1. A Survey of the Problem of Juncture

Most current descriptions of English contain references to phenomena designated as "junctural". There appears to be general agreement that such phenomena exist, and are a part of the English language. It seems, however, that while the phonetic manifestations of juncture are described in approximately the same terms, there is considerable lack of uniformity in the phonemic interpretation of the observed phonetic features. The present paper represents an attempt to investigate experimentally the phonetic manifestations of juncture, and to reconsider the phonemic interpretation of such features in the light of the experimental study. The investigation is limited to a study of internal open juncture. Unless otherwise indicated, the shorter term "juncture" is used to refer to such phenomena as are commonly associated with the term "internal open juncture".

It was observed quite early that there is no one-to-one correspondence between grammatical words – normally written between spaces – and the internal structure of a spoken chain of sounds. More than fifty years ago, *Sweet*[1] considered a phonological or phonetic word as the basic unit of speech and wished to abolish the ordinary word-division in (phonetic) writing[2]. *Daniel Jones*[3] com-

[1] *Henry Sweet:* Primer of phonetics (Oxford 1906).

[2] *Henry Sweet:* Collected Papers of Henry Sweet (Oxford 1913). Cf. especially pages 12–14 of the paper entitled: Words, logic, and grammar, reprinted from Transactions of the Philological Society, *1875–76:* 470–503.

[3] *Daniel Jones:* The "word" as a phonetic entity. Le Maître Phonétique, 3rd series, *36:* 60–65 (1931).

piled an impressive list of words and phrases differing in the placement of what is now called internal open juncture, although he did not use this terminology. The phonetic treatment of features later termed "junctural" continued through the nineteen-thirties; the "word as a phonetic unit" was again considered by *Dietrich*[4] and by *Brøndal*[5]. The phonemic implications were first realized by *Trubetzkoy*[6], whose term for the features later called junctural was "Grenzsignale" (boundary signals), which he considers non-phonemic. It may be of interest to note that *Bloomfield*[7] viewed such pairs as *a name – an aim* as different in stress, i.e. in "the point at which the increase of loudness sets in". He prints spaces between the words in his phonemic transcription without accounting for their presence.

The first full-scale treatment of junctural phenomena as part of the phonemic structure of a language (in this case, English) was published in 1941 by *G. L. Trager and B. Bloch*[8]. The authors provide the following definitions: "The transition from the pause preceding an isolated utterance to the first segmental phoneme, and from the last segmental phoneme to the following pause, we call open juncture. By contrast, the transition from one segmental phoneme to the next within the utterance… we call close juncture." After making some observations about the phonetic nature of such transitions, they then state: "Open juncture is the totality of phonetic features which characterize the segmental and suprasegmental phonemes at the beginning and at the end of an isolated utterance." It is further observed that the features of open juncture may be present internally in some utterances; a distinction is made between external open juncture and internal open juncture. External open junctures are represented in transcription with spaces between symbols, internal open junctures with hyphens.

The theory was further elaborated by the same authors in

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[4] *G. Dietrich:* Das Wort als phonetische Einheit. Le Maître Phonétique *38:* 31–33 (1932).

[5] *V. Brøndal:* Sound and phoneme. Proc. 2nd int. Congr. Phon. Sci., pp. 40–45 (Cambridge 1936).

[6] *N. Trubetzkoy:* Anleitung zu phonologischen Beschreibungen (Edition du Cercle Linguistique de Prague, 1935). – Grundzüge der Phonologie. Travaux du Cercle Linguistique de Prague fasc. 7 (Prag 1939).

[7] *L. Bloomfield:* Language, p. 113 (New York 1933).

[8] *George L. Trager* and *Bernard Bloch:* The syllabic phonemes of English. Language *17:* 223–246 (1941). The definitions are on p. 225.

1942[9], and by *G. L. Trager and Henry Lee Smith*, Jr., in 1951[10]. In the latter publication, the newly described intonation and stress phenomena were combined with the features described as junctural in 1941, and a system of juncture phonemes for English was established, comprising three terminal junctures and one internal open juncture. The phonetic characteristics of these phonemes were described in somewhat greater detail, and the theory was essentially codified in the form in which it appears in various later presentations in elementary textbooks[11].

In the meantime, the problem was being considered from several other aspects. The original definition of open juncture ("the totality of phonetic features", *Trager-Bloch*, 1941) had been broad enough to cover a variety of diverse events; when it was attempted to sharpen the definition, numerous problems seemed to arise. In 1942, *Charles F. Hockett*[12] assigned junctural features to the level of suprasegmental phonemes[13]. In 1948, *Bernard Bloch* questioned the phonemic status of the so-called junctural phonemes[14]:

> "There is nothing in our assumptions to cover the term juncture. Indeed, we may go so far as to say that the so-called juncture phonemes of English and German, as they have hitherto been described, are not phonemes at all in the sense of our definition: they are not, or at least not obviously, classes of segments or spans containing a given feature, but rather fictions created ad hoc to account for the difference between certain sets of phonetically different segments."

Bloch does not express a value-judgement, although the sentence just quoted might be thus interpreted, if one disapproves of "fictions created ad hoc" to explain certain phenomena. As a matter of fact, *Bloch* refers rather approvingly to an instance where a zero allophone of a pause phoneme had been used to explain certain phonetic

[9] *Bernard Bloch* and *George L. Trager:* Outline of linguistic analysis, pp. 35–36 and p. 47 (Baltimore 1942).

[10] *George L. Trager* and *Henry Lee Smith*, Jr.: An outline of English structure. Studies in Linguistics: Occasional Papers 3, p. 38 (Norman, Okla. 1951).

[11] *H. A. Gleason*, Jr.: An introduction to descriptive linguistics, Ch. 4 (New York 1955).

Charles F. Hockett: A course in modern linguistics (New York 1958).

Archibald A. Hill: Introduction to linguistic structures (New York 1958).

[12] *Charles F. Hockett:* A system of descriptive phonology. Language *18:* 3–21 (1942).

[13] It is interesting to note that in 1941, *Trager* had not included junctures in his "The theory of accentual systems", which systematized the suprasegmental phonemes. (*George L. Trager:* The theory of accentual systems. Language, Culture, and Personality: Essays in Memory of Edward Sapir, pp. 131–145 [Ed. Leslie Spier, Menosha, Wisc. 1941].)

[14] *Bernard Bloch:* A set of postulates for phonemic analysis. Language *24:* 3-46 (1948). The quotation is from p. 41.

data. The case in point is *William G. Moulton*'s analysis of German[15]. The problem concerns the phonemic status of the two fricatives in German, [x] and [ç], and is relevant enough to be considered in somewhat more detail.

The three possible alternatives in analyzing the German data are as follows. First, it is possible to set up two separate phonemes, /x/ and /ç/, since they clearly occur in contrast in identical environments (for example, *Kuchen* 'cake' [kʰu:xən], *Kuhchen* 'littlecow' [kʰu:çən]). The second alternative, the one adopted by *Moulton*, is to set up a segmental phoneme of open juncture. According to *Moulton*, this phoneme has two allophones: at the beginning or end of an utterance, it appears as a pause of indeterminate duration; within an utterance it appears as a brief pause or, in free variation, as zero. The phoneme of juncture is present whenever a pause (of whatever duration) occurs. In addition, its presence is assumed to account for the occurrence of every aspirated voiceless stop, glottal stop, and the sound [ç] following a central or back vowel or semivowel. In a considerable number of such instances it is impossible to detect any phonetic manifestation of the juncture other than the presence of the listed sounds themselves. In such cases, *Moulton* assumes the presence of a zero allophone of the juncture phoneme.

Moulton rejects the third possible interpretation of the German data: consideration of the fact that the brief pause allophones occur commonly only at syntactic boundaries, the zero allophones primarily at morphological boundaries. Within words only the zero allophone occurs. This is pointed out by *Werner F. Leopold*[16], who suggests that the zero allophone of open juncture actually amounts to recognition of a boundary in word-formation. The question becomes one of principle in two articles by *Kenneth L. Pike*[17]: Can and should phonemic analysis be carried on without using knowledge from other than phonological levels of the language in describing its structure. *Pike* sees no theoretical reason why the interpenetration of layers cannot be as much a part of structure as the layers themselves. In *Pike*'s view,

[15] *William G. Moulton:* Juncture in modern standard German. Language *23:* 212–226 (1947).

[16] *Werner F. Leopold:* German ch. Language *24:* 179–180 (1948).

[17] *Kenneth L. Pike:* Grammatical prerequisites to phonemic analysis. Word *3:* 155–172 (1947); the following quotation is from p. 162. – More on grammatical prerequisites. Word *8:* 106–121 (1952).

"In many languages certain grammatical units – such as words – have as one of their characteristics the induction of subphonemic modification of some of the sounds. When modifiable sounds happen to occur at the borders of such units, the juncture becomes phonologically recognizable. If no modifiable sounds happen to occur at a grammatical boundary, the boundary is not phonetically perceptible but is nonetheless present and just as important in the total structure of the language. The phonemics of a language, in other words, cannot be presented completely until something is known of the grammar, just as the grammar cannot be presented completely until something is known of the phonemics."

This interpenetration has become one of the basic tenets of linguistic analysis according to *Pike*[18].

Apart from a certain implicit admission that junctures do, indeed, often correlate with morpheme boundaries, the approach of *Zellig S. Harris*[19] is radically different from that of *Pike*. *Harris* sets up a segmental phoneme of juncture for the purpose of simplifying description. According to *Harris*, two or more parallel sets of tentative phonemes, which cannot be combined into one set because they represent distinct segments in identical environments, could thus be combined if there were a technique for altering the environment of one of the sets so that its environment would no longer be identical with that of the other. This alteration is effected by taking the features which distinguish the two sets of tentative phonemes, and setting them up as the definition of a new phonemic element, called a juncture. That juncture occurs with the set which had the features now assigned to the juncture[20].

In such an operation, the juncture is a "zero" phoneme – a phoneme having no phonetic properties at all, whose only function is to function as environment for ordinary phonemes. Since the juncture phoneme has no phonetic properties of its own, in a certain way all its allophones are phonetically homogeneous (i.e. have no

[18] Formulated most recently in *Pike*'s report to the 8th International Congress of Linguists in Oslo, 1957: Interpenetration of phonology, morphology, and syntax. Proc. 8th int. Congr. Ling., Oslo 1958, pp. 363-371.

[19] *Zellig S. Harris:* Methods in structural linguistics, pp. 79–80 (Chicago 1951).

[20] The most straightforward equation of junctures with morpheme boundaries appears in an article by *N. Chomsky, M. Halle* and *F. Lukoff:* On accent and juncture in English. *For Roman Jakobson*, pp. 65–80 (The Hague 1956). According to these authors, junctures do not represent physical entities, but are introduced for the purpose of reducing the number of physical features that must be considered phonemic. Junctures appear only at morpheme boundaries; different junctures correspond to different morphological and syntactical processes. However, not every morpheme boundary is marked by a juncture, and neither can syntactic structure be determined by distribution of junctures. Junctures are postulated only where phonetic effects can be correlated with a morpheme boundary.

phonetic properties at all). This is one way to solve the somewhat puzzling problem of describing the allo-junctures of juncture phonemes. Another is that of *Hockett*, of 1949[21]. *Hockett* admits that juncture phonemes may have allo-junctures that have nothing in common phonetically with one another. His solution is rather ingenious:

"Mathematically, a class can be defined by specifying a *property*, so that possession of that property by an object puts it in the class, lack of that property leaves it out of the class. But another perfectly satisfactory way to define a class is by itemization. If we insist on tying up a class with a property, in the case of a class of this kind we can regard the property of *membership in the class enumerated* as the associated property. That is, a class can be defined in terms of a property, or vice versa. So we see that the failure of all the allophones of some juncture phonemes to have some (articulatory or acoustic) property in common is no logical defect. We may with perfect validity define a juncture phoneme as consisting of all occurrences in certain specified contexts of certain specified phenomena... Juncture phonemes, where recognized, do consist of allophones with a *structural* property in common."

To be sure, *Hockett* states in the same article that "the phonemic structure of a language is not to be equated to any single phonemicization; rather it is the 'least common denominator' of every possible sufficient phonemicization". It follows that "it is always possible to phonemicize without junctures, though perhaps only sometimes possible to phonemicize in a way that gives us juncture phonemes".

Some connection between junctures and morphemes was also sensed by *Einar Haugen*, who considered juncture "morphologically determined displacement of syllable timing"[22]. *R. H. Stetson*[23] looked for physiological manifestations of junctures and rejected junctures as phonemes; *W. F. Twaddell*[24] reinterpreted *Stetson*'s data and set up a hypothesis for the transition phonemes. According to this "Stetson-model" hypothesis, internal open juncture is related to the occurrence of the removal of a consonant-obstruction before or after, but not during the build-up phase of an intercostal pulse. *Stetson*'s basic unit of speech is the syllable, which he defines in articulatory terms. The syllable as a phonetic and phonemic entity has received considerable attention during the last decade[25];

[21] *Charles F. Hockett:* Two fundamental problems in phonemics. Studies in Linguistics *7:* 29–51 (1949); the quotation is from page 36.

[22] *Einar Haugen:* Phoneme or prosodeme? Language *25:* 278–282 (1949).

[23] *R. H. Stetson:* Motor phonetics: 2nd ed. (Amsterdam 1951).

[24] *W. Freeman Twaddell:* Stetson's model and the "suprasegmental phonemes". Language *29:* 415–453 (1953).

[25] *Kenneth L. Pike* and *Eunice V. Pike:* Immediate constituents of Mazateco syllables. IJAL *13:* 78–91 (1947).

Einar Haugen: The syllable in linguistic description. *For Roman Jakobson;* pp. 213–221. – Syllabification in Kutenai. IJAL *22:* 196–201 (1956).

perhaps the most thorough analysis of both is given in *Hockett*'s *Manual of Phonology* in 1955[26]. A syllable, according to *Hockett*, consists of onset, peak, and coda; *Hockett* describes one type of internal open juncture as a contrast between an interlude and a coda-onset sequence, where an interlude is a structural unit which is coda-like and onset-like at the same time, and structurally belongs both to the syllable which contains the preceding peak and to that which contains the following peak. When two successive syllables in a language like English are linked by an interlude, there is no "point of syllable division" between them. All interludes can be divided, in at least one way, into two successive parts, the first of which occurs also as a coda, the second of which occurs also as onset; yet the possibility of such a division does not mean that an interlude can be interpreted as a coda plus onset: the fact that the /tr/ of *nitrate* can be broken into either zero and /tr/, or /t/ and /r/, does nothing to eliminate the contrast between that interlude and the coda-onset sequences of *night-rate* and *dye trade*[27].

In *Hockett*'s manual, internal open juncture is set up as a phoneme; the various phonetic manifestations of internal open juncture are described in quite careful detail, and it is admitted that in different environments juncture may be composed of almost completely diverse phonetic features. However, *Hockett* considers that to be an advantage rather than an embarrassment:

> "Juncture phonemes achieve their power precisely because of their phonetic heterogeneity. When we say of English that segments bounded by /-/ are in general isolable, we are covering a large number of specific facts: a segment which begins with crescendo voicing on a voiced stop or spirant, with clear voicing on a sonorant, with slight glottal catch (or at least clear point of syllable division) before a vowel, with a voiceless stop which is well aspirated, and so forth, and which ends with diminuendo voicing on a voiced stop or spirant, with drawl on a stressed vowel, and so forth, is in general isolable. It takes longer to describe all the allophones of a juncture, but once the juncture has been described it constitutes a powerful tool."

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[26] *Charles F. Hockett:* A manual of phonology. Memoir No. 11 of IJAL (Baltimore 1955).

[27] *Hockett*'s "interlude" appears quite similar to the "compound phone" suggested by *Shiro Hattori* in 1950 (*Shiro Hattori:* Phoneme, phone and compound phones. Gengo Kenkyu *16:* 92–108 [Tokyo 1950]). *Hattori* explains the difference between *night-rate* and *nitrate* as a difference between a sequence of two separate phones [t] and [r] (in *night-rate*) contrasting with a compound phone [tr] (in *nitrate*), which, according to *Hattori*, belongs to the preceding and following syllable at the same time. *Hattori* also sets up a segmental zero phoneme to account for the difference between *a name* and *an aim*, the latter containing the zero phoneme before /ejm/ (*Hattori*'s phonemic transcription).

This same point of view appears, essentially unmodified, in *Hockett*'s recent book, *A Course in Modern Linguistics* (see footnote 11 above).

A completely new approach to linguistic analysis has been developed by *Kenneth L. Pike* within the last five years[28]. Since juncture plays a relatively minor part within the framework of the theory, no general review of the hierarchical, tri-modal structure of language is being offered here. According to this more recent theory, junctures are not phonemes themselves, as may be concluded from *Pike*'s earlier work[29], but occupy a rather different place within his phonological hierarchy. Briefly, junctures are identificational-contrastive features of higher-layered units in the manifestation mode.

Except for *Pike*'s recent work, the junctures have been mostly described, up to now, in terms of the modifications of segmental phonemes before and after the juncture. There is one recent treatment where the differences are described not in terms of allophonic modifications, but in terms of timing. This is *Archibald A. Hill*'s *Introduction to Linguistic Structures* (see footnote 11 above). *Hill*'s analysis is largely based on unpublished work by *Martin Joos*[30].

According to *Hill*,

> "If a pair like *that stuff: that's tough* are repeated several times, the distinction begins to be audible in terms of prolongation. In the first utterance, the *t*-sound which occurs before *s* is prolonged, in the second it is the *s*-sound. Plus juncture is then like the others in being a phenomenon of timing. The prolongation differs, however, in being a half-unit only, 'unit' being used in the sense given above as a period of time about equal to the length of one average sound."

[28] *Kenneth L. Pike:* Language in relation to a unified theory of the structure of human behavior; Parts I and II (Glendale, Calif. 1954 and 1955).

[29] *Kenneth L. Pike:* Intonation of American English (Ann Arbor 1945), where a pause phoneme is postulated; in the second volume of Language in relation to a unified theory of the structure of human behavior (p. 66), the phenomenon is analyzed as an emic, but non-emc ending of a pause group, or as a set of contrastive emic features of abdominemes.

[30] In footnote 7 to page 26 *Hill* refers to work done by *M. Joos* and *Robert P. Stockwell*. A reference to *Joos*' unpublished work is contained also in an article by *Robert P. Stockwell, J. Donald Bowen,* and *I. Silva-Fuenzalida:* Spanish juncture and intonation. Language *32:* 641–665 (1956). In the meantime, a brief direct reference has been published by *Martin Joos* in his English language and linguistics, p. 45 (Institute for Experimental Phonetics, Beograd 1958). Discussing suprasegmental phonemes, *Joos* states: "/+/. Transcribed in sequence with segm. phonemes, but essentially suprasegmental. Constant phonetic feature: delay of $^1/_{40}$ second ($^1/_3$ length of segm. phonemes), not separately perceptible, but heard indirectly through allophonic effects."

Hill does not give any data about the actual duration of the "average sound"[31]. Admitting that although /+/ can be defined as a time phenomenon, it still has important effects on the sounds around it, *Hill* raises the question whether the difference produced by the juncture on the surrounding sounds is contrastive. In other words, if /+/ is a feature of timing, and if the presence or absence of /+/ is a contrast, then the allophonic differences in the sounds preceding and following are redundant. Since *Joos*' material is not directly available except for the above references, it is not possible at the moment to verify the basis for this most recent theory about juncture.

At this point, then, the following interpretations of juncture appear to be current: a) the internal open juncture is a segmental phoneme (*Moulton*, *Harris*); b) the juncture is a suprasegmental phoneme (*Hockett*, 1942, *Haugen*, *Joos*); c) juncture is a phoneme *sui generis*, a "junctural" phoneme (*Trager-Bloch*, *Bloch-Trager*, *Trager-Smith*, *Hockett*, 1955, *Hill*); d) juncture is a non-phonemic modification of sounds at grammatical boundaries (*Pike*, 1947 and 1952); e) juncture is a contrastive emic feature of higher-layered units in the manifestation mode, but not an eme in its own right (*Pike*, 1955). The phonetic manifestation of juncture includes a) the totality of phonetic features that characterize the segmental and suprasegmental phonemes at the beginning and at the end of an isolated utterance (*Trager-Bloch*, 1941); b) a pause of indeterminate duration, a brief pause, or, in free variation, zero (*Moulton*); c) the internal open juncture has no phonetic features of its own (*Harris*); d) the internal open juncture is a "morphologically determined displacement of syllable timing" (*Haugen*); e) the internal open juncture is a coda-onset sequence, where coda and onset refer to syllable margins (*Hockett*, 1955); f) juncture is a feature of timing, definable in terms of prolongation of the segmental sound preceding the juncture (*Joos*, *Stockwell*, *Hill*). It may be pardonable to conclude this list with a quotation from an editorial comment made by *Joos*[32]: "The semantics of the word 'juncture' is confusing and fateful."

[31] Already in 1948, *Joos* had suggested that discriminations between phonemes can be managed by a listener at a maximum rate of 20 per second (*Martin Joos*: Acoustic Phonetics. Language Monograph 23, p. 79 (Baltimore 1948). As appears from the quotation in footnote 30, *Joos* still assumes that the average length of segmental phonemes is $^1/_{20}$ of a second, or 5 centiseconds.

[32] *Martin Joos* (ed.): Readings in Linguistics, p. 216.

2. Description of the Experimental Approach used in this Study

2.1 Problem

The present investigation is an inquiry into the acoustic cues which signal division of the stream of speech into smaller self-contained units. As indicated above, several previous investigators have sensed some connection between certain phonetically describable modifications of the speech continuum and the boundaries of meaningful linguistic entities, such as morphemes. One type of internal open juncture, for example, involves contrastive distribution of a sequence of segmental phonemes among two or more smaller self-contained sequences. The sequence /kipstɪkɪŋ/ may represent either /kip + stɪkɪŋ/ or /kips + tɪkɪŋ/. Some have thought that sequences of this type may be distinguished by contrastive placement of a morpheme boundary. Thus it was decided to attempt to determine the extent to which morpheme boundaries are actually signalled by information present in the sound waves. It seemed that a systematic study of internal open juncture should make it possible to determine whether acoustical clues to morpheme boundaries exist, and if so, what is the character of such clues.

This paper deals, then, with an acoustic-phonetic investigation of internal open juncture in American English.

2.2 Procedure and materials

In order to obtain a corpus of material for analysis, a list was first compiled, consisting of pairs of words or phrases containing contrastive open juncture. Care was taken to include a reasonably complete set of the pairs which have been quoted in previous works treating the question of juncture. When this material was systematized, it appeared that some types of juncture were represented by numerous examples, whereas some other types appeared not to have been considered. Additional pairs were constructed to fill the gaps. The total inventory included 304 individual words and phrases, grouped into 138 pairs. (The number is smaller than half of 304, since in some instances, the contrastive placement of internal open juncture involved more than two phrases.)

These individual phrases were randomized, and sentences were constructed incorporating the words in a context where the purpose of the inclusion of the word would not be immediately obvious. Only a relatively small part of the phrases were minimal pairs, consisting of the same segmental phonemes with contrastive placement of the internal open juncture. Also, not many of the phrases belonged to the same substitution class. In only a very restricted number of instanees, therefore, was it possible to use a frame technique. To reduce the number of sentences, it was attempted to include more than one test phrase in every sentence. 192 such sentences were constructed.

The individual phrases were typed on 5×8 index cards and alphabetized. Each phrase was assigned a code number. The index card for each word contains the code number, references to the occurrence of the word in previous research literature, and a record of all spectrograms made of the word.

Two lists of sentences were prepared. In one list, all test words were underlined and provided with their code numbers. The other list was typed without any indication as to which of the words in the sentence was under study. This second list was later presented to the informants.

In addition, a separate set of 3×5 file cards was prepared, on which the words appeared arranged into contrastive pairs. This set of cards was also alphabetized.

2.3 *Informants*

Three informants were selected; all speak a similar form of the Midwestern type of Standard American English. Informant GEP was born and raised in Central Illinois, approximately 120 miles south of Chicago; informants JB and AMC were born approximately 20 miles northwest of Chicago. The only noticeable dialect difference among the three informants is the use of the voiceless [hw] by informant GEP as against voiced [w] used by informants JB and AMC in such words as *which*, *when*, *why*.

One of the speakers (GEP) is a trained linguist and phonetician, and was familiar with the problem under study; informants JB (a mathematician) and AMC (an anthropologist and zoologist) may be considered linguistically non-prejudiced.

Tape recordings of the corpus of materials were then prepared in the following order. All three speakers recorded first the total set of 192 sentences. After the speakers had recorded the corpus where the test words appeared in random order presumably hidden in the context, they were requested to read the list of words and phrases arranged in contrasting pairs. In reading the sentences, each speaker selected his own tempo, stress and intonation patterns. In reading the contrastive pairs, the speakers were instructed to use a reasonably uniform tempo and pitch pattern. The speakers were directly aware of the intended contrasts, but they were requested to read the words in a manner in which they would normally pronounce them in an isolated occurrence. While the contrasts were then produced consciously, in general they were not exaggerated, except in a few isolated instances. The total set of data thus consists of six utterances of each of the 304 test words: the test word uttered in the same context by the three speakers, and the test word uttered as a member of a contrastive pair by each of the three speakers.

The above-described corpus was recorded on magnetic tape in a sound-treated recording room, using a high quality microphone and an Ampex 350 tape recorder. The tapes were then submitted to a detailed spectrographic study.

2.4 *The spectrographic analysis of the data*

Basically, spectrographic analysis of speech involves transforming the acoustic patterns of speech into visual form. The techniques of spectrographic analysis have been explored and developed during the last fourteen years. The bibliography at the end of this paper contains a rather detailed set of references to works dealing with the various aspects of spectrographic analysis of speech and language. At the present time, the following four kinds of analyses have been found most useful.

a) The broad-band analysis. In this type of analysis, an analyzing filter of a bandwidth of 300 cps is used to scan the acoustic spectrum. The resulting spectrogram displays the formant structure of voiced sounds, the energy concentrations of voiceless sounds, and a time pattern of changes in the frequency dimension. The broad-band spectrograms allow one to study the rate of change of the phonetic quality of speech sounds, reflecting the dynamics of articulatory movements.

b) The narrow-band analysis. In this setting of the spectrograph, a narrow (45 cps) analyzing filter is used, resulting in a display of the harmonic structure in the time-frequency plane of the stream of speech. The narrow-band spectrograms are especially useful in the study of pitch and intonation.

c) The amplitude sections. Using this type of analysis, it is possible to present the harmonic structure of a very brief segment. The duration of the segment is the reciprocal value of the filter bandwidth, i.e. $^1/_{30}$ seconds when the narrow filter is used. The amplitude section displays the intensity of each harmonic and thus provides a possibility of closer study of the internal structure of the formants, whose positions in frequency may also be studied from a broad-band spectrogram. The broad-band spectrogram, however, displays the relative amplitudes only very crudely by lighter or darker markings.

d) The continuous amplitude display. The model D spectrograph available at the Communication Sciences Laboratory of the University of Michigan possesses a special circuit, by means of which it is possible to represent the overall intensity of the speech wave as a continuous function of time. This display is based on the overall rectified waveform, so that amplitude variations from one vocal fold cycle to another may be observed.

Broad-band spectrograms and continuous amplitude displays were made of the total corpus. Narrow-band spectrograms were made of the words in context of informant GEP and of a restricted sample of the material recorded by informants JB and AMC. Only a few exploratory amplitude sections were made, but it appeared that the broad-band spectrograms and the coutinuous amplitude displays revealed the most significant clues for solving the problem under study. The measurements taken from the spectrograms were tabulated, and comparisons were made between the various occurrences of the same word, as well as the various occurrences of its contrastive pair. Certain regularities were observed, and it was possible to set up a tentative hypothesis of the various phonetic manifestations of internal open juncture.

2.5 *The listening experiment*

It appeared that certain phonetic differences were regularly associated with certain of the contrastive pairs. In order to check whether the observable phonetic differences between two members of a contrastive pair were actually correlatable to an observed difference in meaning, a listening experiment was designed. Twenty-five pairs were selected from the corpus, most of which were true minimal pairs in the pronunciation of the informants. A listening tape was prepared in the following manner. From the tapes containing recorded paired contrasts, the selected pairs were transferred to the listening tape. The order of words was randomly either retained or reversed in copying. The 25 pairs uttered by each of the three informants were thus copied; a separate decision as to sequence was made in each instance. A test form was then prepared to accompany the tape on which the listeners had to indicate which of the two presented stimuli occurred first. In arranging the items into columns on the test sheet, a random decision was again made as to whether each item would be offered in the same order as on the listening tape, or whether the order would be reversed. It was considered that the influence of the order of presentation in the identification of the members of the pair would thus be minimized.

The listening test was given to 40 native speakers of English. Half of the group were undergraduate students of Speech, the other half were graduate students of Linguistics. No significant difference was observed in the responses of these two groups, and the results are therefore combined in the final presentation.

The forty listeners identified a considerable number of pairs unanimously in the manner the speaker had presumably intended to produce them, i.e., ordered the utterances in the same sequence as they had appeared on the cards presented to the speakers at the time the recordings were made. In general, in more than two thirds of the cases the judgement was either unanimous or nearly so (see tables I and II). It appeared reasonable to conclude that the phonetic cues identifiable in those utterances had actually contributed to the identification of the words and phrases as one of the members of a contrastive pair.

The description of some of the phonetic manifestations of internal open juncture, presented in the following chapter, is based on the observations made in connection with the spectrographic analysis. The evaluation of the relative contribution of the various phenomena to the identification of internal open juncture is based on the results of the listening test.

Table I

Results of the Listening Test

The values indicate the number of listeners (from a group of 40) who identified the given pair correctly.

Pair	Correct identification for each speaker		
	GEP	JB	AMC
1. a nice man – an iceman	40	40	40
2. beef-eater – bee-feeder	33	36	30
3. be quiet – Beck Wyatt	40	40	40
4. Kay toe – Cato	40	39	40
5. free Danny – freed Annie	40	40	26
6. get a board – get aboard	10	38	37
7. grade A – gray day	40	40	35
8. Hy ate us – hiatus	40	40	39
9. wholly – holy	27	23	12
10. home-acre – hoe-maker	40	36	11
11. I scream – icecream	40	34	40
12. it sprays – it's praise	39	40	39
13. it swings – its wings	40	38	40
14. keeps ticking – keep sticking	40	40	39
15. nude eel – New Deal	40	39	40
16. night-rate	37	39	39
nitrate	37	37	39
Nye trait	40	38	39
17. plump eye – plum pie	40	40	40
18. see lying – seal eying	40	40	39
19. see the meat – see them eat	26	40	40
20. seize ooze – see zoos	24	39	38
21. seem able – see Mabel	40	40	37
22. the sun's rays meet – the sons raise meat	14	21	20
23. tulips – two lips	40	39	39
24. twenty-six ones – twenty sick swans	40	40	40
25. white shoes – why choose	40	39	40

Table II

Number of Correct Identifications for the Total Set of 51 Words

The number in each cell indicates how many words out of 51 were identified correctly by the number of listeners indicated by the number above each column.

Speaker	40	39	38	37	36	35	34	33	30	27	26	24	23	21	20	14	12	11	10
GEP	35	2		2				2		2	2	2				2			2
JB	24	11	5	1	4		2						2	2					
AMC	20	13	2	4		2			2	2					2		2	2	

3. Results of the Listening Test

3.1 The listening test

The results of the listening test will now be discussed in more detail. Six sets of readings will be presented. First are the values measured from the words as they occurred in the contrastive pairs uttered by the three speakers; these are the words which occurred in the listening test. Second are the values measured from the words occurring in context. From now on, the contrastive pairs uttered by the three speakers will be called Set One and the words occurring in context will be called Set Two. All three speakers pronounced the words in the same context, and therefore the sets are comparable from speaker to speaker. However, the two members of each pair did not occur in the same context, and therefore the readings taken from spectrograms made of the words in context are not directly comparable within each pair. For that reason, detailed information about the values that occurred when the words appeared in context will be presented only for those words that correspond to the eleven representative pairs from the listening test which are reproduced on figures 1-11. Similar information is available for all items included in the study. The descriptive statements regarding the character of pre- and post-junctural allophones made in the next chapter are based on this information in addition to the material presented below.

3.2 a nice man – an iceman

Figure 1 represents the pair *a nice man – an iceman*. Figure 1 contains broad-band spectrograms and continuous amplitude displays of the two phrases in both sets uttered by JB. (Spectrograms for GEP and AMC are not reproduced.)

The members of the pair were correctly identified by all 40 listeners for all three informants. In Set One, the duration of [n] in *a nice man* was 8 centiseconds for GEP, 7 cs for JB, 9 cs for AMC; in *an iceman* the durations were 4 cs for GEP, 5 cs for JB, 4 cs for AMC. In Set Two, the duration of [n] in *a nice man* was 6 cs for GEP, 8 cs for JB, 9 cs for AMC; the corresponding durations in *an iceman* were 3 cs for GEP, 4 cs for JB, and 4 cs for AMC. There was a consistent difference in duration, the initial [n] being approximately twice as long as the final [n].

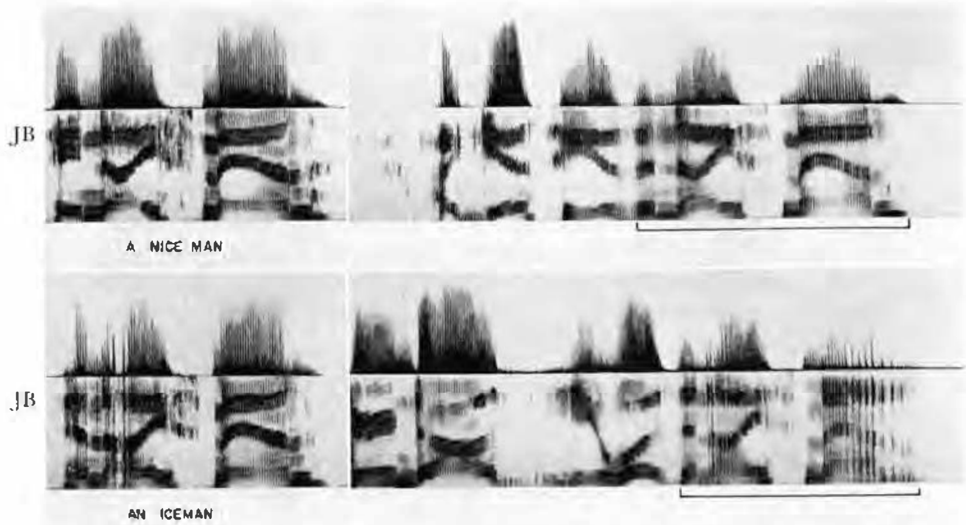

Fig. 1. Broad-band spectrograms and continuous amplitude displays of *a nice man – an iceman*, spoken by informant JB.

In addition, a difference was observed in the starting frequency of the second formant of the following vowel (the [ɑ] of the words *nice* and *ice*). In the word *nice*, the second formant of [ɑ] started at 1400 cps (GEP, Set One), 1800 cps (JB), 1800 cps (AMC), and at 1400 cps (GEP, Set Two), 1700 cps (JB), 1700 cps (AMC); in *an iceman*, the second formant started at 1300 cps (GEP, Set One), 1500 cps (JB), 1500 cps (AMC), and 1200 cps (GEP, Set Two), 1400 cps (JB), and 1400 cps (AMC). Laryngealization of the vowel in *an iceman* occurred once in Set One (JB) and twice in Set Two (JB and AMC); the laryngealized part of the vowel was from 3 to 6 cs long and consisted of irregular vocal fold flaps. A laryngealized onset of this type is heard as a glottal stop. Only in very rare instances was a real glottal stop (produced by complete closure of the glottis) observed in post-junctural position.

In *a nice man*, the intensity was rising on [n] in four instances (Set One, GEP and JB; Set Two, GEP and JB), level in two instances (Sets One and Two, AMC); in *an iceman*, the intensity was falling on [n] in four instances (Set One, JB; Set Two, GEP, JB, AMC), level in two instances (Set One, GEP and AMC).

In summary, the distinction between the two members of the pair seems to have been effected primarily by the durational difference of the initial and final allophones of the /n/, which occurred in all instances without exception. The difference in second formant onset was present also without exception. Rising intensity on the initial [n] occured in 4 cases out of 6, falling intensity on the final [n] in the same number of cases. The glottal stop (i.e. laryngealized onset) was present in half of the occurrences of *an iceman;* perhaps significantly, two of the cases occurred in context in Set Two, and only one out of three contrastive pairs was differentiated by means of the glottal stop.

3.3 grade A – gray day

Figure 2 represents the pair *grade A – gray day*. Figure 2 contains broad-band spectrograms and continuous amplitude displays of the two phrases in both sets uttered by AMC. (Spectrograms for GEP and JB are not reproduced.)

The members of the pair were correctly identified by 40 listeners for informants GEP and JB, and by 35 listeners out of 40 for speaker AMC. The segmental durations were as follows. In *grade A*, the duration of the sequence [reɪ] was 14 cs (GEP, Set One), 24 cs (JB), 32 cs (AMC), and 18 cs (GEP, Set Two), 21 cs (JB),

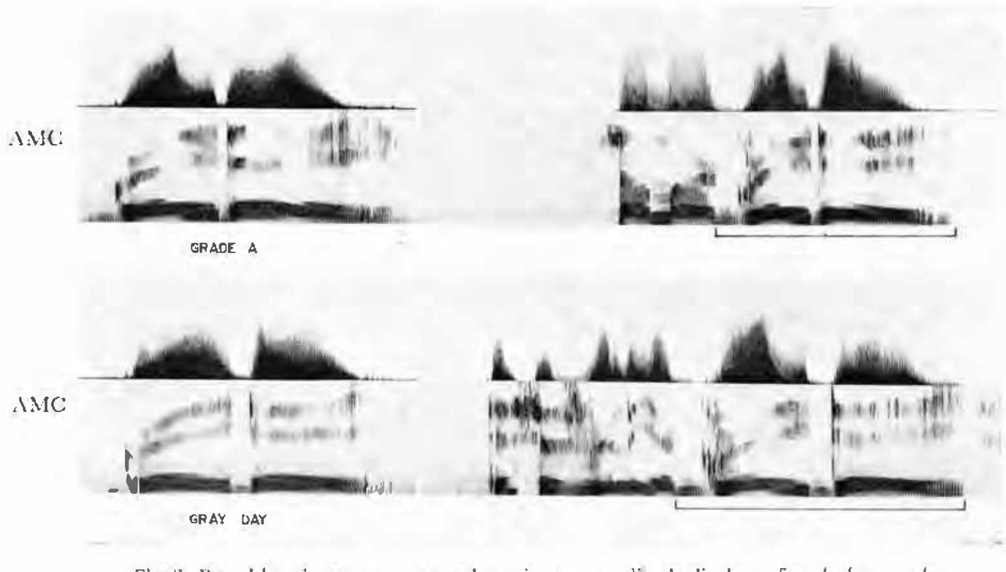

Fig. 2. Broad-band spectrograms and continuous amplitude displays of *grade A – gray day*, spoken by informant AMC.

22 cs (AMC). The duration of the sequence [reɪ] in *gray day* was 28 cs (GEP, Set One), 24 cs (JB), 32 cs (AMC), and 24 cs (GEP, Set Two), 26 cs (JB), 32 cs (AMC). In the contrastive Set Two of the informants (JB and AMC) made no durational contrast between the two members of the pair.

The duration of [d] in *grade A* was 6 cs (GEP, Set One), 5 cs (JB), 3 cs (AMC), and 4 cs (GEP, Set Two), 3 cs (JB), 2 cs (AMC); the duration of [d] in *gray day* was 6 cs (GEP, Set One), 7 cs (JB), 6 cs (AMC), and 6 cs (GEP, Set Two), 9 cs (JB), 8 cs (AMC). The [d] was followed by a glottal stop in *grade A* in two instances, both of which occurred in Set One, where presumably a conscious contrast was produced. GEP had a full glottal stop lasting 14 cs; JB had a 10 cs period of laryngealization. AMC had no glottal stop; if, as might be assumed, the unanimous identification of the contrastive pairs of GEP and JB was based on the presence of the glottal stop, then the 35/40 correct identification of the pair uttered by AMC was probably based on the durational difference in the consonant [d] (3 cs in *grade A*, 6 cs in *gray day*), since the duration of the sequence [reɪ] was identical in both instances.

Normally, increase in intensity suggests presence of an initial allophone, decrease in intensity signals the possible presence of a final allophone. It is probably worth pointing out that this intensity cue appears to be inoperative in the case of voiced stops, which start with a greater amount of intensity and experience a gradual decay immediately before the release in both initial and final position. An additional feature may be the distribution of intensity over the sequence [reɪ]: it appeared that the word *grade* had fairly high intensity for the whole duration of the vowel, dropping abruptly before the onset of the consonant, whereas in the sequence *gray day* the intensity drop seemed to take place over a relatively longer period of time. This contrast occurred consistently in the speech of both GEP and JB. This may be a concomitant feature: it did not occur in the speech of AMC, and the lack of this characteristic intensity distribution may have been another reason for the smaller identification score which the listeners achieved with informant AMC.

3.4 *home-acre – hoe-maker*

Figure 3 represents the pair *home-acre – hoe-maker*, as uttered by informant JB. Broad-band spectrograms and continuous ampli-

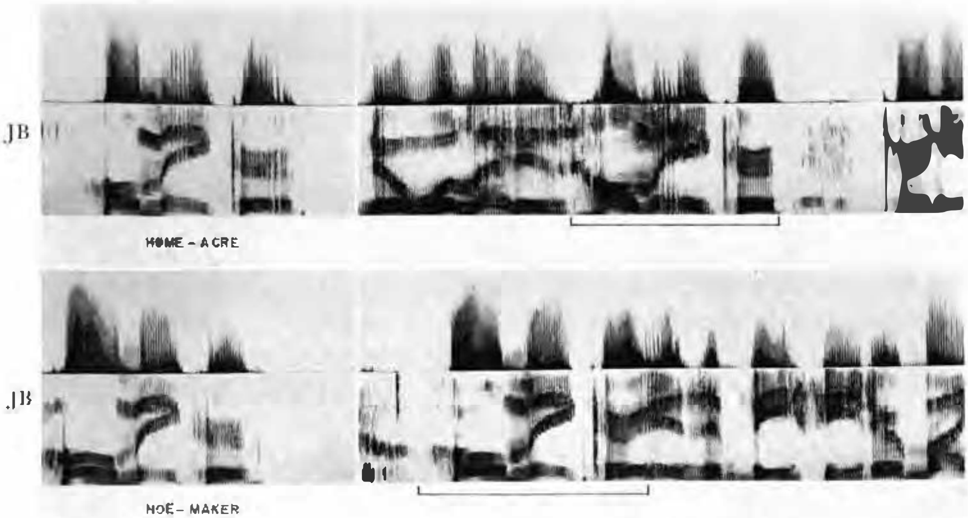

Fig. 3. Broad-band spectrograms and continuous amplitude displays of *home-acre – hoe-maker*, spoken by informant JB.

tude displays for both sets of utterances are presented. (Spectrograms for GEP and AMC are not reproduced.)

The identification of the members of the contrastive pair was correct in all 40 cases for GEP, in 36 cases out of 40 for JB, and only 11 times out of 40 for AMC (in other words, the judgement was reversed in the great majority of instances – 29 out of 40). In *home-acre*, the duration of [oʊ] was 14 cs (GEP, Set One), 11 cs (JB), 18 cs (AMC), and 10 cs (GEP, Set Two), 14 cs (JB), 13 cs (AMC); in *hoe-maker*, the duration of [oʊ] was 17 cs (GEP, Set One), 17 cs (JB), 14 cs (AMC), and 14 cs (GEP, Set Two), 17 cs (JB), and 16 cs (AMC). The duration of [oʊ] was shorter in the contrastive pairs in *home-acre* than in *hoe-maker* for GEP and JB in both sets, whereas the durational cue was reversed for AMC in the contrastive pair.

The duration of [m] in *home-acre* was 8 cs (GEP, Set One), 7 cs (JB), 6 cs (AMC), and 8 cs (GEP, Set Two), 5 cs (JB), and 6 cs (AMC). In *hoe-maker*, the duration of [m] was 11 cs (GEP, Set One), 7 cs (JB), 8 cs (AMC), and 9 cs (GEP, Set Two), 8 cs (JB), and 6 cs (AMC). The initial [m] was slightly longer than the final one in 4 out of 6 instances.

The intensity pattern on [m] was rising on *hoe-maker* in all instances for all three speakers; in *home-acre*, the intensity was falling in the utterances by speakers GEP and JB, but either level or slightly rising in the two utterances by AMC.

Laryngealization of the vowel in *home-acre* occurred in both sets of GEP and JB, where the duration of the laryngealization was quite considerable. As appears in figure 3, the [eɪ] of informant JB consisted of a 10 centiseconds long period of laryngealization, followed by a 5 cs long period of relatively even phonation. The other occurrences had ratios of laryngealized to non-laryngealized vowel of 10/13 (GEP, Set One), 8/10 (GEP, Set Two), and 8/10 (JB, Set Two). AMC used no glottal stop in either set. It appears that the reversed durational cue of the vowel in the first word of the contrastive phrases, the lack of the glottal stop in *home-acre*, combined with the slightly rising intensity on [m], were sufficient to cause the majority of listeners to reverse their judgement.

3.5 *it sprays – it's praise*

Figure 4 represents the contrastive pair *it sprays – it's praise* uttered by all three informants in Set One. Broad-band spectrograms of the six utterances are displayed.

The pairs were correctly identified by 40 out of 40 listeners for JB, and by 39 out of 40 listeners for GEP and AMC.

The segmental durations for the two phrases are as follows. In *it sprays*, the duration of [t] was 8 cs (GEP, Set One), 8 cs (JB), 10 cs (AMC), and 4 cs (GEP, Set Two), 6 cs (JB), 5 cs (AMC); in *it's praise*, the [t] lasted for 10 cs (GEP, Set One), 14 cs (JB),

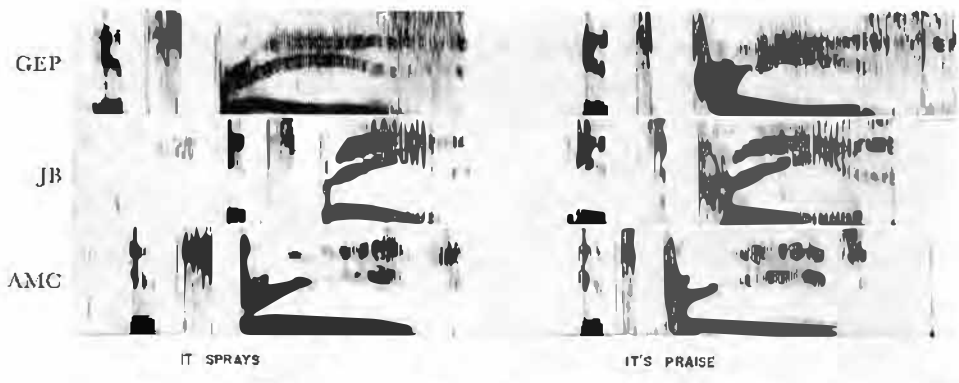

Fig. 4. Broad-band spectrograms of *it sprays – it's praise*, spoken by informants GEP, JB, and AMC.

7 cs (AMC), and 4 cs (GEP, Set Two), 4 cs (JB), and 6 cs (AMC). Perhaps the only regularity in the duration of [t] is that it appears to be longer when the two phrases are pronounced in isolation than when the phrases appear in context. No significance could be attached to any durational feature of the [t].

The duration of [s] in *it sprays* was 12 cs (GEP, Set One), 9 cs (JB), 9 cs (AMC), and 7 cs (GEP, Set Two), 5 cs (JB), and 5 cs (AMC). In *it's praise*, [s] lasted 4 cs (GEP, Set One), 6 cs (JB,) 4 cs (AMC), and 4 cs (GEP, Set Two), 4 cs (JB), and 4 cs (AMC). Here the [s] was regularly almost twice as long initially as the [s] that occurred in prejunctural position.

The duration of [p] in *it sprays* was 12 cs (GEP, Set One), 8 cs (JB), 10 cs (AMC), and 8 cs (GEP, Set Two), 8 cs (JB), 8 cs (AMC); in *it's praise*, [p] lasted 14 cs (GEP, Set One), 11 cs (JB), 10 cs (AMC), and 10 cs (GEP, Set Two), 8 cs (JB), and 11 cs (AMC). [p] appears to be significantly longer in *it's praise* than in *it sprays*, where /p/ has a medial allophone.

The duration and type of the release of [p] appears to be the most significant clue. While [p] is followed by a period of aspiration in *praise*, which takes the form of a voiceless [r], there is no such aspiration present in *sprays*, where a voiced [r] follows immediately after the brief period of frication associated with the release of an unaspirated plosive. The duration of the aspiration (voiceless [r]) was 6 cs (GEP, Set One), 8 cs (JB), 4 cs (AMC), and 4 cs (GEP, Set Two), 3 cs (JB), 4 cs (AMC); the releases in *it sprays* were less than two centiseconds in all cases, amounting to no more than a weakening of the intensity of the first one or two vocal fold flaps.

The longer duration of the initial [s], combined with the voiced onset of [r] (lack of aspiration) appears to have been the sufficient clue for the high degree of identification.

3.6 *keep sticking – keeps ticking*

Figure 5 represents the utterances *keep sticking – keeps ticking* spoken by informants GEP and AMC. Broad-band spectrograms of Sets One and Two are presented. (Spectrograms for JB are not reproduced.)

The sets were identified with complete agreement (40 out of 40) for GEP and JB; 39 out of 40 listeners identified the contrastive pairs uttered by AMC correctly.

A = keep sticking
B = keeps ticking

Fig. 5. Broadband spectrograms of *keep sticking* – *keeps ticking*, spoken by informants GEP and AMC.

The duration of [s] in *keep sticking* was 10 cs (GEP, Set One), 10 cs (JB), 12 cs (AMC), and 12 cs (GEP, Set Two), 6 cs (JB), 8 cs (AMC); in *keeps ticking*, the duration of [s] was 12 cs (GEP, Set One), 5 cs (JB), 5 cs (AMC), and 8 cs (GEP, Set Two), 5 cs (JB), and 5 cs (AMC). It appears that in all cases except one (GEP, Set One) the duration of the initial [s] was considerably greater than that of the final [s].

The duration of [t] in *keep sticking* was 8 cs (GEP, Set One), 6 cs (JB), 6 cs (AMC), and 4 cs (GEP, Set Two), 8 cs (JB), 6 cs (AMC); in *keeps ticking*, the duration of [t] was 10 cs (GEP, Set One), 9 cs (JB), 6 cs (AMC), and 10 cs (GEP, Set Two), 7 cs (JB), and 6 cs (AMC). It appears that the initial [t] is longer than the medial [t] in 3 instances, shorter than medial [t] in 1 instance, and has the same length in 2 instances (all utterances by AMC). There is perhaps a slight informational value to the longer duration of the initial [t].

The most significant factor appears the aspiration *versus* lack of aspiration of the [t] in the two contrastive pairs. Initial [t] is followed by a period of aspiration, whose duration is 6 cs (GEP, Set One), 5 cs (JB), 5 cs (AMC), and 6 cs (GEP, Set Two), 4 cs (JB), and 6 cs (AMC); in *keep sticking*, where [t] is unaspirated, the releases are uniformly below 2 cs long.

The aspiration cue was present in all utterances, and therefore should probably be considered the primary cue. The duration of the initial allophones of /s/ and /t/ is probably a secondary cue. The identification was uniformly high regardless of the presence or absence of the secondary cues.

3.7 night-rate – nitrate – Nye trait

Figure 6 represents the three words and phrases uttered by informant GEP. Broad-band spectrograms and continuous amplitude displays of Sets One and Two are displayed. (Spectrograms for JB and AMC are not presented.)

The listeners identified *night-rate* correctly in 37 instances out of 40 for GEP; the confusion in three instances was with *nitrate*,

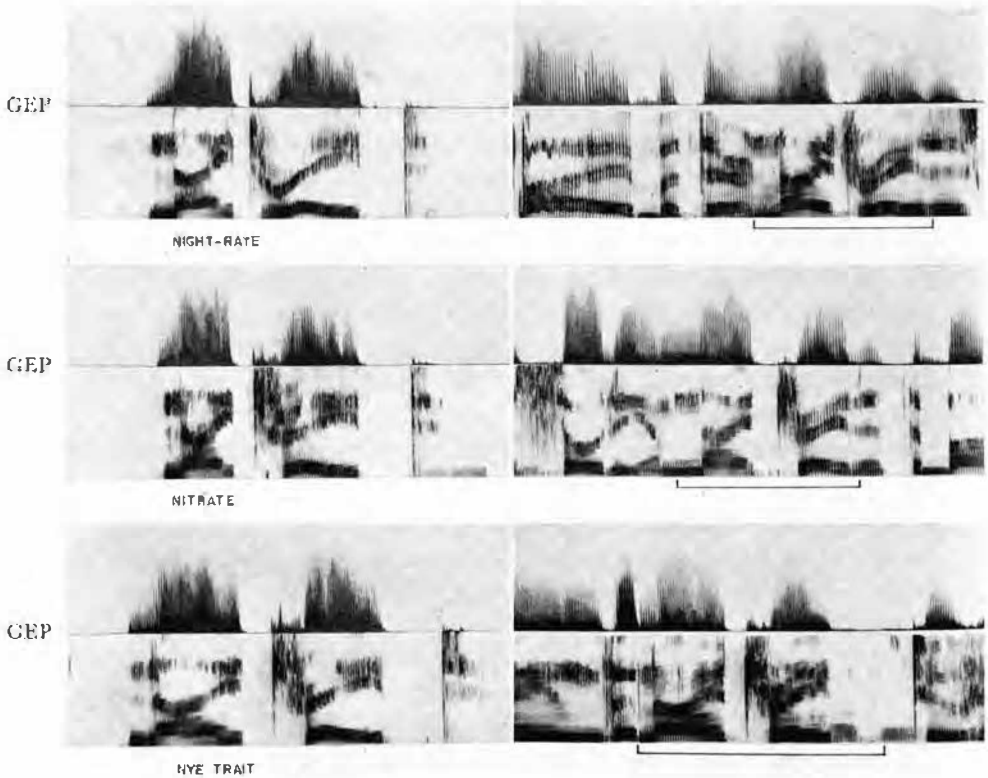

Fig. 6. Broad-band spectrograms and continuous amplitude displays of *night-rate – nitrate – Nye trait*, spoken by informant GEP.

which was also identified by 37 listeners, whereas *Nye trait* was identified correctly by all 40 listeners. In the case of speaker JB, *night-rate* was correctly identified 39 times, *nitrate* 37 times, and *Nye trait* 38 times. For speaker AMC, the identification of all three items was correct 39 times out of 40.

The durations of the segmental sounds were as follows. In *night-rate*, [aɪ] had the values of 18 cs (GEP, Set One), 18 cs (JB), 16 cs (AMC), and 18 cs (GEP, Set Two), 20 cs (JB), and 13 cs (AMC). The duration of [t] was 6 cs (GEP, Set One), 6 cs (JB), 5 cs (AMC), and 3 cs (GEP, Set Two), 6 cs (JB), and 7 cs (AMC). The release following [t] lasted 4 cs (GEP, Set One), 6 cs (JB), 5 cs (AMC), and 3 cs (GEP, Set Two), 2 cs (JB), and 2 cs (AMC). In the case of informant JB, the brief fricative release was followed by a glottal stop lasting 3 cs. The sequence [reɪ] started fully voiced in each case, regardless of the duration of the release of [t]; the sequence lasted 30 cs (GEP, Set One), 29 cs (JB), 29 cs (AMC), and 20 cs (GEP, Set Two), 19 cs (JB), and 15 cs (AMC).

In *nitrate*, [aɪ] had the duration 17 cs (GEP, Set One), 16 cs (JB), 14 cs (AMC), and 16 cs (GEP, Set Two), 14 cs (JB), and 13 cs (AMC). The [t] lasted 7 cs (GEP, Set One), 7 cs (JB), 6 cs (AMC), and 8 cs (GEP, Set Two), 8 cs (JB), and 6 cs (AMC). The [t] was followed by a period of aspiration in the form of a voiceless [r] in all instances. The aspiration lasted 9 cs (GEP, Set One), 6 cs (JB), 6 cs (AMC), and 6 cs (GEP, Set Two), 6 cs (JB), and 6 cs (AMC). Since most of the duration of [r] is voiceless, the sequence [reɪ] becomes comparable with the corresponding sequence in *night-rate* only when the duration of the voiceless [r] is added to the duration of the [eɪ]. The duration of the sequence [reɪ] was 9+25 cs (GEP, Set One), 9+22 cs (JB), 6+17 cs (AMC), and 16+16 cs (GEP, Set Two), 6+10 cs (JB), and 6+14 cs (AMC).

In *Nye trait*, [aɪ] lasted 28 cs (GEP, Set One), 29 cs (JB), 34 cs (AMC), and 22 cs (GEP, Set Two), 28 cs (JB), and 26 cs (AMC). The duration of [t] was 10 cs (GEP, Set One), 7 cs (JB), 6 cs (AMC), and 7 cs (GEP, Set Two), 5 cs (JB), and 6 cs (AMC). The [t] was followed by a period of aspiration (voiceless [r]), lasting 11 cs (GEP, Set One), 8 cs (JB), 8 cs (AMC), and 8 cs (GEP, Set Two), 11 cs (JB), and 8 cs (AMC). The duration of the sequence [reɪ] was 11+25 cs (GEP, Set One), 8+26 cs (JB), 8+23 cs (AMC), and 8+20 cs (GEP, Set Two), 11+18 cs (JB), and 8+13 cs (AMC).

It appears that the differences between the three items can be associated with four factors. One is the duration of the [t]: initial [t] in *trait* appears rather consistently somewhat longer than the final [t] in *night*. This is perhaps a rather insignificant difference. The aspiration cue appears to be the primary factor separating *night-rate* from the two other items: [r] is voiced in *night-rate*, whereas the aspiration of [t] in *nitrate* and *Nye trait* devoices the [r] in those two words almost completely. The third factor, the one separating *Nye trait* from both *night-rate* and *nitrate*, is the duration of the [ɑɪ]. In both the latter phrases, [ɑɪ] is considerably shorter than in *Nye trait*. This is accompanied by a characteristic distribution of the energy over the [ɑɪ]: in the case of *Nye*, [ɑɪ] has the relatively fast rise and slow decay in energy associated with a word ending in a vowel or diphthong – in other words, the energy pattern associated with a final allophone, whereas in *night* and in *nitrate*, the energy pattern on [ɑɪ] is that of a medial allophone of a vowel and diphthong.

Thus it appears that in *night-rate* the juncture is preceded by a final allophone of /t/, followed by an initial allophone of /r/; in *Nye trait*, the juncture is preceded by a final allophone of the diphthong /ɑɪ/, and followed by an initial allophone of /t/. In *nitrate* a non-final allophone of /ɑɪ/ is followed by what phonetically is essentially an initial allophone of /t/. The implications that arise from this fact will be treated in the following chapter.

3.8 plum pie – plump eye

Figure 7 represents the two phrases *plum pie* and *plump eye* uttered by informant AMC. Broad-band spectrograms and continuous amplitude displays of both sets are presented. (Spectrograms for GEP and JB are not reproduced.)

The utterances were identified with complete accuracy (40 listeners out of 40) for all three speakers.

The significant durational differences were as follows. In *plum pie*, the duration of [m] was 13 cs (GEP, Set One), 9 cs (JB), 19 cs (AMC), and 12 cs (GEP, Set Two), 11 cs (JB), and 14 cs (AMC). The duration of [p] was 4 cs (GEP, Set One), 5 cs (JB), 6 cs (AMC), and 4 cs (GEP, Set Two), 4 cs (JB), 4 cs (AMC). The [p] was followed by a period of aspiration, which lasted 8 cs (GEP, Set One), 4 cs (JB), 4 cs (AMC), and 4 cs (GEP, Set Two), 6 cs (JB), and 4 cs (AMC).

In *plump eye*, [m] had the duration of 4 cs (GEP, Set One),

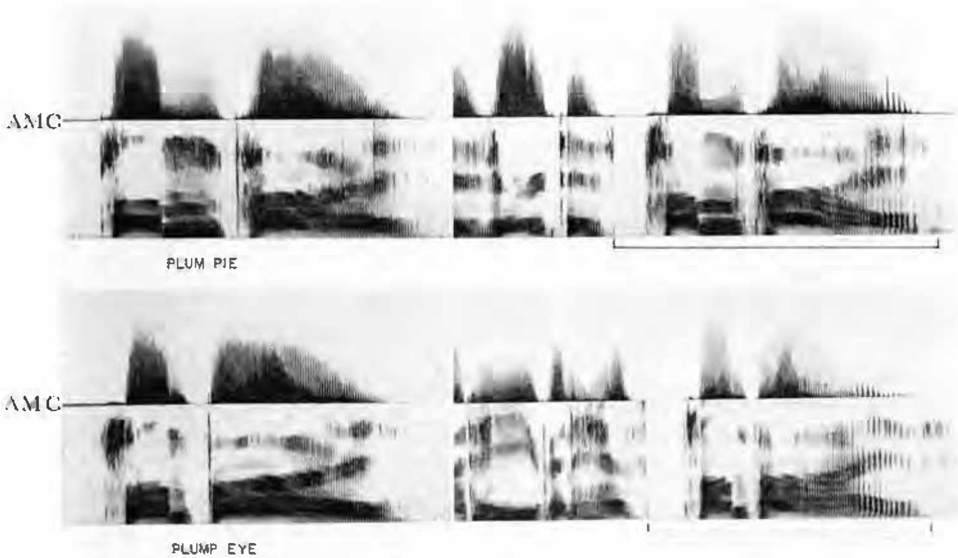

Fig. 7. Broad-band spectrograms and continuous amplitude displays of *plum pie – plump eye*, spoken by informant AMC.

4 cs (JB), 6 cs (AMC), and 4 cs (GEP, Set Two), 4 cs (JB), 4 cs (AMC). [p] lasted 7 cs (GEP, Set One), 4 cs (JB), 6 cs (AMC), and 4 cs (GEP, Set Two), 4 cs (JB), and 4 cs (AMC).

The [p] was followed by either a complete glottal stop or by laryngealization of the following vowel in 4 cases out of 6. GEP had a full glottal stop, lasting 8 cs, in Set One, and a 2 cs glottal stop in Set Two. JB had a 9 cs long laryngealization period in Set One, a glottal stop of 4 cs followed by a 6 cs long period of laryngealization in Set Two. However, AMC had neither a glottal stop nor a laryngealized vowel onset in either set; the release of the [p] was shorter than 2 cs in both cases. In the case of the utterances of AMC, it appears then that the glottal stop was no factor in the 100% correct identification achieved by the listeners.

The most significant clue appears to be the durational difference of [m], which is quite prominent in the illustrated set, and the presence *versus* absence of aspiration of [p].

3.9 see lying – seal eyeing

Figure 8 represents the pair *see lying – seal eyeing*. Figure 8 contains broad-band spectrograms and continuous amplitude displays

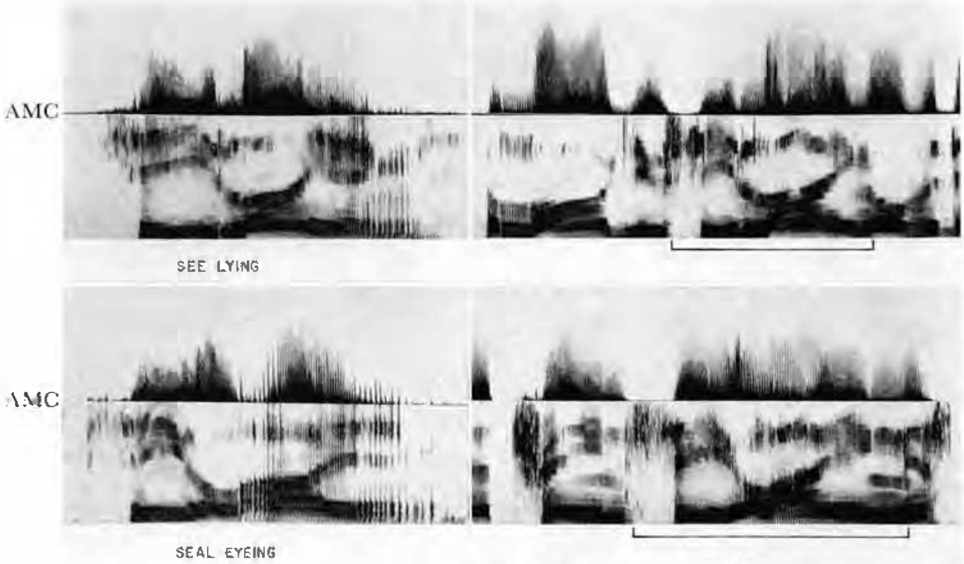

Fig. 8. Broad-band spectrograms and continuous amplitude displays of *see lying – seal eyeing*, spoken by informant AMC.

of the two phrases in both sets uttered by AMC. (Spectrograms for GEP and JB are not presented.)

The members of the pair were correctly identified by 40 listeners for the utterances of GEP and JB, and by 39 out of 40 listeners for AMC.

The segmental durations were as follows. In *see lying*, [i] lasted 14 cs (GEP, Set One), 12 cs (JB), 25 cs (AMC), and 12 cs (GEP, Set Two), 10 cs (JB), and 12 cs (AMC). The duration of [l] was 8 cs (GEP, Set One), 8 cs (JB), 8 cs (AMC), and 6 cs (GEP, Set Two), 8 cs (JB), and 8 cs (AMC).

The corresponding durations for *seal eyeing* were as follows. [i] lasted 14 cs (GEP, Set One), 12 cs (JB), 20 cs (AMC), and 14 cs (GEP, Set Two), 14 cs (JB), and 18 cs (AMC). It was rather difficult to ascertain the exact boundary between [i] and the final [l]; perhaps the most significant clue for this segmentation is provided by the intensity pattern, where [l] consistently has more energy than [i]: the formant transition signifying the articulatory change from an [i]-position to the position of the velarized allophone of /l/ is accompanied by a rather abrupt rise in intensity. The duration of the [l], then, was 14 cs (GEP, Set One), 16 cs (JB), 14 cs (AMC), and 12 cs (GEP, Set Two), 14 cs (JB), and 12 cs (AMC). The [l] was followed by a period of laryngealization in all occurrences of the phrase in Set One, but in only one instance in Set Two. The duration of the laryngealization was 8 cs (GEP, Set One), 10 cs (JB), 10 cs (AMC), and 10 cs (JB, Set Two); in Set Two, GEP and AMC had no glottal stop or laryngealization.

Additional differences were observed in the formant structure of the [l] and in the intensity patterns. In *see lying*, the first formant of [l] was consistently lower than in *seal eyeing:* F_1 had values of 400 cps (GEP, Set One), 350 cps (JB), 400 cps (AMC), and 400 cps (GEP, Set Two), 400 cps (JB), and 400 cps (AMC) in the first phrase, whereas in the second phrase, F_1 was located at 500 cps (GEP, Set One), 500 cps (JB), 400 cps (AMC), and 500 cps (GEP, Set Two), 550 cps (JB), and 500 cps (AMC). In both phrases, the second formant of [l] started close to the second formant position of [i], but in *see lying*, the second formant of [l] became stationary at approximately 1200 cps, whereas in *seal eyeing*, the second formant descended to approximately 800 cps. The exact values were as follows. In *see lying*, F_2 of [l] moved from 1400 cps to 1200 cps (GEP, Set One), 1600 to 1200 cps (JB), 1600 to 1300 cps (AMC), and 1400 to 1200 cps (GEP, Set Two), 1400 to 1100 cps (JB), 1400 to 1300 cps (AMC). In *seal eyeing*, F_2 of [l] moved from 1400 cps to 800 cps (GEP, Set One), 1800 cps to 900 cps (JB), 1200 to 800 cps (AMC), and 1200 to 800 cps (GEP, Set Two), 1250 to 900 cps (JB), and 1100 to 1000 cps (AMC).

The intensity on [l] was clearly rising for the initial [l] allophone in all instances, and falling on the final [l] in all instances.

Although the final allophone of /l/ thus appears longer than the initial allophone, the other phonetic characteristics of the two allophones are prominent enough to cause a remarkably high rate of correct identification.

3.10 see Mabel – seem able

Broad-band spectrograms and continuous amplitude displays of the pair *see Mabel – seem able* for both sets uttered by informant JB are presented in figure 9. (Spectrograms for GEP and AMC are not reproduced.)

The pairs were identified correctly by all 40 listeners for GEP and JB, and by 37 out of 40 listeners for AMC.

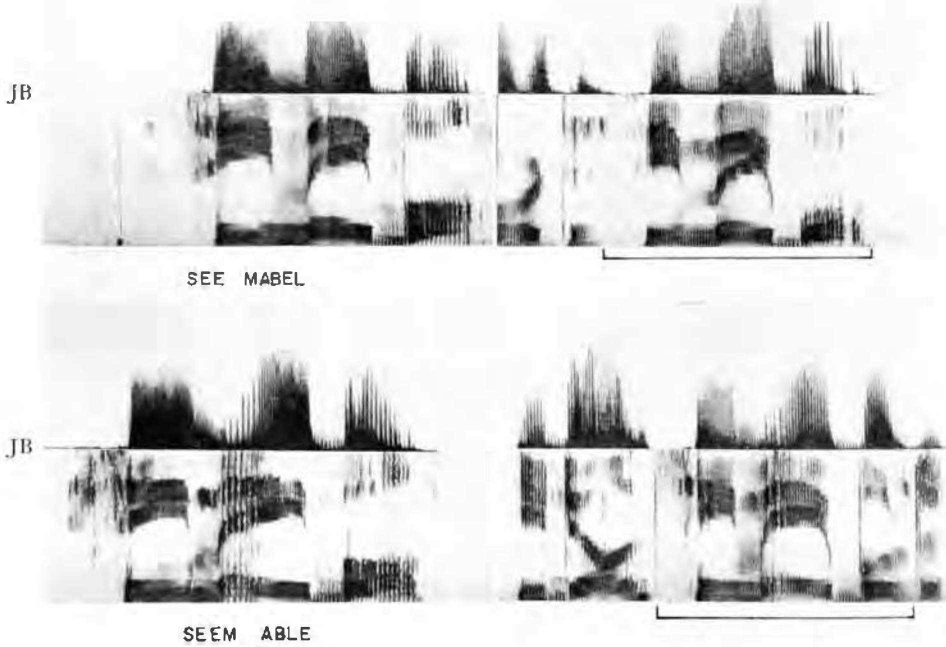

Fig. 9. Broad-band spectrograms and continuous amplitude displays of *see Mabel* – *seem able*, spoken by informant JB.

The segmental durations were as follows. In *see Mabel*, [i] had values of 13 cs (GEP, Set One), 13 cs (JB), 16 cs (AMC), and 9 cs (GEP, Set Two), 8 cs (JB), and 14 cs (AMC). [m] lasted for 11 cs (GEP, Set One), 9 cs (JB), 8 cs (AMC), and 9 cs (GEP, Set Two), 8 cs (JB), and 10 cs (AMC).

In *seem able*, the duration of [i] was 12 cs (GEP, Set One), 14 cs (JB), 20 cs (AMC), and 10 cs (GEP, Set Two), 9 cs (JB), and 9 cs (AMC). The duration of [m] was 8 cs (GEP, Set One), 7 cs (JB), 9 cs (AMC), and 5 cs (GEP, Set Two), 6 cs (JB), and 5 cs (AMC). While there appears to be no significant difference between the two sets in the duration of [i], the initial [m] allophone is consistently longer than the final [m] allophone.

The final [m] is followed by a period of laryngealization in four instances out of 6. The laryngealization occurred in all three utterances in Set One, having the values of 8 cs (GEP), 10 cs (JB), and 10 cs (AMC); in Set Two only informant JB had a 5 cs period of laryngealization.

The intensity on [m] in *see Mabel*, Set One, was rising for GEP, level for JB, slightly rising for AMC. In Set Two, the intensity on [m] was level for all three informants. In *seem able*, the intensity was falling in all six utterances of the three informants.

The main clue for differentiating between the two members of this pair appears to be the difference in duration between the initial and final allophones of the /m/. Additional clues are the presence of laryngealization in the majority of occurrences of *seem able*, and the falling intensity regularly associated with the final [m] allophone.

3.11 two lips – tulips

Figure 10 represents broad-band spectrograms and continuous amplitude displays of the pair *two lips – tulips*, uttered by speaker AMC. Both the set of contrastive pairs and the set of utterances in context are presented. (Spectrograms for GEP and JB are not reproduced.)

All 40 listeners identified correctly the contrastive pair uttered by GEP; the utterances of JB and AMC were correctly identified by 39 listeners out of 40.

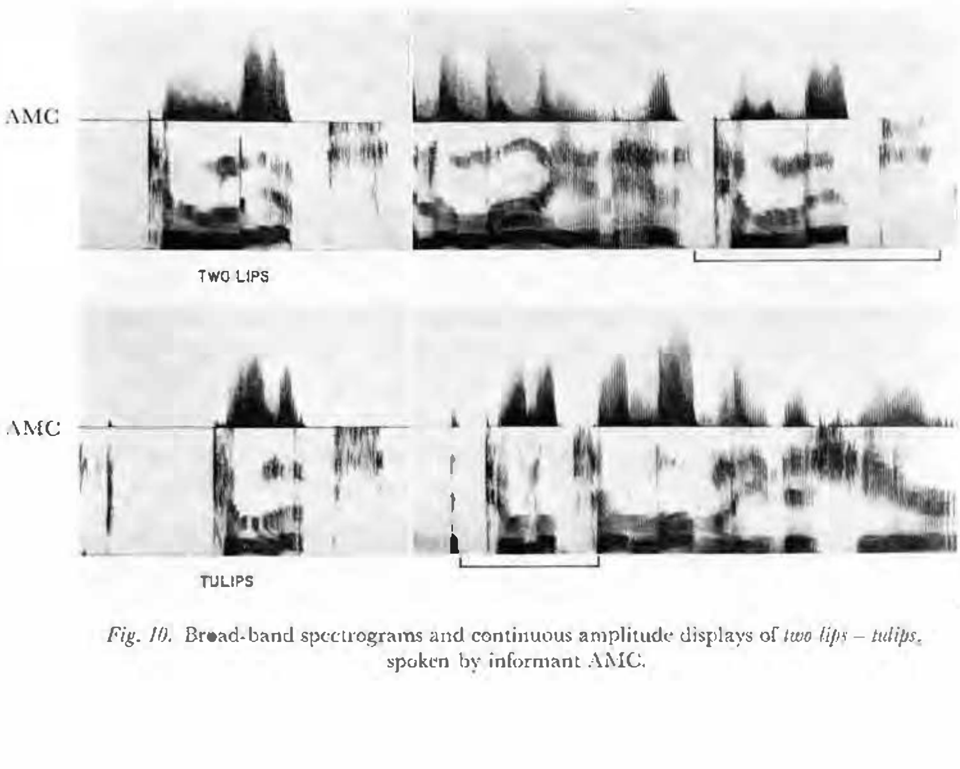

Fig. 10. Broad-band spectrograms and continuous amplitude displays of *two lips – tulips*, spoken by informant AMC.

The segmental durations were as follows. In *two lips*, the [u] lasted 6+13 cs (GEP, Set One; the two numbers refer to the period of aspiration following the initial [t] plus the period of clearly phonated [u]), 6+18 cs (JB), 4+17 cs (AMC), and 4+12 cs (GEP, Set Two), 6+11 cs (JB), and 4+14 cs (AMC). The duration of [l] was 8 cs (GEP, Set One), 8 cs (JB), 6 cs (AMC), and 8 cs (GEP, Set Two), 7 cs (JB), and 9 cs (AMC).

The corresponding durations in *tulips* were the following. [u] lasted 6+10 cs (GEP, Set One), 4+11 cs (JB), 4+11 cs (AMC), and 6+10 cs (GEP, Set Two), 4+10 cs (JB), and 3+8 cs (AMC). The duration of [l] was 6 cs (GEP, Set One), 6 cs (JB), 5 cs (AMC), and 6 cs (GEP, Set Two), 4 cs (JB), and 3 cs (AMC).

A significant durational difference appears associated with both [u] and [l]. In *two lips*, the [u] is, on the average, five centiseconds longer than in *tulips*, their ratio being 19/14.5; the [l] in the phrase *two lips* has an average duration of 8 cs, that in *tulips* 5 cs, with a ratio of 8/5.

The formant structure of the occurrences of [l] in the two different words showed no significant difference. The values of F_1 and F_2 for [l] in *two lips* were 400 and 1200 cps (GEP, Set One), 400 and 1100 (JB), 400 and 1150 (AMC), and 400 and 1200 (GEP, Set Two), 400 and 1300 (JB), and 400 and 1050 (AMC). In *tulips*, the values were 400 and 1200 (GEP, Set One), 400 and 1100 (JB), 400 and 1000 (AMC), and 400 and 1200 (GEP, Set Two), 400 and 1100 (JB), and 350 and 1100 (AMC).

The distribution of intensity over the [u] showed a rather regular pattern associated with the two phrases. In *tulips*, there was a considerable increase in overall energy toward the end of the [u], whereas in *two lips*, the energy was greater during the first half of the total length of [u]. This "left-handed peak" in intensity appears associated with most words ending in a long vowel or diphthong. It appears, then, that in *two lips* a final allophone of /u/ is directly followed by an initial allophone of /l/, whereas in *tulips* a medial allophone of /u/ is followed by a medial allophone of /l/.

3.12 *white shoes – why choose*

Figure 11 represents broad-band spectrograms of the pair *white shoes – why choose* uttered by all three informants in both sets.

The contrastive pairs uttered by GEP and AMC were correctly

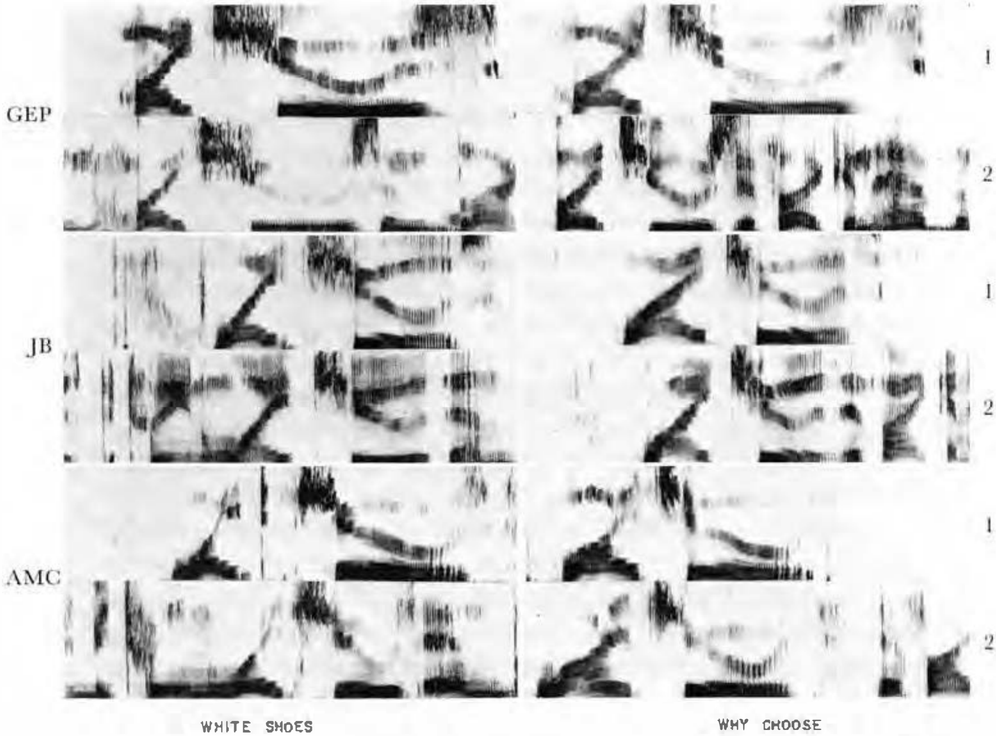

Fig. 11. Broad-band spectrograms of *white shoes – why choose*, spoken by informants GEP, JB, and AMC.

identified by all 40 listeners; the pair spoken by JB was identified by 39 listeners out of 40.

The duration of the sequence [waɪ] in *white shoes* was 24 cs (GEP, Set One), 17 cs (JB), 22 cs (AMC), and 23 cs (GEP, Set Two), 28 cs (JB), and 24 cs (AMC). The duration of [t] was 7 cs (GEP, Set One), 10 cs (JB), 7 cs (AMC), and 4 cs (GEP, Set Two), 8 cs (JB), and 4 cs (AMC). The [ʃ] lasted 20 cs (GEP, Set One), 17 cs (JB), 12 cs (AMC), and 16 cs (GEP, Set Two), 11 cs (JB), and 14 cs (AMC). Informant AMC used an unaspirated [t], followed by fricative release of less than 2 cs and a glottal stop of 8 cs in *white shoes*.

In *why choose*, the duration of the sequence [waɪ] was 30 cs (GEP, Set One), 26 cs (JB), 22 cs (AMC), and 20 cs (GEP, Set Two), 21 cs (JB), and 30 cs (AMC). The duration of [t] was 8 cs (GEP, Set One), 8 cs (JB), 6 cs (AMC), and 4 cs (GEP, Set Two), 6 cs (JB), and 6 cs (AMC). The [ʃ] lasted 13 cs (GEP, Set One), 10 cs (JB), 10 cs (AMC), and 9 cs (GEP, Set Two), 8 cs (JB), and 10 cs (AMC).

The intensity pattern of [wɑɪ] seemed significantly different. In *white shoes*, there was a rising-falling intensity on [ɑɪ] that was rather evenly distributed; the slight fall that did occur is probably attributable to the considerable difference of intrinsic energy associated with the two members of the diphthong. Allowing for the smaller intrinsic energy of [ɪ], the pattern is actually rising, i.e., energy is increasing during the production of the diphthong. In *why choose*, on the other hand, there is a quick rise in energy followed by a long period of gradual decay which starts already during the [ɑ] part of the diphthong. The characteristic left-hand peak in intensity identifies the diphthong in *why* as a final allophone contrasting with a medial allophone in *white*.

In addition to the intensity clue, the difference in the segmental duration of [ʃ] appears to be most significant. In *white shoes*, the average duration of [ʃ] is 15 centiseconds; in *why choose*, the average duration is 10 centiseconds. There is also a slight average difference in the duration of [wɑɪ] (25 cs in *why*, 23 cs in *white*). The final allophone of /t/ had an average duration of 7 cs, compared with an average initial duration of the [t] (in the sequence [tʃ]) of somewhat less than 6 cs. There is a question whether [t] may be called an initial allophone of /t/ here, since [tʃ] – without juncture in between – is commonly analyzed as a single phoneme in English. It is worth noticing, that the average duration of the [ʃ] here is considerably longer than the duration of the aspiration following an initial [t].

It appears, then, that the identification was based mainly on the different durations of the [ʃ] and the [ɑɪ], as well as the intensity patterns associated with [ɑɪ] in the two members of the contrastive pair.

4. The Phonetic Characteristics of Internal Open Juncture

4.1 The physical manifestation of juncture

It has been shown above that in a great majority of instances it is possible to demonstrate the existence of phonetic factors that indicate the presence of internal open juncture. The results of the listening test make it possible to associate certain of these phonetic factors with observed differences in linguistic interpretation. It may be concluded, therefore, that internal open juncture has a reality that can be described in physical terms. An attempt will be made in this chapter to furnish such a description.

4.2 Classification of bounded sequences

A given ordered set of phonemes may constitute a bounded sequence. In this case, the utterance starts with an initial allophone, which is followed by a sequence of medial allophones, and terminates in a final allophone. Initial, final, pre-junctural and post-junctural allophones will henceforth often be referred to as marginal allophones. The bounded sequence possesses certain duration and intensity characteristics peculiar to such entities; these will be described later in more detail. This type of sequence will be referred to in the following discussion as a sequence of Type I.

The same ordered set of phonemes may be uttered as two (or more) bounded sequences; in other words, a juncture may be introduced. Each of the bounded sequences now starts and ends with a marginal allophone. The introduction of internal open juncture results in a sequence where, at some point in the sequence, a final allophone is immediately followed by an initial allophone of the next phoneme in the sequence. In addition, both parts now have the intensity and durational characteristics of a bounded sequence. The point at which a final allophone is followed by an initial allophone is defined as the point of juncture; juncture, then, is a boundary between two bounded sequences. An utterance containing such a juncture (i.e. consisting of two bounded sequences) will be referred to as a sequence of Type II. Sequences of Type II may contrast with sequences of Type I. The pair *two lips* – *tulips* is an illustration of this kind of contrast, where the phrase *two lips* is a sequence of Type II, contrasting with the word *tulips* which constitutes a sequence of Type I.

In numerous instances, there are several points in a given sequence of phonemes where a juncture may be introduced, i.e. a sequence of segmental phonemes may be distributed among bounded sequences in several different ways. Contrasts of the type *it sprays – it's praise* are contrasts between sequences of Type II.

Sequences of Type III involve sequences of phonemes, where at some point a non-final allophone is immediately followed by an initial allophone. Such "half-open" internal junctures occur regularly in connection with a proclitic, unstressed indefinite or definite article or unstressed verbal prefix. It appeared clearly from the acoustic analysis of the data that members of a pair like *aboard* and *a board*, although different morphologically and lexically, are not differentiated phonetically: both contain a sequence of a non-final allophone of /ə/ followed by an initial allophone of /b/. In the isolated case where *a board* was pronounced [eɪ bɔ:rd], the [eɪ] appeared as an independent bounded sequence (Type II), and a contrast was established[33].

Sequences of Type III may contrast either with sequences of Type I, or with sequences of Type II. For example, *nitrate* is a sequence of Type III, where a medial allophone of /aɪ/ is followed by an initial allophone of /tr/. It contrasts with two sequences of Type II: in *Nye trait*, a final allophone of /aɪ/ is followed by an initial allophone of /tr/, whereas in *night-rate* a medial allophone of /aɪ/ is followed by a final allophone of /t/ to form a bounded sequence, and an initial allophone of /r/ starts a second bounded sequence.

In English, junctures of Type II may occur only at points where a final allophone of a phoneme of English is immediately followed by an initial allophone. It follows that a distribution of a sequence of segmental phonemes between different bounded sequences, resulting in a difference in juncture placement, is possible only when the phonemes and phoneme sequences in question may occur in English both as final and as initial sounds. Table III illustrates the sequences where junctures occurred in the tested materials.

In table III, the pre-junctural phoneme or phoneme cluster is indicated in the vertical columns, and the post-junctural phoneme or phoneme sequence appears in the horizontal rows. A dot in a

[33] *Einar Haugen* remarked in The syllable in linguistic description. 1956. p. 215. that *attire* and *a tire* are homonyms in his pronunciation. According to the present investigation, both constitute sequences of Type III, and are indeed identical with respect to internal open juncture.

Table III

Occurrence of Juncture in the Analyzed Material

POSTJUNCTURAL PHONEME or PHONEME CLUSTER (columns); PREJUNCTURAL PHONEME or PHONEME CLUSTER (rows)

	V	p	b	t	d	k	g	m	n	ŋ	f	v	θ	ð	s	z	ʃ	ʒ	r	l	č	ǰ	h	w	wh	y	sp	st	sk	spr	str	skr	pr	tr	kr	dr	fr	kl	kw	sw
V	•	•	•	•	•			•	•		•	•	•		•	•				•	•		•				•	•	•		•	•		•		•	•		•	
p	•																											•												
b	•																																							
t	•														•		•		•											•										•
d	•		•																																				
k			•																					•			•	•												•
g	•																																							
m	•	•			•			•																																
n	•			•	•						•				•								•													•		•		
ŋ	•																																							
f	•																																							
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θ	•																																							
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mp	•																																							
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ns	•																																							
ls				•																																				
lst	•																																							
ks'	•																																							
mt								•																																
lθ															•																									
lθs	•																																							
rm	•																																							
ksθ	•																																							

square signifies that the tested material included at least one example of that particular pre-junctural – post-junctural phoneme sequence. Of course, many more contrastive pairs could be constructed to fill some of the gaps on the chart; however, in a great number of instances the absence of examples is significant.

4.3 Phonetic properties of juncture: marginal allophones

It appears that there are two determining factors in deciding whether a juncture has occurred. One arises from the nature of the segmental allophones, the other from the overall intensity and duration pattern that characterizes the larger units between which the juncture forms a boundary. The marginal allophones will be discussed first.

Initial (post-junctural) allophones of almost all phonemes are considerably longer than either medial or pre-junctural allophones (final allophones may be drawled, and thus be longer than pre-junctural allophones). This feature of duration was observed with great regularity; therefore the theory associating internal open juncture with a lengthening of the pre-junctural allophone cannot be accepted, at least not until some actual evidence is offered to substantiate it. Furthermore, it was observed that there was a considerable durational difference between initial, medial, and final allophones of the same phoneme on one hand, and positionally equivalent allophones of different classes of sounds on the other hand. Initial sibilants, for example, last considerably longer than initial nasals; initial stop may have five times greater duration than a medial flapped /t/, which may last less than 2 centiseconds. The "average duration of a phoneme", associated with the *Joos-Hill* theory (see footnotes 30 and 31 above), thus becomes something of a fiction. The greater duration of an initial allophone was observed regularly in the speech of all three informants in both sets of data, and must therefore be considered a rather general characteristic of the initial allophone starting a bounded sequence.

English initial voiceless stops are aspirated. If the sound immediately following is a vowel, the aspiration takes the form of a voiceless segment of the vowel; if the following sound is /l, r, w/, or /y/, the aspiration appears as a voiceless segment of one of these sounds. In other words, in a sequence like *trait* (in *Nye trait*) there is no separate period of aspiration followed by an [r], but the [r] is devoiced for almost its whole duration. The same aspirated /t/, followed by voiceless /r/, occurs in *nitrate*. Neither the /t/ nor the /r/

have a medial allophone here, which necessitates assigning *nitrate* to Type III rather than to Type I.

A non-initial stop is usually unaspirated; a vowel or /l r w y/ starts immediately with full voicing after the release of the stop. The release involves an explosion and a period of frication, which, however, are normally shorter than two centiseconds, while aspiration durations of four to eight centiseconds appeared most common. The presence *versus* absence of aspiration appeared a very potent clue in keeping apart such pairs as *it sprays – it's praise*, *keep sticking – keeps ticking*, and a considerable number of others.

The medial allophones of /t/ and /d/ occupy a special position. The so-called "voiced /t/" appeared more often than not as only a brief reduction of the acoustic intensity during two or three (never less than two) vocal fold periods. A complete closure was present in a minority of instances; the duration of this medial /t/ was mostly only approximately two centiseconds, and the acoustic pattern was very similar to that of a flapped /r/. The medial allophone of /d/ was more frequently a brief voiced stop, but instances were observed where the contrast between medial /t/ and /d/ was completely obliterated (for example, in the pair *beef-eater – bee-feeder*). The flap never occurred in *Cato*, which must be considered an example of Type III: non-final allophone of /eɪ/ followed by an initial allophone of /t/. On the other hand, the /t/ in *get aboard* and *get a board* had a medial allophone in several instances, and therefore in those particular occurrences both phrases must be considered bounded sequences of Type III (since /b/ had an initial allophone in each case).

Initial voiced stops are considerably longer than initial voiceless stops. The voicing within a voiced stop decreases noticeably in energy before the plosive release, regardless of the position of the voiced stop within the sequence. The same decrease in energy was observed initially, medially, and finally. This observation contrasts with the general assumption that the energy increases toward the end of the initial voiced stop, as illustrated, for example, in the *Haskins* painted spectrograms[34].

Initial allophones of fricatives are again longer than medial allophones; sibilants appear to have a certain intrinsic relative duration

[34] One recent example may be found on p. 123 of the paper "Effect of third-formant transitions on the perception of the voiced stop consonants" by *K. S. Harris*, *H. S. Hoffman*, *A. M. Liberman*, *P. C. Delattre*, and *F. S. Cooper*, J. acoust. Soc. Amer. *30*: 122–126 (1958).

that causes them to appear as longer than any other initial sound. The intensity within any continuant increases during the production of an initial allophone and decreases during a final allophone.

Initial allophones of nasals are usually longer than medial and pre-junctural ones. Medial /n/ may be as short as two centiseconds, corresponding in length to the flapped /t/. The length of final nasals depends considerably on the structure of the whole word: after a "short" or "checked" vowel (such as /ə/), the nasal is longer than after a "long" vowel (such as /i/). As mentioned above, the intensity pattern on all continuants is rising on initial allophones, falling on final allophones; however, in the case of nasals, almost completely level intensity patterns were occasionally observed in all positions except absolute final.

Initial /w/ is voiced, and there is a steady state (i.e. the formant positions remain constant) lasting approximately as long as an initial nasal or lateral. When /w/ follows an initial stop, the aspiration devoices the following /w/. Initial /r/ is voiced, with often a fricative onset. Initial /h/ is voiceless, medial /h/ voiced. /l/ is longer in initial position than in medial position, but final /l/ is often longer than the initial allophone. Initial /l/ has steady formants at approximately $F_1 = 400$ cps, $F_2 = 1200$ cps; final /l/ has F_1 and F_2 positions at approximately 500 cps and 800 cps, with a rather smooth glide from the second formant position of the preceding vowel. Final /l/ has a rather considerable amount of intrinsic relative intensity: when compared to a low-intensity vowel, such as /i/, the final allophone of /l/ regularly has a greater intensity than the preceding vowel[35].

In medial position there appear two kinds of allophones of /l/. While their formant structure resembles that of an initial allophone, the duration and intensity may differ considerably. One medial allophone of /l/ is similar in duration and intensity to a medial /n/ allophone, the other involves a rapid dip in energy and a flap-like movement. These flapped /l/ sounds occurred in the speech of all informants in contrast with non-flapped medial /l/ in the pair *holy* – *wholly*.

Initial vowels may either start with a gradual rise in intensity, or with a glottal stop followed by immediate onset of full energy.

[35] For an elaboration of the problem of intrinsic relative intensity of speech sounds, cf. *I. Lehiste* and *G. E. Peterson:* Vowel amplitude and phonemic stress in American English. J. acoust. Soc. Amer. *31:* 428–435 (1959).

In post-junctural position, this glottal stop may be realized as laryngealization. The term is used here to refer to irregular, slow vocal fold activity with considerably reduced overall energy. This type of laryngealized onset may last as long as ten centiseconds or even more, and still be heard as a glottal stop. Complete glottal stops at the beginning of a post-junctural vowel allophone were comparatively rare in the analyzed corpus.

Final vowels are lengthened and decay gradually in energy. Although in terms of assimilation, silence often acts as a voiceless consonant, in terms of duration it acts as a voiced consonant: the final drawl before silence is directly comparable to a final drawl before a voiced consonant. The term "drawl" applied to the terminal phase of a bounded sequence includes both increase in duration and decrease in energy.

The formant positions of vowels are also a contributing factor in determining whether they are initial or medial allophones, i.e. indicating whether the juncture falls before or after the consonant preceding the vowel[38]. It was observed that in pairs like *a nice man* – *an iceman*, the second formant of /a/ began considerably higher after /n/, when the word started with /n/ (at approximately 1700–1800 cps in *nice*) than when the /n/ was a final allophone and /a/ began the next bounded sequence (approximately 1300–1400 cps in *ice*). The cues present in formant positions deserve a separate, more thorough analysis.

A certain amount of variability in these cues was observed both from speaker to speaker and from utterance to utterance by the same speaker. No absolute durational values can be postulated, since the durations of various allophones are obviously a function of speaking tempo. The regularities, however, were great and consistent enough to associate them definitely with differences in juncture placement. It is hoped that a testing procedure can be developed to explore further the relative contribution of the various above-described phonetic features to the recognition of internal open juncture.

4.4 *Phonetic properties of juncture: characteristics of bounded sequences*

The term "bounded sequence" is used here to refer to an utterance that begins with sound features that characterize the

[38] *Bertil Malmberg* tested a similar hypothesis with respect to syllable boundary; cf. The phonetic basis of syllable division. Studia Linguistica 9: 80–87 (1955).

beginning of an utterance, and ends with sound features that characterize the end of an utterance. No marginal allophones occur within a bounded sequence; every bounded sequence begins and ends with a marginal allophone. The sound features that characterize a bounded sequence are, however, not definable in terms of initial and final allophones alone, since they may occur over an utterance that consists of only one phoneme. For example, /a/ may be a complete utterance, constituting what is here being called a bounded sequence, with a buildup and decay period that characterize it as such. If the conditions were definable in terms of initial and final allophones, /a/ then would have to be described as being an initial and final allophone at the same time, which is a misrepresentation of the data. Similarly, in a longer phrase that consists of several segmental phonemes, the features that characterize a bounded sequence are not restricted to the initial and final sounds of the sequence. Therefore, the bounded sequence itself is set up as a unit, having a characteristic set of features that determine its occurrence.

A bounded sequence consists of an initial phase, a body, and a terminal phase. The initial phase may have several phonetic characteristics, all or some of which may be present at any one time. In addition to the presence of an initial allophone, the initial phase is characterized by a rather rapid increase in articulatory energy (rapid in comparison to the decay in the terminal phase), expressed in its acoustic counterpart, an increase in acoustic intensity. The body of a bounded sequence usually contains an intensity peak, the extent and shape of which are determined by the intrinsic amplitudes of the sounds that comprise the sequence, and by the degree of stress applied to each part of the sequence. The terminal phase usually involves "drawling" – deceleration of tempo and decrease of energy – in addition to the presence of a final allophone at the end of the sequence. Allowing for the differences in intrinsic amplitude, the intensity peak may usually be located closer to the beginning of the sequence than to its end: the buildup of energy associated with the initial phase is usually accomplished faster than the decrease in energy associated with the terminal phase. Both the initial and the terminal phases usually extend over more than one sound.

5. The Phonemic Status of Internal Open Juncture: Conclusion

It has been a basic assumption during this study that the primary source of information about the occurrence or non-occurrence of junctures are the actual phonetic data. An attempt has been made to analyze the data, discover the underlying regularities, and to relate these findings to the reactions of native observers. Any interpretation of the findings should reflect actual data without omission of relevant details, distortion of facts, or misrepresentation of their internal relationships. There is often an interaction between the techniques that we develop and the methods of analysis that they suggest. Instrumental techniques not only allow us to verify our previous conjectures; they also suggest new abstractions which may find their place among the future units of descriptive linguistics[37]. As a result of the acoustic analysis, it appears now that a reinterpretation of the phonemic status of internal open juncture is necessary. An attempt is made below to offer such a reinterpretation.

The present study started as an attempt to discover whether there are acoustical clues to morpheme boundaries. In a number of utterances meaning appeared to be distinguished by contrastive placement of morpheme boundary. When such utterances were analyzed acoustically, it was discovered that although certain boundary features could be identified and described, the presence of such features seemed to be independent of the presence of morpheme boundaries. The boundaries characterized by features hitherto often called "junctural" appear to correlate rather significantly with word boundaries; the correlation with morpheme boundaries appears determined by the fact that lexical word boundaries do indeed often coincide with morpheme boundaries. In other words, such morpheme boundaries as are not at the same time also lexical word boundaries are not characterized by junctural features. Again, the juncture phenomena appeared not to be exclusively determined by lexical word boundaries: since a lexical word is often defined as a "minimal free form", and since, according to my analysis, junctures are boundaries between bounded sequences, there is a potential juncture at the lexical word boundaries, which may or may not be realized when the sequence of words is uttered. On the other hand, a lexical word may occasionally con-

[37] *Peter Ladefoged:* The function of a phonetics laboratory. Orbis 6: 211–219 (1957).

sist of more than one bounded sequence, thus containing an internal open juncture. The bounded sequence, then, appears as a significant phonological unit; *internal open juncture is here defined as the boundary between two bounded sequences.* The phonetic properties attributed to juncture are characteristics of initial and terminal phases of bounded sequences; internal open juncture is a point in time, not a phoneme in its own right. It follows then that there are no "allojunctures" of internal open juncture: the allophonic characteristics are a part of the units themselves, not of the boundary point between them. When no phonetic manifestations are present, there is no juncture (i.e. no boundary point between bounded sequences): zero allophones of internal open juncture, which are to account for morpheme boundaries, are expressly rejected within the system presented here.

To a certain extent, the present study confirms the view expressed by *Pike*[38] that language is structured simultaneously in several hierarchies. The bounded sequence appears clearly as a higher-leveled unit (than the phoneme) within the phonological structure of the language. The phonetic characteristics of the bounded sequence have been described; it remains to consider its phonemic status.

Although certain parts of the evidence presented in this paper might be used to postulate the existence of a "phonetic word", the bounded sequences still constitute distinctive units within the English phonological system. The distribution of phonemes within the sequence conforms to the phonotactic rules of English; there is no reason to assume that the general characteristics of bounded sequences, as described in chapter 4, could ever be found to exist in precisely the same configuration in any other language. The described sequences, while unquestionably phonological in nature, cannot be exhaustively described in reference to segmental phonemes alone. The bounded sequences have certain characteristics of duration and intensity which may be called suprasegmental, but this does not make the internal open juncture a suprasegmental phoneme: rather, the bounded sequence is a unit which is defined by the presence of a certain segmental (distributional and allophonic) and suprasegmental pattern. All segmental phonemes occur within bounded sequences; thus the bounded sequence

[38] *K. L. Pike:* Language in relation to a unified theory of the structure of human behavior; Parts I and II (Glendale, Calif. 1954 and 1955).

constitutes a phonetically manifested higher-level unit in the phonological structure of English.

Zusammenfassung

Die vorliegende Arbeit behandelt die phonetische und phonematische Natur der sogenannten «internal open juncture» im standardisierten amerikanischen Englisch. Die Hypothese eines kausalen Zusammenhanges zwischen Morphemgrenzen und der «internal open juncture» wird erwogen und verworfen. Die Untersuchung besteht aus einer experimental-phonetischen Bearbeitung eines ausgedehnten Testmaterials, 304 Einzelwörter und Phrasen umfassend. Magnettonbandaufnahmen des Materials, gesprochen je zweimal von drei Versuchspersonen, wurden spektrographisch analysiert. 25 von den Wörtern und Phrasen, als Minimalkontraste zusammengestellt und gesprochen von den drei Versuchspersonen, wurden von 40 Hörern beurteilt. Begründet auf der spektrographischen Analyse und den Hörerurteilen, wird die phonetische Natur der verschiedenen Arten von «internal open juncture» beschrieben und auf 11 Bildtafeln illustriert. Die Theorie wird vorgetragen, daß die «internal open juncture» einen Grenzpunkt zwischen zwei «bounded sequences» darstellt. Die «bounded sequences» sind phonologische Einheiten höheren Ranges als ein Phonem; obgleich die Grenzen der «bounded sequences» oft mit den Grenzen eines lexikalischen Wortes zusammenfallen, sind sie ausschließlich phonologisch bestimmt und stehen in keinem kausalen Zusammenhang mit Einheiten der morphologischen und grammatischen Hierarchien der Sprache.

Résumé

Le présent travail traite du caractère phonétique et phonématique (phonologique) de la soit-disante «internal open juncture» dans l'anglais-américain standardisé. L'hypothèse d'une connexion causale entre les limites de morphème et «internal open juncture» est considérée, mais rejetée. La recherche s'accomplit par l'examen, par le moyen de méthodes de phonétique expérimentale, des matériaux consistant en 304 paroles isolées et phrases. Les enregistrements magnétophoniques des matériaux, énoncés deux fois par trois sujets, sont analysés par spectrogrammes. Vingt-cinq des paroles et des phrases, rassemblées à titre de contraste minime et énoncées par trois sujets, sont jugées par 40 auditeurs. Le caractère phonétique des différents types de «internal open juncture» est décrit comme fondé sur l'analyse spectrographique et sur le jugement des auditeurs, et expliqué sur 11 illustrations. On propose la théorie que la «internal open juncture» représente la limite entre deux «bounded sequences». Les «bounded sequences» sont des unités phonologiques d'un rang supérieur à celui du phonème; bien que les limites d'une parole coincident fréquemment avec les limites d'une parole au sens lexicographique, ils sont quand même déterminés exclusivement par la phonologie et ne se trouvent en aucun rapport avec les unités des hiérarchies morphologiques et grammatiques de la langue.

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