An Electromyographic Investigation of the Tense-Lax Feature in Some English Vowels

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INTRODUCTION

Traditional phonetic literature presents us with a picture of vowel articulation often referred to as the vowel triangle or quadrilateral. In part, this vowel triangle appears as follows for English vowels:

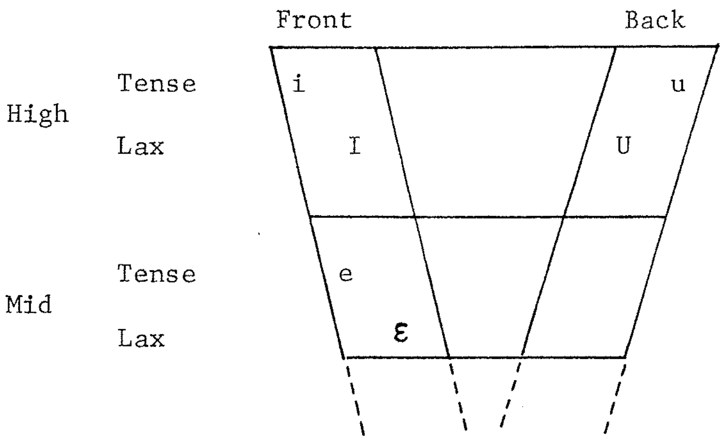

Fig. 1: A Portion of the Vowel Triangle for English Vowels

The two pairs of high vowels and the pair of mid vowels are said to enter into a tense-lax relationship in which the higher member of each pair is articulated with greater muscular effort than the lower member. The difference in height in such a view is often interpreted as a reflection of the difference in tongue tension.[1]

It has been suggested (Perkell, 1969) that the differences in muscular tension between the members of a tense-lax pair of vowels are attributable to the actions of the extrinsic muscles which position the tongue in the oral cavity. The experiment described below was designed to test the traditional

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[1] Other features or combinations of features have been put forth as distinctive in the opposition of these pairs of vowels. Thus they are variously described as long-short (with regard to duration), diphthong-monophthong, close-open (with regard to jaw opening), high-low (independent of the tenseness feature), and free-checked (with regard to their occurrence in English words, without direct reference to their articulation).

tense-lax hypothesis vis-à-vis the vowel triangle, principally in terms of the action of the genioglossus, one of the major extrinsic tongue muscles, to front and bunch the tongue.

PROCEDURE

The corpus of test utterances consisted of the six vowels shown in Figure 1.[2] The vowels were produced in a /əCVC/ context. The initial consonant was /p/ and the final consonants were variously /p,b,t,d,k,g,s,z/. Each vowel was paired with each of the final consonants, yielding a total of forty-eight utterance types. In addition, a small set of twelve utterances was produced, consisting of /ə/, followed by /t/, followed by each of the six vowels, followed by either /p/ or /b/. Thus a total of sixty utterance types was produced in the experiment. The utterances were grouped into two lists of thirty each. Each of the two groups was randomized in several ways. Fifteen tokens of each utterance type were analyzed. The activity of the genioglossus (and of the other muscles considered here) was inferred from the EMG signal transmitted by hooked-wire electrodes inserted into the muscle by means of a hypodermic needle. The insertions are described by Hirose (1971) and the data processing by Port (1971).

RESULTS AND DISCUSSION

The data derived from the action of the genioglossus clearly reflect a tense-lax difference along the traditional lines mentioned above. The differences are most clearly observable in the /əpVp/ and /əpVb/ syllables, since in these cases neither the initial nor the final consonant involves genioglossus activity (Figures 2-4). (The zero point in these figures refers to the onset of voicing of the stressed vowel.)

The data do not, however, arrange the vowels in a manner congruent with a picture of the traditional vowel triangle. A comparison of the peak values of genioglossus activity (Table I) reveals that the front vowels are resolved into two groups: /i-e/ and /I-ɛ/. To whatever extent the genioglossus activity does reflect tongue height, it would appear that the data present a picture in which the vowels are arranged in the following order:

i
e
I
ɛ,

although the differences between /i-e/ and between /I-ɛ/ are often small and occasionally in a direction opposite to that suggested by the ordering given above. In any event, /I/ and /e/ are clearly transposed from their usual positions in the vowel triangle.

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[2] These vowels were chosen because they are the ones most generally agreed upon as being paired. Although the literature contains claims that various other pairs exist, almost all writers posit those pairs which are investigated here.

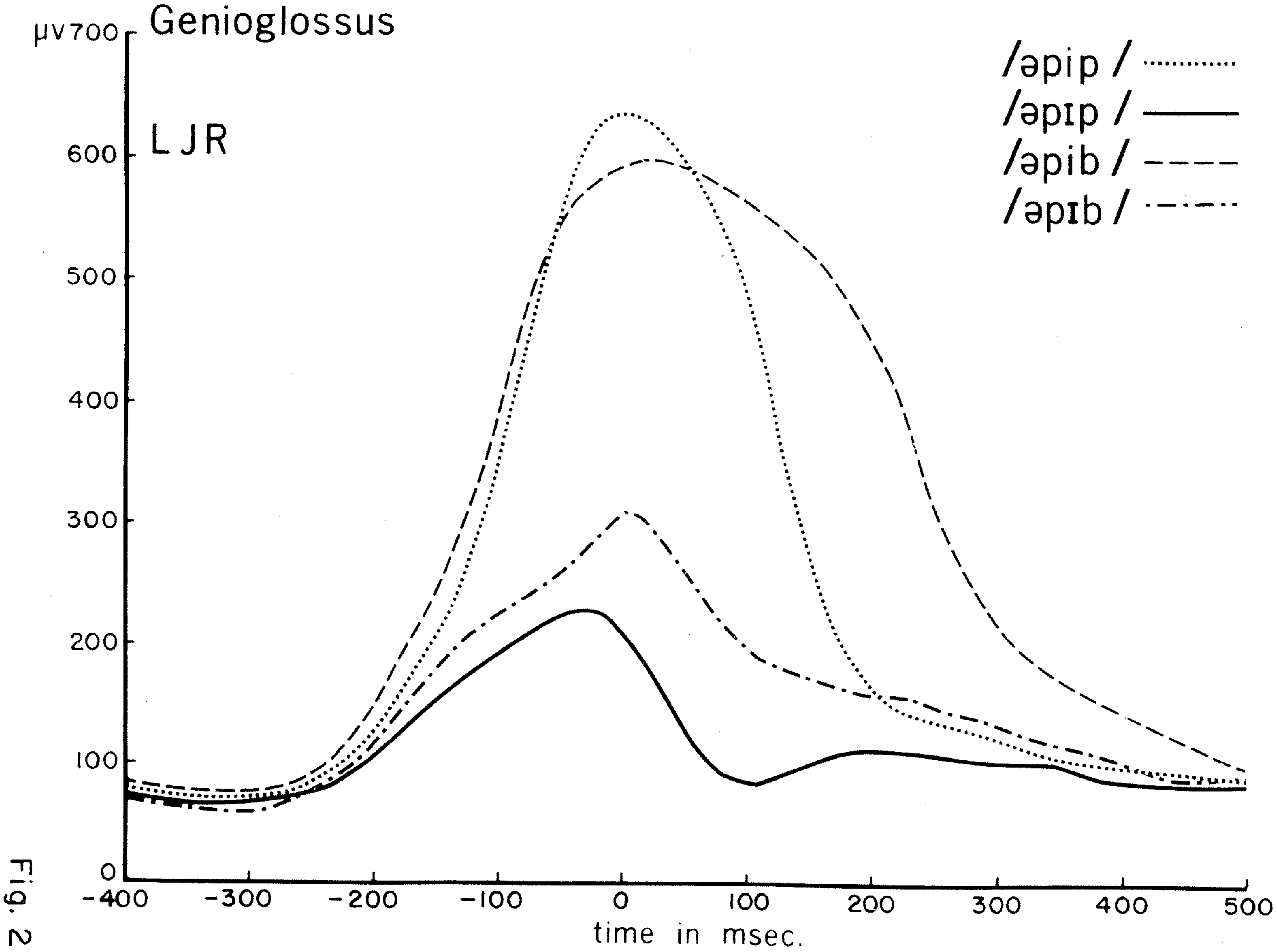
Genioglossus
LJR
µv
700
600
500
400
300
200
100
0
-400
-300
-200
-100
0
100
200
300
400
500
time in msec.
/əpip/
/əpɪp/
/əpib/
/əpɪb/

Fig. 2

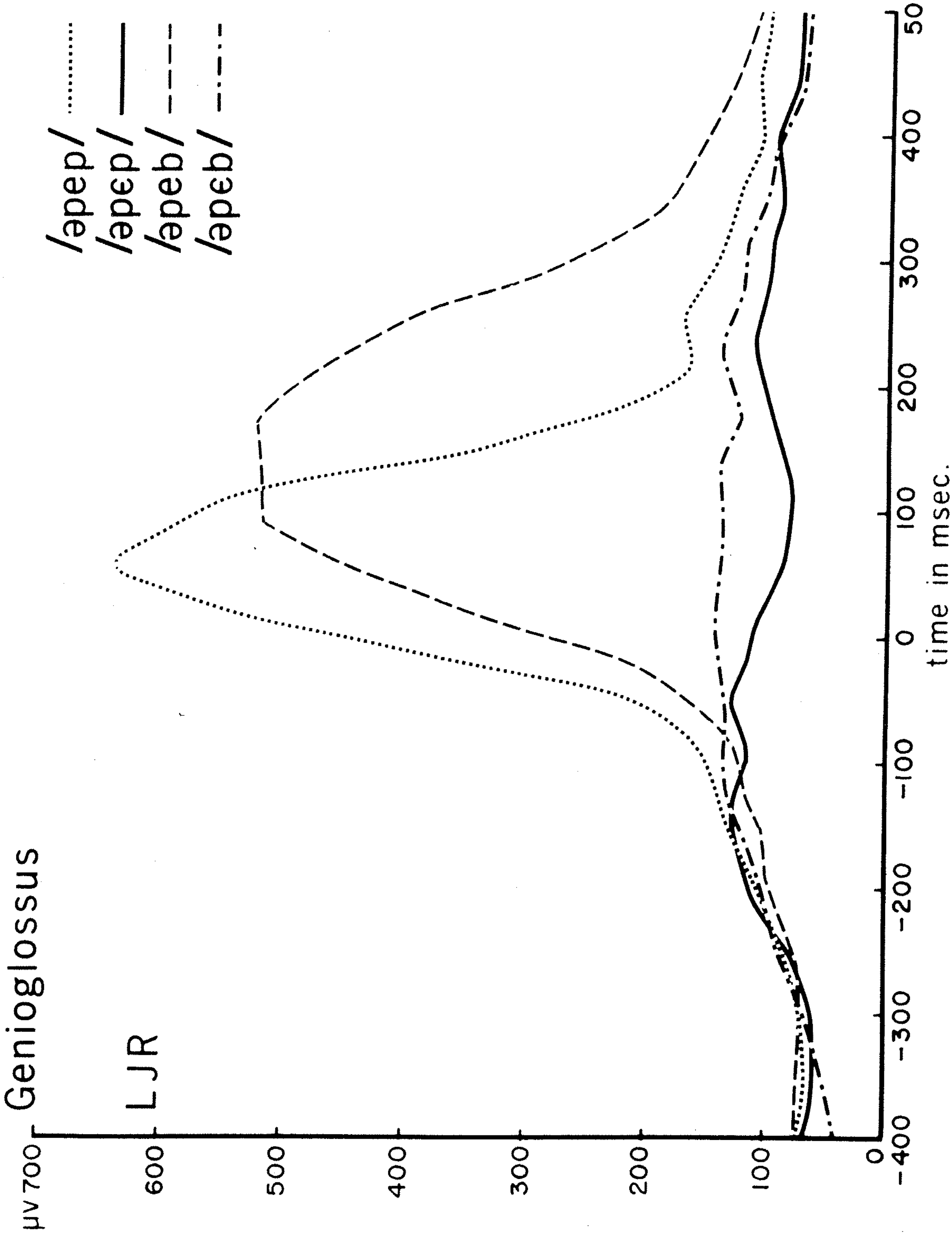
Genioglossus
LJR
μv 700
600
500
400
300
200
100
0
−400
−300
−200
−100
0
100
200
300
400
500
time in msec.
/əpep/
/əpɛp/
/əpeb/
/əpɛb/

Fig. 3

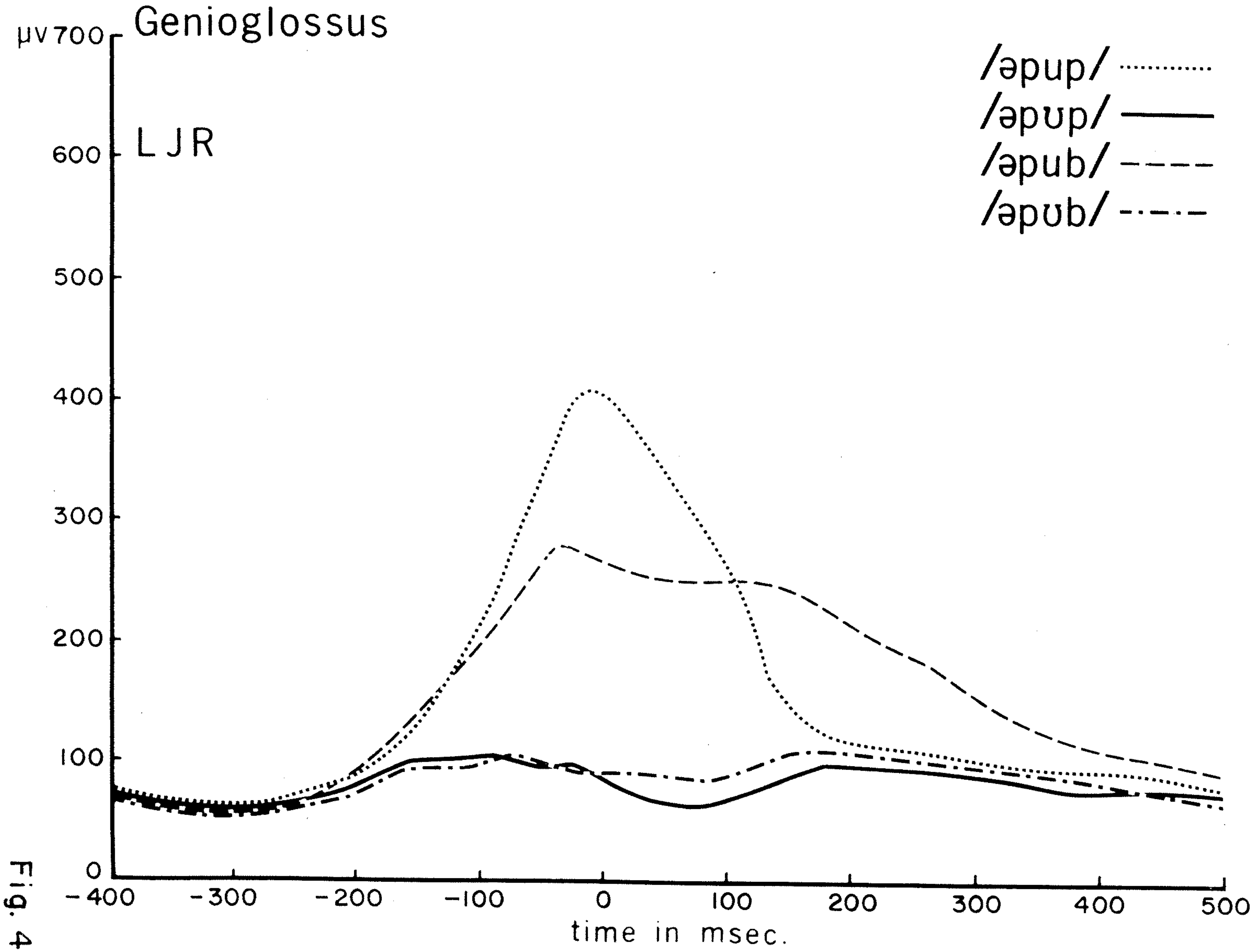
Genioglossus
LJR
µV 700
600
500
400
300
200
100
0
-400
-300
-200
-100
0
100
200
300
400
500
time in msec.
/əpup/
/əpʊp/
/əpub/
/əpʊb/

Fig. 4

TABLE I

PEAK VALUES IN MICROVOLTS OF THE EMG SIGNAL FROM THE GENIOGLOSSUS DURING VOWEL ARTICULATION

VOWEL	CONSONANT CONTEXT									
	p-p	p-b	p-t	p-d	p-k	p-g	p-s	p-z	t-p	t-b
i	653	606	702	644	694	625	532	537	582	579
I	236	319	316	360	268	494	223	294	271	243
e	643	533	710*	538*	643	571	530	500	562	447
ɛ	140	154	179*	331*	206	481	172	195	108	153
u	410	289	433	342	302	257	325	246	380	302
U	112	110	143	251	60	100	118	148	68	85

*These four figures are typical of an effect found generally throughout the data: the tense vowels show a decrease of activity from a following voiceless to a following voiced context; the lax vowels show an increase in activity in the same context. As yet, this effect awaits explanation in the light of further analysis of the data and of additional data from other subjects.

There are at least two possible explanations for this result. The first is based on the assumption that the genioglossus data do not present a complete picture of tongue height. Rather, tongue height is most likely the result of the combination of two factors: (1) tongue bunching, accounted for largely by the activity of the genioglossus,[3] and (2) jaw opening (Lindblom and Sundberg, 1969). That is, a given tongue height, measured from the palate to the high point of the tongue can be attained in more than one way: e.g., wide jaw opening with extreme tongue bunching or narrow jaw opening with minimal tongue bunching. If, in fact, /I/ is a high vowel to be paired with /i/, and if it is higher than /e/, we could expect to find less jaw opening for /I/ than for /e/ to compensate at least partially for the greater tongue bunching of the latter vowel.

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[3] That is, in this experiment, since the superior longitudinal is generally recognized as playing a prominent role in this function (MacNeilage and deClerk, 1969).

Among the muscles investigated in this experiment was the sternohyoid, which is described as a muscle accompanying jaw opening (Ohala and Hirose, 1970). The data for the activity of the sternohyoid do consistently reveal a greater jaw opening for /e/ (and /ɛ/) than for /I/ (and /i/) (Table II). In fact, the data for these front vowels generally (but not with complete consistency) show just what the traditional vowel triangle would lead us to expect: increasing values for the series /i,I,e,ɛ/, which we take here to mean increased jaw opening for the vowels as they descend from high to low. Figures 5 and 6 display the data for the labial bounded syllables. The relevant portions of the displays are found between the vertical lines.

TABLE II

PEAK VALUES IN MICROVOLTS OF THE EMG SIGNAL
FROM THE STERNOHYOID DURING
VOWEL ARTICULATION

VOWEL	CONSONANT CONTEXT*							
	p-p	p-b	p-t	p-d	p-k	p-g	p-s	p-z
i	41	44	35	55	62	67	62	52
I	43	53	45	48	58	56	58	57
e	82	74	55	68	96	89	72	96
ɛ	99	91	76	75	113	119	106	105

*Because of the involvement of the sternohyoid in the articulation of /t/, no separate peaks of activity are discernible for the vowels in the /t-p/ and /t-b/ contexts. Thus, they have been omitted from the table.

The second possible explanation for the transposition of /I/ and /e/ in the usual height ordering involves the matter of tongue backing. The vowel triangle (Figure 1) shows both /I/ and ɛ/ to be retracted from the more extreme front positions of /i/ and /e/. Since the genioglossus displays greater activity the more fronted the tongue is (Hirano and Smith, 1967; also compare the values for /i-e/ vs. those for /u-U/ in Table I above), one would naturally expect lower values for the activity of this muscle for /I/ (and /ɛ/) if, in fact, these vowels are less fronted than are /i/ and /e/.

A muscle tapped in this experiment which is taken to be an indicator of tongue backing is the superior constrictor. The data from this muscle do often reveal a greater degree of tongue retraction for /I/ and /ɛ/ as

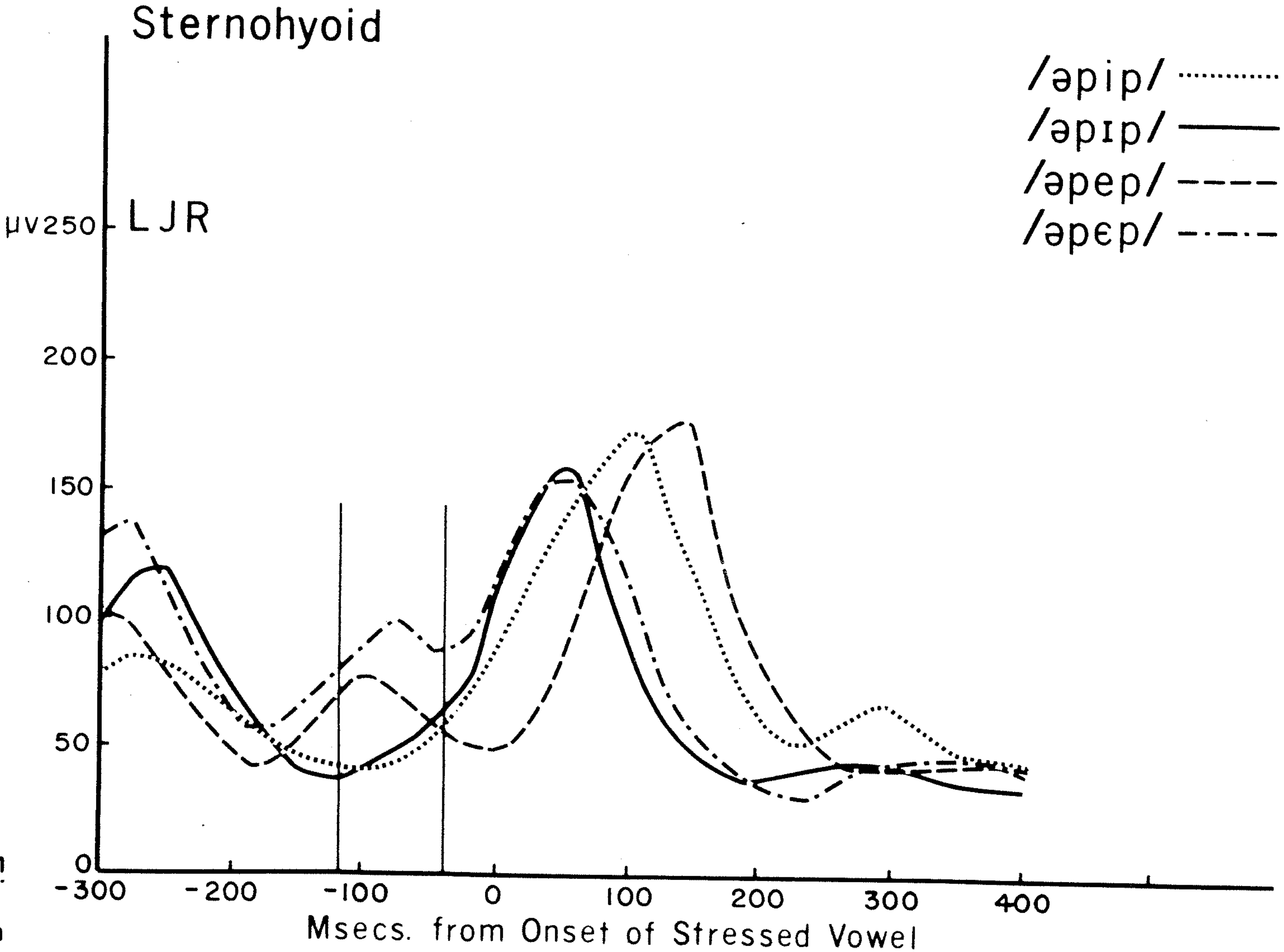
Sternohyoid
LJR
μv250
200
150
100
50
0
-300
-200
-100
0
100
200
300
400
Msecs. from Onset of Stressed Vowel
/əpip/ ⋯⋯
/əpɪp/ ——
/əpep/ – – –
/əpɛp/ –·–·–

Fig. 5

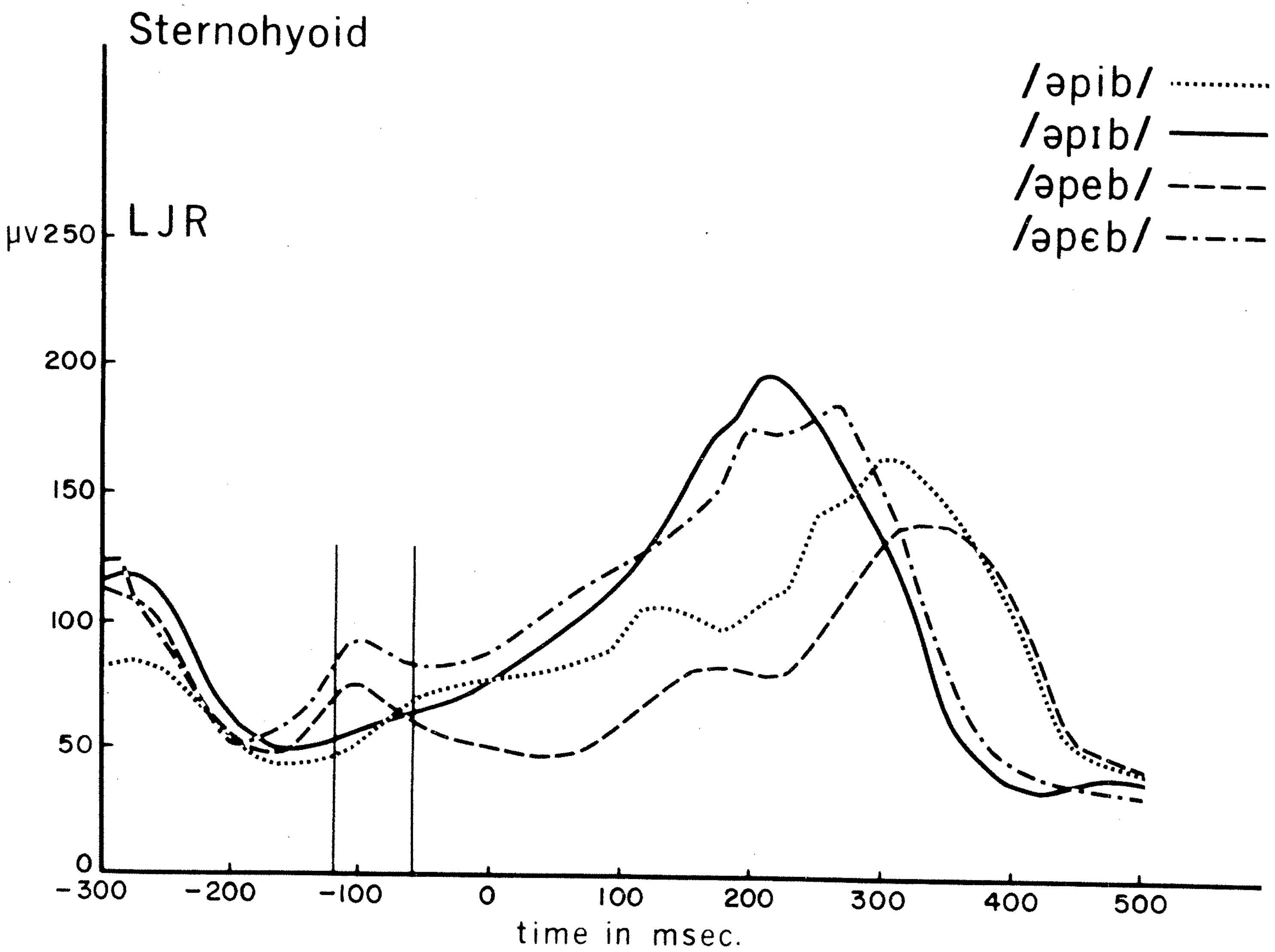
Sternohyoid
LJR
/əpib/ ··········
/əpɪb/ ———
/əpeb/ – – – –
/əpɛb/ –·–·–
μv 250
200
150
100
50
0
-300
-200
-100
0
100
200
300
400
500
time in msec.

Fig. 6

opposed to /i/ and /e/, but the results are not consistent, differences occasionally being small and/or in the unhypothesized direction.

CONCLUSION

The possibilities discussed above, then, reduce but do not eliminate the discrepancy between the usual height ordering of the front vowels and their grouping into tense-lax pairs on the one hand and the data from the experiment for the genioglossus on the other. Although the data do not allow for a strong reaffirmation of the traditional view of the vowel triangle along tense-lax and high-low lines simultaneously, there is some reason to believe that with the addition of more data from other muscles and other subjects, and perhaps with the consideration of other factors besides jaw opening and tongue fronting vs. backing, the traditional picture of vowel articulation may be confirmed.

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