

**EXPERIMENTAL PHONETICS IN  
PHONOLOGY : VOWEL DURATION IN THAI**

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Up to a few years ago, experimental phoneticians, even those whose disciplinary base was linguistics, were not well received by linguists. The effort to unravel the mechanisms used in the production and perception of speech seemed to have little to offer the linguist writing the description of a language. Even for the phonological part of the grammar, he was sure that he could depend upon his training in auditory and articulatory phonetics to determine what phonetic features enabled speakers of the language under analysis to differentiate utterances. Many were probably influenced by Leonard Bloomfield (1933 : 127-28), who seemed to feel that this was the proper approach until such time as we had a full and trustworthy scientific description of speech from the laboratory of the future.

The reluctance of the linguist to embrace the methods and findings of the laboratory phonetician may have stem-

1) This article was written while the author was on sabbatical leave in Thailand as a Fellow of the American Council of Learned Societies and the Ford Foundation Southeast Asia Fellowship Program, July 1973-July 1974.

med in part from the fact that for some decades most experimentalists were drawn from the fields of acoustics, communications engineering, physiology, psychology and speech pathology. Members of these disciplines were usually not well grounded in principles of linguistic theory and seldom went out of their way to make it clear to the linguist that they had something of relevance to offer. The linguist, for his part, was guilty, perhaps, of failing to see that the study of linguistic phenomena was not exclusively his concern. The typical linguist apparently did not understand that even while playing a central role in coming to grips with the nature of language, he was going to have to depend upon interdisciplinary cooperation for discoveries that would hasten him on the road toward full enlightenment. Such an interdisciplinary group came into being at the Haskins Laboratories in the early 1950's, but its pioneering work found a home in the pages of the *Journal of the Acoustical Society of America* (e.g., Cooper 1950, Cooper et al. 1952) and some of the psychological journals rather than in organs aimed at a linguistic readership. In the late fifties and early sixties, at least in the United States of America, the few of us with credentials in linguistics who made so bold as to take experimental phonetics seriously, found a good forum for the presentation of oral papers on our research not at meetings of the Linguistic Society of America but at meetings of the Acoustical Society of America and, thanks to the zeal of the late Pierre Delattre, the Modern Language Association

of America. During that era, it must be said, phoneticians with strong linguistic interests were welcome to present oral reports for discussion at the meetings of the International Congress of Phonetic Sciences, if they were prepared to travel to one country or another every three or four years. Also, certain Continental and British journals dedicated to studies of speech and linguistic communication<sup>2</sup> were very receptive to linguistically oriented articles on phonetics at a time when most journals of general linguistics were not.

Happily, during those years, the notion that experimental phonetics had a role to play in linguistics received occasional encouragement. As an example, let me bring to mind how the advent of the sound spectrograph during World War II (Koenig et al. 1946) and its early use by an American linguist, Martin Joos, led to the publication of *Acoustic Phonetics* (Joos 1948), a monograph which stimulated much of the thinking about speech acoustics and its relation to language structure among the few linguists of the immediately following decade who immersed themselves in experimental phonetic research. Today there can be no question but that linguists are much more reluctant to ignore the data and inferences of the experimentalist even though, as D.B. Fry (In press) has so effectively stated, there has been in this century a series of wide swings

2) E.g., *Language and Speech*, *Phonetica*, and *Zeitschrift für Phonetik, Sprachwissenschaft, und Kommunikationsforschung*.

between theory and observation in linguistics. Meetings of the Linguistic Society of America now frequently have a noticeable number of experimental papers on the program. More and more departments of linguistics see fit to give their students basic training in the physiology, acoustics and perception of speech.

What, then, does the experimental phonetician have to offer to linguistics? On the most basic level, he can supply phonetic data to the phonologist. That is, before the phonologist posits a particular set of features as distinctive, let him be aware of the complex of intersecting phonetic features actually involved in the production of a given expression. This alone will prevent so much of the phonetic vagueness and even naivete that one often finds in descriptions of languages. At a higher level, the experimental phonetician stands ready to test hypotheses as to the communicative relevance of distinctive features that have been posited. Surely the disinterested objectivity of the laboratory is to be encouraged in a discipline that likes to think of itself as a science. Indeed, there are welcome signs that in the hands of the psycholinguists this approach is beginning to be applied in the realms of syntax (Greenbaum & Quirk 1970) and semantics (Goldman-Eisler 1968).

#### Phonological hypotheses

The extent to which the linguist is willing to submit his phonological statements to experimental validation

varies considerably according to his era, school of thought and individual temperament. In arguing that the initial affricate of an English word like *choke* represented one phoneme or a sequence of two, the structuralist of the forties may have been considering his own analytic convenience or the symmetry of his description. In positing *serēn* as the underlying form of *serene* and *serenity*, the generative phonologist of today claims that he can thus most easily and elegantly write the rules that will yield the correct variants of this word for different syntactic contexts. Once, however, the phonologist offers hypotheses as to links between aspects of the sound pattern he proposes and psychological, physiological and acoustical phenomena of the production and perception of speech, he should behave in accord with normal scientific practice. That is, he should draw upon available phonetic data to form his hypotheses and be sure that they are vulnerable to experimental testing. If, for example, a feature of tensivity is advanced, let its proponents state clearly what it is that is supposed to be tense relative to what so that the experimentalist can insert electrodes or do whatever else is feasible to assess the reasonableness of the claim (Lisker & Abramson 1971).

In arguing that the linguist's statements should be testable, L. Lisker and his co-authors say (Lisker et al. 1962: 87):

Although the analytic processes which intervene between phonetic extraction and phoneme crystallization may obscure, or even eliminate, the basis for any "straightforward" physical definition of the phonemes, it is nevertheless true that the phonological description of a language must enable one to recover the phonetic specification of an utterance from its phonemic representation. It seems reasonable, moreover, to suggest that the phonetic specification of an utterance must somehow be convertible to an audible signal which can be presented to an informant for identification. In other words, one may regard the symbols of a phonemic transcription as representing a sequence of instructions which should lead more or less directly to a token of the utterance type symbolized.

The authors of this important article then go on to explain how speech synthesizers can be used in a far more flexible way than human informants to "permit the manipulation of acoustic signals subject to very precise control, and in ways that make it possible to determine just what acoustic features contribute most to the identifiability of a signal as some particular utterance of the language" (Lisker et al. 1962 : 90). A detailed extension of this argument, in the light of recent developments in the effort to synthesize speech by rule, is available in a new article on the subject by I.G. Mattingly (In press).

#### Vowel length in Thai

As an example of an experimental approach to an aspect of phonological analysis, let us consider the topic of distinctive vowel length in Central Thai (Siamese). It

is now commonplace for linguists and language teachers to transcribe such Thai words as มักร 'card' and มกบ 'monk's alms bowl,' /bàt/ and /baàt/ respectively. What does a transcription like /aa/ mean? Taken literally, it would seem to mean a sequence of two occurrences of the vowel /a/ (Gedney 1947 : 11-13, Noss 1964 : 14) analogous to such other ostensible sequences as /ia/. At the same time, it is generally observed that the geminate vowels are somewhat longer than their single counterparts in a given context, thus suggesting that vowel length is a distinctive feature in Thai. A. Haudricourt (1948 : 200-1) posits "short" and "long" vowels. In his earlier work R.B. Noss (1954 : 1.2.1) extracts a feature of "weak voicing" for short vowels, and Foongfuang Kruatrachue (1960 : 33), a "phoneme of reduction of length". All the foregoing solutions appear to regard relative vowel length as distinctive, as does traditional Thai grammar; the choice of one of them probably depends much of the time on the linguist's taste, his theoretical bent or even typographical convenience. To the extent, however, that any one of these proposals is meant to reflect something in the behavior of the speaker (Lieberman et al. 1967), it should be possible to demonstrate the communicative relevance of the feature in question. The linguistic interpretation of quantity presents certain difficulties (Lehiste 1970 : 43-51). For example, the experimental phonetician, interested in models of the production and perception of speech, would want to know whether an interpretation of long vowels as geminates merely reflects the analytic convenience of the linguist who sees distributional parallels with the vowel

“clusters” /iä ia ua/ or is in fact an assertion to the effect that speakers are programmed neuro-muscularly to rearticulate short vowels to form sequences. After all, the existence of the vocalic clusters proves nothing; one could view them, as Haudricourt (1948) seems to do, as mono-phonematic vowels of changing quality.

Another class of interpretations sees the matter rather differently. Observers often point out certain qualitative differences between the members of the short-long pairs (Noss 1964: 15-17). Might it not be the case then that at least for part of the vowel system, as appears to be the situation in Southern Swedish (Hadding-Koch & Abramson 1964), length is less important than other features? G.L. Trager (1957: 25) thinks that the “long” vowels of Thai are indeed sequences but not geminates; for him they are sequences of vowel + /j w/ or /h/. In this view, it should be something in the quality of the final portion of the syllabic vowel that is relevant rather than length as such. The late M. Durand (1946: 185) throws into question the primacy of relative physical duration as the feature which distinguishes vowels heard as “short” from those that are heard as “long” in any language. She maintains that the auditory impression of length results from the persistence of a physiological response that is caused by such vocalic attributes as fortisness, intensity, pitch change, linkage with the following consonant, quality *and* duration. Duration as such, in her view, has little if any bearing on the “length” distinction. Among the various studies cited by Durand is an early instrumental examination of vowel duration in Thai (Sibunruang 1940).

### An experimental approach to vowel duration in Thai

Some years ago (Abramson 1962: Chap. II) observations and speculations like the foregoing led me to test the hypothesis that a sufficient basis for the phonemic distinction between “short” and “long” or “single” and “geminate” vowels in Thai is vowel duration. It may be worthwhile to summarize this research as an example in support of the argument presented in this article concerning the role of experimental phonetics in phonology, even though there recently appeared a brief study on the same topic (Sittachit 1972) which, regrettably, failed to build on more extensive previous work still available in the literature. My approach was twofold: (1) to determine, through measuring a representative sampling of vowels, whether duration is a sufficient criterion for distinguishing the two sets, and (2) to establish, if the first investigation had a positive outcome, whether duration is a sufficient auditory cue to the phonemic distinction. The reader interested in the handling of the various procedural and technical complications and full data displays is referred to the 1962 monograph. Native speakers of Central Thai, all university graduates, were used for this study.

Two male informants, W.N. and E.N., recorded the nine long vowels on all five tones, and the short vowels on the high and low tones, following the distributional norms of the language for vowels in final position. The short vowels ended, for the most part, in a glottal stop, as is to be expected in Thai. Wideband spectrograms were made of all the utterances, and vowel beginnings and endings were found by looking for prominent energy in at

least one of the first three formants. Durations were specified to the nearest five milliseconds as a reasonable estimate of attainable accuracy. The results are outlined in Table 1 (Abramson 1962: 81-5).

Table 1

## Vowels in Isolation

Speakers :	W.N.		E.N.	
	v	vv	v	vv
Number :	27	45	18	45
Averages in msec :	140	475	160	380
Ranges in msec :	80-200	385-560	130-240	320-480
VV/V ratio :	3.39		2.38	

It would seem, then, that long vowels in isolation are likely to be from two to three times as long as short vowels; furthermore, for each speaker the ranges are quite discrete. It could be objected, of course, that isolated monosyllables provide a rather artificial speech form; nevertheless, if duration were merely a subsidiary redundant feature and not an important feature for the distinction, we might not expect to find such a clear difference in duration itself.

As a step away from citation forms toward running speech, a substitution frame was composed which could serve as a carrier sentence for any minimal pair of Thai words. The frame was /phôm phuút kham wâa \_\_\_\_ háj khun fan/ 'I'm saying the word \_\_\_\_ for you to listen to.' Fourteen pairs of words minimally distinguished by vowel length were recorded in the carrier sentence by E.N. They included six of the vowel phonemes and all five tones; minimal pairs could not readily be found for the other four vowels. The words used are listed with glosses in Table 2.

Table 2

## Minimal Pairs in a Carrier Sentence

Word	Gloss
/hàt/	'to practice'
/hàat/	'beach'
/bàt/	'card'
/bàat/	'Baht (unit of currency)'
/cip/	'to sip'
/ciip/	'to fold'
/khùt/	'to dig'
/khùut/	'to rub off'
/baŋ/	'to hide'
/baaŋ/	'some'
/òt/	'to abstain'
/òot/	'to lament'
/than/	'on time'
/thaan/	'alms'
/hèt/	'mushroom'
/hèet/	'reason'
/phæ/	'goat'
/phææ/	'to be defeated'
/phrá/	'priest'
/phráa/	'jungle knife'
/khán/	'to press'
/kháan/	'to hinder'
/khâm/	'dusk'
/khâam/	'to cross'
/sŷn/	'wealth'
/siin/	'precept'
/khǎj/	'to wind'
/khǎaj/	'to sell'

Measurements were made from wide-band spectrograms and are summarized in Table 3 (Abramson 1962: 89-93).

Table 3

**Durations of Vowels in Minimal Pairs in a Carrier Sentence**

	Speaker: E.N.	
	V	VV
Number:	14	14
Averages in msec:	87	215
Ranges in msec:	60-150	160-330
VV/V ratio:	2.5	

Although the two ranges nearly abut, they are distinct. Interestingly enough, E.N.'s ratio of long to short vowels here is not less than for his citation forms of vowels in isolation.

Finally, a sampling of vowels was chosen at random from about half an hour of unrehearsed narration recorded by E.N. This consisted of personal anecdotes, folktales and glimpses of Thai history. Seventeen phonemically short vowels and 13 phonemically long vowels that could be measured without too much difficulty were found in this sampling. The spectrographic data are summarized in Table 4 (Abramson 1962: 84-9).

Table 4

**Vowel Durations in Running Speech**

	Speaker: E.N.	
	V	VV
Number:	17	13
Averages in msec:	72	180
Ranges in msec:	35-120	110-300
VV/V ratio:	2.5	

When one considers that a more thorough study of this contrast in connected discourse would require that.

for each set of measurements only vowels occurring under the same environmental and rhythmic conditions be compared, the results here are striking. The ratio for this speaker has not diminished, and the ranges overlap by a mere ten milliseconds.

At this point it seemed clear that relative duration, at the very least for analogous environments, is a sufficient criterion for distinguishing "long" and "short" vowels in Thai, yet this finding alone does not demonstrate the sufficiency of duration as an acoustic cue to the perceptual differentiation of the two classes of vowels. After all, relative duration might simply be a redundant consequence of other more basic speech gestures that really carry the burden of the distinction. If so, it should be possible to prove experimentally that variations in vowel duration have little or no effect on the perceptual discrimination of the two classes.

Although, as stated earlier, speech synthesis is the commonly preferred technique for the testing of hypotheses on acoustic cues, in the present study manipulation of humanly produced speech signals was feasible and seemed desirable as an experimental method. The procedure (Abramson 1962: 94-6, 102-3) was to cut and splice magnetic tape to remove successively longer central portions of the long vowel of each of the minimal pairs in Table 2. Many copies were made of the recording of each carrier sentence embedding a long vowel, and progressively longer segments, usually starting with 50 milliseconds and increasing in steps of 25 milliseconds, were cut from succes-

sive copies until the original long vowel had been shortened to a value no greater than that of the short vowel in the minimal pair. Cutting points were chosen with the help of wide-band spectrograms. Where it was possible to do so without impairing the intelligibility of the word or the quality of the vowel, the shortening process was carried one or two steps below the duration of the original short vowel. Naturally, the longer the original long vowel, the greater the number of cuts made. For two relatively short long vowels, those in /sĭin/ and /khǎaj/, the first segment removed was only 25 milliseconds long. The first cut was made close enough to the beginning of the vowel not to disturb tonal contours but far enough into it not to disrupt any consonant-vowel transitions present. Cuts of 80 degrees were found most satisfactory for noise-free splices that did not extend far along the time axis. These shortened utterances, together with the original pair of words, were recorded five times and randomized to form an identification test for each of E.N.'s 14 pairs and for an additional pair recorded by another informant, K.C., making 15 tests of from 30 to 50 stimuli per test. The purpose of the carrier sentence was to provide a setting of the speaker's speech rhythm (Noss 1972) against which the listeners could judge the vowel durations. From 10 to 13 native speakers of Central Thai responded to the stimuli by deciding which of the two possible words was meant in each utterance and writing it in Thai script. The results are given in Table 5.

Table 5

## Minimal Pair Tests in a Carrier Sentence

Contrasts	Points of Perceptual Ambiguity (% of original VV)	Original Durations in Msec	
		VV	V
/hàat/ : /hàt/	65%	360	130
/bàat/ : /bàt/	51%	225	100
/ciip/ : /cip/	66%	170	60
/hàat/ : /hàt/	55%	200	60
/khùut/ : /khùt/	47%	210	60
/baaŋ/ : /baŋ/	74%	220	100
/òot/ : /òt/	57%	230	100
/thaan/ : /than/	64%	200	70
/hèet/ : /hèt/	59%	210	90
/phǎæ/ : /phǎe/	61%	330	150
/phráa/ : /phrá/	59%	300	120
/kháan/ : /khán/	53%	200	90
/khâam/ : /khâm/	61%	200	80
/sĭin/ : /sĭn/	61%	160	60
/khǎaj/ : /khǎj/	48%	160	80
Average ambiguity point :	59%		
Range :	47%-74%		
Number of pairs :	15		

The first pair in the table was recorded by K.C., a woman, and the rest by E.N., a man. The first column shows the pair of words in contrast (see Table 2 for glosses). The second column shows the points of perceptual ambiguity for the 15 tests. These were obtained by plotting the responses to all the stimuli of each test in a graph with the vertical axis showing the percent response to each



stimulus as a short or long vowel and the horizontal axis representing vowel duration. Where the two identification curves intersect, the response as to phoneme category is pure chance, i.e. 50%. The corresponding vowel duration is read off the horizontal axis below this point. Thus the second column in Table 5 gives the percentages of the durations of the original long vowels at which the responses are completely ambiguous.<sup>3</sup> The third column displays the durations of the original short and long vowels of each pair; except for the first item, these data underlie the figures of Table 3.

Each point of perceptual ambiguity in Table 5 is best viewed as the midpoint of a brief transitional zone of ambiguity (Abramson 1962: 95-105 & Fig. 2.5) on either side of which vowels are judged to be predominantly long or short. Thus we see that relative duration is a powerful acoustic cue to this phonemic distinction. Indeed, the data suggest that for a given type of context the speaker is programmed to provide a greater difference between long and short vowels than the listener requires,<sup>4</sup> as can be seen by comparing Tables 3 and 5. Table 3 shows a VV/V ratio of 2.5 in E.N.'s productions. The perceptual

3) It is understood, of course, that these points of ambiguity are in fact interpolations between real data points. That is, the curves need not intersect at a datum on the graph.

4) See Nootboom 1973 for work on the speaker's "internal representation" of vowel durations in Dutch.

data in Table 5<sup>5</sup> derived from manipulations of these utterances yield a ratio of 1.7 between the average long-vowel duration and the duration of a stimulus that causes chance identifications. Such differences between production norms and perceptual tolerances must be true of phonemic distinctions in general, but the extent to which quantitative differences in this respect may depend upon types of phonetic features is not yet known.

### Discussion

The data from both production and perception lend strong support only to those analysts who posit vowel length as a distinctive feature for the Thai opposition under discussion. Slight effects of other phonetic features present, which can be seen by close inspection of the data in the original work, are so small that they do not weaken the general conclusion.<sup>6</sup> As for the question of gemination versus length, the present study does not seem to provide a definitive answer, yet it may contain some hints. Careful scrutiny of spectrograms, amplitude displays and oscillograms of long vowels does not yield any acoustic evidence of the rearticulation presumably required for

5) The first item, K.C.'s, has been excluded for proper comparison with Table 3.

6) It would take further experiments to learn just how much information can be carried by these concomitant features.

abutting vowel segments.<sup>7</sup> In addition, despite the steepness of the slopes of the identification curves in the perceptual experiments, the zones of ambiguity blending into predominantly "long" judgments suggest a length continuum rather than a sharp boundary between single and double vowels. It must immediately be conceded, however, that this is a rather indirect inference and does not emerge from the data in the overwhelming fashion of the general conclusion concerning the phonological relevance of relative vowel length.

It is to be hoped that the general thesis of this article, namely that the phonologist should exploit experimental phonetics as a useful and powerful tool, has been supported by the research on vowel duration in Thai summarized here.<sup>8</sup> The relevance of experimental phonetics to other lines of research and practical applications has been treated elsewhere (Abramson, in press).

7) This negative conclusion would probably be strengthened by direct probes into the speech musculature through electromyography.

8) A recently published article on quantity in Icelandic vowels. (Garnes 1973) was written in support of the same thesis.

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