minimum pitch (Hertz), and the beginning and end pitch of each vowel. ToBI-style labels [2] were assigned to identify edge tones of the phrases and sentences. The labeling ensured that only tokens in like intonational environments were compared. For example, only tokens which followed the "yes-no question" rising pattern (H-H%) were included for questions; likewise, for the statement-final position, only falling (L-L%) patterns were included.

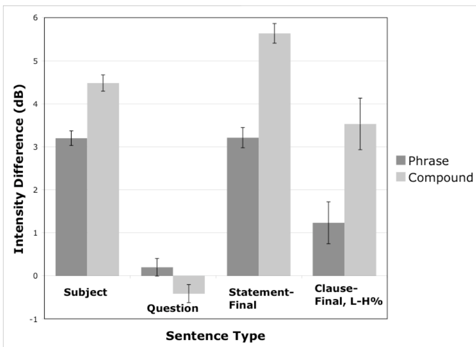
3. RESULTS

The statistical analyses of intensity, duration and pitch were performed separately on the each sentence type. This avoids confounding pitch measurements by combining rising and falling intonation patterns (e.g. statement-final vs. question). In the following presentation of the statistical analyses, significant findings are presented first, followed by other relevant results.

3.1. Intensity

Using the intensity measurements obtained as described above, Analyses of Variance with participants as a random factor were performed on the four different sentence types. In all sentence types except for questions, the change in decibels from V1 to V2 was significantly greater in compounds than in phrases, $p < .005$ (see Figure 1). In a question such as *"...did you see the whitecaps?"* the inherent intensity in raising the pitch may cancel any effect of greater intensity caused by stress on the first syllable.

Figure 1: Intensity Change (dB) from Maximum V1 to Maximum V2 in Phrases vs. Compounds



3.2. Duration

The proportional length of the first vowel to the second vowel was calculated by dividing the duration of V1 by the duration of V2. Analyses of Variance were conducted with word type (compound vs. phrase) as the fixed factor and the ratio of V1:V2 as the dependent variable.

3.2.1. Clause-Final and Question Position

Comparing compounds and phrases in the clause-final "continuation-rise" environment, the mean ratio for compounds was .936 and for phrases, .737. This difference shows that the proportional length of V1 to V2 is greater in compounds than in phrases [$F(1, 38.6)=14.7$, $p<.001$].

Questions with rising intonation exhibited the same effect as the continuation-rise intonation; the mean ratio for compounds was greater than for phrases, .864 for compounds and for phrases, .797. This difference is significant [$F(1,16.5)=6.26$, $p<.05$]. In other words, compounds in both intonational patterns with high boundary tones exhibit a clear effect of lengthening the first syllable in relation to the second.

3.2.2. Subject and Statement-Final Positions

No significant difference between the V1:V2 ratios was found in the subject position [$F(1, 11.9)=1.69$, $p=.22$]. The same was true of the statement-final position. The mean ratio for compounds was .916, and for phrases was .871 [$F(1, 11.5)=1.60$, $p=.207$]. However, the overall trend of V1 lengthening remains consistent for compounds in all intonational environments, although it may not be a salient cue for stress in the sentence-subject or statement-final positions.

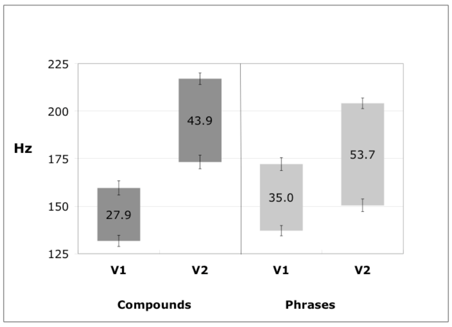
3.3. Pitch

The results for pitch measurements are presented for each of the four stimulus types. Because pitch is inherently related to intonation to a certain degree, the pitch patterns that may be relevant to distinguishing compounds from phrases should also vary according to sentence type.

3.3.1. Question-Position

The "pitch change" within each vowel, V1 and V2, was calculated as the difference between the maximum and minimum pitch (Hz). Analyses of Variance were performed on pitch changes in both vowels. Overall, the pitch change in the V2 of phrases was greater than in compounds. The mean change in phrases was 53.7 Hz, and in compounds it was 43.89 Hz, [$F(1,14.1)=5.77$, $p<.05$]. The main effect of compound vs. phrase for the maximum pitch of both V1 and V2 and the minimum pitch of V2 are all significant, $p<.05$.

Figure 2: Maximum and Minimum Pitch (Hz) of Vowels in Compounds vs. Phrases in Questions



The gray box represents the range from the ***minimum pitch*** *to the* ***maximum pitch*** *in the vowel.*

The pattern of pitch change in compounds visible in Figure 2, a lower and narrower range for V1, and a higher and narrower range for V2, suggests a more distinctive pitch change in compounds than phrases. An Analysis of Variance for the pitch difference from the end of V1 to the beginning of V2 shows a significant effect of compound vs. phrase, with the mean change for compounds at 36.27 Hz, and the mean change for phrases at 17.75 Hz, [$F(1,22.7)=6.93$, $p<.01$]. This shows that in questions, the pitch change from V1 to V2 in compounds makes a jump which is essentially twice as high as that of phrases. In addition, the amount of change within each vowel is significantly less for compounds than for phrases, where the pitch ranges of V1 and V2 overlap (please see "image file 1" for examples).

3.3.2. Clause-Final Position

The series of pitch analyses that were conducted on the question intonation pattern were repeated for the clause-final position. In clauses with L-H% intonation (continuation-rise), the results of the ANOVA revealed an overall narrower pitch range for both V1 and V2 of compounds as compared to phrases. The maximum pitch of V2 was significantly different [$F(1, 17.6))=5.82$, $p<.05$], for compounds at 185.2 Hz, and phrases, 177.0 Hz. Differences approach significance for the minimum of V1, 161.8 Hz for compounds and 142 Hz for phrases, [$F(1, 14.8)=4.367$, $p=.054$], and the minimum of V2, 151.5 Hz for compounds and 118.4 Hz for phrases, and [$F(1, 12.8)=4.15$, $p=.06$].

The maximum pitch of V1 between compound and phrases was not significantly different [F(1, 45.3)=2.47 *p*=.12]. The pitch changes within the vowels themselves were not significantly different between compounds and phrases, but compounds had less change than phrases for both V1 and V2.

3.3.3. Statement-Final Position

The statement-final position showed no effects of pitch differentiating compounds from phrases. This was true across all measurements.

3.3.4. Subject Position

As with question intonation, there was less pitch change within the V1 of compounds than phrases in the subject position. The pitch change from maximum to minimum in V1 for compounds was 35.08 Hz, and for phrases 40.02 Hz. These differences were significant [F(1,11.8)=4.91, *p*<.05]. The results for pitch change in V2 also patterned in this way, but only approached significance; the mean pitch difference for V2 in compounds is 37.34 Hz, and in phrases it is 47.17 Hz, [F(1, 11.3)=4.16, *p*=.07].

4. DISCUSSION

The results of this experiment reveal that the phonetic cues to compound stress vary systematically with the intonational environment. Intensity emerges as a significant cue for compound stress in all environments except for questions. Duration is a reliable cue in exactly this intonational environment, and also in the continuation-rise pattern, both of which have a high boundary tone. Additionally, distinctive pitch patterns emerge in both environments. This suggests that a trading of phonetic cues takes place across different intonational environments.

The pitch pattern found in compounds in rising intonation can be described impressionistically as a low and flat pitch contour on V1 to a high and flat pitch contour on V2. Although pitch differences between compounds and phrases in subject position were not significant, they trended in the same direction as the pattern of the continuation-rise environment, with less pitch change within the V1 of compounds. This pattern indicates that compound stress on the first syllable makes the vowel less subject to fluctuations caused by the surrounding intonational environment.

5. CONCLUSION

The results of this experiment provide empirical evidence for acoustic cues which distinguish the prosodic structures of contrasting compounds and phrases. Most interestingly, the pitch patterns, duration and intensity of stressed syllables in compounds show interactions with the intonational environments that result in a form of cue-trading between the acoustic correlates of stress. While no one phonetic cue distinguishes compounds from phrases across all contexts, the distribution of pitch change over the word or phrase indicates its prosodic status, as does the stress pattern also evidenced in intensity and durational measures. Further investigation could reveal the salience of these cues for the perception of compound stress. These results show that speakers do consistently use specific phonetic markers to indicate whether they are producing a compound or a phrase. The realization of these cues is then influenced by the surrounding intonational environment.

6. ACKNOWLEDGEMENTS

I would like to thank Lisa Davidson and Maria Gouskova for help with the design and other stages of the project, and members of the NYU Ph-Lab for their comments. All errors are my own.

7. REFERENCES

[1] Beckman, M., Edwards, J. 1994. Ariculatory evidence for differentiating stress categories. In: Keating, P. (ed.) *Papers in Laboratory Phonology* 3, 7-33. New York: Cambridge Univeristy Press.

[2] Beckman, M., Edward, G.A. 1997. *Guidelines for ToBI Labeling (version 3.0)*. MS. The Ohio State University.

[3] Boersma, P., Weenink, D. (2006). Praat (Version 4.5.16) http://www.praat.org/

[4] Fougeron, C., Keating, P. 1997. Articulatory strengthening at edges of prosodic domains. *Journal of the Acoustical Society of America* 101, 3728-3740.

[5] Hayes, B. 1995. *Metrical stress theory: principles and case studies*. Chicago: University of Chicago Press.

[6] Keating, P., Cho, T., Fougeron, C., Hsu, C. 2003. Domain-initial articulatory strengthening in four languages. In: Local, J., Ogden, R. Temple, R., (eds.) *Papers in Laboratory Phonology* 6, 143-161. New York: Cambridge University Press.

[7] Ladd, D.R. 1996. *Intonational Phonology*. New York: Cambridge University Press.

[8] Nespor, M., Vogel, I. 1986. *Prosodic Phonology*. Riverton, NJ: Foris Publications.

[9] Vogel, I., Raimy, E. 2002. The acquisition of compound vs. phrasal stress" the role of prosodic constituents. *Journal of Child Language* 29, 225-250.