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TENSE AND LAX VOWELS PAIRS: A PROBLEM REVISITED

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Introduction

Phoneticians and phonologists alike agree that there exist, in English, three pairs of vowels which are close to each other in the vowel space, but differ from each other in some other feature or features. There is, however, disagreement as to what these features might be, whether muscle tension (Chomsky and Halle, 1968; Bloch & Trager, 1942), diphthongization, vowel-height or simple duration (Peterson & Lehiste 1960), and as to whether one quality might be a reflex of others. For example, if one vowel of a pair were characterized by greater displacement from some neutral vowel tract position, caused by greater muscle tension, biomechanical effects might suggest that the vowel might be longer.

Phonetic studies agree in finding "tense" vowels longer than "lax" ones over a wide variety of contexts, in several languages (e.g. Peterson and Lehiste, 1960; Koopmans-van Beinum, 1980). However, the evidence on more literal interpretations of tension is mixed. At least with respect to tongue musculature tension in American English vowels, Raphael and Bell-Berti (1975) have shown that "Although some muscles revealed a consistent difference, most did not. Even for those muscles where a tense-lax difference was found, the data do not support the notion that tension was a necessary or sufficient differentia of production" (op cit p.61).

Even with respect to duration, although the interpretation of duration has been with respect to the upper vocal tract, almost all studies have made measures, using one or another criterion, of acoustic vocal fold fibration duration, sometimes with flanking consonant aspiration included. Thus, if /i/, for example, is concluded to be longer than /ɪ/, the measure of the duration difference does not reflect the behavior of the upper vocal tract directly.

Indeed, it is not immediately clear what aspect of the behavior of the upper vocal tract corresponds to the duration of vocal fold vibration. Certain limited aspects of this problem, especially voice-onset time, have been studied extensively. However, it is well known that movements of the articulators overlap in time in a little studied fashion, and we do not fully understand the relationship of upper vocal tract and larynx.

A specific proposal about the characteristics of the overlap between consonant- and vowel-associated aspects of articulation was made some time ago by Ohman (1966). He proposed that the

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localized movements of the tract associated with consonants were superimposed on the more global longer duration aspects of tract movement associated with vowels. Fowler (1981) has made this suggestion more specific by proposing a relationship between coarticulation and compensatory shortening. Briefly, she suggests that compensatory syllable shortening occurs when multiple consonants are added to the coda of a syllable because the increased number of consonants "cover up" an increasing part of the total syllable duration. When applied to /əpVp/ syllables with long or short vowels, perhaps the relationship of lip articulation, associated with consonants, is different for "long" and "short" vowels.

We attempted to answer this question by examining some data collected by Dr. Peter Alfonso and Dr. Thomas Baer at the x-ray microbeam facility at the Research Institute of Logopedics and Phoniatrics.

Method

A single subject, a native speaker of American English produced nonsense utterances of the form əCVC in sets of five tokens, each with a different vowel and the same initial and final consonant. While the complete corpus included 11 vowels and /p/, /t/ and /k/ in initial and final position, we will consider only that small subset of utterances in which the initial and final consonant was /p/, and the vowel was one of the six vowels traditionally described as forming tense and lax pairs: /i-ɪ/, /æ-ɛ/, and /u-ʊ/.

Small lead pellets were placed on the nasion, the mandibular incisors, the lower lip, and the tongue blade and rear. The pellet positions were tracked in x and y dimensions by a computer-controlled microbeam (Kiritani, Ito & Fujimura, 1975). The output of the system is a set of pellet trajectories in x and y dimensions.

A sample trajectory, as analyzed at Haskins Laboratories, is shown as Figure 1. The sample shows the movement of the rear pellet y dimension as a function of time. An automated program for laying labelled points (ACE) was used to mark the onset, extreme displacement, and offset points for the vowel trajectories, and the closure peaks and maximum open position for lip and jaw. The point of consonant release and vowel offset were marked on the acoustic waveform.

Results

The results of this procedure are shown in Table 1. The duration of the period from consonant release to vowel offset is shown in the right-most column. We see the expected durational difference between tense and lax vowels, although the difference is quite small, probably because the speaker was speaking

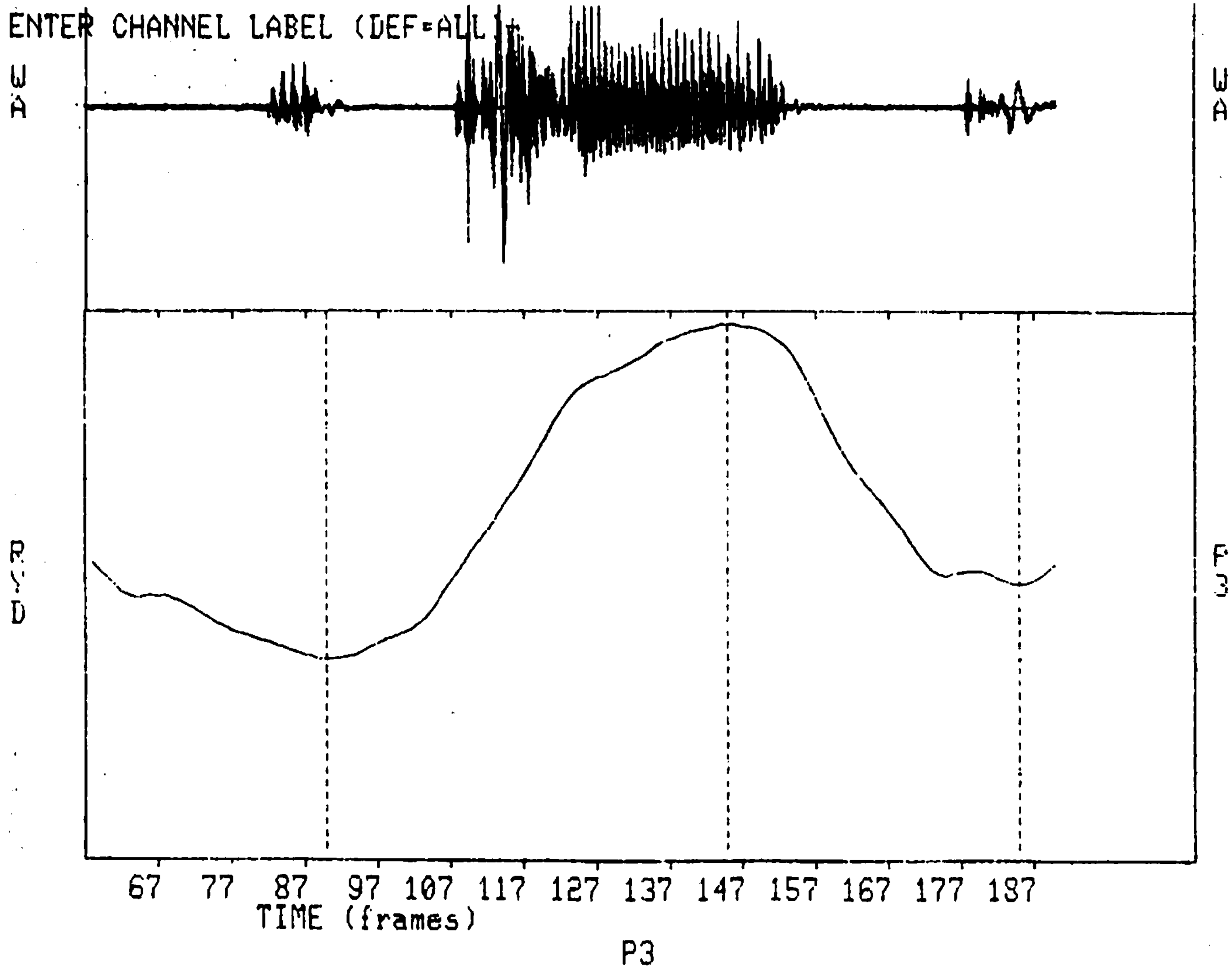

Fig. 1. Tongue pellet trajectory, y axis, vowel /i/

Table 1

Mean Duration of Trajectory Events Relative to
/p/ Burst Release. (Measures in Frames. 1 Frame = 5.72 msec)

	L	J	FX	RX	FY	RY	Vowel Voice Offset
			ONSET				
i	-11	-12	-42	-40	-35	-22	
ɪ	-10	-12	-35	-32	-33	-19	
æ	-11	-14	- 7	- 5	-10	-14	
ɛ	-12	-13	- 7	- 5	- 9	-22	
u	-10	-11	-18	-14	-24	-12	
ʊ	-10	-12	-21	-20	-21	-15	
			EXTREME VALUE				
i	20	14	32	39	33	31	
ɪ	20	10	3	2	2	19	
æ	32	18	37	30	33	20	
ɛ	23	16	32	34	32	14	
u	16	2	23	28	2	36	
ʊ	11	10	16	28	8	25	
			OFFSET				
i	53	51	73	82	69	73	
ɪ	52	51	43	36	33	48	
æ	65	64	65	71	66	47	
ɛ	55	55	58	57	56	45	
u	57	48	63	58	44	75	
ʊ	52	49	53	59	55	60	
			SUM				
i	84	77	147	161	137	126	44
ɪ	82	73	81	70	68	86	41
æ	108	96	109	106	109	81	55
ɛ	90	84	97	96	97	81	46
u	83	61	104	100	136	123	44
ʊ	73	71	90	107	105	100	42

rapidly.

In general, the duration of peak-to-peak lip closure is about twice the duration of the acoustic vowel -- that is, there is an indication of position shift relative to acoustic duration.

The measures of vowel activity show much longer trajectories than the acoustic duration of the vowel -- in some cases, three times as long. In almost all cases, the difference between tense and lax members of the pair is, if anything, exaggerated relative to the acoustic duration ratio. The exceptions for the summed durations are in the JAW /æ-ɛ/ comparison, and the /u-ʊ/ comparisons for two pellets. Two possible reasons for the reversals suggest themselves. The first is that these trajectories are of low amplitude relative to pellet trajectory noise in this recording. The second is that due to tracking errors, while all other duration measures include five to eight measures, there are only two /ʊ/ samples, due to the elimination of tokens because of mistracking.

When we look at the subsegments relative to the burst release, the pattern is somewhat different for lip y (LY) and Jaw pellets and Tongue pellets. There is no evidence for a tense-lax difference between pairs before release, nor would we not expect one on the basis of acoustic measures. For tongue movements, there is somewhat more likely to be a tense-lax difference.

Thus, overall, this data corpus does not support the hypothesis of radical phase restructuring between tense and lax vowel pairs. However, experience with the measurement techniques suggest that trajectory fitting and averaging may be a better technique for teasing out small differences between vowel types than the token-by-token event marking procedure used here. We intend to try such a procedure in further analysis.

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References

1) Block, B., and G.L. Trager: Outline of linguistic analysis: Spec. Pub. L.S.A., Waverly Press, 1942.
2) Chomsky, N., and M. Halle: The sound patterns of English: New York, Harper & Row, 1968.
3) Fowler, C.A.: A relationship between coarticulation and compensatory shortening. Phonetica, 38, 35-50, 1981.
4) Kiritani, S., Ito, K., and O. Fujimura: Tongue-pellet

tracking by a computer controlled microbeam. J. Acoust. Soc. Am., 57, 1516-20, 1975.
5) Koopmans-van Beinum, F.J.: Vowel contrast reduction: Acad. Pers. B.V., Amsterdam, 1980.
6) Ohman, S.E.G.: Numerical model of coarticulation. J. Acous. Soc. Am., 41, 310-320, 1966.
7) Peterson, G.E., and J. Lehiste: Duration of syllable nuclei in English. J. Acoust. Soc. Am., 32, 693-705, 1960.
8) Raphael, L.J., and F. Bell-Berti: Tongue musculature and the feature of tension in English vowels. Phonetica, 32, 61-73, 1975.