An Experimental Approach to Lexical Stress in English

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1. Introduction

Is stress really loudness, or pitch, or duration, or quality? The nature of stress has proved to be one of the most controversial of the prosodic features. We are going to exclude 'quality' in this study, because it is extremely difficult to evaluate acoustically. The aim of this study is to illustrate a point about stress in English by examining acoustically or experimentally which factor contributes more significantly to its prominence and which factor does less so among three factors: loudness (energy), pitch, and duration. The production of stress, or prominence, is generally believed to depend on the speaker using more muscular energy than is used for unstressed syllables. In other words, when we produce stressed syllables, the muscles that we use to expel air from the lungs are more active, producing higher subglottal pressure. The three concomitant factors work together in combination, though they are not equally important. So it is a matter of degree to which each factor contributes to prominence. It is important to understand, however, that the characteristics of prominence are so closely connected with one another that usually it is beyond the speaker's control to emphasize one or two particular factors. There are two different approaches to the nature of stress; one from the productive point of view, the other from the perceptual point of view. This

study may be called an anatomical analysis of the nature of stress mainly from the productive point of view.

2. Procedure

The material chosen was 13 pairs of English words in which a change of function from noun to verb is commonly associated with a shift of stress from the first to the second syllable. These words were: *digest, escort, survey, torment, convict, object, abstract, conduct, contract, contrast, insult, permit, subject.*

Two educated native speakers (an RP speaker and a GA speaker) were asked to read sentences containing the words above and the readings were recorded on tape. In order to keep the rate of utterances as constant as possible, they were asked to say each word in the same frame "Say_____ now". Spectrograms of the selected words were made on both the CSL-Model 4300B (from Kay Elemetrics Corp.) and the PCquirer (from Scicon Research & Development) to measure the vowel duration, loudness and pitch which occur in these words. We can ignore the consonant duration ratios, because they are not materially affected by the shift of stress.

2.1. Acoustic Data

Table 1-1

Measured vowel durations (ms), pitches (Hz) and intensities (dB) for thirteen pairs of words produced by an RP speaker, in which a change of function from noun to verb is associated with a shift of stress from the first to the second syllable.

		ms	ms	Hz	Hz	dB	dB
DI-	gest	218.5	191.8	177.27	86.13	79.08	67.69
di-	GEST	166.3	177.6	121.15	306.25	67.69	77.75
ES-	cort	81.5	238.6	162.13	89.63	72.84	62.25
es-	CORT	120.9	274.6	116.05	225	72.43	72.75
SUR-	vey	154.3	208.3	225	87.5	75.36	62.82
sur-	VEY	144	362.2	134.45	193.42	67.71	71.54
TOR-	ment	106.8	88.9	234.57	167.05	74.44	67.81
tor-	MENT	83.8	101.4	134.45	200.45	74.05	74.13
CON-	vict	44.9	43.5	200.45	162.13	76.55	72.23
con-	VICT	61.9	74.4	134.45	234.57	70.59	72.3
OB-	ject	60.7	62.9	162.13	98.44	79.99	74.71
ob-	JECT	63.3	138.7	121.15	225	77.19	76
AB-	stract	74.1	106.5	159.78	167.05	74.26	69.14
ab-	STRACT	84.2	148.4	119.88	234.57	75.58	76.91
CON-	duct	45.5	74.7	225	110.25	79.69	72.4
con-	DUCT	56.7	120.9	134.45	216.18	75.68	78.59
CON-	trast	35.2	184.9	200.45	186.86	74.12	66.88
con-	TRAST	47.6	198.8	147	216.18	80.12	74.43
IN-	sult	48.5	48	175	87.5	76.31	71.13
in-	SULT	48.2	68.7	125.28	225	77.1	75.76
PER-	mit	118.4	90.6	212.02	167.05	76.94	70.16
per-	MIT	110.9	104.2	162.13	234.57	78.56	75.15
SUB-	ject	46.1	65.5	200.45	92.65	75.02	73.9
sub-	JECT	56.4	123.8	147	225	77.68	77.42
CON-	tract	45.1	102	204.17	167.05	75.23	63.15
con-	TRACT	41.5	118.9	125.28	225	73.11	71.87

Table 2-1

Measured vowel durations (ms), pitches (Hz) and intensities (dB) for thirteen pairs of words produced by a GA speaker, in which a change of function from noun to verb is associated with a shift of stress from the first to the second syllable.

		ms	ms	Hz	Hz	dB	dB
DI-	gest	199.8	157.9	180.74	131.25	75.49	73.51
di-	GEST	136	148.8	131.25	183.75	73.01	79.07
ES-	cort	89.3	188.4	180.74	134.45	77.21	77.57
es-	CORT	74.1	185.2	134.45	225	68.46	79.72
SUR-	vey	171.5	221.9	200.45	141.35	76.84	73.29
sur-	VEY	126.9	275.5	125.28	180.74	74	77.74
TOR-	ment	142.8	133.4	225	136.11	79.37	68.82
tor-	MENT	112.1	161.6	125.28	186.86	73.54	75.44
CON-	vict	130.6	99.1	216.18	121.15	75.16	69.96
con-	VICT	89.6	99.3	145.07	212.02	69.02	77.82
OB-	ject	125.6	132.4	216.18	109.16	76.17	65.68
ob-	JECT	95.1	135.6	141.35	200.45	77.72	77.29
AB-	stract	139.7	181.9	193.42	123.88	75.29	70.77
ab-	STRACT	70.9	178.9	117.29	167.05	72.4	78.54
CON-	duct	108.6	117.3	204.17	121.15	72.78	68.57
con-	DUCT	46.8	142.6	136.11	186.86	66.55	76.85
CON-	tract	96.9	134.1	234.57	128.2	75.73	68.55
con-	TRACT	56.3	137.7	128.2	204.17	69.79	75.8
CON-	trast	70.5	138.6	245	125.28	77.09	73.18
con-	TRAST	68	146.5	131.25	212.02	70.93	78.46
IN-	sult	63.6	65.3	234.57	117.29	72.4	70.7
in-	SULT-	42.1	83.1	121.15	208.02	64.44	78.39
PER-	mit	74.5	107	245	167.05	75.29	73.83
per-	MIT	67.2	112.4	117.29	204.17	70.72	74.79
SUB-	ject	97.8	144.9	225	128.2	75.55	74.14
sub-	JECT	57.6	159	116.05	200.45	69.47	79.41

2.2. Statistical Analysis[1]

Table 1-2 Multiple correlation coefficient.[2]

duration	pitch	energy
0.302791	0.922134	0.76625

Table 1-1 above shows the acoustic factors (duration, pitch, energy) of lexical stress in the thirteen noun-verb pairs produced by an RP speaker, in which the placement of stress signals the syntactic category. And Table 1-2 shows, based on the data in Table 1-1, the multiple correlation coefficient of each factor, and clearly indicates that pitch is the most significant factor, and energy second, and duration third.

Table 2-2 Multiple correlation coefficient.

duration	pitch	energy
0.570642	0.969556	0.848173

Table 2-1 above shows the acoustic factors (duration, pitch, energy) of lexical stress in the thirteen noun-verb pairs produced by a GA speaker, in which the placement of stress signals the syntactic category. And Table 2-2 shows, based on the data in Table 2-1, the multiple correlation coefficient of each factor, and clearly indicates, as Tabli 1-2 does, that pitch is the most significant factor, and energy second, and duration third.

Figures 1-1〜1-3 and Figures 2-1〜2-3 below are scatter diagrams designed to make it much easier to realize what Table 1-2 and Table 2-2 indicate respectively.

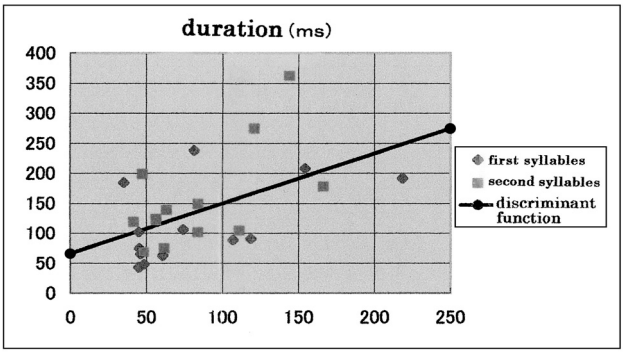

Figure 1-1. A scatter diagram showing the discriminant function of duration (ms).

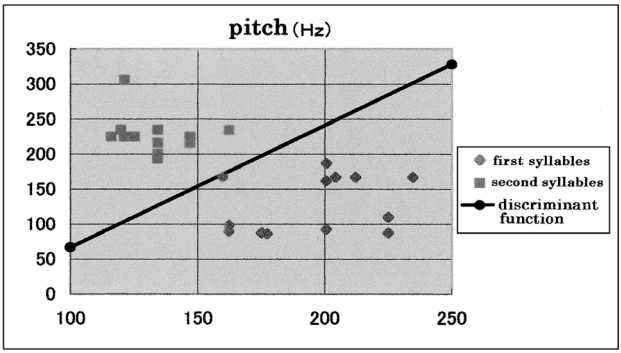

Figure 1-2. A scatter diagram showing the discriminant function of pitch (Hz).

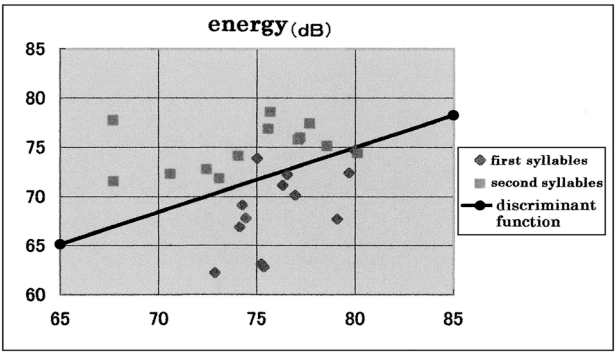

Figure 1-3. A scatter diagram showing the discriminant function of energy (dB).

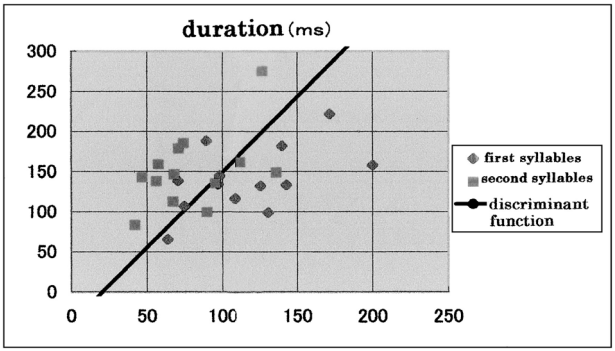

Figure 2-1. A scatter diagram showing the discriminant function of duration (ms).

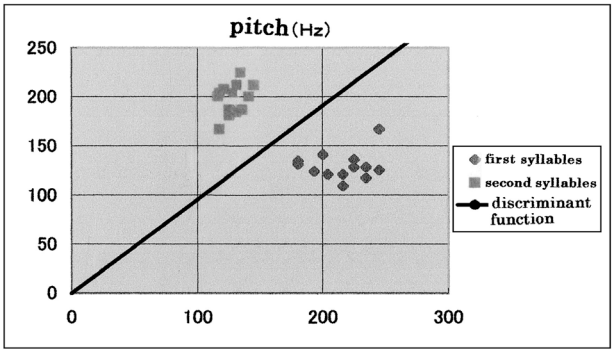

Figure 2-2. A scatter diagram showing the discriminant function of pitch (Hz).

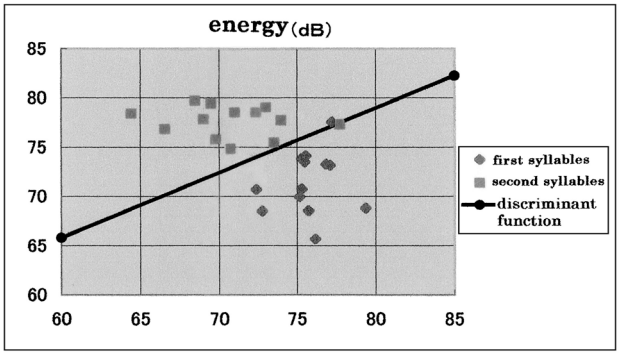

Figure 2-3. A scatter diagram showing the discriminant function of energy (dB).

3. Conclusion

The experiments and statistical analyses reported in this paper represent an attempt to explore the three concomitant factors of stress: duration, pitch and energy. As Tables 1-2 and 2-2 as well as Figures 1-1～3 and 2-1～3 show, pitch is the most important factor, energy is the second, and duration the third. The t-test[3] based on Table 1-1 also confirms what Table 1-2 indicates. And the t-test[4] based on Table 2-1 also confirms what Table 2-2 indicates. Roach (1996: 85) notes, "The strongest effect is produced by pitch, and length is also a powerful factor. Loudness and quality have much less effect." He seems to look at the matter from the perceptual point of view. But perhaps there may be room for difference of opinion about duration and intensity even from the productive point of view. In other words, it would be necessary to look at more date to clarify this point.

Notes

1. I am deeply grateful to Dr. Ikuo Sugiman for his generous help and advice in analyzing the data statistically.
2. Values of the correlation coefficient are always between－1 and＋1. A correlation coefficient of＋1 indicates that two variables are perfectly related in a positive linear sense, a correlation coefficient of －1 indicates that two variables are perfectly related in a negative linear sense, and a correlation coefficient of 0 indicates that there is no linear relationship between the two variables.

3.

duration		pitch		energy	
1st syllable	2nd syllable	1st syllable	2nd syllable	1st syllable	2nd syllable
−0.07848	−3.38209	10.9836	−5.19881	1.325551	−6.94679

4.

duration		pitch		energy	
1st syllable	2nd syllable	1st syllable	2nd syllable	1st syllable	2nd syllable
6.183326	−2.3569	12.02079	−11.5396	6.578543	−8.11696

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