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Length vs. tenseness in the perception of English vowels

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Abstract

This paper focuses on the role that vowel length has in the perception of vowels and how vowel length is treated in the literature. Length-based classifications of vowels are widely used, yet their usefulness and congruity with reality are not apparent. This paper aims to ascertain the validity of the tradition that ascribes the main difference between traditional pairs of vowels (e.g., /i/-/ɪ/) to length. This paper analyses and compares the approaches to vowel length and tenseness by Kenyon, Jones, and Gimson, thereby describing the rationales that constitute the British and American traditions. The former considers vowel length to be phonemic, whereas the latter only treats it as an allophonic variation. The paper also comprises a perception test with 15 non-native participants and 4 native participants. The test consists of 60 tokens; each section of 20 tokens comprises a set of four recorded words with tense and lax vowels that are manipulated to match each other's durations. The test shows that native speakers base their perception of vowels on quality only, whereas non-native participants rely on vowel length to differentiate between lax and tense vowels. The length-based classification of vowel pairs is not effective for the correct discrimination of vowel qualities. However, this vowel classification is still used because it simplifies the relationship between qualitatively similar vowel sounds.

Keywords: vowel length, vowel quality, vowel classification, tense, lax,

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Lindy Robinson recording the sets of words for the perception test in an isolation booth

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1. Introduction

Traditional vowel pairs are distinguished in terms of vowel length in the British tradition and in terms of tenseness in the American one. The former tradition ascribes to vowel length a phonemic property, and the latter understands tenseness in terms of muscular tension or phonotactic distribution.

Despite the numerous arguments against the British tradition, its use is still adopted, and its vowel classification into short and long units is still present. The effects of this interpretation of vowel length on vowel perception merit further research.

This paper aims to show how the length-based classification of vowels affects the perception of vowels. It also aims to analyse the main ideas that constitute each tradition and set them against each other. To this end, the study will summarise, analyse, and compare the treatments of vowel length and tenseness in three books by Jones, Gimson, and Kenyon. Secondly, the study will analyse the data from a perception test devised to elicit the relevance of vowel length to vowel perception. The test consists of 60 recordings of words with lax and tense vowels. The lax vowels are lengthened to the duration of their tense counterparts; similarly, the tense vowels are also lengthened and shortened. There are two groups of participants: 15 non-native English speakers, and 4 native English speakers.

The hypothesis in this study is that non-native speakers will perceive a different quality when vowels are lengthened or shortened; however, native subjects will not perceive different qualities in words with manipulated lengths.

2. Analysis of the Treatment of Vowel Length and Tenseness in the Literature

The following section comprises the analysis and summary of Jones' *An Outline of English Phonetics*, Gimson's *An Introduction to the Pronunciation of English*, and Kenyon's *American Pronunciation*, as well as comparisons with other works by British and American writers.

2.1. An Outline of English Phonetics

After indicating the main parameters by which vowels are classified, Jones introduces the concepts of tenseness and laxness. He defines vowel tenseness as the degree of muscular tension that is created in the tongue and lips when pronouncing vowels (Jones, 1956). He also indicates that "tense vowels are those which are supposed to require considerable muscular tension on the part of the tongue; lax vowels are those in which the tongue is supposed to be held loosely" (Jones, 1956, p. 39). Therefore, Jones' understanding of tenseness subsumes tenseness under the physiological, organic configurations that alter the quality of vowels. However, Jones disagrees with those authors who consider tenseness as a qualitative aspect of vowels (at least to the same extent that tongue-position and lip-rounding determine vowel quality). In fact, Jones (1956) challenges such claims about muscular tension having an important role in producing different sounds:

> The difference in quality between the English vowels in *seat* si:t, and *sit* sit is ascribed by some writers to a difference of tension (the vowel in *seat* being considered tense and the vowel in *sit* lax).
>
> > It is not by any means certain that this mode of describing the sounds really corresponds to the facts. (p. 39, italics in text)

The example that Jones provides illustrates the misleading distinction, based on muscular tension, that some writers draw between two vowel sounds (/i/ and /ɪ/).

According to Jones (1956) the vowel in "sit" differs from that in "seat" in that "the tongue is lowered and retracted from the 'close' position" (p. 39). This means that he understands the quality of these vowels to be determined by relative tongue-position instead of muscular tension. However, Jones also indicates that some authors identify the contrast in quality as one of tenseness, where the vowel in "seat" requires more muscular tension than that in "sit". Even though Jones admits that these vowels differ in muscular tension, he argues that the tense/lax distinction fails to account for the change in quality between the vowels /i/ and /ɪ/. Therefore, he disagrees with this description of vowel quality because it is not congruent with the facts.

Jones (1956) describes the length of a sound as "the length of time during which it is held on continuously in a given word or phrase" (p. 232). Therefore, he understands length as the duration during which the airstream is maintained without interruption in the during the phonation.

Despite mentioning many levels of length, Jones limits the range to two main degrees of length to accommodate a comprehensible, practical approach to sound length: long and short sounds.

These degrees of length are of special significance as regards the classification of vowel sounds in Southern English, for Jones (1956) pairs most monophthongs as single phonemes comprising qualitatively and quantitatively different vowel sounds. In other words, of the twelve English monophthongs that Jones identifies, eight belong to four different phonemes and differ in quality and quantity (short and long). Jones refers to

these phonemes as: “i-phoneme, ɔ-phoneme, u-phoneme, and ə-phoneme”, which comprise the pairs of vowels “long iː and short i, long ɔː and short ɔ, long uː and short u, and long əː and short ə” (Jones, 1956, p. 63), respectively. Therefore, Jones argues that the vowel inventory of Southern British English contains eight vowel phonemes, four of which are constituted by pairs of long and short vowel sounds.

Jones (1956) justifies the arrangement of different vowel sounds into single phonemes as follows:

> The tamber [quality] of the English short i differs considerably from that of the English long iː, but in this kind of English the difference in *tamber* always coincides with a difference of *length*; that is to say iː is always longer than i when surrounded by the same sounds and pronounced with the same degree of stress. (p. 63)

According to Jones, certain vowel sounds such as /i/ and /ɪ/ are conflated into single phonemes because their distinct qualities and quantities exhibit a systematic correspondence in Southern English. This means that the short vowels, such as /ɪ/, which differs in quality from /i/, will invariably be shorter than their longer counterparts when found in the same phonetic environments and sharing the same degree of stress. Therefore, Jones’ dichotomy between long and short vowels is predicated on the notion that quality and quantity are defining, inherent properties of most vowels in Southern English.

Although vowel sounds exhibit intrinsic, natural lengths, their actual length is ultimately determined by their surrounding sounds and stress (Jones, 1956). In this

respect, Jones lays out a series of rules that account for the possible phonetic environments that can alter the lengths of short and long vowels.

For instance, Jones (1956) claims that long vowels are shortened when they precede a voiceless consonant but are normally long when preceding a voiced consonant or in final position. Therefore, the voicing of the consonant affects the duration of the preceding long vowel sound.

Though to a lesser extent, the length of short vowels also varies according to the phonetic environment. Jones (1956) notes that short vowels are lengthened when followed by voiced consonants but remain short when followed by voiceless consonants. Moreover, Jones (1956) notes that stress also affects the length of long vowels. Firstly, Jones points out that the length of long vowels in stressed syllables is reduced when they precede an unstressed syllable.

2.2. American Pronunciation

In this regard, Kenyon indicates that his explanations about English phonology and phonetics are based mainly on his own American English variety from "the Western Reserve of Ohio" (Kenyon, 1956, p. vi); however, he also comments on other English varieties. Kenyon, nevertheless, remains circumspect in his treatment of English pronunciation, in that he eschews prescriptive judgements in favour of a descriptive approach to pronunciation, thus avoiding considerations of correctness of pronunciation.

Kenyon (1956) briefly explains tenseness in relation to tongue position and jaw opening when he compares the articulation of the vowels /i/ and /ɪ/. Kenyon states that in producing /ɪ/ "the tongue is lower and retracted a trifle [compared to /i/]" (p. 57). Additionally, Kenyon claims that these vowels may also differ in muscular tension

(tenseness): in producing /i/ the tongue is tenser than for /ɪ/. Thus, Kenyon understands vowel tenseness as the degree of muscular tension that is felt in the tongue when producing a vowel sound. However, he does not ascribe the main difference between these vowels to tenseness.

According to Kenyon (1956), other pairs of vowels also differ in the same terms as /i/-/ɪ/; namely, /e/-/ɛ/ and /u/-/ʊ/. These vowels differ in tenseness and tongue position; the first member of each pair is a tense vowel, whereas the second is a lax vowel. Kenyon, however, points out that the difference between the vowels in each pair is best described in terms of tongue position rather than muscular tension. In this respect, Kenyon observes that in contrast with the tense vowels, their lax counterparts have a lower position of the tongue, like the lax /ɪ/.

However, distinctions based on tenseness are less clear for lower vowels since they are more difficult to classify in terms of muscular tension (Kenyon, 1956). At any rate, Kenyon does not consider tenseness as important a feature as tongue position in distinguishing vowel sounds. In fact, Kenyon suggests that tongue position has a more significant bearing on vowel classification, since it accounts for the qualitative differences of vowels better than tenseness.

In general, Kenyon's observations on tenseness are limited to marginal comments that only highlight differences in muscular tension between certain vowels when relevant. For example, Kenyon (1956) differentiates between the vowels [ɚ] and [ɝ] in terms of tenseness (the former being lax and the latter tense) because their differences are best described in relation to muscular tension, since their tongue positions are similar.

By contrast, Kenyon's treatment of vowel length is more extensive. Kenyon (1956) identifies four levels of vowel quantity: "short, half-long, long, and overlong" (p. 62). Moreover, Kenyon notes that "these terms [short, half-long…] refer to the relative lengths of vowels uttered by the same speaker under the same conditions, not to absolute duration" (p. 62). Therefore, Kenyon understands vowel length as the duration of a vowel sound relative to its surrounding vowels; thus, the status of a vowel as short or long depends on the length of adjacent vowels. In this respect, Kenyon does not consider vowel length as a definite measurement of duration, whereby vowels can be independently classified as long or short. Instead, he understands it as a continuum whose ends are relative to the length of adjacent vowels.

Kenyon (1956) mentions that British and American varieties are subject to different laws of quantity and highlights that length in American English is generally not distinctive or significant. Kenyon et al. (1949) consider vowel length as distinctive when it is "used to distinguish from each other words otherwise alike" (p. xxvi). Therefore, Kenyon suggests that vowel quantity does not have the same bearing on the perception of vowels as quality, which is mainly defined by tongue position. In comparing the words "seat" and "sit", Kenyon exemplifies the difference between quality and quantity: while the former is the main factor in the distinction between the two words, the latter is not significant in distinguishing between the two.

Nevertheless, Kenyon et al. (1949) observe that vowel length is distinctive in some varieties of American English. In this respect, Kenyon et al. (1949) point out that some speakers distinguish "*halve* hæːv from *have* hæv by a longer æ, or *vary* vɛːrɪ from *very* by a longer ɛ" (p. xxvi). In the example that Kenyon gives, the words "halve" and "have" as well as "vary" and "very" are homophones in American English, and thus cannot be

distinguished by vowel quality only. This means that the words in each pair share the same vowel sound and speakers resort to other factors to interpret their meanings such as context. However, some speakers use vowel length as a contrastive feature (distinctively) between these words to distinguish their meanings and circumvent the homophony.

Nonetheless, the length of vowels is subject to great variation and is governed by what Kenyon (1956) terms "laws of vowel quantity" (p.62). In *American Pronunciation*, Kenyon describes four of these laws succinctly. Two of them are concerned with the effect of consonants on the length of a preceding vowel. For instance, Kenyon (1956) states that vowels are longer when they appear in final position or precede a voiced consonant; conversely, they are shorter when they precede a voiceless consonant. Kenyon also explains that vowels are longer when they appear in a stressed syllable, either open or closed, at the end of a word. However, vowels in stressed syllables are shorter when they precede an unstressed syllable.

2.3. An Introduction to the Pronunciation of English

Gimson partly shares the viewpoint of Jones with respect to many aspects of Received Pronunciation, particularly vowel length and the classification of vowels in terms of quality and quantity.

Gimson (1980) refers to tenseness as a "particular secondary stricture […] which may accompany the primary articulation" (p. 19). This explanation is congruent with Gimson's description of vowels, since he treats tenseness as a secondary, dependent feature of the articulation of vowel sounds (largely defined by tongue position). In this respect, Gimson understands tenseness as the degree of tension of the tongue that occurs

when pronouncing vowels, and thus as a physiologically defined variable in the articulation of sounds.

Moreover, Gimson (1980) suggests that, unlike vowel length, tenseness does not have a significant bearing on the distinction of vowel sounds. In describing vowel sounds, Gimson mainly indicates vowel tenseness to highlight differences in muscular tension in some pairs of vowels such as /i/-/ɪ/.

On the other hand, vowel length has an important role in Gimson's description of vowel sounds and their perception. In this respect, Gimson (1980) says, "[in] the English system […] we know that only two degrees of length [long and short] are linguistically significant and all absolute durations will be interpreted in terms of this relationship" (p. 28). Here Gimson refers to the significance of vowel length in the perception of vowels, which is closely related to his understanding of speech perception. In this sense, Gimson argues that an utterance contains a string of sounds or segments which manifest intricate and numerous acoustic features, which are stringently variable in nature. Gimson identifies these features as "sound quality", "pitch", "loudness", and "length".

As mentioned above, Gimson (1980) identifies two values of vowel length as linguistically meaningful: long and short. This means that listeners distinguish between long and short vowels to understand an utterance in a similar manner in which listeners discriminate between different patterns of intonation to distinguish between questions and statements. In this respect, Gimson considers vowel length as a phonemic contrast in pairs of vowels that differ in both quality and quantity.

For example, the vowel sounds /i/ and /ɪ/ in the words "bead" and "bid" are contrasted by quality and quantity; however, Gimson (1980) argues that "of the two

factors it is likely that quality carries the greater contrastive weight" (p. 97). Therefore, /i/ differs from /ɪ/ firstly because it has a fronter and closer tongue position, and secondly because its duration is longer than its counterpart in the same phonetic environment.

In describing vowel sounds, Gimson (1980) considers vowel length as a secondary, contrastive feature used largely to differentiate the general duration between two vowels in equivalent phonetic environments. In this respect, vowel length is determined by means of contrasting length patterns of related vowels. This means that a vowel is short because its counterpart is longer in duration in the same phonetic contexts. For example, Gimson considers that the vowel /i/ is longer than /ɪ/ when both are followed by a voiced consonant (e.g., "mead" and "mid", respectively).

With respect to vowel pairs, Gimson (1980) states that "[o]nly in the case of /ə/-/ɛː/ can there be said to exist an opposition solely of length […] In the other cases the opposition between the members of the pairs is a complex of quality and quantity" (p.97). Gimson acknowledges the relationship between quantity and quality that vowels exhibit in RP English. However, quality and quantity are greatly variable across pairs. For instance, in terms of quality the pair /i/-/ɪ/ is closer than /ɑ/-/æ/. In the former, both vowels are high and front, albeit more central in the case of /ɪ/; whereas in the latter, the vowels are opposite in terms of backness: /ɑ/ being a back vowel and /æ/ a front vowel.

According to Gimson (1980) the quantity distinction of some vowel pairs may be neutralised in some phonetic contexts. This is because of the great length variation to which vowels are subject. Gimson claims that long vowels may undergo greater durational changes than short vowels. The presence of a fortis or lenis consonant affects the duration of the preceding vowel: when followed by a fortis consonant the vowel is

shortened, whereas it is lengthened when followed by a lenis consonant. In this sense, Gimson argues that some shortened long vowels may coincide in duration with lengthened short vowels. For instance, the vowel sound /i/ may have a similar duration to the vowel /ɪ/, when they appear in the words “meat” and “mid”, respectively. The former is closed by a fortis consonant, thus shortening the long vowel, whereas the latter is lengthened by a lenis consonant.

Gimson’s approach to vowel length is predicated on the notion of length as a linguistically significant feature, albeit subordinate to vowel quality for most vowel sounds. Moreover, Gimson uses length marks in broad transcription to indicate the conventional duration attached to certain vowel phonemes and to differentiate them from their short counterparts.

2.4. Analysis of the sources

The approaches to vowel length and vowel tenseness by Jones, Kenyon, and Gimson discussed above reveal different degrees of similarity and discrepancy as regards the rationale behind vowel description and classification. They also differ significantly in the scope and role that length has in the distinction of vowels; in this sense, Jones and Gimson view vowel length as a contrastive, phonemic feature, while Kenyon only views length as an allophonic variation.

It is possible, therefore, to establish a correlation between English varieties and the approaches to vowel length that the three authors take. In this respect, Jones and Gimson discuss English pronunciation from a British tradition and approach vowel length as a distinctive aspect of vowels, although they differ in the relation between vowel

quality and quantity. On the other hand, Kenyon approaches English pronunciation from an American tradition and treats vowel length mainly as a suprasegmental feature.

Nevertheless, Jones, Gimson, and Kenyon seem to share a similar understanding of tenseness. In this regard, they consider tenseness to be a physiological variable that describes the degree of muscular tension of the tongue which accompanies the articulation of vowel sounds. Moreover, none of the authors consider vowel tenseness to be phonemically relevant and only provide supplementary information about tenseness when describing certain vowels.

Additionally, all authors agree that the differences of quality between such pairs as /i/-/ɪ/ and /u/-/ʊ/ are better described in terms of tongue position than in tenseness. Indeed, although the three authors point out that some writers see tenseness as a significant feature in the quality of vowels, they reject such views on tenseness. Moreover, the three authors consider that tenseness (as muscular tension) is more difficult to determine in the case of lower vowel sounds.

By contrast, vowel length represents a point of contention among the three authors even though they show some parallelisms in their arguments and viewpoints about vowel length.

Despite the numerous discrepancies in their arguments about vowel length, the three authors converge on one aspect of length: its prosodic property. In this respect, the authors agree that speakers use length to contrast, foreground, and stress syllables in a word. Therefore, all authors appreciate the role that length plays on a suprasegmental level, even though only Jones and Gimson ascribe to length a phonemic function in the perception of vowel.

Another point on which the three authors agree is allophonic length. All authors claim that vowel sounds are lengthened in syllables closed by voiced consonants (lenis consonants), but they are shortened when closed by voiceless consonants (fortis consonants). Moreover, they also agree that the number of unstressed syllables affects the length of the preceding vowel sound; in this sense, the stressed vowel will be shortened incrementally with every unstressed syllable that follows. Therefore, the three authors acknowledge the great variability in length to which vowels are subject in English.

Moreover, Kenyon, Jones, and Gimson differentiate between absolute duration and length of a vowel. They describe the former as a measurable, acoustic feature of a vowel sound which describes the time during which the sound is produced in a physical dimension. On the other hand, they understand vowel length as a phonological, linguistic interpretation of the duration of vowels in an utterance. While absolute duration can be measured exactly, vowel length is relative and shows no direct correspondence with absolute duration of vowels. In this respect, the authors agree that vowel length must be interpreted within the context of each utterance and in relation to the length of surrounding vowel sounds.

The discrepancy in the number of vowel lengths that the authors identify in notation may be due to the different functions that the authors ascribe to vowel length. For instance, Jones and Gimson (for British English) identify only two degrees of vowel length (short and long) because they consider these lengths to be significant for the perception and discrimination of vowel sounds. Specifically, short and long vowel lengths, like vowel quality, are contrastive features of phonemes; these vowel lengths sometimes accompany the contrast in quality between members of vowel pairs such as /i/-/ɪ/, referred to as long and short vowels, respectively. Therefore, Jones and Gimson see

in vowel length a phonemic property of the English vowels, although they estimate its contrastive weight differently, especially as regards its relationship with vowel quality. In this respect, Jones and Gimson encode vowel duration as a phonological category (vowel length), which comprises two discrete units of lengths: short and long vowel lengths.

However, Kenyon treats vowel length only as an allophonic variation and a supra-segmental feature. Therefore, in Kenyon's approach most vowel sounds do not exhibit natural, intrinsic lengths and only external factors such as stress placement and the voicing of following consonants determine the length of most vowel sounds. In this regard, Kenyon suggests that vowel length does not represent a phonemic contrast, and thus has no bearing on the perception of qualitatively different vowel sounds in American English.

Jones and Gimson classify vowel phonemes in terms of quality and quantity. However, Jones argues that quantity is the most significant distinctive aspect in distinguishing members of vowel pairs, whereas Gimson claims that quality is a more important distinctive feature.

Jones' rationale behind his classification of vowel phonemes is largely based on his notion of chroneme. According to Jones (1957), a chroneme is a significant unit of length of sound – especially vowel sound – and has the same codification as a phoneme. This means that a chroneme consists of different allochrones in complementary position and has a contrastive property.

Moreover, Jones identifies two types of chronemes: long and short chronemes, which distinguish between members of vowel pairs. For example, Jones (1956) describes

the members of such vowel pairs as /i/-/ɪ/ and /u/-/ʊ/ as being different chronemes of the same phoneme. In particular, the vowels /u/ and / i/ are the long chronemes of the u-phoneme and the i-phoneme, respectively; conversely, the vowels /ʊ/ and /ɪ/ are the short chronemes of their respective phonemes.

Jones suggests that vowel length accounts for the phonemic differences in certain vowels better than vowel quality. Specifically, the length dichotomy (short and long chronemes) that Jones proposes only applies to members of vowel pairs that share similar qualities and exhibit a correlation between length and quality – e.g., /iː/-/i/, /uː/-/u/, and /əː/-/ə/. In this sense, Jones considers the phonemes /æ/, /ɑː/, and /ʌ/ as comprising one single sound because they are not sufficiently similar in quality to other vowels and do not manifest a correlation between quality and quantity with other vowels.

In contrast with Kenyon and Gimson, Jones' approach to vowel length is marked by great abstraction. In this respect, Jones encodes vowel length as a phonological category in a phonemic dimension. This means that Jones treats vowel length as a contrastive property of segments and compartmentalises this property in discrete units: short and long chronemes. Neither Kenyon nor Gimson distinguishes between the two levels of chronemes in their descriptions of vowels; instead, they base their descriptions on qualitative considerations.

The phonemic notation of the three authors is revealing of their approaches to vowel length because it shows which phonological features (namely vowel quality and quantity) each author considers more significant on a phonemic level. For instance, Jones' phonemic notation exclusively accounts for the quantitative contrasts between phonemes (e.g., /iː/-/i/), whereas Gimson's notation expresses both qualitative and quantitative

contrasts between phonemes (e.g., /iː/-/ɪ/). This discrepancy shows how Gimson and Jones regard vowel quantity as a phonemic contrast, but they estimate its contrastive value differently. Jones considers vowel quantity to be more significant a feature than quality, hence the diacritic symbol [ː] as the sole contrast between phonemic symbols, whereas the reverse is true for Gimson, who shows contrasts of both quality and quantity, the former being of more importance.

Regarding the authors' rationales, the similarities and differences discussed above help define the dichotomy between the American and British traditions as regards the treatment of vowel length and its role in vowel perception.

Jones and Gimson belong to the British tradition and most of their explanations about English pronunciation are based on RP English. The coalescence of these authors into the same tradition is also warranted by their mutual interpretation of vowel length as a phonemic, contrastive feature. Moreover, their rationale for their interpretation of vowel length derives from the correlation between quality and quantity in numerous vowel pairs in RP English. This recurrence in the English vowels allows the authors of the British tradition to ascribe an intrinsic length to vowels, which are classified as short and long vowels according to their conventional length.

However, Gimson and Jones also appreciate the prosodic function that vowel length performs across segments. In this respect, Gimson and Jones understand vowel length as working both on a suprasegmental as well as a segmental level.

Secondly, Kenyon's approach to vowel length is representative of the American tradition because he treats vowel length exclusively as a suprasegmental feature, since it has no phonemic, contrastive value in American English – although some consider

quantity to be phonemic in that it changes the meaning of an utterance in the same manner as intonation (see Pike, 1949). In this respect, Kenyon describes vowel phonemes in terms of quality only, whereas he treats vowel quantity solely as an allophonic variation. Vowel phonemes are more often distinguished in terms of tenseness in the American tradition than in the British tradition (cf. Jones, 1957; Gimson, 1980). In this sense, Kenyon resorts to distinctions of tenseness when comparing phonemes more often than length because the latter is not an intrinsic feature of phonemes and is mostly dependent on context.

2.5. Comparison with other sources

The works by Jones, Gimson, and Kenyon discussed above are representative of the British and American approaches to vowel length and to its relationship with vowel quality.

Despite the many nuances and differences, most writers follow either the British or American tradition when they deal with vowel length as a phonemic or only allophonic feature, respectively. Moreover, writers of the American tradition tend to describe vowel sounds in terms of tongue position and regard vowel length as a secondary aspect of vowels.

Like Kenyon, Trager and Bloch (1942) classify vowels according to two parameters mainly: tongue position and lip rounding; length distinctions are incidental to the qualitative description of vowels. Trager and Bloch do not agree with the dichotomy between short and long vowels since it fails to account for the actual variability of vowel length. They argue that short and long lengths are two ends of a continuum, which cannot be defined exactly, and whose segmentation must serve a particular purpose.

For instance, Trager and Smith (1957) identify four levels of vowel length in their transcription because these levels reflect the numerous contexts in which a vowel is lengthened or shortened: in closed or open syllables, preceding voiced or unvoiced consonants, and in stressed or unstressed syllables.

Vowel length has been used in the British tradition to distinguish between members of vowel pairs; conversely, distinctions based on tenseness are more common in the American tradition. However, authors understand tenseness differently: Kenyon, for example, treats tenseness mainly as the degree of muscular tension or constriction, whereas other authors understand tenseness in phonotactic terms. For instance, Giegerich (1992) uses tenseness to account for the environments in which vowel phonemes can and cannot appear within a word: while tense vowels can appear in open and closed syllables, lax vowels can only appear in closed syllables.

Giegerich (1992) ascribes to tense vowels a specific quality that differentiates them from their lax counterparts. For example, Giegerich (1992) claims that "the tenseness of /u/ is manifested by greater rounding, height, backness" (p. 98). Although tenseness is not as precise a parameter as tongue position for describing vowels, it is convenient in that it can be used in discrete, abstract, units (tense/lax) that account for the broad qualitative contrasts and phonotactic constraints of vowels.

Indeed, the usefulness of tenseness as a phonological feature is well demonstrated especially as regards the distinction of qualitatively similar vowels. In this respect, Yavaş (2006) argues that some writers use tenseness by way of a solution to the similarity of some vowel pairs, which, if not distinguished in finer detail in terms of tongue position, risk being confused with one another. For example, the phonemes /i/ and /ɪ/ are often

described as high front unrounded vowels and distinguished solely by tenseness: the former being tense, and the latter lax.

This rationale of tenseness explains Kenyon's criteria behind his description of vowels. Kenyon does not refer to tenseness when dealing with such vowel pairs as /i/-/ɪ/ because he describes them as the high-front and lower high-front vowels, thus distinguishing them in terms of tongue position. However, he differentiates the vowel phonemes /ɜ˞/ and /ə˞/ as tense and lax vowels, respectively, because their qualities are very similar – more similar than /i/-/ɪ/, and thus more difficult to distinguish according to tongue position.

Vowel tenseness, understood as muscular tension, is difficult to measure, especially for low vowels (Durand, 2005). In fact, Jones, Gimson, and Kenyon fail to provide an accurate account of the physiological features that tenseness describes. However, some attempts have been made to represent the physical articulation of tense and lax vowels, most notably the system of advanced tongue root (Halle, 1977). According to Halle, this system could describe tense vowels as being articulated with a pharyngeal constriction caused by the advancement of the tongue root; conversely, lax vowels are produced with a retraction of the tongue root. Nevertheless, Halle points out that advanced tongue root does not correspond with the specific formant frequencies of vowels in English. Therefore, the advancement or retraction of the tongue root does not account for the qualitative differences between tense and lax vowels such as /i/-/ɪ/.

3. Perception Experiment

The following section focuses on the practical objective of this project. It explains the methodology adopted for the experiment and the structure of the perception test, as well as the results obtained from it and their analysis.

3.1. Methodology

The perception experiment aims to ascertain whether vowel length is a significant feature in the perception of vowels, and thus test the long-standing tradition that ascribes the main difference between such vowel pairs as /ɪ/-/i/ to vowel length. Additionally, this project also aims to elicit the role that vowel length has in the perception of the voicing of consonants in postvocalic positions through a perception test.

Therefore, this project intends to answer the following questions: does vowel length have a bearing on vowel perception? Does vowel length affect the perception of the voicing of the following consonant?

The project aims to test the hypothesis that vowel length affects the perception of vowel quality in the non-native group, but it does not affect the native group's perception of vowels in the perception test. Moreover, the paper also intends to test the hypothesis that vowel length affects the perception of the voicing of the following consonant for the native subjects.

3.1.1. Data collection

The paper adopts a mixed method for data analysis: it gathers qualitative and numerical information for the descriptive analysis of the results. The experiment consisted of a perception test comprising 60 tokens of monosyllabic CVC forms. The tokens analysed comprised three sets of four words, which contained tense and lax high

front vowels, and were manipulated in length. The words selected for the first group were *beat, bead, bit, bid*; the second group comprised the words *heat, heed, hit, hid*; and the third group contained the words *meat, mead, mitt,* and *mid*. In each of the groups, two words contained tense vowels closed by a voiced and unvoiced consonant, and the same was true for the other words containing lax vowels.

The words in each group were recorded by a native English speaker. The length of each of the words was then manipulated to different durations and with different purposes. For the words with lax vowels, their vowel lengths were lengthened to the same duration as their tense counterparts in such a way that lax vowels closed by voiceless and voiced consonants were lengthened to the same duration as the tense vowels closed by voiceless and voiced consonants, respectively. This length manipulation aimed to ascertain whether the perceptual difference between /ɪ/ and /i/ could be ascribed to length alone.

The second length manipulation consisted of the tense vowels. The vowel lengths of the tense vowels closed by voiceless consonants was lengthened to the same duration as the tense vowels closed by voiced consonants; conversely, the tense vowels closed by voiced consonants were shortened. Additionally, after the length manipulation, in another category, the aspiration of the resulting lengthened tense vowel closed by a voiceless consonant was removed; conversely, the aspiration was added to the shortened tense vowels closed by voiced consonants. These manipulations aimed to test the effect that vowel length has on the perception of the voicing of the following consonant.

The perception test comprised three groups of recorded words divided into three sections. Each section consisted of the four original words of one group, in addition to

the six manipulated words. These items were repeated and ordered randomly with a total of 20 items per section. Participants were asked to listen to the recordings and choose which of the four original words they understood in each of the recordings.

3.1.2. Subjects

The experiment gathered data from two groups of participants: 4 natives and 15 non-native subjects. The non-native group of participants were Spanish fourth-year students of the English BA at URV, whereas the native group were American graduate students at the same university. The answers from both groups were compared and analysed for patterns.

The undergraduate students had taken a course in phonetics and phonology of English, and thus understood the sound system of English and the classification of vowels and their qualities in terms of tongue position.

3.1.3. Instruments

The perception test was conducted on Microsoft Forms. The computer software *Praat* (Boersma & Weenink, 1992) was used for the acoustic analysis and manipulation of the items. The items wore recorded in a soundproof booth with a mobile phone.

3.2. Results

The results of the perception test are divided into three categories: the vowel perception of the original three groups of words, the perception of the lengthened lax vowels, and the perception of the lengthened and shortened tense vowels (as well as those with aspiration removed/added). In each of these categories different pie charts show the aggregate responses of both native and non-native subjects for all the items of each category.

3.2.1. Lengthened lax vowels

The total responses of the non-native group are represented in Figure 1 for those words with lax vowels that were lengthened to the same duration as their tense counterparts (e.g., “bit” to “beat” and “bid” to “bead”). Figure 1 shows disparity in the responses of the non-native group. Most of the subjects perceived the lengthened lax vowels (bit-bid, hit-hid, mitt-mid) as lax. However, 39% of the non-native subjects recognised the lengthened vowels as tense.

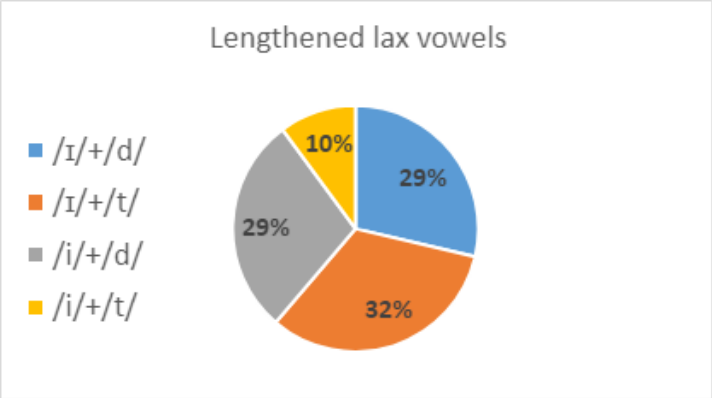

Figure 1. *Total responses of the non-native group for lengthened lax vowels. The legend represents the vowels and consonant perceived; the pie chart comprises all the lax vowels with length manipulation.*

Nevertheless, the responses of native speakers in Figure 2 stand in stark contrast to those of non-native subjects. All the native subjects recognised lengthened lax vowels as lax in all groups of words. In this sense, the responses of the native subjects exhibit a consistency and uniformity that is not present in the non-native group. For the native group, the lengthening of the lax vowels did not change the qualitative perception of the vowel; conversely, it altered the quality perception of some items for the non-native group.

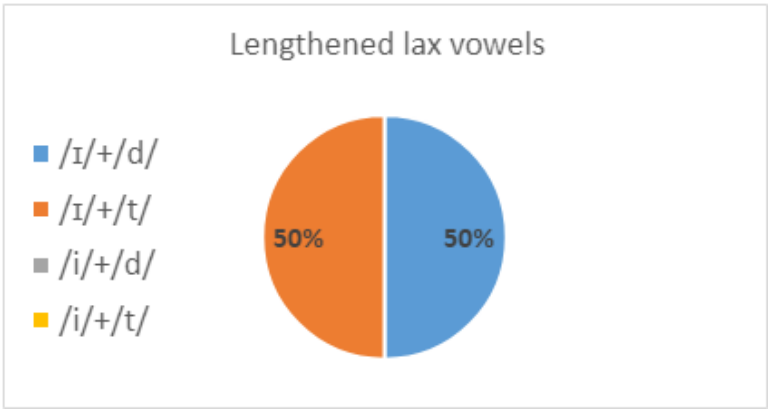

Figure 2. *Total responses of the native group for lengthened lax vowels. The legend represents the vowels and consonant perceived; the pie chart comprises all the lax vowels with length manipulation.*

3.2.2. Lengthened and shortened tense vowels

Figure 3 shows how most non-native participants perceived the lengthened tense vowel followed by voiceless /t/ as such.

For the shortened tense vowel followed by /d/ (outer circle in Figure 3), 67% of the subjects perceived it as lax /ɪ/. On the other hand, the lengthened tense vowel followed by /t/ was perceived as tense /i/ by 88% of the subjects. Therefore, when the tense vowel was shortened, most subjects perceived it as its lax counterpart, but when tense /i/ was lengthened, subjects still perceived the quality of /i/.

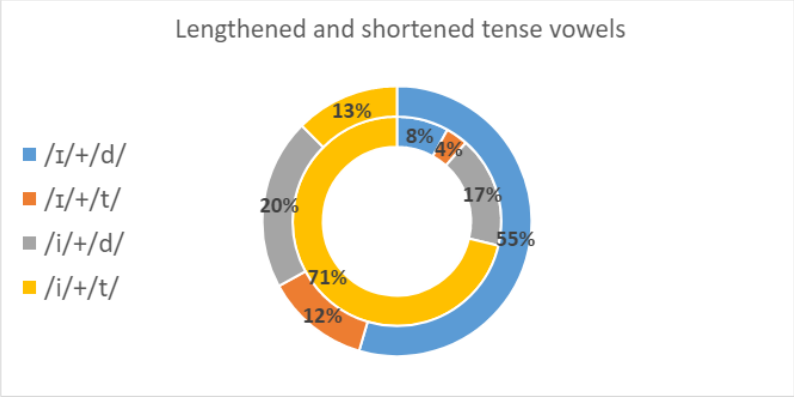

Figure 3. *Total responses of the non-native group. The inner circle represents the perception of the lengthened tense vowels followed by /t/ (e.g., "beat" to "bead"), whereas the outer circle represents the perception of the shortened tense vowels followed by /d/ (e.g., "bead" to "beat").*

Figure 4 shows relatively small difference between lax (48%) and tense (52%) perceptions of the shortened tense vowel with added aspiration (outer circle). However, for the lengthened tense vowel without aspiration (inner circle), almost all subjects perceived the tense vowel /i/ (91%).

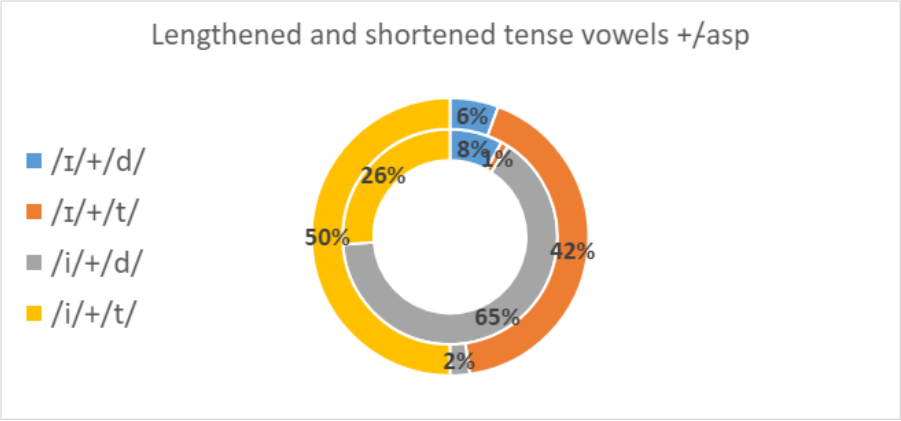

Figure 4. *Total responses of the non-native group. The inner circle represents the responses for the lengthened tense vowels followed by /t/, without aspiration. The outer circle represents the responses for the shortened tense vowel followed by /d/ with added aspiration.*

In contrast with Figures 3 and 4, Figure 5 shows little disparity. Most native subjects perceived the shortened tense vowel followed by /d/ (outer circle) as such. Similarly, most subjects also identified the lengthened tense vowel followed by /t/ as such.

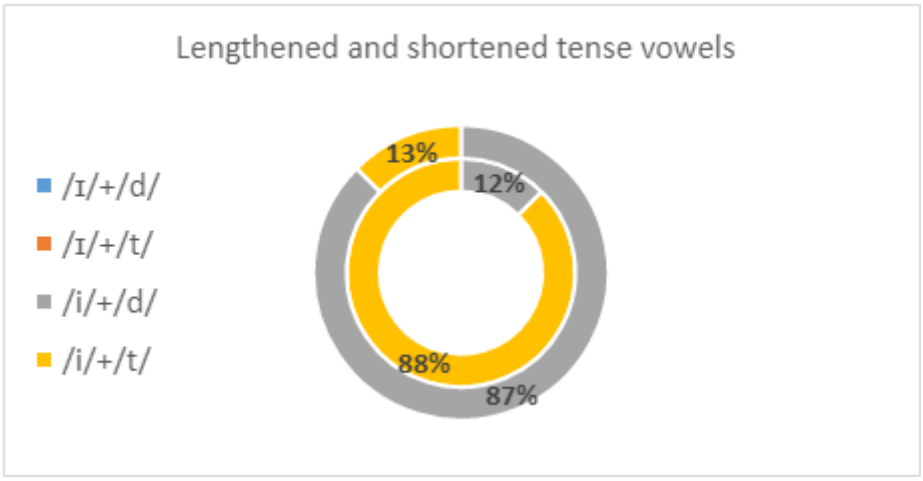

Figure 5. *Total responses of the native group. The inner circle represents the responses for the lengthened tense vowels followed by /t/, whereas the outer circle represents the responses for the shortened tense vowels followed by /d/.*

In Figure 6, all subjects perceived the tense vowel with added aspiration as a tense /i/ followed by /t/. However, 75% the subjects identified the vowel with removed aspiration as tense /i/ followed by /d/, while the remaining 25% perceived a tense followed by /t/.

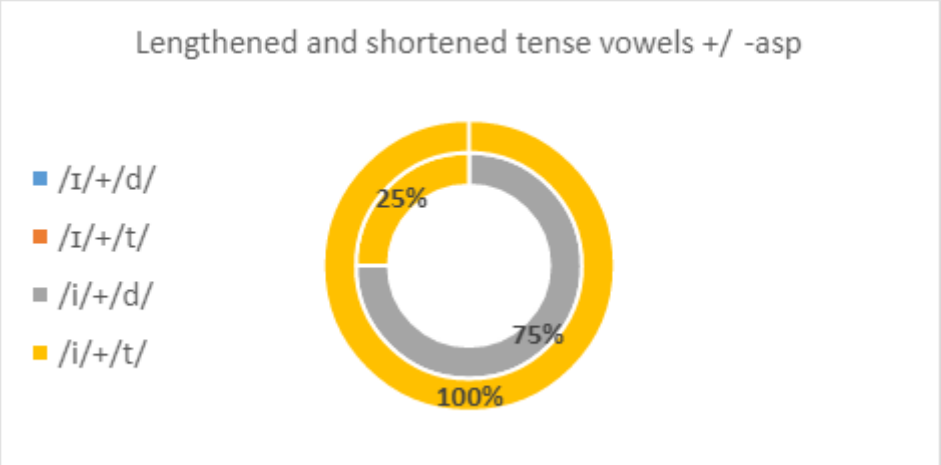

Figure 6. *Total responses of the non-native group. The inner circle represents the responses for the lengthened tense vowels followed by /t/, without aspiration. The outer circle represents the responses for the shortened tense vowel followed by /d/ with added aspiration.*

3.2.3. Original vowels

The following pie charts represent the perception of the original, unaltered words. Figure 7 shows how non-native subjects perceived 29% of the words with lax /ɪ/ as tense /i/. On the other hand, they understood 39% of the words with tense /i/ as lax /ɪ/.

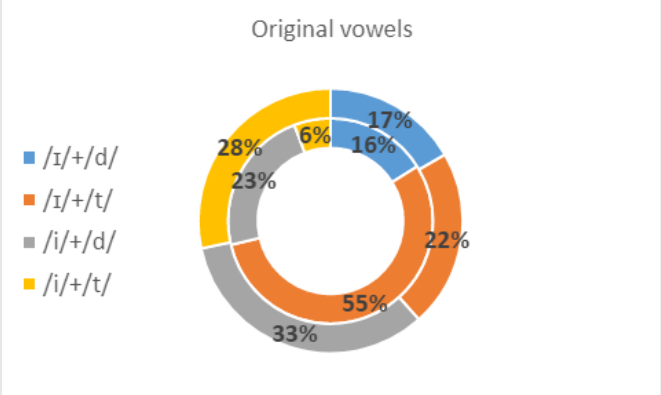

Figure 7. *Total responses of the non-native for the original, unmanipulated vowels. The inner circle represents those words with /ɪ/; the outer circle represents words with /i/.*

However, in Figure 8 all native participants could discriminate between words with tense /i/ and lax /ɪ/ as well as the voicing of their following consonant.

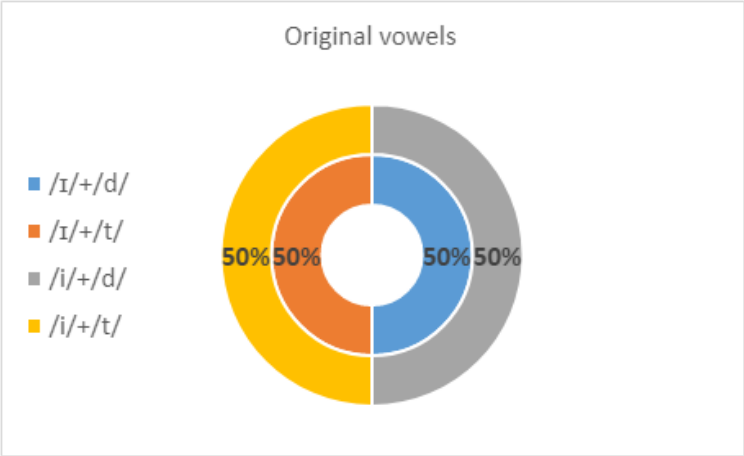

Figure 8. *Total responses of the native group for the original, unmanipulated vowels. The inner circle represents those words with /ɪ/; the outer circle represents words with /i/.*

4. Discussion

In order to answer the research questions stated in the methodology, two main aspects should be observed from the data gathered: the durational effect of the consonant voicing, and the role of vowel length in the perception of lax and tense high front vowels.

4.1. The effect of consonant voicing on vowel length

Voiced consonants lengthen the duration of the preceding vowel, whereas voiceless consonants shorten it in final positions. Therefore, vowel length serves as an indicator of the voicing of the following consonant, and thus becomes a relevant feature in the distinction between consonants differing only in voicing (Tanner et al., 2019).

In the perception test, vowel length did not affect the perception of the voicing of the final consonant for most native participants. Figures 5 shows how native speakers identified the consonant as voiceless even though the preceding vowel was lengthened to the same duration as the vowel with a final voiced consonant. However, Figure 6 shows how the perception of the consonant voicing changes with the addition and deletion of aspiration. Therefore, native subjects rely more on aspiration and lack thereof for the discrimination between voiced and voiceless consonants to a higher extent than vowel length.

The hypothesis put forward in the methodology cannot be accepted. Even though some native subjects perceived voiced consonants as voiceless in items with shortened tense vowels, and perceived voiceless consonants as voiced ones in items with lengthened tense vowels (Figure 5), most of the native subjects identified the original voicing of the consonant despite the manipulated vowel length.

4.2. The role of vowel length

Vowel length has different roles in the perception of vowels in each participant group. While the native group perceived vowel quality irrespective of vowel length, the non-native group correlated vowel length with vowel quality, and thus vowel perception. In numerous cases non-native subjects perceived vowels with the quality of tense /i/ as

lax /ɪ/ not only in the manipulated tokens, but also in the original, unaltered ones. This pattern evinces a strong association between vowel length and vowel perception among the non-native subjects.

Vowel length affected most notably the perception of lengthened lax vowels in the non-native group. Table 1 shows how subjects perceived lax vowels as tense more often when they were followed by a voiced consonant. However, subjects identified lax vowels as lax more frequently when they were followed by a voiceless consonant. This is because the absolute duration of the tense vowel followed by /d/ is longer than that of the tense vowel followed by /t/. Therefore, considering the subjects' correlation of vowel length and perception, lax vowels are perceived as tense whey they reach a certain "threshold" (in terms of duration) beyond which the high front vowel is perceived as tense.

Table 1. Summary of responses from non-native group for lax to tense manipulation.

Manipulation	**/i/ + /t/**	**/i/ + /d/**	**/ɪ/ + /t/**	**/ɪ/ + /d/**
Bit → Beat	5	6	17	2
Bid → Bead	1	17	1	13
Hit → Heat	8	0	16	4
Hid → Heed	4	10	0	14
Mitt → Meat	0	3	23	4
Mid → Mead	0	15	1	14
Total	**18**	**51**	**58**	**51**

Additionally, non-native subjects identified original, unaltered tense vowels as lax (see Appendix A); they also perceived shortened tense vowels as lax (see Figure 3).

The perception test suggested that ascribing the perceptual difference between tense and lax vowels to length is neither accurate nor effective, as it can lead to

misjudgements of qualitatively different vowels. Non-native subjects' perception of vowels was not congruent with the quality of the vowels in many instances and did not correspond with the perception of the native participants.

The first hypothesis of this paper has been proved. Native participants perceived the qualities of the tense and lax vowels correctly despite the length manipulations; however, non-native subjects perceived different vowel qualities as a result of length manipulations.

4.3. Limitations

One limitation of this study is the non-native group's lack of familiarity with the vowel phonemes /i/ and /ɪ/ and their acoustic differences. In this sense, non-native participants may not have established different conceptual categories for these vowels, and they may identify them as one single vowel instead. Therefore, this affects the data in such a way that the first section of the perception test serves as a training for the subjects to familiarise themselves with the qualitative difference between the tense and lax vowels; the responses in the first section are not as representative of the effect of vowel length as the later sections. Future research could add a preparatory part that would serve as a training exercise to familiarise subjects with the different qualities of the tense and lax vowels.

5. Conclusion

This paper aimed to analyse and compare the main ideas and rationales that constitute the two traditions as regards vowel pair classification and description. The British tradition was represented by Jones and Gimson, whereas the American tradition was represented by Kenyon.

The two traditions differ mainly in their consideration of vowel length as a phonemic feature. While in American English, vowel length is independent from vowel quality, in British English vowel length always accompanies vowel quality, according to Jones. However, Jones warns that this correlation is only present in his variety of Southern English in Britain and indicates that the relationship between quality and quantity is far from being indelible and it may disappear in time.

Despite the numerous inaccuracies of the length-based vowel classification, this model is still used today to teach the production of tense and lax vowel pairs. The justification for using this model is that it is convenient in that it is easy and simple enough for students to readily understand the difference between similar vowel qualities. However, although it is true that tense and lax vowels are accompanied by a general duration, tense vowels being longer than lax ones, this duration is too variable to derive discrete, phonemic units from it. The length-based classification of vowels is not tenable: it is not congruent with how native speakers perceive and produce vowels and it can lead to misjudgements of the quality of similar vowels.

The second part of the paper focused on how length affected the perception of vowels for native and non-native speakers of English. It was found that native speakers relied on vowel quality for the perception and distinction of the tense and lax vowels; vowel length did not affect the perception of vowels. However, non-native subjects strongly relied on vowel length for the distinction of tense and lax vowels. The perception of the vowels depended on its duration in such a way that short tense vowels were often perceived as lax; likewise, lengthened lax vowels were often identified as tense. Research could be conducted on the duration threshold beyond which vowels are perceived as tense.

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Appendix A

Record of questions and answers for non-native group

ID	1-beat→bead (-asp.)	2-bid→bead	3-bead→beat (+asp.)	4-bead→beat (+asp.)	5-bead	6-bit	7-bit→beat	8-bead
6	Bead	Bid	Beat	Beat	Bead	Bit	Beat	Bead
7	Beat	Bid	Bit	Bead	Bead	Beat	Bead	Bit
8	Bid	Bead	Beat	Beat	Bid	Bit	Bit	Bead
9	Bid	Bead	Bit	Beat	Beat	Bead	Bead	Bid
10	Beat	Bid	Bit	Bit	Bead	Bit	Bit	Bead
11	Bead	Bid	Beat	Beat	Bid	Bit	Bit	Bead
12	Bit	Bead	Beat	Beat	Bead	Bead	Bead	Bid
13	Bid	Bead	Bit	Beat	Bead	Bit	Bit	Bead
14	Beat	Bead	Bit	Bit	Bead	Bid	Bid	Bead
15	Beat	Bead	Bit	Bit	Bid	Bead	Bead	Beat
16	Bead	Bid	Bit	Bit	Bead	Bit	Bit	Bead
17	Bid	Bead	Bit	Bit	Bid	Bead	Beat	Bid
18	Bead	Beat	Bid	Bid	Beat	Bit	Bit	Bead
19	Bead	Bid	Bit	Beat	Bead	Bit	Bit	Bead
20	Bead	Bid	Beat	Beat	Bead	Bit	Bit	Bead

9-bit→beat	10-beat→bead	11-bid	12-beat→bead (-asp.)	13-beat	14-bead→beat	15-bit	16-beat	17-beat→bead
Bit	Beat	Bit	Beat	Bead	Bid	Bit	Bid	Beat
Beat	Bid	Beat	Bead	Beat	Bid	Bit	Beat	Beat
Bit	Bead	Beat	Bead	Bit	Bead	Bit	Beat	Bead
Bit	Beat	Bid	Bead	Bit	Bead	Bid	Beat	Beat
Bit	Beat	Bid	Bead	Beat	Bit	Bit	Beat	Beat
Bit	Beat	Bid	Bead	Beat	Bead	Bit	Beat	Bead
Beat	Beat	Bead	Bid	Bit	Bid	Beat	Beat	Beat
Bead	Bid	Bead	Bid	Beat	Bid	Bead	Bit	Beat
Bid	Beat	Bid	Bead	Bit	Bid	Bit	Bit	Beat
Bead	Beat	Bead	Beat	Bit	Bid	Bead	Bit	Bid
Bit	Bead	Bid	Bead	Bid	Bit	Bit	Bid	Bid
Beat	Bid	Bead	Bid	Bit	Bit	Beat	Bit	Beat
Bit	Beat	Bead	Bead	Bit	Bid	Bit	Bit	Beat
Bit	Beat	Bid	Bead	Beat	Bead	Bit	Beat	Beat
Bit	Beat	Bid	Bead	Beat	Bid	Bit	Beat	Bead

18-bid	19-bead→beat	20-bid→bead	21-heed	22-heed→heat (+asp.)	23-hit→heat	24-hid	25-heed
Bead	Bid	Bead	Heed	Hit	Heat	Hid	Heed
Bead	Bead	Bid					
Bit	Bid	Bead	Heed	Heed	Hit	Hid	Heed
Bid	Bead	Bit	Hid	Heat	Hit	Hid	Heed
Bid	Bid	Bid	Heed	Heat	Hit	Hid	Heed
Bid	Bid	Bid	Heed	Heat	Hit	Hid	Heed
Bead	Bid	Bead	Heed	Heat	Hit	Hid	Heed
Bead	Bid	Bead	Heed	Heat	Hit	Heed	Hid
Bead	Bid	Bead	Heed	Hit	Hid	Heat	Heed
Bead	Beat	Bead	Heed	Hit	Hid	Hid	Heed
Bead	Bit	Bead	Heed	Hit	Hid	Hid	Heed
Bead	Bit	Bead	Heat	Hit	Hit	Hid	Heat
Bead	Bit	Bead	Heed	Hit	Heat	Heat	Heed
Bid	Beat	Bead	Heed	Heat	Hit	Hid	Heed
Bid	Beat	Bid	Heed	Heat	Hit	Hid	Heed

25-heed	26-heat→heed (-asp.)	27-hid	28-heat→heed	29-hid→heed	30-heed→heat	31-hit
Heed	Heat	Hid	Heat	Hid	Heat	Hit
Heed	Heat	Hid	Heat	Heed	Hid	Hit
Heed	Heat	Hit	Heat	Hid	Heat	Heed
Heed	Heat	Hid	Heat	Hid	Heed	Hit
Heed	Heed	Hid	Heat	Hid	Hit	Hit
Heed	Heat	Hid	Heat	Heed	Hid	Hit
Hid	Heed	Heat	Hid	Heat	Hid	Hit
Heed	Heed	Hid	Heat	Heed	Hit	Hid
Heed	Heed	Hid	Heed	Hid	Heat	Hit
Heed	Heat	Hid	Heat	Heed	Hid	Hit
Heat	Heed	Hid	Heat	Hid	Hid	Hit
Heed	Heed	Heat	Heat	Heed	Hid	Hit
Heed	Heed	Hid	Heat	Hid	Heed	Hit
Heed	Heat	Hid	Heat	Hid	Heat	Hit

32-heat	33-hit	34-heat→heed (-asp.)	35-heat	36-heed→heat (+asp.)	37-hit→heat	38-heed→heat
Heat	Hit	Heed	Hid	Hit	Heat	Hid
Hit	Hid	Heed	Hit	Hit	Heat	Hid
Hit	Hit	Heed	Heat	Hit	Hid	Heat
Heat	Hit	Heed	Heat	Heat	Hit	Heed
Heat	Hit	Heed	Heat	Heat	Hit	Hid
Heat	Hit	Heat	Heat	Hit	Hit	Hit

Heat	Hit	Heed	Hit	Hid	Heat	Hid
Hit	Hid	Heat	Hid	Hid	Heat	Hid
Heat	Hit	Heed	Heat	Heat	Hit	Heat
Heat	Hit	Heed	Hid	Hit	Heat	Hid
Heat	Hit	Heed	Hit	Hit	Hit	Hid
Hit	Hit	Heed	Hit	Hit	Heat	Hid
Heat	Hit	Heed	Heat	Heat	Hit	Heed
Heat	Hit	Heed	Heat	Heat	Hit	Hid

39-heat→heed	**40-hid→heed**	**41-mead→meat (+asp.)**	**42-mead→meat (+asp.)**	**43-mid→mead**	**44-meat→mead**	**45-mitt→meat**	**46-mitt→meat**	**47-mead→meat**
Heat	Heed	Meat	Meat	Mead	Meat	Mitt	Mitt	Mid
		Meat	Mitt	Mid	Mid	Mead	Mitt	Mead
Heat	Heed	Meat	Meat	Mid	Meat	Mead	Mead	Mid
Heat	Heed	Meat	Mitt	Mead	Meat	Mitt	Mitt	Mid
Heat	Hid	Meat	Meat	Mid	Meat	Mitt	Mitt	Mead
Heed	Hid	Meat	Meat	Mid	Mead	Mitt	Mitt	Mead
Heat	Heed	Mitt	Mitt	Mid	Meat	Mitt	Mitt	Mid
Heed	Heat	Meat	Meat	Mead	Mitt	Mid	Mid	Mid
Heed	Heat	Mitt	Mitt	Mead	Meat	Mid	Mid	Mitt
Heed	Hid	Meat	Meat	Mid	Mead	Mitt	Mitt	Meat
Heed	Heat	Mitt	Mid	Mead		Mitt	Mitt	Mid
Heat	Hid	Meat	Mitt	Mead	Meat	Mitt	Mitt	Mid
Heat	Heed	Mitt	Mitt	Mead	Meat	Mitt	Mitt	Mid
Heat	Hid	Meat	Meat	Mid	Meat	Mitt	Mitt	Mead
Heat	Hid	Meat	Meat	Mid	Meat	Mitt	Mitt	Mid

48-meat→mead (-asp.)	**49-mead**	**50-mead**	**51-mitt**	**52-meat**
Mead	Mead	Meat	Mitt	Meat
Mead	Meat	Mead	Mitt	Mid
Meat	Meat	Meat	Mid	Meat
Meat	Mead	Mead	Mitt	Meat
Mead	Mead	Mead	Mitt	Meat
Mead	Mead	Mead	Mitt	Meat
Meat	Mead	Mead	Mitt	Meat

Mead	Mid	Mid	Mid	Mitt
Meat	Mead	Mead	Mid	Mid
Mead	Mead	Mead	Mitt	Meat
Mead	Mead	Mead	Mitt	Meat
Mead	Mead	Mead	Mitt	Meat
Mead	Mead	Mead	Mitt	Mitt
Mead	Mead	Mead	Mitt	Meat
Mead	Mead	Mead	Mitt	Meat

53-mid	**54-meat**	**55-meat→mead (-asp.)**	**56-mitt**
Mead	Mitt	Mead	Mitt
Mid	Mitt	Mead	Meat
Mead	Mitt	Meat	Mitt
Mid	Meat	Mead	Mitt
Mid	Meat	Mead	Mitt
Mid	Meat	Mead	Mitt
Mid	Mitt	Meat	Mead
Mead	Mitt	Meat	Meat
Mead	Mitt	Mead	Mitt
Mid	Meat	Mead	Mitt
Mead	Meat	Mead	Mitt
Mid	Mitt	Mead	Mitt
Mead	Mitt	Meat	Mitt
Mid	Meat	Mead	Mitt
Mid	Meat	Mead	Mitt

57-mead→meat	**58-mid→mead**	**59-meat→mead**	**60-mid**
Mid	Mead	Meat	Mead
Meat	Mead	Mitt	Mead
Mid	Mead	Meat	Mead
Mead	Mid	Meat	Mead
Mead	Mid	Meat	Mid
Mid	Mid	Mead	Mid
Mid	Mead	Meat	Mid
Mid	Mead	Mitt	Mead
Mid	Mead	Meat	Mid
Mead	Mid	Mead	Mid
Mid	Mead	Meat	Mead
Mitt	Mid	Meat	Mid
Mid	Mead	Meat	Mead
Mead	Mid	Meat	Mid

Mid	Mitt	Meat	Mitt

Appendix B

Record of questions and answers for the native group

ID	1-beat→bead (-asp.)	2-bid→bead	3-bead→beat (+asp.)	4-bead→beat (+asp.)
2	Bead	Bid	Beat	Beat
3	Bead	Bid	Beat	Beat
4	Beat	Bid	Beat	Beat
5	Beat	Bid	Beat	Beat

5-bead	6-bit	7-bit→beat	8-bead
Bead	Bit	Bit	Bead
Bead	Bit	Bit	Bead
Bead	Bit	Bit	Bead
Bead	Bit	Bit	Bead

9-bit→beat	10-beat→bead	11-bid	12-beat→bead (-asp.)	13-beat
Bit	Beat	Bid	Bead	Beat
Bit	Beat	Bid	Bead	Beat
Bit	Beat	Bid	Bead	Beat
Bit	Beat	Bid	Bead	Beat

14-bead→beat	15-bit	16-beat	17-beat→bead	18-bid
Bead	Bit	Beat	Bead	Bid
Bead	Bit	Beat	Beat	Bid
Bead	Bit	Beat	Beat	Bid
Bead	Bit	Beat	Beat	Bid

19-bead→beat	20-bid→bead	21-heed	22-heed→heat (+asp.)	23-hit→heat
Beat	Bid	Heed	Heat	Hit
Bead	Bid	Heed	Heat	Hit
Bead	Bid	Heed	Heat	Hit
Bead	Bid	Heed	Heat	Hit

24-hid	25-heed	26-heat→heed (-asp.)	27-hid	28-heat→heed
Hid	Heed	Heat	Hid	Heat
Hid	Heed	Heat	Hid	Heat
Hid	Heed	Heat	Hid	Heat
Hid	Heed	Heed	Hid	Heat

28-heat→heed	29-hid→heed	30-heed→heat	31-hit	32-heat
Heat	Hid	Heed	Hit	Heat
Heat	Hid	Heed	Hit	Heat
Heat	Hid	Heed	Hit	Heat
Heat	Hid	Heat	Hit	Heat

33-hit	34-heat→heed (-asp.)	35-heat	36-heed→heat (+asp.)	37-hit→heat	38-heed→heat
Hit	Heed	Heat	Heat	Hit	Heed
Hit	Heed	Heat	Heat	Hit	Heed
Hit	Heat	Heat	Heat	Hit	Heed
Hit	Heat	Heat	Heat	Hit	Heat

39-heat→heed	40-hid→heed	41-mead→meat (+asp.)	42-mead→meat (+asp.)	43-mid→mead
Heat	Hid	Meat	Meat	Mid
Heat	Hid	Meat	Meat	Mid
Heat	Hid	Meat	Meat	Mid
Heat	Hid	Meat	Meat	Mid

44-meat→mead	45-mitt→meat	46-mitt→meat	47-mead→meat	48-meat→mead (-asp.)
Meat	Mitt	Mitt	Mead	Mead
Meat	Mitt	Mitt	Mead	Mead
Meat	Mitt	Mitt	Mead	Mead
Meat	Mitt	Mitt	Mead	Meat

49-mead	50-mead	51-mitt	52-meat	53-mid
Mead	Mead	Mitt	Meat	Mid
Mead	Mead	Mitt	Meat	Mid
Mead	Mead	Mitt	Meat	Mid
Mead	Mead	Mitt	Meat	Mid

54-meat	55-meat→mead (-asp.)	56-mitt	57-mead→meat	58-mid→mead	59-meat→mead	60-mid
Meat	Mead	Mitt	Mead	Mid	Meat	Mid
Meat	Mead	Mitt	Mead	Mid	Meat	Mid
Meat	Mead	Mitt	Mead	Mid	Meat	Mid
Meat	Mead	Mitt	Mead	Mid	Meat	Mid