UNIVERSITAT ROVIRA I VIRGILI

AN EXPERIMENTAL STUDY OF COARTICULATION IN AMERICAN ENGLISH V+/L/ AND V+/R/ SEQUENCES

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DOCTORAL DISSERTATION

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Supervised by Dr. Joaquín Romero Gallego

Department of English and German Studies

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I hereby certify that the present study, *An Experimental Study of Coarticulation in American English V+/l/ and V+/r/ Sequences*, submitted by María Riera Toló in partial fulfillment of the requirements for the degree of Doctor of Philosophy, has been carried out under my supervision at the Department of English and German Studies (Universitat Rovira i Virgili), and that it complies with the requirements for the "International Doctorate" diploma.

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Doctoral dissertation advisor

Dr. Joaquín Romero Gallego

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Abstract

This dissertation presents an experimental study of coarticulation in final V+/l/ and V+/r/ sequences in American English stressed monosyllables. The details of the VC coarticulatory processes are investigated in an attempt to contribute to a better understanding of the phonetic and phonological nature of these sequences. Previous accounts of this phenomenon provided phonological explanations in terms of segmental epenthesis/insertion, were limited to a small set of vowels and did not consider speaking rate. The present study sets out to show that VC transitions are best understood as the result of a phonetic process of coarticulation which can be observed in sequences involving all the strong/stressed vowels of the language. For this purpose, two variables, speaking rate and context, were manipulated and acoustic data were obtained from six native speakers of American English. The roles of speaking rate and context are determined by looking into the durational and spectral variability in the vowel and the transition as well as by comparing durational and spectral values in the vowel and the transition across different speaking rates (i.e., slow and fast) and contexts (i.e., each of the vowels in the V+/l/ and V+/r/ sequences). Two hypotheses were formulated: the first one predicted the presence of vocalic transitional elements in all the sequences, while the second one emphasized the coarticulatory nature of these elements by concentrating on rate, context and the interaction of both in terms of spectral distances. The results not only provide evidence of the existence of such coarticulatory processes in all contexts, but they also reveal the nature and extent of VC coarticulation in V+/l/ and V+/r/ sequences. In particular, these data show the durational and spectral characteristics of both the vowel and a dynamic vocalic element in the VC transition whose presence is explained in relation to the vowel. The high variability observed in the transitional element as a function of context and, especially, rate is taken as evidence that the transition is the result of a process of coarticulation rather than epenthesis/insertion.

Key words: acoustic analysis, American English pronunciation, articulatory dynamics, breaking, coarticulation, epenthesis, first derivative, gestures, insertion, intrusion, /l/, pronunciation dictionaries, pronunciation manuals, /r/, schwa, segmentation, segments, speaking rate, speech production, target vowels, transcription systems, variability, VC transitions, vowel formant normalization

Declaration

I, María Riera Toló, hereby declare that this dissertation, carried out at Universitat Rovira i Virgili in partial fulfillment of the requirements for the degree of Doctor of Philosophy, is entirely my own work and that it has not been submitted as an exercise for a degree at any other university.

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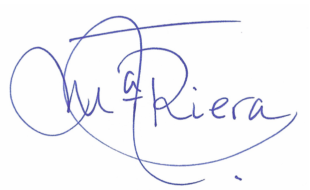

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Chapter 1 Introduction

1.1 Overview and structure

The main goal of this dissertation is to present an experimental study of final V+/l/ and V+/r/ sequences in American English[1] stressed monosyllables in an attempt to contribute to a better understanding of the phonetic and phonological nature of these sequences by investigating the VC coarticulatory processes that take place in them. Acoustic data show the presence of a vocalic element in the VC transitions which is explained in relation to the vowel. The roles of speaking rate and context are determined by looking into the durational and spectral variability in the vowel and the transitional vocalic element as well as by comparing durational and spectral values in the vowel and the transitional vocalic element across different speaking rates (i.e., slow and fast) and contexts (i.e., each of the vowels in the V+/l/ and V+/r/ sequences). The hypothesized findings reveal the coarticulatory, rather than epenthetic, nature of this element.

This dissertation is organized as follows. The remaining part of Chapter 1 consists of four sections. Section 1.2 provides an account of the basic articulatory and acoustic characteristics of /l/ and /r/, with particular reference to these consonants in final V+/l/ and V+/r/ sequences. Section 1.3 offers a review of how these sequences are phonologically transcribed according to different authors. Section 1.4 examines a variety of phonological and phonetic approaches. Finally, the research questions, objectives and hypotheses are formulated in section 1.5. Chapter 2 deals with the methodological aspects. Chapter 3 presents the results of the inferential statistical analyses. Chapter 4 is devoted to the discussion and conclusions. A list of bibliographical references and a series of appendices close this dissertation.

1.2 /l/ and /r/ in V+/l/ and V+/r/ sequences

This section provides an account of the basic articulatory and acoustic characteristics of /l/ and /r/, with particular reference to these consonants in final V+/l/ and V+/r/ sequences. Sections 1.2.1 and 1.2.2 are devoted to the treatment of /l/ and V+/l/ sequences, and /r/ and V+/r/ sequences, respectively.

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[1] The term *American English* is used throughout this dissertation to refer to the standard variety of American English (i.e., General American (GA) English).

1.2.1 /l/ and V+/l/ sequences

The English consonantal phoneme /l/ has two main allophones: a clear one, conventionally referred to as clear /l/ and allophonically represented as [l], which is produced in pre-vocalic position; and a dark or velarized one, conventionally referred to as dark /l/ or velarized /l/ (henceforth *dark /l/*) and allophonically represented as [ɫ], which is produced in pre-consonantal or word-final position (Ball & Rahilly, 1999; Catford, 1977, 1988; Ladefoged, 2001; Laver, 1994; Rogers, 2000). According to this distinction, the /l/ in V+/l/ sequences can be described as a voiced alveolar lateral approximant with a marked degree of velarization. As stated by Ball and Rahilly (1999), “this type of pronunciation has been termed ‘dark-l’ due to the lower pitch found in velar and velarized consonants” (p. 127).

Velarization is considered a type of secondary articulation whereby the back of the tongue is raised towards the soft palate (Ball & Rahilly, 1999; Catford, 1977, 1988; Ladefoged, 2001; Laver, 1994; Rogers, 2000) to form a constriction of approximation (Catford, 1977, 1988; Laver, 1994; Rogers, 2000). In the production of the /l/ in V+/l/ sequences, this secondary articulation takes place simultaneously with a basic primary articulation whereby either the tip or the blade of the tongue is raised towards the alveolar ridge, becomes in contact with it and stops the airflow at that point only to allow it to immediately escape along one or both sides of the tongue (Catford, 1977, 1988; Ladefoged, 2001; Laver, 1994).

Sproat and Fujimura (1993) distinguish both a consonantal gesture (involving tongue tip raising and/or fronting) and a vocalic gesture (involving tongue dorsum/ body lowering and/or backing) which are present in both the clear and dark allophones of /l/. The consonantal gesture is more prominent than and takes place at the same time as the vocalic gesture in the realization of clear /l/, whereas the vocalic gesture is more prominent than and takes place prior to the consonantal gesture in the realization of dark /l/.

Since /l/ is an approximant consonant and approximants are the consonants that most resemble vowels as far as their manner of articulation is concerned, the clear and the dark allophones of /l/ have been associated with a high front unrounded vowel (e.g., /i/) and a high back unrounded vowel (e.g., /ɯ/), respectively, to the extent that they are said to present resonances typical of these vowels (Kenyon, 1989; Ladefoged, 2001; Laver, 1994; O’Connor, 1980; Roach, 1983). In the case of dark /l/, Laver (1994) has pointed out that, “when the velarizing component is released relatively slowly, the offset of the primary stricture (or the onset of the following segment) has an [ɯ]-like quality" (p. 325). Ladefoged (2001) and Kenyon (1989) have gone further to account for cases of /l/-vocalization, whereby dark /l/ is produced with no primary articulation, that is, with no contact on the alveolar ridge. In such cases, the resulting sound is a consonant with an auditory quality closer to that of an /ɯ/-like vowel than of a consonant, and it is often perceived as a vowel rather than as a consonant.

The phoneme /l/ has acoustic characteristics similar to those of vowels. Acoustic waveforms of /l/ often look too similar to those of vowels to be of much help in the identification of /l/. Sound spectrograms, on the other hand, have proven more helpful because they provide information about formant structure. Average formant frequencies for the first three formants of American English /l/ are set at around 250 Hz for F1, 1200 Hz for F2 and 2400 Hz for F3 (Davenport & Hannahs, 1998; Ladefoged, 2001). As these figures show, all three formants have relatively low values. Apart from this, sound spectrograms quite easily reveal the considerably reduced intensity of the higher formants of /l/ if compared to the intensity of vowels. Instances of clear /l/ are, however, usually easier to identify than those of dark /l/. Clear /l/ tends to present well-defined CV transitions marked by formant discontinuity which are enough to establish the end of the consonant and the beginning of the vowel. On the other hand, in the reverse context, that is, dark /l/ in post-vocalic final position, VC transitions are often difficult to discern, and they are often too smooth to determine where the vowel ends and where the consonant begins, and especially so in cases of /l/-vocalization. The /l/ in the V+/l/ sequences under study complies with the characteristics of dark /l/ in post-vocalic final position.

1.2.2 /r/ and V+/r/ sequences

There exist two main varieties of English as regards the pronunciation of the consonantal phoneme /r/: a rhotic one, in which /r/ is pronounced in all contexts, that is, pre-vocalically, pre-consonantally and pre-pause; and a non-rhotic one, in which /r/ is pronounced only pre-vocalically (Giegerich, 1992; Ladefoged, 2001; Laver, 1994; Roach, 1983). The variety of American English under study is a rhotic one, and the focus of attention of the present work is on the pre-pause context.

Two main allophonic realizations of the phoneme /r/ can be distinguished in English: a voiced postalveolar approximant, allophonically represented as [ɹ]; and a voiced retroflex palato-alveolar approximant, allophonically represented as [ɻ] (Laver, 1994). While [ɹ] is more typically found in pre-vocalic position and, by extension, in non-rhotic varieties, [ɻ] is more common in pre-consonantal and pre-pause positions and, by extension too, in rhotic varieties, and especially so in American English. Hence, the /r/ in V+/r/ sequences as pronounced by most speakers of American English conforms to the latter type.

Olive, Greenwood, and Coleman (1993) distinguish between two allophonic variants of /r/ in a way similar to how the two main allophonic variants of /l/ are often differentiated. They establish a contrast between light /r/ and dark /r/, with light /r/ occurring in post-vocalic position within the same syllable and with dark /r/ being found in pre-vocalic position. The contexts for /r/ are thus the reverse than for /l/. According to these authors, the /r/ in V+/r/ sequences is a light /r/ and, in common with light /l/, it is characterized by "an advancement and raising of the tongue toward the palatal region, resulting in a high, front, vowel-like quality" (p. 126).

In American English, a process of vowel neutralization takes place in the context of vowel sounds being followed by /r/ (Avery & Ehrlich, 1992; Giegerich, 1992; Ladefoged, 2001). The vowel contrast that is present in many other contexts between five pairs of vowel sounds (i.e., /i/ vs. /ɪ/, /e/ vs. /ɛ/, /ɑ/ vs. /æ/, /o/ vs. /ɔ/ and /u/ vs. /ʊ/) disappears in this context, with the resulting combinations of vowel+/r/ being /ir/, /ɛr/, /ɑr/, /ɔr/ and /ʊr/.[2]

Such contrast has often been defined as one involving tense versus lax vowels. Nevertheless, there is controversy as regards the tense-lax distinction and no agreement has to this day been reached as to what distinguishes the so-called tense vowels from the so-called lax ones (Catford, 1977; Giegerich, 1992; Ladefoged, 2001; Rogers, 2000). With little success, phoneticians have tried to account for this distinction by stating that tense vowels are higher and more peripheral, that they tend to be produced with greater muscular tension and that, all contexts being equal, they are relatively longer than their lax counterparts. Phonologists, on the other hand, have been more successful in their attempts to justify the differences in terms of distribution, that is, the contexts in which ones and the others can appear. Tense vowels are, from a phonological point of view, said to appear in both closed and open syllables, whereas lax vowels are restricted to closed syllables.

[2] The author's choice of phonetic symbols in /ɛr/, /ɑr/, /ɔr/ and /ʊr/ to represent the vowel sounds in the V+/r/ sequences has been made in accordance with American English transcription convention. Because both /ir/ and /ɪr/ are conventionally used, the choice of /ir/ has been made on the basis of the author's personal preference.

Even though the phonological distinction is closer to reality, or can at least be more easily attested, than the phonetic one, it is not flawless. For example, with regard to the /ɑ/ vs. /æ/ pair, /ɑ/ is found in open syllables in only a very small number of words, such as *ma*, *pa* and *spa*, which makes its inclusion in the tense vowel group dubious. Moreover, as for the /o/ vs. /ɔ/ distinction, both members of the pair are considered tense vowels, so the tense-lax contrast is ruled out in this pair. A better account for sound contrast concerning these two vowels may be that of /o/ vs. /ʌ/, with /ɔ/ having no contrasting member in American English, despite having /ɒ/ in British English. However, the /o/ vs. /ʌ/ contrast is not very logical, since /ʌ/ is often regarded as the lax counterpart of the tense vowel /ɝ/, which suggests the more logical contrasting pair /ɝ/ vs. /ʌ/, with both members being mid central vowels.

Many authors (Avery & Ehrlich, 1992; Baker & Goldstein, 1990b; Calvert, 1986; Dauer, 1993; Giegerich, 1992; Ladefoged, 2001) claim that, in the possible V+/r/ combinations, the exact realization of the vowel varies rather substantially between the two members of each contrasting pair. Thus, in the case of high front vowels, for example, opinions differ as to the vowel symbol to be used to represent the vowel sound in V+/r/ sequences, with /i/ being favored by some authors (Avery & Ehrlich, 1992; Dauer, 1993; Edwards, 1997) and /ɪ/ being preferred by others (Calvert, 1986; Celce-Murcia, Brinton, & Goodwin, 1996; Kenyon, 1989; Kenyon & Knott, 1953; Orion, 1997; Prator & Robinett, 1985; Van Riper & Smith, 1992). The same holds true for the remaining pairs of vowels, although for these a general consensus among authors is reached, with /ɛ/, /ɑ/, /ɔ/ and /ʊ/ being chosen by most instead of /e/, /æ/, /o/ and /u/. Clark and Hillenbrand (2003, 2007) conducted a series of experiments involving acoustic measurements, discriminant analysis and listening tests in order to determine which of /i/ or /ɪ/, /e/ or /ɛ/, and /o/, /ɔ/ or /ɑ/ was more appropriate to represent American English vowels followed by /r/. In their 2003 study of front vowels before /r/, they favored /i/ over /ɪ/ for *beer*, and /e/ over /ɛ/ for *bear*, while in their 2007 study of back vowels before /r/, they found /o/ to be preferable to /ɔ/ for *door*/*war* and /ɑ/ to /ɔ/ for *star*. Nevertheless, they acknowledged that, despite their choices, these vowels were actually of a quality intermediate between the two in each contrasting pair.

Vowels before /r/ (i.e., /ir/, /ɛr/, /ɑr/, /ɔr/, /ʊr/, /aɪr/, /ɔɪr/ and /aʊr/) are often called rhotacized, retroflexed or r-colored (henceforth *rhotacized*) as a result of the influence exerted on them by the following /r/ (Avery & Ehrlich, 1992; Clark, Yallop, & Fletcher, 2007; Davenport & Hannahs, 1998; Ladefoged, 2001; Olive et al., 1993;

Rogers, 2000). Two other vowels are also considered rhotacized in American English: strong, stressed /ɝ/ and weak, unstressed /ɚ/ (Edwards, 1997; Ladefoged, 2001; Laver, 1994; Olive et al., 1993; Rogers, 2000). These have rhotacization as an inherent quality rather than as the result of the influence of /r/. For this reason, they are often phonemically transcribed with only the vowel symbol with the diacritic for rhotacization /˞/ attached to them rather than as a sequence of vowel followed by /r/. Nevertheless, some authors (Avery & Ehrlich, 1992; Celce-Murcia et al., 1996; Dauer, 1993; Prator & Robinett, 1985) include /ɝ/ and /ɚ/ within the group of vowels that can appear before /r/, and some of them even transcribe these vowels with a following /r/ (Avery & Ehrlich, 1992; Celce-Murcia et al., 1996; Prator & Robinett, 1985). What distinguishes the two groups of vowels is mainly the temporal overlap, which is much more extreme for /ɝ/ and /ɚ/ (Rogers, 2000), making it impossible for a sequence of two phonemes to be distinguished in such cases. In addition, /ɝ/ and /ɚ/ always have a rhotacized quality, whereas the other vowels have it only when they are followed by /r/ within the same syllable.

In the rhotacized vowels under study, the basic tongue configuration is retained, but the tongue tip is curled back in anticipation of the /r/ (Clark et al., 2007; Ladefoged, 2001; Olive et al., 1993; Rogers, 2000). The rhotacized effect may also be produced by keeping the tongue tip down and bunching the tongue body upwards towards the roof of the mouth (Ladefoged, 2001; Olive et al., 1993). Ladefoged (2001) claims that "there may be in-between positions" (p. 212) to produce the rhotacized effect on the vowel and that in all cases "there is a slight narrowing of the pharyngeal cavity" (p. 212).

In a way similar to that whereby the two approximant consonants /j/ and /w/ are phonetically associated with the vowels /i/ and /u/, respectively, the approximant consonant /r/ is said to be phonetically related to /ɝ/ and to have acoustic characteristics close to those of /ɝ/ (Edwards, 1997; Kenyon, 1989; Laver, 1994; Olive et al., 1993; Rogers, 2000). Acoustic waveforms of /r/ resemble those of vowels so much that they are not useful to distinguish /r/ from adjacent vowels. Formant structure information included in sound spectrograms, however, provides a more reliable means of identification. Average frequencies for the first three formants of American English /r/ are all relatively low, at around 425 Hz for F1, 1300 Hz for F2 and 1600 Hz for F3 (Kent & Read, 1992). Rhotacized vowels before /r/ tend to show a considerable gradual and slow lowering of the third formant as a result of the influence of the low-frequency third formant of /r/ (Ladefoged, 2001; Olive et al., 1993; Rogers, 2000). Despite this, it is still difficult to determine the boundaries of /r/ because this consonant shows no formant discontinuity to and from adjacent vowels (Olive et al., 1993).

Sequences of V+/r/ are inexistent syllable-finally in non-rhotic varieties of English, except in the case of linking /r/ (e.g., *here is fine*, *far and away*, *poor and rich*). Instead, these varieties have the centering diphthongs /ɪə/, /eə/ and /ʊə/ as well as the centering triphthongs /aɪə/, /eɪə/, /ɔɪə/, /aʊə/ and /əʊə/, which can also be regarded as combinations of rising diphthong+/ə/ (Roach, 1983). The development of the /ə/ in all these cases is understood as the result of the historic loss, also referred to as *dropping* or *vocalization*, of /r/ (Beal, 1999; Giegerich, 1992; Jones, 1989; Ladefoged, 2001; Laver, 1994; Rogers, 2000).

Nevertheless, the equivalence between the diphthongs and triphthongs of the non-rhotic varieties and the V+/r/ sequences of the rhotic ones is not straightforward. In a rhotic variety such as American English, although /ɪə/, /eə/, /ʊə/, /aɪə/ and /aʊə/ have their equivalents in /ir/, /ɛr/, /ʊr/, /aɪr/ and /aʊr/, the three triphthongs /eɪə/, /ɔɪə/ and /əʊə/ have no V+/r/ counterpart. According to standard descriptions (Kenyon & Knott, 1953; Edwards, 1997), diphthongs in American English are limited to /aɪ/, /ɔɪ/ and /aʊ/, whereas /e/ and /o/ are considered diphthongized monophthongs. In addition, American English is described as having no triphthongs. In spite of this interpretation, some authors within the American tradition (Dauer, 1993; Kenyon, 1989; Prator & Robinett, 1985; Van Riper & Smith, 1992) use the term *centering diphthong* to refer to either the vowel in the V+/r/ sequences or the whole sequence. Clark and Hillenbrand (2003, 2007) refer to the front vowel+/r/ and back vowel+/r/ sequences of their studies as diphthongs as well.

1.3 The transcription of V+/l/ and V+/r/ sequences

This section offers an overview of how V+/l/ and V+/r/ sequences are phonemically/ phonologically transcribed according to a variety of authors in an attempt to illustrate some of the motivations for the present study. Even though there is considerable agreement concerning the articulatory and acoustic description of American English /l/ and /r/, it will be shown that there is no agreement as regards the transcription (i.e., phonemic/phonological representation) of the sequences.

The generally agreed vowel inventory of American English includes the 14 monophthongs /i/, /ɪ/, /e/, /ɛ/, /æ/, /ɑ/, /ɔ/, /o/, /ʊ/, /u/, /ʌ/, /ɝ/, /ə/ and /ɚ/ and the three diphthongs /aɪ/, /ɔɪ/ and /aʊ/. [3] Twelve of the monophthongs (i.e., /i/, /ɪ/, /e/, /ɛ/, /æ/, /ɑ/, /ɔ/, /o/, /ʊ/, /u/, /ʌ/ and /ɝ/) and the three diphthongs (i.e., /aɪ/, /ɔɪ/ and /aʊ/) can be found in stressed position. All the monophthongs and diphthongs that can appear in stressed position can be followed by /l/. However, due to the process of vowel neutralization mentioned in section 1.2.2, only five of the monophthongs (i.e., /i/, /ɛ/, /ɑ/, /ɔ/ and /ʊ/) and two of the diphthongs (i.e., /aɪ/ and /aʊ/) can be followed by /r/.

Transcription systems based on the International Phonetic Alphabet (IPA) tend to be consistent in their choice of symbols to represent English consonants. However, attempts to find a standard transcription system for English vowels have led to the existence of two clearly distinguished traditions. On the one hand, there is a well-established British tradition, represented by the transcription systems devised by Jones (1956, 1976) and Gimson (1962). The British tradition can be said to have been successful at standardization insofar as today most transcription systems for British English vowels follow Gimson's system, with only a few still following either one or the other of Jones's two. On the other hand, there is a not-so-well-established American tradition in the sense that no standard system for the transcription of American English vowels has been agreed upon. Two of the most commonly used systems are Kenyon and Knott's (1953) and Trager and Smith's (1951). In addition, there are systems based on either Kenyon and Knott's or Trager and Smith's but with variations concerning symbol choice which are also used.

The British tradition, relying on its preference for the distinction between long and short vowels, presents a transcription system based on either vowel length (i.e., Jones's (1956, 1976)) or vowel length and vowel quality (i.e., Gimson's (1962)). However, the American tradition, relying on its preference for the distinction between tense and lax vowels, presents a transcription system based on only vowel quality. Moreover, Jones's (1956, 1976), Gimson's (1962), and Kenyon and Knott's (1953) systems are phonetic and in accordance with the symbols of the IPA, whereas Trager and Smith's (1951) is more orthographic to the extent that in some instances it makes use of combinations of vowel and consonant symbols to represent vowels. Finally, only Kenyon and Knott's system is completely faithful to the Phoneme Principle, whereby one symbol represents one phoneme.

The three most popular English pronunciation dictionaries (i.e., Jones's (2011), Wells's (2008) and Kenyon & Knott's (1953)) make use of transcription

[3] Transcription system in accordance with Kenyon & Knott's (1953)

systems based on the IPA, using exactly the same symbols for the representation of consonants but differing in the use made of symbols to represent vowels. Whereas Jones's (2011) and Wells's (2008) dictionaries include both British and American pronunciations and use a transcription system for vowels based on Gimson's (1962) system to transcribe both varieties, Kenyon and Knott's (1953) dictionary is devoted only to American pronunciation but includes variation within the United States.

There exist numerous pronunciation manuals on the market which provide a treatment of the sound system of English, including articulatory and acoustic sound descriptions, phonological transcriptions, advice on the teaching of pronunciation, and even exercises. In addition, many English language manuals currently used in English language courses for foreign and second language learners of English introduce students to the sound system of either the British or the American standard variety of English as well as to transcription systems within either the British or the American tradition. As a general rule, those manuals within the British tradition follow Gimson's (1962) system, whereas those within the American tradition follow, usually with variations concerning symbol choice for vowels in particular, either Kenyon and Knott's (1953) or Trager and Smith's (1951) systems.

The reference sources considered in this section include pronunciation dictionaries and manuals that adhere to both traditions. Three main areas of disagreement related to the following can be detected: (i) an array of symbols from which to choose for the transcription of certain vowels that varies in extent depending on the vowel being represented, both from system to system and within a system; (ii) discrepancies between those systems that use vowel symbols exclusively and those that use vowel symbols as well as combinations of vowel and consonant symbols; and, (iii) the inclusion or non-inclusion of an epenthetic schwa symbol between the two elements of V+/l/ and V+/r/ sequences. It is around this third area of disagreement that sections 1.3.1 and 1.3.2 will be centered.

As will be observed, a situation of confusion is created by disagreement among authors as regards (i) whether to transcribe V+/l/ and V+/r/ sequences with epenthetic schwa or not, (ii) whether to transcribe this epenthetic schwa as a superscript schwa or as a phonemic schwa, (iii) after which vowels to transcribe it, (iv) in front of which of the two consonants to transcribe it, and (v) the number of syllables the sequences consist of.

In very general terms, those authors who consider the possibility of transcribing V+/l/ and V+/r/ sequences with epenthetic schwa agree on doing so when the preceding vowel is high, whether front or back, with a clear preference for tense, rather than lax, vowels (Baker & Goldstein, 1990a, 1990b; Calvert, 1986; Celce-Murcia et al., 1996; Dauer, 1993; Orion, 1997; Prator & Robinett, 1985; Van Riper & Smith, 1992; Wells, 2008). Some authors also favor the transcription with schwa epenthesis in V+/l/ sequences containing low front vowels (Prator & Robinett, 1985) as well as in V+/r/ sequences containing low back vowels (Dauer, 1993; Van Riper & Smith, 1992).

In his English pronunciation dictionary, Wells (2008) refers to cases of schwa epenthesis as examples of *pre-l breaking* and *pre-r breaking*, whereby, as a result of the development of a schwa-like glide between the two elements in the sequences, monophthongs and diphthongs become diphthongs and triphthongs, respectively. The superscript symbol /ᵊ/ is used by Wells to show where schwa epenthesis[4] is likely to take place and stands for a sound that is sometimes optionally inserted. According to him, the choice of schwa epenthesis is speaker-dependent as well as situation-dependent, and it is more common in slow speaking rates than in fast ones. The instances in which schwa epenthesis is shown in his dictionary are intended to aid second and/or foreign language learners of English in their pronunciation.

1.3.1 The transcription of V+/l/ sequences

Tables 1.1 and 1.2 show the symbols used by a variety of authors in their pronunciation dictionaries and manuals, respectively, for the transcription of V+/l/ sequences.[5]

Of the three dictionaries referenced in Table 1.1, only Wells's (2008) introduces schwa epenthesis, which he shows with an /ᵊ/ symbol only after the front vowels /iː/, /eɪ/, /aɪ/ and /ɔɪ/ (i.e., /iːᵊl/, /eɪᵊl/, /aɪᵊl/ and /ɔɪᵊl/) to mark pre-l breaking. However, despite not being shown in his dictionary, Wells points out that in American English pre-l breaking can also take place after the back vowels /uː/, /oʊ/ and /aʊ/ (i.e., /uːᵊl/, /oʊᵊl/ and /aʊᵊl/).

Like Wells (2008), those authors who present instances of schwa-epenthesis (Baker & Goldstein, 1990b; Calvert, 1986; Celce-Murcia et al., 1996; Orion, 1997; Prator & Robinett, 1985) do so together with instances of non-schwa epenthesis on the basis of frequency of occurrence as well as of usefulness for second and/or

[4] The term *schwa epenthesis* will be used throughout this section to refer to the schwa-like element transcribed between the vowel and the consonant in the V+/l/ and V+/r/ sequences. A treatment of epenthesis and breaking as phonological processes will be provided in section 1.4.
[5] Throughout this section, vowel symbols will be represented in accordance with each author's choice.

foreign language learners of English. However, opinions differ among authors as regards the vowels in the V+/l/ sequences after which schwa epenthesis may take place. All these authors agree that schwa epenthesis is possible after the high front unrounded tense vowel /i/, as in *feel*. All of them except Calvert (1986) agree on the possibility of having schwa epenthesis after the mid-high front unrounded tense diphthongized vowel /e/, as in *pale*. Only Celce-Murcia et al. (1996) and Orion (1997) include schwa epenthesis after the mid-high back rounded tense diphthongized vowel /o/, as in *hole*, as well as after the diphthong /ɔɪ/, as in *boil*. Only Calvert and Celce-Murcia et al. propose schwa epenthesis after the high back rounded tense vowel /u/, as in *pool*. Only Celce-Murcia et al. make reference to schwa epenthesis occurring after the diphthong /aɪ/, as in *pile*, as well as after the diphthong /aʊ/, as in *howl*. Finally, only Prator and Robinett (1985) suggest having schwa epenthesis after all front unrounded vowels in addition to /i/ (i.e., high /ɪ/, as in *bill*; mid-high /ɛ/, as in *fell*; and low /æ/, as in *pal*).

Table 1.1 *Symbols for V+/l/ sequences in pronunciation dictionaries*

Word	Pronunciation dictionaries		
	Kenyon & Knott (1953)	Jones (2011; AmE)	Wells (2008; AmE)
feel	/il/	/iːl/	/iːᵊl/
bill	/ɪl/	/ɪl/	/ɪl/
pale	/el/	/eɪl/	/eɪᵊl/
fell	/ɛl/	/el/	/el/
pale	/æl/	/æl/	/æl/
Poll	/ɑl/	/ɑːl/	/ɑːl/
Paul	/ɔl/	/ɔːl/	/ɔːl/
hole	/ol/	/oʊl/	/oʊl/
pull	/ʊl/	/ʊl/	/ʊl/
pool	/ul/	/uːl/	/uːl/
hull	/ʌl/	/ʌl/	/ʌl/
furl	/ɝl/	/ɝl/	/ɝːl/
pile	/aɪl/	/aɪl/	/aɪᵊl/
boil	/ɔɪl/	/ɔɪl/	/ɔɪᵊl/
howl	/aʊəl/ /aʊl/	/aʊəl/	/aʊl/ /aʊəl/

Front tense vowels + possible /ə/+/l/
Back tense vowels + possible /ə/+/l/

/ ᵊ / Sound sometimes optionally inserted

Table 1.2 *Symbols for V+/l/ sequences in pronunciation manuals*

Word	Pronunciation manuals									
	Kenyon (1989)	Van Riper & Smith (1992)	Edwards (1997)	Calvert (1986)	Dauer (1993)	Baker & Goldstein (1990a & 1990b)	Avery & Ehrlich (1992)	Orion (1997)	Prator & Robinett (1985)	Celce-Murcia et al. (1996)
feel	/il/	/il/	/il/	/il/ /iəl/	/il/	/iyl/ /iyəl/	/iyl/	/iyl/ /iyəl/	/iyl/ /iəl/	/iyl/ /iyəl/
bill	/ɪl/	/ɪl/	/ɪl/	/ɪl/	/ɪl/	/ɪl/	/ɪl/	/ɪl/	/ɪl/ /ɪəl/	/ɪl/
pale	/el/	/el/	/el/	/eɪl/ /el/	/eɪl/ /el/	/eyl/ /eyəl/	/eyl/	/eyl/ /eyəl/	/eyl/ /eəl/	/eyl/ /eyəl/
fell	/ɛl/	/ɛl/	/ɛl/	/ɛl/	/ɛl/	/ɛl/	/ɛl/	/ɛl/	/ɛl/ /ɛəl/	/ɛl/
pal	/æl/	/æl/	/æl/	/æl/	/æl/	/æl/	/æl/	/æl/	/æl/ /æəl/	/æl/
Poll	/ɑl/	/ɑl/	/ɑl/	/ɑl/	/ɑl/	/ɑl/	/ɑl/	/ɑl/	/al/	/ɑl/
Paul	/ɔl/	/ɔl/	/ɔl/	/ɔl/	/ɔl/	/ɔl/	/ɔl/	/ɔl/	/ɔl/	/ɔl/
hole	/ol/	/ol/	/ol/	/oʊl/ /ol/	/oʊl/ /ol/	/owl/	/owl/	/owl/ /owəl/	/owl/	/owl/ /owəl/
pull	/ʊl/	/ʊl/	/ʊl/	/ʊl/	/ʊl/	/ʊl/	/ʊl/	/ʊl/	/ʊl/	/ʊl/
pool	/ul/	/ul/	/ul/	/ul/ /uəl/	/ul/	/uwl/	/uwl/	/uwl/	/uwl/	/uwl/ /uwəl/
hull	/ʌl/	/ʌl/	/ʌl/	/ʌl/	/əl/	/ʌl/	/ʌl/	/əl/	/əl/	/ʌl/
furl	/ɝl/	/ɝl/	/ɝl/	/ɝl/	/ɚl/	/ɜrl/	/ərl/	/ərl/	/ərl/	/ɜʳl/
pile	/aɪl/	/aɪl/	/aɪl/	/aɪl/	/aɪl/	/ayl/	/ayl/	/ayl/	/ayl/	/ayl/ /ayəl/
boil	/ɔɪl/	/ɔɪl/	/ɔɪl/	/ɔɪl/	/ɔɪl/	/ɔyl/	/ɔyl/	/ɔyl/ /ɔyəl/	/ɔyl/	/ɔyl/ /ɔyəl/
howl	/aʊl/	/aʊl/	/aʊl/	/aʊl/	/aʊl/	/awl/	/awl/	/awl/	/awl/	/awl/ /awəl/

Front tense vowels + possible /ə/+/l/
Front lax vowels + possible /ə/+/l/
Back tense vowels + possible /ə/+/l/

Those authors who advocate for schwa epenthesis (Baker & Goldstein, 1990b; Calvert, 1986; Celce-Murcia et al., 1996; Orion, 1997; Prator & Robinett, 1985; Wells, 2008) do so mainly on the grounds that it reflects quite accurately how V+/l/ sequences are both produced and perceived. Calvert (1986), for instance, acknowledges that a schwa is created after /i/ and /u/ when these are followed by /l/ as a result of the tongue movement required to go from the vowel to the /l/. As far as he is concerned, this schwa is an "understood influence" (p. 148) of the /l/ and it "is not transcribed unless very prominent" (p. 148). Similarly, Prator and Robinett (1985) understand this epenthetic schwa as the result of the tongue movement produced in passing from the front of the mouth, right after pronouncing a front vowel, to the back of the mouth, right before pronouncing /l/. When producing this movement, the tongue passes through the intermediate position in the mid central area of the mouth where schwa is produced. The sound produced while the tongue is in this position is perceived as a schwa, which is particularly noticeable when the production takes place at a slow speaking rate. According to Prator and Robinett, such movement is not necessary when the vowels involved are back vowels, since these are already produced in the back part of the mouth, where dark /l/ is produced. Although these authors make no reference to epenthetic schwa occurring after the diphthongs /aɪ/ and /ɔɪ/, which end in a front vowel, these could be included within the group of vowels that would set the right context for schwa epenthesis.

Even though Olive et al. (1993) make no reference to transcription systems, their account focuses on three relevant aspects: whether the vowel is tense or lax, tongue movement and first formant patterns. Firstly, they state that the tense vowels /i/, /e/, /o/, /u/, /ɝ/, /aɪ/, /ɔɪ/ and /aʊ/, because they are produced with extreme articulations, are more likely to lead to a schwa-like configuration in their transition to /l/ than the lax vowels /ɪ/, /æ/ and /ʌ/. Secondly, they mention the tongue movement required to pass through a mid central position in going from a high or mid-high front vowel to a dark /l/. Unlike Prator and Robinett (1985), however, they do not consider /ɪ/, /ɛ/ or /æ/ as possible triggers for schwa epenthesis. Finally, they make reference to the first formant movement from a low position to a higher one (i.e., similar to that of schwa) and back to a low one that takes place in the production of the vowels /i/ and /ɝ/ when they are followed by /l/.

Some authors (Calvert, 1986; Prator & Robinett, 1985; Wells, 2008) consider that epenthetic schwa before /l/ leads to a change from a monophthong or a diphthongized monophthong into a diphthong and, in turn, from a diphthong into a triphthong rather than to a change involving the addition of one syllable. Prator and Robinett (1985) refer to the instances of monophthongs and diphthongized monophthongs followed by epenthetic schwa in front of /l/ as centering diphthongs, which implies that no additional syllable is derived from the inclusion of epenthetic schwa. Olive et al. (1993) do not take sides and simply reveal that, as far as perception is concerned, both options are possible. Likewise, Ladefoged (2001) states that "many people will say that 'meal, seal, reel' contain two syllables, but others will consider them to have one" (p. 226).

1.3.2 The transcription of V+/r/ sequences

Tables 1.3 and 1.4 present the symbols used by a variety of authors in their pronunciation dictionaries and manuals, respectively, for the transcription of V+/r/ sequences.[6]

Of the three dictionaries referenced in Table 1.3, only Wells's (2008) includes some instances of schwa epenthesis (i.e., /ɪᵊr/, /eᵊr/, /ʊᵊr/, /aɪ‿ᵊr/ and /aʊ‿ᵊr/). The diacritic /‿/ that is present in the transcriptions of *hire* and *power* reflects the possibility of considering these words as composed of either one syllable or two.

Table 1.3 *Symbols for V+/r/ sequences in pronunciation dictionaries*

Word	Pronunciation dictionaries		
	Kenyon & Knott (1953)	Jones (2011; AmE)	Wells (2008; AmE)
fear	/ɪr/	/ɪr/	/ɪᵊr/ /iᵊr/
fair	/ɛr/	/er/	/eᵊr/
par	/ɑr/	/ɑːr/	/ɑːr/
pore	/ɔr/	/ɔːr/	/ɔːr/
poor	/ʊr/	/ʊr/	/ʊᵊr/ /ɔːr/
hire	/aɪr/	/aɪr/[a]	/aɪ‿ᵊr/
howl	/aʊər/	/aʊɚ/	/aʊᵊr/

[a] *fire* is transcribed as /faɪɚ/

Front vowels + possible /ə/+/r/
Back vowels + possible /ə/+/r/
Back vowels + /ɚ/

/ ᵊ / Sound sometimes optionally inserted
( ) Other possible, less common, transcriptions
/ ‿ / Possible compression of adjacent syllables

There is disagreement among authors concerning whether to phonemically represent the last element in V+/r/ sequences as /r/ or /ɚ/. Only Dauer (1993) favors the latter option, though Van Riper & Smith (1992) present it as a secondary option. As with the case of *power* in Jones (2011), advocating for /ɚ/ instead of /r/ leads to interpreting the sequences as composed either of diphthongs or monophthongs+/ɚ/,

[6] Throughout this section, vowel symbols will be represented in accordance with each author's choice.

on the one hand, or of triphthongs or diphthongs+/ɚ/, on the other hand, rather than of monophthongs+/r/ or diphthongs+/r/, thus generating confusion. Considering such sequences as diphthongs, triphthongs, monophthongs+/r/ or diphthongs+/r/ would imply the existence of one syllable, whereas considering them as monophthongs+/ɚ/ or diphthongs+/ɚ/ would suggest the presence of two.

Table 1.4 *Symbols for V+/r/ sequences in pronunciation manuals*

Word	Pronunciation manuals									
	Kenyon (1989)	Van Riper & Smith (1992)	Edwards (1997)	Calvert (1986)	Dauer (1993)	Baker & Goldstein (1990a & 1990b)	Avery & Ehrlich (1992)	Orion (1997)	Prator & Robinett (1985)	Celce-Murcia et al. (1996)
fear	/ɪr/ (/ir/)	/ɪr/ (/ɪɚ/)	/ir/ (/ɪr/)	/ɪr/ (/ir/)	/iɚ/ (/ɪɚ/)	/ɪr/ (/iyr/) (/ɪ^{ə}r/)	/ir/	/ɪr/	/ɪər/	/ɪr/ (/iyr/)
fair	/ɛr/ (/er/)	/ɛr/ (/ɛɚ/)	/ɛr/	/ɛr/ (/er/) (/eɪr/)	/ɛɚ/ (/eɪɚ/)	/ɛr/ (/eyr/) (/ɛ^{ə}r/)	/er/	/ɛr/	/ɛər/	/ɛr/ (/eyr/)
par	/ɑr/ (/ær/)	/ɑr/ (/ɑɚ/)	/ɑr/	/ɑr/	/ɑɚ/	/ɑːr/	/ar/	/ɑr/	/ar/	/ɑr/
pore	/ɔr/ (/or/)	/ɔr/ (/ɔɚ/)	/ɔr/	/or/ (/ɔr/) (/oʊr/)	/ɔɚ/ (/oʊɚ/)	/ɔːr/	/or/	/ɔr/	/ɔr/	/ɔr/ (/ɔwr/)
poor	/ʊr/	/ʊr/ (/ʊɚ/)	/ʊr/	—	/ʊɚ/ /ɔɚ/ (/oʊɚ/)	/ʊr/ (/uwr/) (/ʊ^{ə}r/)	/ʊr/	/ʊr/	/ʊr/	/ʊr/ (/uwr/)
hire	/aɪr/	/aɪr/ (/aɪɚ/)	—	—	/aɪɚ/	/aɪr/ (/aɪ^{ə}r/)	—	—	/aɪər/	/ayr/ (/ay^{ə}r/)
power	/aʊr/	/aʊr/ (/aʊɚ/)	—	—	/aʊɚ/ /aʊwɚ/	/aʊr/ (/aʊ^{ə}r/)	—	—	/aʊər/	/awr/ /awə^{r}/

- Front vowels + possible /ə/+/r/
- Front vowels + /ɚ/
- Back vowels + possible /ə/+/r/
- Back vowels + /ɚ/

/ ^{ə} / Sound sometimes optionally inserted
( ) Other possible, less common, transcriptions
— Not considered

The inclusion of /ɚ/ can be regarded as epenthetic, and especially so in those cases where the combinations of V+/ɚ/ are considered to belong to the same syllable, with the sequences then being preferably defined as diphthongs. In their study of American English front vowels before /r/, Clark and Hillenbrand (2003) choose "to use [ɚ] as the second part of the diphthong in question, based on the assumption that their first part is prominent and the second is an offglide to a relatively weaker centralized endpoint" (p. 1). In their study of American English back vowels before /r/ (Clark & Hillenbrand, 2007), they transcribe the second element in the same way. However, because their main object of study is the first element of the diphthongs, they do not provide an analysis of this second element in either of these studies.

Dauer (1993) is the only author who refers to V+/r/ sequences as centering diphthongs and uses a transcription system that is in accordance with the term. Her transcriptions include epenthetic schwa in all cases. Van Riper & Smith (1992) also refer to these sequences as centering diphthongs, but they present the transcription with /ɚ/ only as a secondary option. They do this on the grounds, first, that /ɚ/ "seems to be weaker and more fricative in nature (less vowel-like) than [ɚ] in such words as mother" (p. 137); and, second, that "it is the style used in most transcription today" (p. 137). Kenyon (1989) also uses the term *centering diphthongs* to refer to V+/r/ sequences, but on no occasion does he suggest transcribing the sequences with epenthetic schwa, transcribing them instead with vowel+/r/. In Jones (2011) the centering diphthongs in *fear*, *fair* and *poor* are transcribed without epenthetic schwa and with vowel+/r/ as well, but *fire* and *power* are transcribed with final /ɚ/. Moreover, the words *par* and *pour* are not considered to contain any centering diphthong. Prator and Robinett (1985) advocate for the term *centering diphthongs* as well, but their phonemic representation of the sequences is with final /r/ in all cases and with epenthetic schwa included in /ɪər/, /ɛər/, /aɪər/ and /aʊər/ but not in /ɑr/, /ɔr/ and /ʊr/. For them, the vocalic elements are the ones that constitute the centering diphthong and the /r/ is not part of it. All these authors consider the V+/r/ sequences in the words *hire* and *power* as centering diphthongs. A more appropriate term for these sequences, however, might be *centering triphthongs*, to distinguish them from those in the words *fear*, *fair*, *par*, *pore* and *poor*.

Other authors (Baker & Goldstein, 1990b; Celce-Murcia et al., 1996) do not talk of centering diphthongs, but they suggest epenthetic schwa as an option in at least some cases. Baker and Goldstein (1990b), for instance, consider /ɪᵊr/, /ɛᵊr/, /ʊᵊr/,

/aɪᵊr/ and /aʊᵊr/ possible, but they do not present epenthetic schwa in /ɑːr/ or /ɔːr/. Celce-Murcia et al. (1996) associate epenthetic schwa directly only with the diphthongs /ayəʳ/ and /aʊəʳ/, but indirectly with at least one other case, when they state that the conventional transcription of the V+/r/ sequence in *beard* as /ɪr/ "may not completely represent or capture the precise articulation of this /r/-colored vowel" (p. 104).

Even though the rest of authors do not transcribe the V+/r/ sequences with epenthetic schwa and do not even recommend doing so, some (Calvert, 1986; Edwards, 1997) acknowledge the presence of such a schwa between the two elements in the sequence. Moreover, Calvert (1986) states that this schwa "creates a diphthong sound" (p. 148). Similarly, Edwards (1977) points out that "some phoneticians transcribe the final sound in the vowel+/r/ offglides with the reduced r-colored vowel, /ɚ/" (p. 302), but that he keeps the use of /ɚ/ "for those productions when the off-glide is so pronounced that two syllables are approximated, as in /fiɚ/" (p. 302).

Both Calvert (1986) and Prator and Robinett (1985) refer to the tongue movement required in going from the vowel to the consonant as the reason for the existence of epenthetic schwa in these sequences. In common with V+/l/ sequences, the sound produced while the tongue is passing through the mid central area of the mouth is perceived as a schwa and is particularly noticeable in slow speaking rates.

As with V+/l/ sequences, some authors (Baker & Goldstein, 1990b; Calvert, 1986; Celce-Murcia et al., 1997; Dauer, 1993; Prator & Robinett, 1985) make a point of the inclusion of epenthetic schwa in V+/r/ sequences as a way for second and/or foreign language learners of English to associate the phonemic representation of the sequences with how they are both produced and perceived. Both Calvert (1986) and Prator and Robinett (1985) account for the existence of epenthetic schwa in these sequences in the same way as they did with V+/l/ sequences, that is, as the result of the tongue movement required in passing from the vowel to the consonant. Finally, Olive et al. (1993) again make no reference to transcription systems, but this time their account of V+/r/ sequences focuses on the difference between light /r/ and dark /r/ rather than on the possibility of and the reasons for the existence of schwa epenthesis. In fact, they only mention schwa epenthesis in relation to the diphthong /aɪ/. For them, the frequent insertion of a neutral vowel in the sequence /aɪɚ/ is the result of the slow gradual formant movement required for the transition from the diphthong to the /r/.

1.4 Phonological versus phonetic approaches

This section will provide an examination of different approaches to a variety of processes of 'vowel insertion' from a phonetic/phonological point of view. This, together with the information presented in sections 1.2 and 1.3, will establish the background to formulate the research questions, objectives and hypotheses of the present study (see section 1.5).

Epenthesis is a phonological process, defined by Trask (1996) as "the insertion of a segment into a word in a position in which no segment was previously present" (p. 132). A well-known case of epenthesis in English takes place in past simple and past participle forms of regular verbs whose infinitive form ends in /t/ or /d/, as in *accepted* /əkˈsɛptɪd; əkˈsɛptəd/ and *decided* /dɪˈsaɪdɪd; dɪˈsaɪdəd/ (Davenport & Hannahs, 1998; Jensen, 1993). A similar case of epenthesis is found in third-person singular present simple verb forms, plural noun forms and Saxon Genitive forms of words ending in one of the sibilant consonants /s, z, ʃ, ʒ, tʃ, dʒ/, as in *finishes* /ˈfɪnɪʃɪz; ˈf ɪnɪʃəz/, *churches* /ˈtʃɝtʃɪz; ˈ tʃɝtʃəz/ and *Alice*'s /ˈælɪsɪz; ˈælɪsəz/ (Davenport & Hannahs, 1998; Jensen, 1993). Although there is a choice between /ɪ/-epenthesis and schwa epenthesis in both cases, /ɪ/-epenthesis is more common in most varieties of English and is the transcription adopted by convention. What distinguishes these two cases of epenthesis from the case suggested by the insertion of the schwa-like element in the phonological transcriptions detailed in section 1.3 is the fact that they are well attested in the phonology literature and are often presented as typical examples of epenthesis. In addition, they are obligatory and thus apply in all cases without exception among native speakers of English.

A further example of schwa epenthesis (Davenport & Hannahs, 1998; Lass, 1984) is found in some dialectal varieties of English, such as Scots and Geordie, in which words like *film* /fɪlm>ˈfɪləm/ and *athlete* /ˈæθlit>ˈæθəlit/ are pronounced with epenthetic schwa in the liquid+nasal consonant cluster. In these cases, schwa epenthesis, though not compulsory, is characteristic of the speech of most speakers of those varieties.

Finally, there is the case of epenthetic stops in English (Ladefoged, 2001; Lass, 1984), which are found in words like *dreamt* /drɛmpt/, *prince* /prɪnts/ and *length* /lɛŋkθ/. In these words the oral stops /p/, /t/ and /k/ are inserted between their homorganic nasal stops and the final voiceless fricative as the result of "a timing lag between a nasal consonant and a following oral [consonant], where the velum closes before the 'target' post-nasal closure is formed" (Lass, p. 184). The cases of epenthetic stops resemble those of the schwa-like element in V+/l/ and V+/r/ sequences in that neither are obligatory requirements and both are speaker-dependent as much as dependent on speaking rate, being more typical of slow speaking rates than of fast ones. However, while epenthetic stops are widely recognized as a phonological process in the phonology literature (Ladefoged, 2001; Lass, 1984), the case of the schwa-like element in V+/l/ and V+/r/ sequences is not, as shown by the lack of agreement among authors concerning the transcription of these sequences as well as by the lack of reference to the process as one of schwa epenthesis. Therefore, it is doubtful whether the process under study is of a phonological nature and whether it should be termed schwa epenthesis.

In section 3.1 the terms *pre-l breaking* and *pre-r breaking* were introduced to refer to the process of insertion that results in the development of a schwa-like element in V+/l/ and V+/r/ sequences whereby monophthongs become diphthongs and diphthongs become triphthongs (Wells, 2008). Along similar lines is Lavoie and Cohn's (1999) study of vowel-liquid syllables, which investigates monosyllables consisting of non-low tense monophthongs or diphthongs followed by /l/ or /r/. They conclude that the words can be pronounced with either one or two syllables and that they in fact consist of one and a half syllables, accordingly terming them *sesquisyllables*. Their interpretation is that monophthongs can be best classified as being in between the categories of monophthong and diphthong and, likewise, that diphthongs can be best classified as being in between the categories of diphthong and triphthong.

Vowel breaking refers to the development of a sound change whereby monophthongs diphthongize in certain environments. This is a phonological process that is well attested historically in a variety of Germanic languages and is particularly characteristic of Old English. Jones (1989) and Lass (1994) explain Old English breaking as the insertion of [u] after front vowels that are followed by the consonants [l], [r] or [x], which are considered back consonants. According to these authors, the insertion of a transitional vowel of a back quality would be the assimilatory result of the front-to-back movement required in going from the front vowel to the back consonant. These authors then propose a subsequent process of diphthong height harmony which turns the inserted [u] vowel into a central, schwa-like vowel which is assumed to be the standard pronunciation of the Old English diphthongs spelled *ea* and *eo*. The pre-l and pre-r breaking processes put forward by Wells (2008) would suggest that this two-step process (i.e., breaking + harmony) can be simplified as one single process of a coarticulatory nature that takes place in equivalent V+/l/ and V+/r/ sequences in present day American English.

Table 1.5 shows examples of Old English words that underwent breaking and diphthong height harmony compared with their pre-Old English (i.e., Old High German and Gothic) cognates according to Jones (1989) and Lass (1994). Table 1.6 shows examples of present-day American English words undergoing pre-l and pre-r breaking according to Wells (2008).

Table 1.5 *Breaking and diphthong height harmony: from Pre-Old English to Old English*

Pre-Old English & Old English (Jones, 1989; Lass, 1994)							
Pre-Old English		Old English					
		Breaking [u] Insertion	Diphthong height harmony [u] > [ə]				
	[i]	[i] > [iu] >	[io] >	[eo] >	[eə]		
OHG	*hirti*		*hiorde*	*heorde*		*'shepherd'*	Short
Gothic	*mihst*		*miox*	*meox*		*dung'*	Front
	[e]	[e] > [eu] >	[eo] >	>	[eə]		Vowel
OHG	*elaho*					*'elk'*	
OHG	*erda*					*'earth'*	+
OHG	*sehs*					*'six'*	
	[a]	>[æ] > [æu] >	[æa] >	>	[æə]		[l]
OHG	*ald*		*eald*			*'old'*	[r]
OHG	*barn*		*bearn*			*'child'*	[x]
OHG	*ahto*		*eahta*			*'eight'*	

Table 1.6 *Pre-l and pre-r breaking in present-day GA English*

Present-day GA English (Wells, 2008)					
Pre-l breaking				Pre-r breaking	
feel [fiᵊl]	*pile* [paɪᵊl]	*pool* [puᵊl]	*howl* [haʊᵊl]	*fear* [fiᵊr]	*hire* [haɪᵊr]
pale [peᵊl]	*boil* [bɔɪᵊl]	*hole* [hoᵊl]		*fair* [fɛᵊr]	*power* [paʊᵊr]

Hall (2003, 2004, 2006) provides a comprehensive account of the differences between epenthetic and intrusive vowels. In particular, she distinguishes between schwa epenthesis/insertion and schwa intrusion, claiming that the schwa-like element in the CC clusters of her studies belongs to the latter type. According to this author, intrusive vowels are phonologically invisible, are inserted late in the phonological derivation, cannot act like syllable nuclei, do not add a syllable to the word, and do not involve the addition of a vowel segment. Moreover, they are not likely to occur in the most marked types of CC clusters, tend to occur between heterorganic consonants, copy only over sonorants or gutturals and are either copy vowels or neutral and schwa-like in quality. Finally, they come in a restricted range of qualities, are often variable in duration and have a tendency to disappear in fast and/or casual speech.

Other authors, who have carried out experimental studies to look into V+/l/ and V+/r/ sequences and have focused their analyses on the schwa-like element that is often perceived in some of these sequences, have used terms like *excrescent schwa* (Gick & Wilson, 2001, 2006), *targetless schwa* (Browman & Goldstein, 1992) or *epenthetic schwa* (Warner, Jongman, Cutler, & Mücke, 2001) to refer to this element.

Gick and Wilson (2001, 2006) attribute the perceptual presence of their *excrescent schwa* to the movement required by the tongue when two tongue-body targets are articulatorily in conflict. Their ultrasound studies focus on non-low vocalic targets moving through a schwa-like configuration in their attempt to reach the target for the liquid consonants /l/ and /r/. They explain the perceptual presence of this excrescent schwa in words like *feel* and *file* as the result of the tongue movement required in passing through a schwa-like configuration, or 'schwa space', as it moves from the advanced tongue root position for the vowel to the retracted tongue root position for the /l/ or /r/. Gick, Min Kang, and Whalen (2002) find that /l/ and /r/ share a similar post-oral gesture implying tongue dorsum backing, which would account for this excrescent schwa not being present in sequences containing back vowels. As shown in sections 1.3.1 and 1.3.2, explanations along similar lines to account for the presence of a schwa-like element in American English V+/l/ and V+/r/ sequences are provided by other authors like Calvert (1986), Prator and Robinett (1985) or Olive et al. (1993).

Browman and Goldstein (1992), in their analysis of CVCCVCV sequences, refer to the schwa-like element in those sequences as a targetless schwa. This is a vocalic element with spectral and duration values similar to those that are often attributed to canonical schwa but, at the same time, it somehow differs from it. In fact, their synthesized targetless schwa implies the existence of "different" schwas, which are defined as targetless because of the characteristics of the syllables in which they are found (i.e., unstressed) and because of the influence exerted on them by neighboring vocalic segments, to the point that they may even not sound schwa-like, as is the case when they are preceded and followed by syllables containing high vowels. Van Bergem (1994) corroborated the findings by Browman & Goldstein (1992) regarding the targetless nature of schwa. In a study that used nonsense words to investigate the coarticulation of Dutch schwa in open and closed syllables, the author concluded that there was no clear articulatory target for the schwa and that the specific realization of this vowel was completely dependent on the phonological context.

Barry (1998), however, provides evidence for the existence of a schwa which has a target. He carried out a study on German schwa that manipulated speaking rate as well as vowel and consonant contexts. The results obtained for duration appeared to be incompatible with the notion of schwa as a targetless element. Specifically, the fact that the context influenced the schwa differently depending on speaking rate was taken as evidence that there was some kind of neutral target for the schwa, rather than a completely targetless vowel. Warner et al. (2001) used articulatory data to determine whether epenthesis of schwa in Dutch was the result of a phonological process of vowel insertion or of a phonetic process related to gestural timing. After examining the behavior of /l/ in different syllabic positions, they found that the variability observed in the /l/ must be conditioned by the schwa, which led them to conclude that this schwa should be understood as an actual epenthetic segment, rather than as the result of the timing of articulatory gestures. Hence their referring to this schwa as *epenthetic schwa*.

Riera and Romero (2007) and Riera, Romero, and Parrell (2009) conducted two experimental studies in which canonical schwa was compared to a vocalic element of a mid central unstressed nature (i.e., schwa-like) present in the VC transitions of V+/l/ (see the 2007 study) and V+/r/ (see the 2009 study) sequences. The canonical schwa which was analyzed in these studies was a vowel that showed relatively stable spectral characteristics and was not subject to significant contextual variability, as in the first syllable of the words *alive* and *arrive*, in opposition to the transitional vocalic element in words like *feel* or *fear*. The results of these studies revealed significant durational and spectral differences between canonical schwa and the transitional element. They suggested the presence of a highly variable element which differed from canonical schwa as a function of both speaking rate and the preceding vowel. Canonical schwa exhibited longer duration and smaller F1, F2 and F3 variability than the transitional element.

Coarticulation is defined by Hammarberg (1976) as "a process whereby the properties of a segment are altered due to the influences exerted on it by neighboring segments" (p. 357). Kühnert and Nolan (1999) state that coarticulation "refers to the fact that a phonological segment is not realized identically in all environments but often apparently varies to become more like an adjacent or nearby segment" (p. 7). Ladefoged (2001) defines it as "the overlapping of adjacent articulatory gestures" (p. 247). Along similar lines, Recasens (1999) defines coarticulation as "temporal coproduction of gestures" (p. 81), though he also hints at a possible distinction between what he calls *coarticulation proper* and *gestural overlap*. This distinction is proposed on the basis of existing evidence that the nature and effects of coarticulatory processes are different depending on whether they involve independent articulators or specific tongue regions. Thus, in this view gestural overlap would be a more accurate term for situations where independent articulators are involved (e.g., lips and tongue, or tongue and velum), whereas coarticulation proper would be reserved for those cases where the articulatory structures are intrinsically connected (e.g., tongue tip and tongue dorsum, or different parts of the dorsum). Given that the V+/l/ and V+/r/ sequences under investigation in this dissertation are composed of gestures that involve different parts of the tongue exclusively, the use of the term *coarticulation* to describe the phonetic effects observed in them seems adequately justified.

Whatever the definitions, a process of coarticulation requires two or more sounds to become in contact and to influence each other, either in a progressive manner (i.e., from left to right: *carryover coarticulation*) or in a regressive manner (i.e., from right to left: *anticipatory coarticulation*). Consequently, a process of coarticulation implies that, far from being independently produced, neighboring sounds overlap, blend and even, in extreme cases, disappear. Coarticulation processes take place continuously in connected speech, but they may also be present in words pronounced in isolation. In fact, some authors (Hammarberg, 1976, 1982; Kühnert & Nolan, 1999) consider it necessary to take both the phonetic and the phonological levels into account when studying coarticulation. According to these authors, in any instance of coarticulation, behind the phonetic representation of the allophone (i.e., a physical tangible unit), there is always the phonemic representation of the phoneme (i.e., a mental abstract unit).

It is not clear from the transcription accounts reported in section 1.3 whether the schwa-like element that is often transcribed between the vowel and the consonant in some V+/l/ and V+/r/ sequences is to be understood as the result of a phonological process such as epenthesis/insertion, or of a phonetic one like coarticulation. If it is considered the result of an epenthetic process, then phonemic/phonological transcriptions should include this element, which would be considered a schwa segment. On the other hand, if it is viewed as the result of a coarticulatory process, only allophonic/phonetic transcriptions should include it, and it would not necessarily have to be considered a schwa segment, but rather it could simply be regarded as a transitional element. It seems, therefore, quite reasonable to state that, in order to avoid confusion, the phonemic/phonological and the allophonic/phonetic levels should be kept separate in transcription.

None of the authors referred to in section 1.3 actually use the terms *epenthesis* or *coarticulation* in their analyses of the sequences, although some (Baker & Goldstein, 1990b; Celce-Murcia et al., 1996; Olive et al., 1993; Prator & Robinett, 1985; Wells, 2008) refer to the process at play as one of insertion. Thus, according to these authors, at least, the process may be considered as one of epenthesis. However, as seen in section 1.3, the presence of this schwa-like element is often attributed to the influence exerted by the /l/ and the /r/ on the preceding vowel. In particular, it is seen as the result of the tongue movement required in passing from the vowel to the consonant. The articulatory nature of the transitions between high vowels and /l/ or /r/ involves a rather large tongue dorsum movement which can be identified auditorily as a central, schwa-like vowel (Calvert, 1986; Gick & Wilson, 2001, 2006; Gick et al., 2002; Olive et al., 1993; Prator and Robinett, 1986). After low and central vowels, however, this transition is much less obvious since these vowels already involve the tongue dorsum and therefore the auditory impression may be simply that of a longer vowel. In line with this interpretation, and as corroboration of Recasens's (1999) proposal mentioned above, the process could thus be regarded as one of lingual coarticulation.

1.5 Research questions, objectives and hypotheses

As stated in section 1.1, the general goal of this dissertation is to contribute to a better understanding of the phonetic and phonological nature of the V+/l/ and V+/r/

sequences under study by investigating the extent of the VC coarticulatory processes that take place in them. Two objectives will now be presented which will expand on this general goal, will set the ground to look for answers to two research questions and will lead to the formulation of four hypotheses (i.e., one for the first research question and objective, and three for the second ones). In the two following subsections, the research questions are outlined in first place, the objectives in second and the hypotheses in third. After the formulation of the hypotheses, the implications for them are detailed.

1.5.1 The first research question, objective and hypothesis

The first research question that this dissertation addresses is the following:

> Are there identifiable VC transitions in all the V+/l/ and V+/r/ sequences?

The first objective aims to identify the presence of VC transitions containing a vocalic element of a mid central unstressed type (i.e., schwa-like) in all the V+/l/ and V+/r/ sequences under study (i.e., in the 15 V+/l/ and the seven V+/r/ contexts, as well as in slow and fast speaking rates). This objective leads to the formulation of the following hypothesis:

Hypothesis 1:

> A transitional vocalic element will be present in all the sequences.

Spectrographic inspection (i.e., visual and auditory), speech signal segmentation (i.e., manual and automatic) and acoustic measurements (i.e., duration, F1 and F2) will make it possible to identify the presence of this element in all the sequences (see Chapter 2, sections 2.4 and 2.5). The findings, especially those of the statistical tests regarding duration, will reveal that the process under study is a generalized one involving slow and fast speaking rates and covering all contexts rather than just some like those containing high front and high back tense vowels.

Identifying the existence of VC transitions will be the fist step to determine the nature of the vocalic element in them. The next step will require looking into the roles of speaking rate and context, which will be dealt with in the second research question, objective and hypotheses.

1.5.2 The second research question, objective and hypotheses

The second research question that this dissertation addresses is the following:

> Can the coarticulatory nature of the vocalic element in the VC transitions of V+/l/ and V+/r/ sequences be explained in terms of rate and context?

The second objective aims to study the role of speaking rate and context in order to explain the coarticulatory nature of the transitional vocalic element. This will be done by exploring speaking rate differences between slow and fast productions as well as by examining the relationship between this element and its preceding vowel, which is the one that is responsible for setting the context. In particular, it seeks to investigate the extent to which the spectral (i.e., F1 and F2) characteristics of this element are related to those of its preceding vowel. This second objective leads to the formulation of the following three closely related hypotheses:

Hypothesis 2a:

> The acoustic characteristics of the transitional vocalic element will vary as a function of rate.

Hypothesis 2b:

> The acoustic characteristics of the transitional vocalic element will vary as a function of context.

Hypothesis 2c:

> The faster the rate, the more similar to the preceding vowel the acoustic characteristics of the transitional vocalic element will be.

For the transitional vocalic element to be considered the outcome of a coarticulatory process, the results of the statistical tests carried out to test these hypotheses (see Chapter 3) will reveal significant differences in this element due to speaking rate. Given the fact that an increase in speaking rate entails a decrease in time for articulatory gestures to attain their targets, results are expected to show significant rate differences in F1 and F2 values for this element. Likewise, a comparison of the mean formant values of the transitional vocalic elements in the different contexts (i.e., determined by each of the preceding vowels in the V+/l/ and V+/r/ sequences) is expected to yield significant differences, revealing their variability caused by the preceding vowel. Such variability could be explained in terms of the resemblance of the acoustic characteristics of the elements to those of their preceding vowels. Moreover, a shorter transitional period ought to give rise to more similar values between the elements and their preceding vowels.

Chapter 2 Method

This chapter deals with the methodological aspects of this dissertation and is divided into the following eight sections. Section 2.1 introduces the subjects. Section 2.2 reports the experimental design and the stimuli. Section 2.3 focuses on the data collection. Section 2.4 describes the data inspection process, with reference to auditory inspection in section 2.4.1, acoustic signal inspection in section 2.4.2 and further auditory and acoustic signal inspection in section 2.4.3. Section 2.5 elaborates on the segmentation procedure. Section 2.6 details the measurements, calculations and descriptive statistics. Section 2.7 is devoted to vowel formant normalization. Finally, section 2.8 presents the inferential statistical analyses.

2.1 Subjects

The subjects that participated in the experiment were six educated native speakers of American English. Their ages ranged from 24 to 40. Four were male and two female. Even though they came from different parts of the United States and thus spoke American English with slightly different accents, all of them had rhotic accents. They were all living in the Barcelona (Spain) area when they performed the experiment and were proficient in Spanish and knowledgeable in Catalan. In all cases, English was their mother tongue, they spoke English on a daily basis at home, with friends and in the workplace, and they considered any other languages they knew as second or foreign. A seventh subject that also took part in the experiment was discarded because he was bilingual in English and Spanish.

Subject 1 was a 25-year-old female from Tennessee with an upper-southern accent who had also lived in Texas and had been living in Spain for ten years. Subject 2 was a 24-year-old male who had a mid-western accent and had lived in Wisconsin, Oregon, Illinois and California. Subject 3 was a 24-year-old male from Utah who had also lived in New Mexico, and Subject 4 was a 27-year-old male from Wyoming who had lived in Utah as well. Subjects 2, 3 and 4 were temporarily living in Spain for one year. Subject 5 was a 30-year-old male from California and had been living in Spain for three years. Subjects 3, 4 and 5 all had western accents. Subject 6 was a 40-year-old female who, despite having lived in New York, New Jersey and Florida, self-identified her accent as mid-western. She had been living between Spain and the United States for twenty-two years.

Any differences concerning age, sex, geographical origin, knowledge of foreign languages, education, profession, phonetic training or previous participation in speech production experiments were considered minor or irrelevant for the purposes of the study. Only Subject 2 had some specialized phonetic training and only Subjects 1 and 2 had taken part in similar experiments. None of the subjects reported having any visual, hearing or speaking impairment. All of them were unaware of the purposes of the experiment at the time of the recording and were only informed of them after they had finished it. Right before the experiment, the subjects were asked to fill out a questionnaire to provide some general personal information about themselves. The information that was considered directly relevant for the purposes of the study (i.e., sex, age, self-identified accent and place of residency) is presented in Table 2.1. A blank version of this questionnaire is reproduced in Appendix A.

Table 2.1 *Subjects' personal information relevant for the purposes of the study*

Subject	Sex	Age	Self-identified accent	Place of residency (from age...-to age...)	
1	F	25	upper-southern	Jackson, TN (0-10) Houston, TX (10-12)	Jackson, TN (12-15) Tarragona, Spain (15-25)
2	M	24	mid-western	Madison, WI (0-18) Eugene, OR (18-22) Chicago, IL (22-23)	Barcelona, Spain (23-24) Los Angeles, CA (24-25)
3	M	24	western	Bountiful, UT (0-19) Santa Fe, NM (19-21) Bountiful, UT (21-22)	Layton, UT (22-24) Tarragona, Spain (24-25)
4	M	27	western	Worland, WY (0-19) Powell, WY (19-20)	Ogden, UT (20-26) Tarragona, Spain (26-27)
5	M	30	western	Concord, CA (0-27)	Tarragona, Spain (27-30)
6	F	40	mid-western	Brooklin, NY (0-8) Englewood, NJ (8-11) Eaglelake, TX (11-15)	Miami, FL (15-18) Barcelona, Spain (18-21) Tarragona, Spain (21-40)

Accent differences, whether due to dialectal or idiolectal characteristics, were not regarded as particularly relevant. However, as will be shown in section 2.4.3, some of these differences had to be taken into consideration when carrying out the data inspection and, in consequence, some tokens had to be discarded.

2.2 Experimental design and stimuli

In order to test the hypotheses presented in Chapter 1 (section 1.5), the experimental design included two variables: rate and context. Rate had two levels: slow and fast. Context had 15 levels for the V+/l/ sequences (i.e., /il/, /ɪl/, /el/, /ɛl/, /æl/, /ɑl/, /ɔl/, /ol/, /ʊl/, /ul/, /ʌl/, /ɝl/, /aɪl/, /ɔɪl/ and /aʊl/) and seven levels for the V+/r/ sequences (i.e., /ir/, /ɛr/, /ɑr/, /ɔr/, /ʊr/, /aɪr/ and /aʊr/). The stimuli that were selected for the experiment were all English stressed monosyllables containing strong, stressed vowels and consisted of target words and distracters. Table 2.2 shows these stimuli, separated into target words and distracters and with the transcription provided for each word.

Table 2.2 *Stimuli used for the experiment*

Target words				Distracters			
V+/l/		V+/r/		V+/t/		V+/d/	
feel	/fil/	*fear*	/fir/	*heat*	/hit/		
bill	/bɪl/			*fit*	/fɪt/		
pale	/pel/			*hate*	/het/		
fell	/fɛl/	*fair*	/fɛr/	*vet*	/vɛt/		
pal	/pæl/			*fat*	/fæt/		
Poll	/pɑl/	*par*	/pɑr/	*hot*	/hɑt/		
Paul	/pɔl/	*pore*	/pɔr/	*fought*	/fɔt/		
hole	/hol/			*vote*	/vot/		
pull	/pʊl/	*poor*	/pʊr/			*hood*	/hʊd/
pool	/pul/					*food*	/fud/
hull	/hʌl/			*hut*	/hʌt/		
furl	/fɝl/					*heard*	/hɝd/
pile	/paɪl/	*hire*	/haɪr/			*hide*	/haɪd/
boil	/bɔɪl/					*void*	/vɔɪd/
howl	/haʊl/	*power*	/paʊr/			*vowed*	/vaʊd/

The stimuli were inserted in the carrier sentence *Say ___ for me again*. The target words for the V+/l/ sequences were CVC words where V was one of the 15 strong, stressed vowels of GA English, all of which can precede /l/. The target words for the V+/r/ sequences were CVC words in which V was one of the seven strong, stressed vowels of GA English that can appear before /r/. The distracters were 15 CVC words where V was one of the 15 strong, stressed vowels of GA English, which coincide with the vowels that can precede /l/, and coda C was either /t/ or /d/.

In all the target words and distracters, onset C was restricted to non-lingual (unlike /r/ and /l/) and oral (like /r/ and /l/) consonants (i.e., /p/, /b/, /f/, /v/ and /h/). Likewise, onset C in the word *for* in the carrier sentence was non-lingual and oral. The choice of these consonants was made for the purposes of avoiding, or at least minimizing, coarticulatory influence. Any possible carry-over effect of onset C on V, or even on coda C, was not considered for the analysis or the results, and neither was any possible anticipatory influence of the /f/ in *for* on coda C.

In addition to the target words and distracters, 25 words were selected for the trial session that the participants performed before they took part in the experimental session proper. These trial words were CVC, CVCC or CCVC monosyllables containing the 15 strong, stressed vowels of GA English and a variety of onset and coda consonants. They were inserted in the same carrier sentence as the target words and distracters (i.e., *Say ___ for me again*). Table 2.3 shows these stimuli, with the transcription provided for each word.

Table 2.3 *Stimuli used for the trial session prior to the experiment*

Trial words			
beach	/bitʃ/	*seem*	/sim/
ship	/ʃɪp/		
mail	/mel/	*rain*	/ren/
pen	/pɛn/	*yes*	/jɛs/
cat	/kæt/		
shop	/ʃɑp/	*car*	/kɑr/
course	/kɔrs/		
phone	/fon/	*soul*	/sol/
book	/bʊk/	*wood*	/wʊd/
soup	/sup/	*fruit*	/frut/
love	/lʌv/	*sun*	/sʌn/
church	/tʃɝtʃ/	*nurse*	/nɝs/
height	/haɪt/		
noise	/nɔɪz/		
house	/haʊs/	*loud*	/laʊd/

2.3 Data collection

The data collection took place in the Speech Analysis Unit at *Universitat Rovira i Virgili* (Tarragona, Spain) over a period of one year. Three of the subjects, as well as the subject that was discarded, were recorded in April 2008; two more subjects were recorded in November 2008; and the last subject was recorded in April 2009. The data collection was carried out in two experimental sessions for each speaker, who sat inside a 170x85x60-centimeter (i.e., height x length x width) soundproof booth while performing the readings of the target words and distracters reported in section 2.2 (Tables 2.2 and 2.3). These stimuli were automatically displayed on a computer screen in the form of a Power Point slide presentation. During the first session, the subjects read the tokens at a slow speaking rate. During the second session, they read the same tokens, presented in the same order, at a faster rate. The two sessions were separated by a 30-minute break and were preceded by a trial session each. Right before each of the trial sessions, the subjects were given oral and written instructions as to how to proceed during the trial and experimental sessions. The subjects were also referred to the stimuli display on the computer presentation while they were being given the instructions. The written instructions are reproduced in Appendix B in the same format as they were presented to the subjects (i.e., in outline format and on paper). It was thought more appropriate to accompany the oral instructions with an outline than to only give them orally or to provide them in text format for the subjects to read. Appendix B also includes a reproduction of part of the Power Point slide presentation used for the trial sessions.

The trial productions, though recorded, were not considered for analysis. The trial sessions allowed for seat, body position, microphone and volume adjustments. They also made it possible for the subjects to get used to sitting inside a small soundproof booth as well as to familiarize themselves with the dynamics of the experiment. In addition, they were useful to monitor their performances (i.e., by pointing to them from outside the booth, by means of signaling and gesticulation, to speak more slowly or faster, to raise or lower their voices, or to get closer to or move away from the microphone). These trial sessions were separated from the experimental ones by a 5-to-10-minute break during which the subjects received feedback on their performances and were given further instructions or recommendations. They were also conceived as an anxiety-reduction mechanism, especially taking into consideration that four of the six subjects had never taken part in any experiment before.

Speaking rate was controlled for by presenting the slow-rate tokens at different time intervals than the fast-rate ones in both the trial and experimental sessions. The inclusion of an intermediate speaking rate, which might be termed *normal*, had been discarded after pilot studies had provided evidence that it was difficult for the subjects to maintain differences between three speaking rates, despite the tokens still being presented at different time intervals. The main problem caused by having three different speaking rates was that some of the normal productions would have had to be considered as either slow or fast instead of normal.

The slow-rate tokens appeared at 4-second intervals separated by a 1-second blank slide. The sentences were typed in black and were enclosed in a rectangle with a yellow background that stood out against a black screen background (see Appendix B). They were presented in groups of 75 sentences. After each group, a slide with the word *REST* typed in yellow and enclosed in a black rectangle that stood out against a yellow screen background appeared (see Appendix B). This was meant as a signal for the subjects to stop reading and take a short break.

Due to the high speed at which the fast-rate tokens had to be read, these were organized in a slightly different manner from the slow-rate ones. They appeared at 1-second intervals in series of five sentences with no blank slide between them. Each series was separated from the next by a 5-second pause marked by a countdown from 5 to 1 during which the subjects could comfortably breathe and swallow. The yellow background in the rectangle changed to green every other sentence as an aid for the subjects to know when they were presented with a new sentence to read. As with the slow-rate tokens, a *REST* slide appeared after every 75 sentences (see Appendix B).

The end of the sessions was marked by the words *THE END* in the same format as the word *REST* (see Appendix B). Each corresponding sound file was saved during each rest period and at the end of each session. This was done for convenience purposes in case the experiment had to be unexpectedly stopped. In order to prevent the subjects from giving too much emphasis to the target words and distracters, the sentences were typed in normal (i.e., no italics, no boldface and no underlining) font type. The subjects were also instructed to try not to give too much emphasis to these words.

Each subject performed 10 semi-randomized repetitions of 37 carrier sentences that contained the 22 target words and the 15 distracters, yielding a total of 370 sentences per experimental session. Each of the 37 words appeared only once in each group of repetitions. As for the trials that preceded each experimental session, each subject read a total of 78 sentences, equivalent to three semi-randomized repetitions of the carrier sentences containing the 25 trial words plus three more words that were added at the end. Each of the 25 trial words appeared only once in each group of repetitions. The last three words were randomly chosen among the 25.

Appendix C lists all the stimuli presented in the order in which they were shown to the subjects to read in the trial and experimental sessions.

As shown in Tables 2.4 and 2.5, the time involvement required of each subject to perform the trial and experimental sessions was around 45-50 minutes for the slow productions (Table 2.4) and around 20-25 minutes for the fast ones (Table 2.5). There was a 5-to-10-minute break between the trial and the experimental sessions. With a 10-minute instructions session at the beginning, the total time involvement was around 55-60 minutes for the slow productions and around 30-35 minutes for the fast ones. There was a 30-minute break between the slow and fast sessions.

Table 2.4 *Time involvement for slow productions for the trial and the experiment*

Time involvement: Slow productions						
Trial			Break	Experiment		
Tokens	Time (approx.)	Breaks		Tokens	Time (approx.)	Breaks
1-75	6 min 30 s	REST		1-75	6 min 30 s	REST
76-78	15 s	THE END		76-150	6 min 30 s	REST
				151-225	6 min 30 s	REST
				226-300	6 min 30 s	REST
				301-370	6 min	THE END
	6 min 45 s	+	5-10 min	+	32 min	= 45-50 min
						+ 10 min
						55-60 min

Table 2.5 *Time involvement for fast productions for the trial and the experiment*

Time involvement: Fast productions						
Trial			Break	Experiment		
Tokens	Time (approx.)	Breaks		Tokens	Time (approx.)	Breaks
1-75	2 min 30 s	REST		1-75	2 min 30 s	REST
76-78	5 s	THE END		76-150	2 min 30 s	REST
				151-225	2 min 30 s	REST
				226-300	2 min 30 s	REST
				301-370	2 min	THE END
	2 min 35 s	+	5-10 min	+	12 min	= 20-25 min
						+ 10 min
						30-35 min

The data were recorded at a 44100 Hz sampling rate directly into an Apple Macintosh laptop computer using an M-Audio Nova condenser microphone, an M-Audio Firewire Solo mobile interface, and the Praat speech analysis software (Boersma & Weenink, 2010). A Studio Projects SP-MPF metal pop filter was positioned at a distance between 8 and 12 centimeters from the microphone. This was particularly useful to reduce the effect of large bursts of air resulting mainly from the production of aspirated stops and, to a lesser extent, fricatives.

All the recording sessions took place without any serious incidents. However, one of the sound files of Subject 6's fast productions happened to be damaged for some unknown reason and was impossible to restore. Consequently, part of the data for this subject was missing from the beginning. In particular, the words affected were all the words in the third randomized repetition, except *pile*, as well as all the words in the fourth randomized repetition. The consequences that not having these data might have led to were not considered important enough to discard this speaker. After all, it only involved the fast tokens, and having eight instead of ten productions for this speaker was still regarded as representative of her pronunciation. Because of requirements posed by the statistical analyses presented in sections 2.6 and 2.8 and the vowel formant normalization procedure described in section 2.7 (e.g., data from 10 tokens is necessary in all cases), mean values were used in place of the missing values of these words.

2.4 Data inspection

2.4.1 Auditory inspection

The first stage of the data inspection consisted of the auditory inspection of all the productions. Once individual files for each token had been created, all the files were listened to at least twice to check on production accuracy in order to identify tokens that needed to be discarded at this early stage. A total of eight slow-rate and 30 fast-rate problematic cases were detected. This was considered an acceptable outcome, especially because it affected the fast tokens in a higher proportion than the slow ones (i.e., resulting in a ratio of 3.75:1) and because of the difficulties inherent in the task, which were caused mainly by the high speed at which the sentences needed to be uttered. Also, there were 32 cases affecting V+/l/ words but only six affecting V+/r/ words (i.e., yielding a ratio of 5.3:1). This might be interpreted as being in accordance with the fact that the V+/l/ words outnumbered the V+/r/ ones in a ratio of 2.1:1, although the ratios are not equivalent to each other. Similarly to what had been done with Subject 6's missing tokens reported in section 2.3, the values that corresponded to these discarded tokens were replaced with mean values so that the statistical analyses presented in sections 2.6 and 2.8 and the vowel formant normalization procedure described in section 2.7 could be carried out appropriately.

Most of the discarded cases involved mispronunciations caused by slips of the tongue (e.g., pronouncing /pe...pæl/ instead of *pal*, /pɛ...fɛl/ instead of *fell* or /pɑl...ɹd/ instead of *Poll*), confusing one target word for another with immediate self-correction (e.g., *boil...bill*, *fell...feel* or *fair...fear*) or without self-correction (e.g., *feel* instead of *fell*, *pal* instead of *pale* or *Paul* instead of *pal*), and saying a different word from the intended one or any of the other target words (e.g., *fool* instead of *pool*, *food* instead of *poor* or *pair* instead of *par*). Many of these cases had to do with mistaking one word for the other word in the following pairs of words: *bill*-*boil*, *feel*-*fell*, *pal*-*pale*, *pal*-*Poll* and *fear*-*fair*. This was understandable given the spelling similarity between the two words in most of these pairs. Apart from these cases, there were others involving repetition of the same word (e.g., *pal...pal*), not finishing the sentence (e.g., *Say hire...*), or not being able to keep up with the pace required to read the fast tokens (e.g., *pull...fought...fear* instead of *Say pull for me again*, *Say fought for me again* and *Say fear for me again*). Finally, there were two cases involving excess noise that made the utterances difficult to understand (i.e., Subject 3's *bill 3* and *par 3* productions).

2.4.2 Acoustic signal inspection

The second stage of the data inspection required acoustic signal inspection in order to determine the most appropriate *maximum formant (Hz)* value in Praat (Boersma & Weenink, 2010) for each speaker as a means to control for differences in each speaker's fundamental frequency (F0). The *Praat Tutorial* (Boersma & Weenink, 2010) points out the importance of finding the suitable value for each speaker so as to end up with the right number of formants in each of the frequency regions. The parameter to change this value is to be found in Praat under *Praat: Formant: Formant Settings: Maximum formant (Hz)*. A manual change of this value results in an automatic change in the ceiling of the formant search range (in Hertz) and, subsequently, in a modification of formant tracking alignment in the spectrogram.

The better aligned the formants are, the smaller the presence of spurious formants is, and thus the easier any segmentation procedure like the ones described in section 2.5 becomes and then the more reliable the results of the procedure are expected to be.

All the tokens were visually inspected for best formant tracking alignment in the corresponding spectrogram. The *maximum formant (Hz)* value that provided the best alignment was recorded for each token. Mean, mode and median values were subsequently obtained for each token and speaker independently. All the values are presented in Appendix D. A rounded-up value between those of the mean and the mode was then chosen as the *maximum formant (Hz)* value to be used for all the tokens of a given speaker. The same value was also used in the scripts that generated the first derivative curves described in section 2.5.

The standard *maximum formant (Hz)* value that is recommended in the *Praat Tutorial* (Boersma & Weenink, 2010) for female voices is 5500 Hz, while the one for male voices is 5000 Hz. Table 2.6 shows the values that were finally chosen for each speaker. As can be observed in this table, the two female speakers have values closer to 5500 Hz than to 5000 Hz (i.e., 5300 Hz). Similarly, two of the male speakers have values closer to 5000 Hz than to 5500 Hz (i.e., 4700 Hz). The other two male speakers may be said to exemplify deviations from the general norm, since the value for one of them is lower than generally expected (i.e., 4300 Hz) and the value for the other is higher, being closer to the one recommended for female voices and exactly the same as the one chosen for the two female speakers (i.e., 5300 Hz).

Table 2.6 *Maximum formant (Hz) value in Praat for each speaker*

Maximum formant (Hz)					
Subject 1 (female)	Subject 2 (male)	Subject 3 (male)	Subject 4 (male)	Subject 5 (male)	Subject 6 (female)
5300	4700	4700	4300	5300	5300

2.4.3 Further auditory and acoustic signal inspection

The third stage of the data inspection involved a combination of auditory and visual acoustic signal (i.e., waveform and, particularly, spectrographic) inspection in an attempt to confirm that some of the target words had been pronounced as expected. No measurements were taken at this stage. Impressionistic examination was deemed sufficient for the intended purposes.

First, it was checked whether *Poll* had been pronounced as /pɑl/ or /pol/. Subjects 1, 2 and 3 had pronounced all instances of *Poll* as /pɑl/, which is what they were expected to do. Subjects 4, 5 and 6, however, had pronounced this word as /pol/, probably as the result of associating it with *opinion poll* rather than with the short form of the female name *Polly*, which is the word that it was meant to be associated with. Because of this, the data for Subjects 4, 5 and 6 concerning *Poll* are missing in the percentages reported in section 2.5 (Tables 2.7 and 2.8) as well as in the measurements and descriptive statistics detailed in section 2.6. Only the data for Subjects 1, 2 and 3 are considered there.

Second, it was deemed necessary to look for evidence of the /ɑ/-/ɔ/ merger, which is characteristic of many speakers of mid-western and western varieties of American English, as a result of which *Poll* and *Paul* would become homophonous, both being pronounced with /ɑ/ or with a vowel closer to /ɑ/ than /ɔ/. The six subjects had pronounced *Paul* with a vowel of a quality intermediate between /ɑ/ and /ɔ/, which was closer to /ɔ/ only in the case of Subject 2 and closer to /ɑ/ in the case of the other five subjects. The three subjects who had pronounced *Poll* as /pɑl/, therefore, had produced *Poll* and *Paul* with different vowels. Because the vowel formant normalization procedure described in section 2.7 and the inferential statistical analyses presented in section 2.8 require the same number of tokens per target word (i.e., 10 x speaker = 60), the word *Poll* was finally discarded.

Third, it was verified that *poor* had not been pronounced like *pore*. Subjects 1 and 6 had pronounced *poor* as /pʊr/. The other four subjects had pronounced it with a vowel intermediate between /ʊ/ and /ɔ/ but closer to /ʊ/. In all cases, *poor* was distinguishable from *pore*.

Fourth, the words *pale* /pel/ and *hole* /hol/ were inspected in order to corroborate that they had been pronounced with diphthongized vowels instead of monophthongs. All the subjects had pronounced these words with diphthongized vowels, the second element of which was auditorily and visually distinguishable from the first element in all cases, though more clearly so in *pale* than in *hole*.

Finally, the V+/l/ sequences containing back rounded vowels (i.e., *Paul* /pɔl/, *hole* /hol/, *pull* /pʊl/, *pool* /pul/ and *howl* /haʊl/) were inspected to confirm that they had not been pronounced with /l/-vocalization. Only in some instances of Subject 1's and Subject 2's slow and fast productions of *hole* and *howl* did auditory perception suggest a slight presence of /l/-vocalization, which proved not to be such, in some cases, or not salient enough, in others, under spectrographic inspection.

2.5 Segmentation procedure

From a segmental point of view, the V+/l/ and V+/r/ sequences under study can most logically be considered as composed of two elements only: a vocalic segment followed by a consonantal segment. However, in order to study the coarticulatory processes and, in particular, to identify the presence of VC transitions in them, the spectrographic signal of sequences containing monophthongs was divided into three parts that corresponded to the monophthong, the transition and the consonant. Likewise, the spectrographic signal of sequences containing diphthongized vowels (i.e., /el/ and /ol/) or diphthongs (i.e., /aɪl/, /ɔɪl/, /aʊl/, /aɪr/ and /aʊr/) was divided into four parts, with the second and third parts corresponding to the first and second elements, respectively, of the diphthongized vowels and diphthongs. In these cases, only the second element was considered for the analysis (i.e., /ɪ/ for /el/, /aɪl/, /ɔɪl/ and /aɪr/, and /ʊ/ for /ol/, /aʊl/ and /aʊr/).

It was possible to identify the presence of VC transitions containing a vocalic element of a mid central unstressed type (i.e., schwa-like) in all the V+/l/ and V+/r/ sequences under study. The segmentation procedure was carried out in three stages by means of a combination of two methods of a different nature: (i) a manual method based on both visual observation of the acoustic signal and auditory perception, and (ii) an automatic method based on formant first derivative curve extraction. Despite being applied at different stages, these methods complemented each other to the point that the two were necessary in most cases in order to provide the most accurate segmentation of the sequences.

At the first stage of the segmentation procedure, boundary placement was performed manually on the basis of acoustic information provided primarily by spectrographic visual observation of formant movement as shown by formant tracks. Information provided by intensity and pitch curves also proved helpful, since discernible changes in these curves often coincided with discernible changes in formant movement that could be taken as reference points for boundary placement. Information provided by acoustic waveforms was considered as well. Spectrographic observation was accompanied by auditory perception in an attempt to corroborate the accuracy of any boundary placement decision taken on the basis of visual observation. The delimitation of the beginning and end of the sequences (i.e., beginning of the vowel and end of the consonant) was carried out in its entirety at this first stage. The dynamic nature of the transition, however, often yielded situations where there were no clearly observable boundary events in the spectrographic signal, thus making the task of boundary delimitation of the transition very difficult or impossible to perform and, in turn, rendering the manual method of segmentation at this first stage unreliable for some tokens and inappropriate for others.

At the second stage of the segmentation procedure, manual adjustment of the boundary placement that had been performed at the first stage was conducted on the basis of reference points provided by formant first derivative curve extraction. Boundaries were now placed for the first time on those tokens where no boundary placement had been possible earlier because the acoustic signal had not supplied enough information. A first-differentiation algorithm was applied to F1, F2 and F3 traces as identified by an automatic formant tracking routine in order to obtain velocity curves for each of these spectral events. This allowed for the automatic identification of exact inflection peaks in the formant traces which corresponded with peaks of formant change given by velocity maxima (*peaks* proper) and minima (*valleys*, actually, but more often conventionally referred to as *peaks* for the sake of simplicity). These peaks were taken as reference points for boundary placement. A series of Praat scripts were written for this purpose. 20 Hz and 30 Hz formant trace smoothing procedures were applied for the slow and fast tokens, respectively, for all speakers alike. The choice of a different smoothing value for the slow and fast tokens was justified on the grounds that, after inspection of a small randomized selection of tokens (i.e., one for each target word per subject), it was detected that 20 Hz smoothing for the fast tokens tended to provide too many peaks while 30 Hz smoothing for the slow ones usually did not provide enough. The same *maximum formant (Hz)* value chosen for each speaker to perform the initial acoustic signal inspection reported in section 2.4.2 (Table 2.6) was used in the scripts that generated the first derivative curves. These scripts are presented in Appendix E.

Finally, the third stage of the segmentation procedure involved further manual adjustment of boundary placement in order to provide the definitive segmentation of the sequences. This was carried out by means of a combination of additional visual observation of the acoustic signal, auditory perception and choice of inflection peak obtained from formant first derivative curve extraction. Although all the tokens underwent inspection at this third stage again, the focus was particularly on sequences whose transition had not been clearly delimited at the two previous stages, such as those containing mid central vowels, low back vowels and, to a lesser extent, low front vowels. Particular attention was also devoted to delimiting the boundaries of the second element in diphthongized vowels and diphthongs. Because the fast tokens were more difficult to segment than the slow ones, they were given special consideration at this third stage as well.

As regards waveform and spectrographic visual observation, the transition was more easily detectable in the slow tokens than in the fast ones. In the slow tokens, it was visually discernible in all cases, more clearly so after high front and high back vowels, but quite discernible as well after low front and low back vowels. In the fast tokens, however, the transition was quite easily identifiable in sequences containing high front vowels, less clearly identifiable in those containing low front, mid central and high back vowels and rather difficult, and in some cases even impossible, to identify in those containing low back vowels. If the position of one peak coincided with a clearly visible change in waveform shape or formant movement as shown in the waveform and spectrographic signals, respectively, a boundary was placed where that peak was positioned.

Auditory perception was far more useful for the segmentation of the slow tokens than of the fast ones. In line with what waveform and spectrographic visual observation suggested, it was possible to auditorily perceive a vocalic transitional element different in quality from its preceding vowel in most of the slow tokens, especially after high vowels and particularly so after diphthongs. Nevertheless, this element was hardly perceptible in the slow tokens of sequences containing back vowels. It was also very difficult to perceive in a few of the fast tokens and not perceptible at all in most of them, no matter which vowel was involved. In those cases in which it was perceptible, the difficulty lay in deciding how much of it sounded different (i.e., more schwa-like) from the preceding vowel.

Figure 2.1 illustrates the automatic segmentation procedure for the /ir/ sequence corresponding to one of the slow productions of the word *fear* by Subject 1. While the upper sections are the same on both sides of the figure except for the oval black shape, which is positioned in a different place, the lower sections differ from each other in certain aspects.

From top to bottom, the upper sections show the waveform, the spectrogram, the F1 derivative tier, the tier for segmentation and the F2 derivative tier. Waveform pulses, intensity and pitch curves in the spectrogram, as well as the entire F3 derivative tier, have been removed for ease of presentation.

As regards the lower sections, the one on the left illustrates the F2 derivative curve extraction and the one on the right the F1. Both curves are drawn in red. Highlighted in green on the left is the smoothed trace of F2 running over the F2 black tracks while on the right is the trace of F1 running over the F1 tracks. On the left, the vertical blue ticks in the F2 derivative tier in the upper section coincide with the discontinuous vertical blue lines in the lower section. Likewise, on the right, the vertical blue ticks in the F1 derivative tier in the upper section coincide with the discontinuous vertical blue lines in the lower section. As can be observed in the lower sections, and especially so in the case of the F2 derivative, these lines coincide

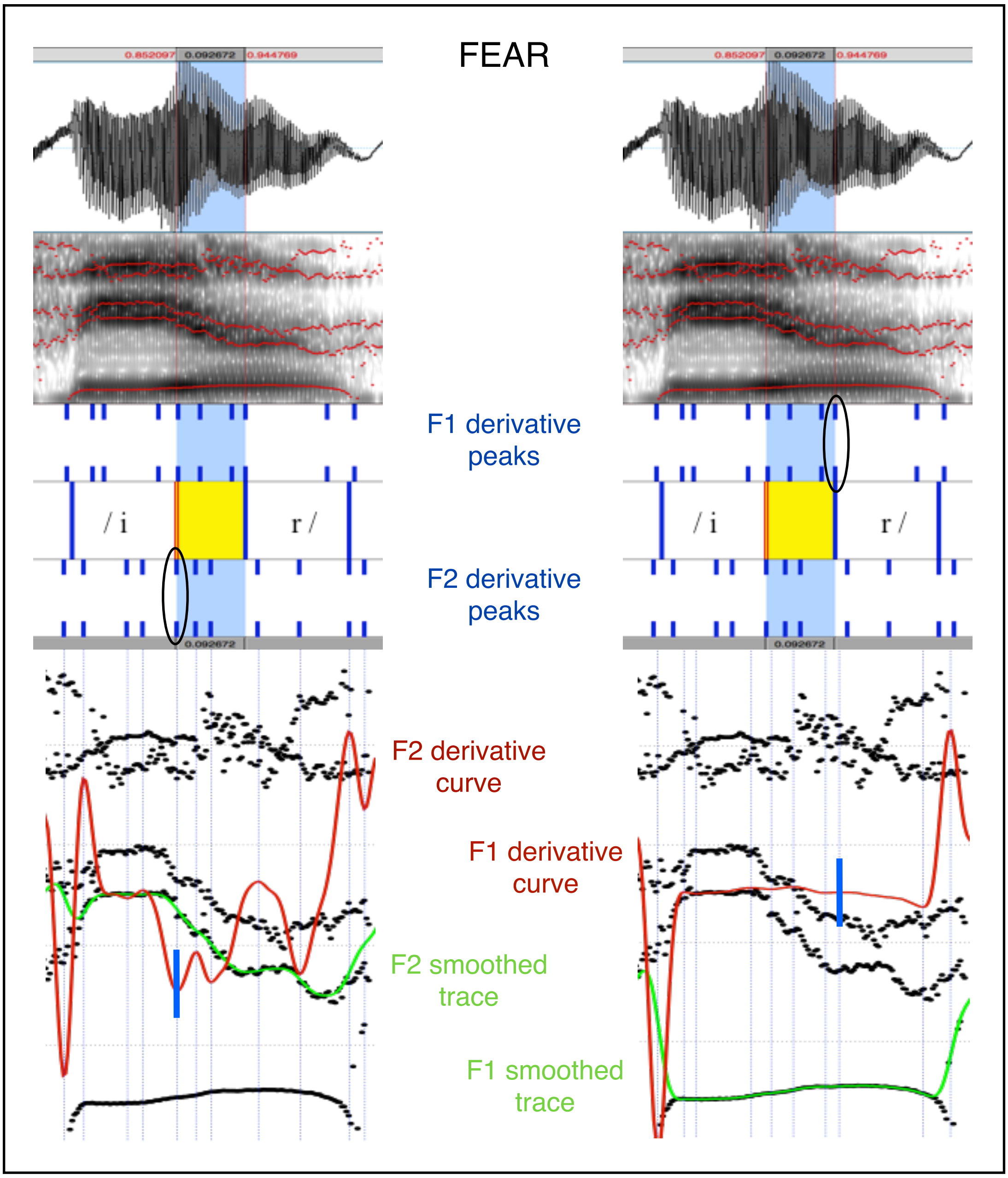


Figure 2.1 Automatic segmentation procedure for the /ir/ sequence corresponding to the slow production of the word *fear*

in turn with the first derivative peaks of formant change indicating velocity maxima and minima of the red curves.

The information that the Praat window provided is what is shown in the upper sections. The images in the lower sections were generated separately by drawing a Praat picture. They were printed out as image files and were taken into consideration together with what the Praat window showed in order to determine which derivative peak was more appropriate for boundary placement.

How prominent the peaks were shown to be by the curve drawing was not usually taken into consideration for boundary placement decisions because it was often not considered very useful. Besides, while the F2 derivative peaks tended to be quite prominent, the F1 and F3 ones were not usually so. This generalized case across speakers was especially noticeable in tokens containing front vowels, and high front vowels in particular, as can also be observed in the red curves of the figure. In the case of low front, mid central and back vowels, which have a much lower F2, the F2 derivative peaks were not as prominent and, therefore, relying on the height of peaks was rather impractical and often misleading.

Finally, the oval black shapes in the segmentation tiers illustrate how one of the F2 derivative peaks on the left part was taken as the reference point to mark the beginning of the transition and how one of the F1 derivative peaks on the right part served the same purpose to determine the end of it. A vertical blue line has been placed on each derivative curve to highlight these peaks.

Visual acoustic signal observation and auditory perception favored the choice of the F2 derivative peak over that of the F1 peak that falls right next to it for the delimitation of the beginning of the transition. Similarly, in the case of the end boundary, observation and perception were decisive to choose that F1 peak instead of the F1 peak that is located on its left or the F2 peak that can be found further to the right. This figure also illustrates that it was unnecessary to rely on F3 for the segmentation of this sequence.

Figures 2.2 and 2.3 show waveforms and spectrograms of a selection of V+/l/ and V+/r/ sequences containing a variety of vowels in order to illustrate the presence of VC transitions in slow and fast productions of the sequences. All the instances belong to Subject 5's productions. In both figures, the slow tokens are presented at the top and the fast ones at the bottom. The duration of the speech signal is the same in the slow and fast tokens for each word (e.g., *feel slow* has the same duration as *feel fast*, *hire slow* as *hire fast*, etc.). As in Figure 2.1, the part corresponding to the transition is shaded in blue in the acoustic waveform and in yellow in the tier below the spectrogram. Due to space constraints, the phonemic transcription for the vowel and the consonant is provided only in the tier of the slow tokens. Figure 2.2 shows examples of sequences containing high front vowels (i.e., *feel* /fil/ and *hire* /haɪr/) and low front vowels (i.e., *fair* /fɛr/ and *pal* /pæl/). Figure 2.3 shows examples of sequences containing low back vowels (i.e., *par* /pɑr/ and *Paul* /pɔl/) and high back vowels (i.e., *power* /paʊr/ and *pool* /pul/). These waveforms and spectrograms show

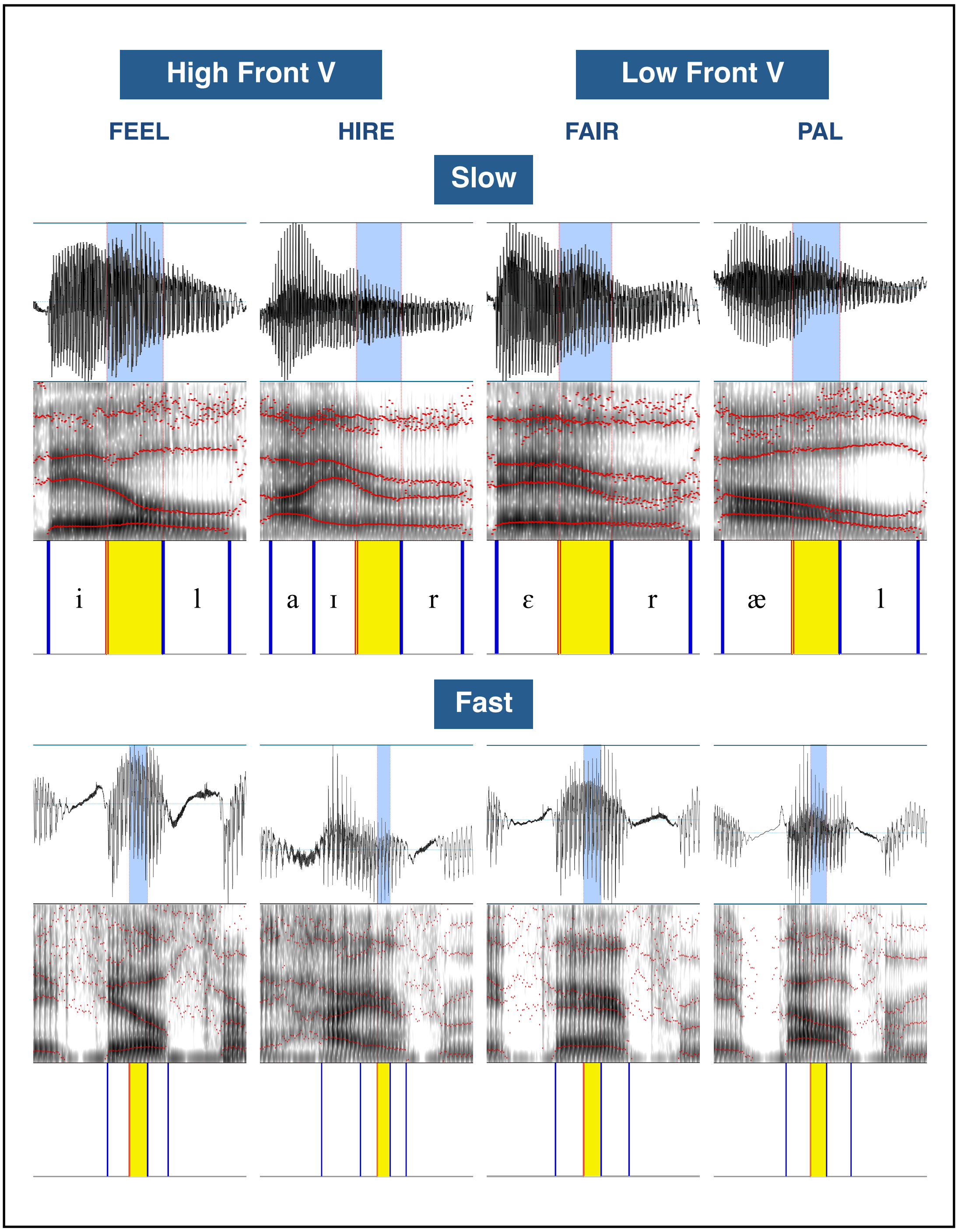


Figure 2.2 Delimitation of VC transitions of a selection of V+/l/ and V+/r/ sequences containing front vowels in slow and fast productions

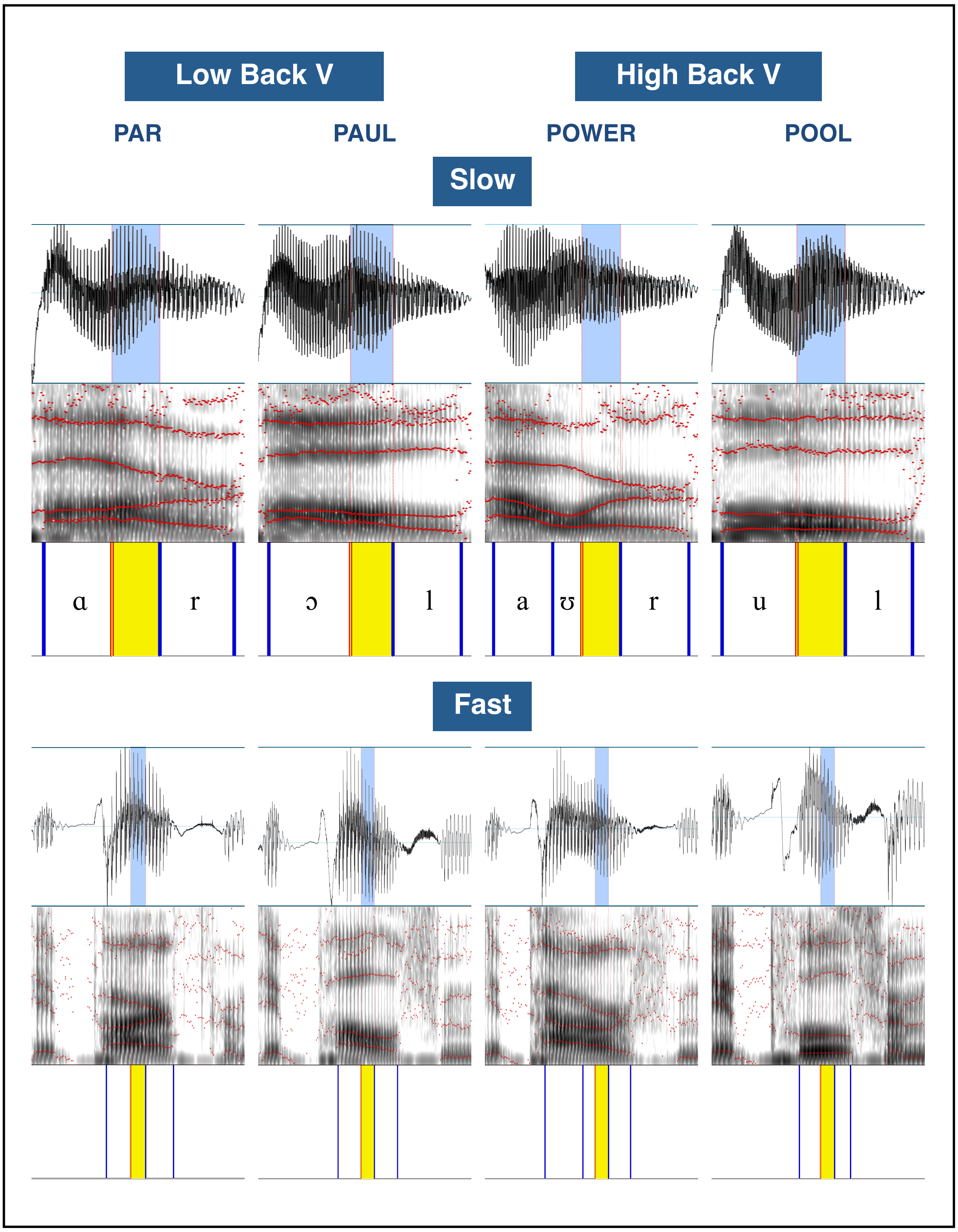


Figure 2.3 Delimitation of VC transitions of a selection of V+/l/ and V+/r/ sequences containing back vowels in slow and fast productions

the extent to which the transition can be visually identifiable, and they reflect at the same time the result of the segmentation procedure carried out at the three stages mentioned earlier.

First derivative curve extraction provided an objective and quantitative basis for the acoustic analysis and proved suitable inasmuch as inflection peaks were taken as reliable reference points for boundary placement. However, despite having chosen the most appropriate *maximum formant (Hz)* and formant track smoothing values, the presence of too many peaks on some occasions or the lack of sufficient peaks on others still posed problems to the segmentation task. In addition, the selection of F1, F2 or F3 peaks was not always straightforward. In some cases, two of them, or even the three of them, were very close to each other. In other cases, there was an almost near coincidence of peaks given by two, or again even the three, first derivative curves. In those cases concerning peak closeness or near coincidence, F2 was chosen over F1, and F1 over F3. This decision was taken for the sake of consistency as well as because, as mentioned earlier, F2 exhibited more movement than F1 or F3 in a greater number of sequences. Apart from these cases, there was no intention of favoring the selection of either F1, F2 or F3 peaks at any point of the segmentation procedure. In some cases, in fact, F3 was more indicative of the existence of a boundary than F1 or F2. Finally, a few sequences exhibited such shortage of peaks that none of the given peaks were considered appropriate. In these cases boundary placement was solely dependent on speech signal observation and auditory perception.

Table 2.7 provides information on the observed frequency of occurrence in percentages of F1, F2 and F3 first derivative peaks chosen to delimit the beginning and end of the transition in V+/l/ sequences. It also shows the percentages of cases in which no peak had been chosen, usually because of an overall absence of peaks. Finally, it reveals the percentages of tokens that had not been analyzed because they had previously been discarded when performing the auditory and acoustic data inspection detailed in sections 2.4.1 and 2.4.3. Included within the discarded tokens are also Subject 6's inexistent tokens corresponding to the damaged file of her fast productions reported in section 2.3. Table 2.8 provides the same kind of information for the tokens containing V+/r/ sequences.

As can be observed in Tables 2.7 and 2.8, F2 peaks were the most commonly selected ones, followed by F1 peaks in some cases and by F3 peaks in a few others. Percentages below 50% are shaded in light gray while those equal to or above 50% are shaded in dark gray. In general terms, words containing high front or high mid vowels exhibit the highest percentages whereas words containing low and back vowels exhibit the lowest. Exceptions, however, are indicative of this being only a generalized tendency. All the subjects were pooled together, but the slow and fast tokens were kept separate, for the obtention of these data. Therefore, n = 60 in all cases except for *Poll*, where n = 30 because, as reported in section 2.4.3, this token had previously been discarded for Subjects 4, 5 and 6.

Table 2.7 *Observed frequency of occurrence in percentages of first derivative inflection peaks chosen to delimit the beginning and end of the transition in V+/l/ sequences*

		F1		F2		F3		None		Discarded	
		Beg %	End %	Beg %	End %	Beg %	End %	Beg %	End %	Beg %	End %
feel	Slow	33	45	60	47	5	7	0	0	2	2
	Fast	25	23	57	43	12	27	0	0	7	7
bill	Slow	28	35	68	58	3	7	0	0	0	0
	Fast	15	18	50	57	27	12	2	7	7	7
pale	Slow	38	33	43	43	15	18	0	2	3	3
	Fast	20	23	53	42	12	23	8	5	7	7
fell	Slow	27	33	60	58	8	5	2	0	3	3
	Fast	18	32	50	35	18	17	0	3	13	13
pal	Slow	45	42	48	43	2	10	2	2	3	3
	Fast	30	30	45	43	17	20	3	2	5	5
Poll	Slow	23	27	73	70	3	3	0	0	0	0
	Fast	40	27	27	40	23	27	10	7	0	0
Paul	Slow	43	37	45	43	5	13	0	0	7	7
	Fast	30	28	45	43	17	20	3	3	5	5
hole	Slow	35	30	42	47	17	18	2	0	5	5
	Fast	28	27	37	30	17	20	13	18	5	5
pull	Slow	33	37	57	43	7	17	0	0	3	3
	Fast	28	23	28	33	28	30	10	8	5	5
pool	Slow	40	38	57	45	2	13	0	2	2	2
	Fast	28	17	30	32	28	30	5	13	8	8
hull	Slow	25	30	52	47	20	22	2	0	2	2
	Fast	20	25	33	37	30	30	13	5	3	3
furl	Slow	37	33	63	53	0	12	0	2	0	0
	Fast	47	13	38	50	5	22	7	12	3	3
pile	Slow	38	42	52	47	7	12	3	0	0	0
	Fast	30	38	32	40	20	18	15	0	3	3
boil	Slow	38	35	50	45	8	15	0	2	3	3
	Fast	15	23	40	40	30	32	10	0	5	5
howl	Slow	38	35	48	57	12	8	2	0	0	0
	Fast	35	27	37	40	15	20	8	8	5	5

2.6 Measurements, calculations and descriptive statistics

Once the segmentation procedure had been completed, and before performing the vowel formant normalization procedure described in section 2.7 and the inferential statistical analyses presented in section 2.8, a series of acoustic measurements, numerical calculations and descriptive statistical analyses were carried out.

Table 2.8 *Observed frequency of occurrence in percentages of first derivative inflection peaks chosen to delimit the beginning and end of the transition in V+/r/ sequences*

		F1		F2		F3		None		Discarded	
		Beg %	End %	Beg %	End %	Beg %	End %	Beg %	End %	Beg %	End %
fear	Slow	32	25	63	73	5	2	0	0	0	0
	Fast	30	7	48	55	15	27	0	5	7	7
fair	Slow	30	18	63	75	7	7	0	0	0	0
	Fast	18	12	60	50	18	32	0	3	3	3
par	Slow	38	30	53	58	8	12	0	0	0	0
	Fast	23	28	33	35	27	25	7	2	10	10
pore	Slow	40	28	50	55	7	13	2	2	2	2
	Fast	20	18	50	45	23	23	3	10	3	3
poor	Slow	33	32	53	52	8	10	0	2	5	5
	Fast	20	13	55	55	18	20	2	7	5	5
hire	Slow	33	45	58	47	7	5	0	2	2	2
	Fast	32	35	42	40	10	13	8	3	8	8
power	Slow	35	37	53	50	12	10	0	3	0	0
	Fast	25	33	43	43	20	17	8	3	3	3

Acoustic measurements were obtained by automatically extracting duration, F1, F2 and F3 values for the vowel, the transition and the consonant for the six subjects, the two rates (i.e., slow and fast) and the 22 contexts (i.e., each of the 15 V+/l/ and seven V+/r/ sequences). As suggested by the segmentation procedure described in section 2.5, in the case of diphthongized vowels and diphthongs, only the values for the second element were obtained. Two different sets of formant values were extracted: mean and midpoint. Mean values were obtained every 3 ms, as specified by the *Window length (s)* value (i.e., .012) in the Praat formant settings as well as by the appropriate logarithm in the Praat log settings (i.e., Query: Log settings: Log 2 format: 'f1:0"tab$"f2:0"tab$"f3:0'). A Praat script, which is reproduced in Appendix F, was written to extract duration and midpoint formant values.

Two main sets of numerical calculations were subsequently performed. First, the mean and standard deviation of the 10 individual values corresponding to each of the 10 individual tokens were calculated for every separate category (e.g., Subject 1, *feel*, slow, vowel, F1, midpoint). Initially inexistent (as explained in section 2.3) or later discarded (as reported in sections 2.4.1 and 2.4.3) tokens, for which no value had been provided, were now given the value of the mean. This allowed for the number of tokens to be the same in all cases (i.e., $n = 10$), which was a requirement for the vowel normalization procedure described in section 2.7 as well as for any statistical analyses, whether descriptive (as presented below in this section), or inferential (as presented in section 2.8). However, the discarded productions of *Poll* by Subjects 4, 5 and 6 (as referred to in section 2.4.3) were not considered.

At this stage, a Pearson product-moment correlation statistical analysis was run to measure the strength and direction of the linear relationship between two of the variables for which data had been obtained (i.e., midpoint and mean formant values) in order to decide which to use in future calculations and analyses. The test yielded statistically significant results, with the two variables being highly correlated in most cases. The Pearson correlation coefficients (r) for F1, F2 and F3 midpoint and mean measurements taken for the vowel, transition and consonant for each subject's slow and fast productions are provided in Appendix G. Midpoint values were favored over mean ones because they were expected to be less influenced by the values of neighboring sounds than were values close to those sounds, which had indeed been taken into consideration for the extraction of mean values. This was done at the risk of obtaining poorly representative values (e.g., outliers or extreme values) which would need to be discarded.

In order to identify outliers, individual values that differed from the mean by more than two standard deviation units were discarded and then the mean of the remaining tokens was substituted for them. Individual values that were two standard deviation units above the new mean were now replaced by the highest value while those that were two units below it were replaced by the lowest one. At this point, a complete descriptive statistical analysis was carried out for every separate category to provide measures and representations of central tendency and variability. It included numerical data given by means, standard deviations, standard errors, variances, maximum and minimum values, ranges, and asymmetry and kurtosis indicators. Graphical representations in the form of histograms, normality curves, boxplots and scatter plots were also generated. The data were carefully scrutinized to check for further outliers and, this time, any outlier that was found to be one standard deviation unit above or below the mean was replaced by the highest or lowest value, respectively. Also, special attention was paid to corroborating that the data were approximately normally distributed (i.e., not remarkably positively or negatively skewed) in each group. The absence of outliers and the assumption of normality were considered crucial for the vowel formant normalization procedure described in section 2.7 to be successful and for the inferential statistical tests presented in section 2.8 to yield reliable results.

The second set of numerical calculations involved obtaining mean values for vowel-transition differences (i.e., the differences between vowel (V) formant values and transition (T) formant values: VF1-TF1, VF2-TF2 and VF3-TF3) as well as for transition-consonant differences (i.e., the differences between transition (T) formant values and consonant (C) formant values: TF1-CF1, TF2-CF2 and TF3-CF3). These were performed after the descriptive statistical analyses had been carried out and no more outliers remained to be identified. Individual differences for each of the 10 tokens per context were first calculated by a simple subtraction mathematical operation. Negative individual values were then transformed into positive ones and the mean values of those 10 individual tokens were finally obtained.

Because the focus of this dissertation is limited to the relationship between the vowel and the transition in the V+/l/ and V+/r/ sequences under study, measurements and calculations involving the consonant (i.e., the consonant itself and transition-consonant differences) were finally not considered for the vowel formant normalization procedure described in section 2.7 or for the inferential statistical analyses presented in section 2.8. In addition, due to the limitations imposed by the normalization method chosen, F3 values, though partly considered for the normalization procedure, were not considered for the inferential statistical analyses either. Time and space restrictions justify the non-inclusion of the transition-consonant treatment in this dissertation. Likewise, although F3 may provide important information about the phonetic nature of the sequences, and of the V+/r/ sequences in particular (e.g., its lowering due to the influence of the /r/), this information was not considered essential for the purposes of the study.

Table 2.9 provides an overview of the measurements and calculations considered for this dissertation. Three classes can be distinguished: those performed and used for the inferential statistical analyses (identified with a tick and shaded in dark gray), those performed but not used for these analyses (identified with a cross and shaded in light gray) and those not performed (identified with a dash).

Table 2.9 *Overview of measurements and calculations*

	Duration	F1		F2		F3	
		Mean	Midpoint	Mean	Midpoint	Mean	Midpoint
Vowel	✓	✗	✓	✗	✓	✗	✗
Transition	✓	✗	✓	✗	✓	✗	✗
Consonant	✗	✗	✗	✗	✗	✗	✗
V-T diff	—	✗	✓	✗	✓	✗	✗
T-C diff	—	✗	✗	✗	✗	✗	✗

2.7 Vowel formant normalization

Flynn (2011) defines *vowel formant normalization* (henceforth *normalization*) as the process of transforming formant frequencies to make them directly comparable with those of other speakers. As Flynn points out, "it has been acknowledged that the raw Hertz formant frequencies of different speakers are not directly comparable, and that it is not ideal to plot formant values in Hertz from different speakers on the same formant chart (Watt, Fabricius, & Kendall, 2010)" (p. 2). The results of Flynn's study, in which he compared and evaluated 20 normalization procedures, revealed that any form of normalization was better than none. Because the acoustic data for the present study comes from the productions of six speakers, the decision to normalize the formant values for the vowels and vocalic transitional elements under analysis was taken. The normalization procedure was carried out using the online vowel normalization and plotting suite NORM (Thomas & Kendall, 2007). After considering (i) the goals of normalization, (ii) the results of studies that have compared and evaluated different methods, and (iii) the availability, advantages and disadvantages of methods under implementation in NORM, Lobanov's method was deemed the most appropriate.

There are four well-acknowledged goals of normalization (Adank, Smits, & van Hout, 2004; Clopper, 2009; Disner, 1980; Fabricius, Watt, & Johnson, 2009; Flynn, 2011; Thomas & Kendall, 2007). First, a successful normalization procedure should maximally reduce inter-speaker biological (i.e., anatomical and physiological) variation caused by gender-related (i.e., male vs. female) and vocal tract-related (e.g., shape and size) differences. Second, it should preserve inter-speaker sociolinguistic, dialectal and cross-linguistic variation as well as differences due to sound change. Third, it should maintain phonemic variation (i.e., phonological distinctions among vowels). Finally, it should model the cognitive processes that allow human listeners to normalize vowels uttered by different speakers. It is impossible to meet all these four goals for one study and it is the nature of each study that should determine the goals to be met. For example, the goals of a sociolinguistic study will most probably differ from those of a phonetic one. Likewise, the goals of a phonetic study that investigates a single dialect or language may be different from those of a cross-dialectal or cross-linguistic one. For the present study, which is phonetic in nature, normalization was carried out in order to meet the first and third goals.

Normalization procedures have traditionally been classified according to the type of vowel, formant and speaker information that they use and to whether they consider this information intrinsically or extrinsically (Adank et al., 2004; Clopper, 2009; Fabricius et al., 2009; Flynn, 2011; Thomas & Kendall, 2007). Vowel-intrinsic procedures use information within vowels, with algorithms applying to individual vowels; vowel-extrinsic ones use it across vowels, with algorithms applying to sets of vowels. To normalize a single formant value, formant-intrinsic procedures use information within formants, taking information from one formant at a time, whereas formant-extrinsic ones use it across formants, taking information from the range of formants of a vowel. To normalize data from single speakers, speaker-intrinsic procedures use information from a single speaker at a time, while speaker-extrinsic ones use it from more than one speaker. No one type of procedure is thought to perform the best for all kinds of study. The appropriateness of one procedure or another will depend on the nature of the study, the research objectives, the goals of normalization and the languages being investigated. However, the results of studies carried out to determine the suitability of one type of procedure over others show that there is a tendency for vowel-extrinsic, formant-intrinsic and speaker-intrinsic procedures to be the most successful (Adank et al., 2004; Clopper, 2009; Disner, 1980; Flynn, 2011).

Among the several vowel-extrinsic, formant-intrinsic and speaker-intrinsic normalization methods in existence, several stand out for their overall effectiveness at reducing biological variation, preserving sociolinguistic variation and maintaining phonemic variation. These are (i) Lobanov's, or Lobanov's Z-Score Transformation (as referred to by Adank et al., 2004 and Recasens Vives, 2008); (ii) Nearey's, or Nearey's Single Log-Mean (as referred to by Adank et al., 2004), Individual Formant Mean (as referred to by Clopper, 2009), or Constant Log Interval Hypothesis (as referred to by Recasens Vives, 2008); (iii) Watt & Fabricius's, both in its original and modified versions; (iv) Gertsman's Range Transformation (as referred to by Adank et al., 2004); and (v) Bigham's. The results of several studies that compared and evaluated two or more of the many available methods (i.e., the above-mentioned and others) ranked Lobanov's method as either the best (Adank et al., 2004; Recasens Vives, 2008) or among the best (Disner, 1980; Clopper, 2009; Flynn, 2011).

The normalization procedure carried out for the present study successfully achieved considerable reduction of "the variance within each group of vowels presumed to represent the same target when spoken by different speakers, while maintaining the separation between such groups of vowels presumed to represent different targets" (Disner, 1980, p. 253). This process has also been referred to as scatter reduction (Disner, 1980) or equalization of vowel space areas (Flynn, 2011).

As a mode of exemplification, Figure 2.4 shows vowel formant plots of the non-normalized (top) and Lobanov-normalized (bottom) F1 and F2 values of the vowels and second elements of the diphthongs (*vowel* for short; left) as well as of the VC transitional vocalic elements (*transition* for short; right) in the slow versions of the V+/r/ sequences (i.e., /i/ in *fear*, /ɪ/ in *hire*, /ɛ/ in *fair*, /ɑ/ in *par*, /ɔ/ in *pore*, /ʊ/ in *poor* and /ʊ/ in *power*). Although the scaling is not exactly the same for the four plots, it was considered most appropriate to reproduce them in the same format as they had been generated by NORM. The vowel under study in *hire* and *power* is the second element of the diphthong (i.e., /ɪ/ in *hire* and /ʊ/ in *power*) rather than the first (i.e., /a/ in both). However, the coarticulatory influence of /a/ causes the quality of the /ɪ/ and /ʊ/ to considerably differ from that of monophthongal /ɪ/ and /ʊ/.

In Figure 2.4, values are given in Hertz: raw Hertz values in the non-normalized plots (indicated as F1 and F2) and scaled Hertz values in the normalized ones (indicated as F*1 and F*2). As can be observed, the formant values of the same target vowel are closer to each other in the bottom (normalized) plots than in the top (non-normalized) ones. This can thus be interpreted as a closer clustering of different speakers' realizations of the same vowels and as an overall improvement of vowel space overlap, with smaller and more similar vowel space areas. In order to determine that the normalization procedure had been successful in all cases, similar pairs of plots to the ones shown in this figure were generated for the slow and fast versions of the vowel and transitional vocalic element in all the V+/l/ and the rest of the V+/r/ sequences.

Lobanov's method, when implemented in NORM, yields formant values that are in z-scores rather than in Hertz. Even though Thomas and Kendall (2007) do not recommend scaling, NORM offers the possibility to do so. For the present study, scaling back to Hertz was considered necessary for an easier interpretation of the normalized data as well as of the results (see Chapter 3). It was also, therefore, a requirement for the inferential statistical tests presented in section 2.8. In order to prevent scaling from undoing part of the work of the normalization procedure, and in particular to avoid scaling each vowel to the relative position it occupies in a single speaker's vowel space, NORM requires the minimum and maximum values for the formants to be determined speaker-extrinsically, which implies that all speakers have to be submitted to NORM at the same time (Thomas & Kendall, 2007).

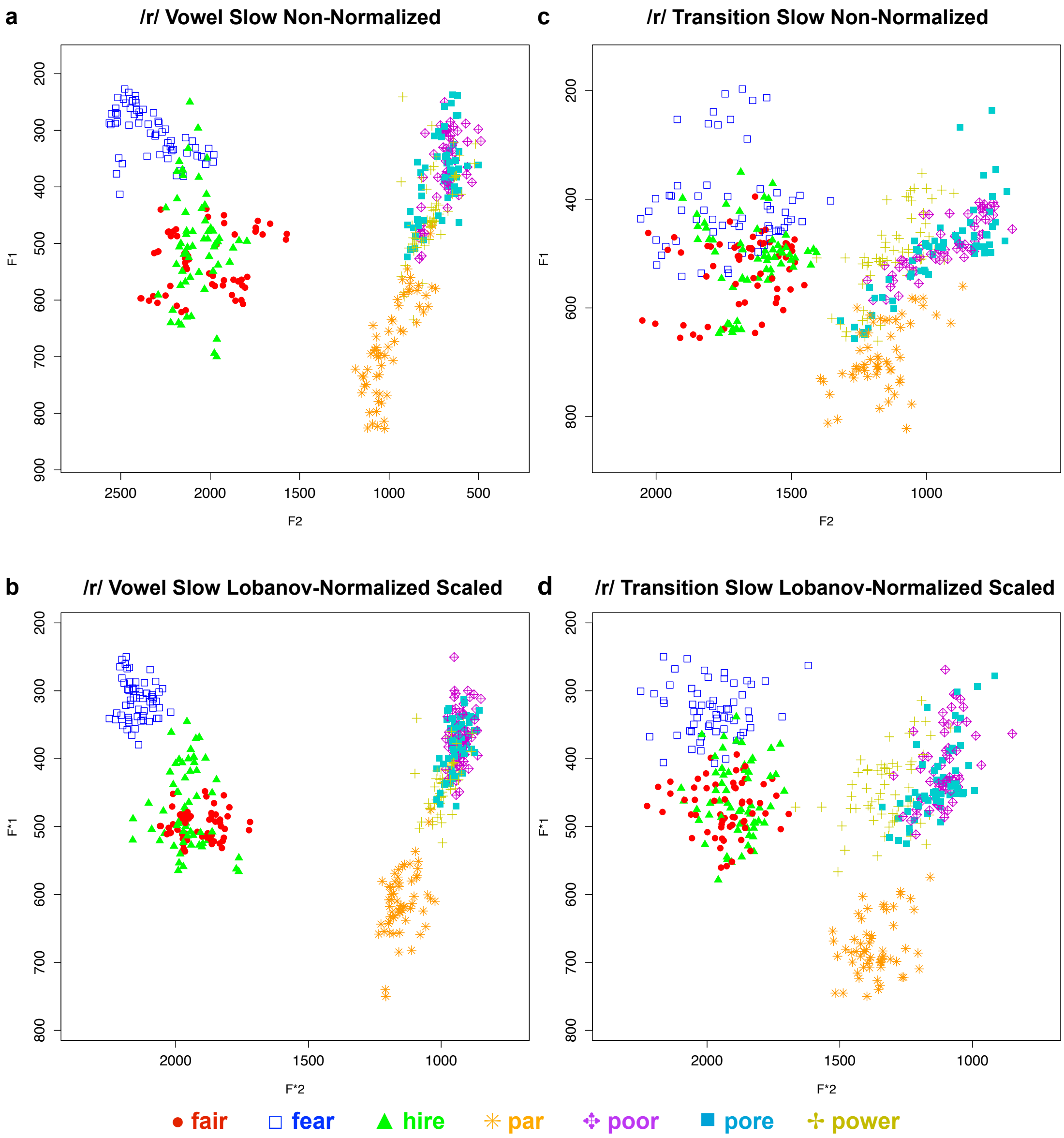


Figure 2.4 NORM plots of non-normalized (a, c) and Lobanov-normalized (b, d) F1/F*1 and F2/F*2 values (in Hz) of the vowels (a, b) and transitions (c, d) in the slow versions of the V+/r/ sequences

NORM poses a further restriction: Lobanov's method is not implemented to use F3. Even though the values for F3 are entered into NORM, they are not returned in the normalized output. This had an effect on the initial experimental design of the study: despite having been considered at earlier stages (i.e., data inspection, segmentation, measurements, calculations and descriptive statistics), F3 was not considered for the inferential statistical analyses presented in section 2.8, and thus only F1 and F2 were considered for the results (see Chapter 3). Because the first two formants are the most important in determining vowel quality, and because they are enough to determine it, these were thought sufficient for the purposes of the study.

Lobanov's method, like all other vowel-extrinsic methods, works at its best when all the vowels of a speaker's vowel system are included. Otherwise, the normalization procedure might result in skewed normalized values (Thomas & Kendall, 2007). Due to the phonological nature of the sequences under study, this requirement could only be partly met. Of the 17 vowels of American English, /ə/ and /ɚ/ were never included. This is because only V+/l/ and V+/r/ sequences containing strong, stressed vowels were the object of study. Excluding /ə/ and /ɚ/ was not regarded as a problem for the vowels in the V+/l/ sequences because all the strong, stressed vowels, with the exception of /ɑ/ in *Poll*, were included. However, as regards the V+/r/ sequences, and owing to the process of vowel neutralization that American English vowels undergo when followed by /r/, apart from excluding /ə/ and /ɚ/, of the 15 strong, stressed vowels, only the seven that can be present in V+/r/ sequences could be included. Since the V+/l/ and V+/r/ sequences were normalized independently of each other, and since the inferential statistical analyses for the two groups of sequences were performed separately (see section 2.8), and thus the results will be presented and discussed separately as well (see Chapter 3), this requirement was not considered a strong enough reason for not normalizing the data. Moreover, the plots in Figure 2.4 show that, despite having been performed with a reduced vowel system, the normalization procedure for the vowels and transitional vocalic elements in the V+/r/ sequences was successful.

For the purposes of normalization, and in line with the segmentation procedure described in section 2.5, the vowels were treated independently of the transitional vocalic elements. Therefore, the data for the vowels and the transitional vocalic elements were entered into NORM separately to be normalized separately as well. NORM requires the second elements of diphthongized vowels and diphthongs to be treated independently of the first elements but to be normalized together with them (i.e., at the same time). The transitional vocalic element was thus never considered as the second element of a diphthong. Apart from this, the second elements of diphthongized vowels and diphthongs were treated as if they were independent vowels, since these are the ones that provide the different contexts. The first elements, despite the coarticulatory influence that they may exert on the second ones, were ignored.

The two rates (i.e., slow and fast) were also normalized separately. The vowels and transitional vocalic elements of the V+/l/ sequences were normalized separately from those of the V+/r/ sequences, but the 14 V+/l/ contexts were normalized at the same time, as were the seven V+/r/ contexts. As stated above, the data for the six speakers were normalized at the same time and the Hertz values (i.e., raw, non-normalized values) were automatically scaled from z-score values back to Hertz values (i.e., normalized values) by NORM. Finally, and as also stated above, F3 values were entered into NORM but were not returned in the normalized output. As can be seen in Table 2.10, there were eight normalized sets of data in total: four for the V+/l/ sequences and four for the V+/r/ sequences.

Table 2.10 *Sets of normalized data*

V+/l/ sequences				V+/r/ sequences			
Vowel		Transition		Vowel		Transition	
Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast

Table 2.11 presents a reproduction of the template provided by NORM to submit the data for normalization. Speakers were identified with numbers (e.g., 1 for Speaker 1, 2 for Speaker 2, etc.). Vowels were identified alphabetically by token name (e.g., *fair*, *fear*, *hire*, etc.). The columns for context were left blank (i.e., NA for *non-applicable*). The formant values for monophthongs, the second elements of diphthongized vowels and diphthongs, as well as the transitional vocalic elements were entered under F1, F2 and F3. The values for the second elements of diphthongized vowels or diphthongs, if any, are meant to be entered under gl F1, gl F2 and gl F3. The columns corresponding to these were left blank in all cases (i.e., NA). Table 2.12 shows, in a simplified manner, how the input data (under F1, F2 and F3) to be submitted to NORM were organized for the values of the monophthongs and second elements of diphthongs (under Vowel) in the slow tokens of the V+/r/ sequences. This table also includes the data for the normalized output (under F*1, F*2 and F*3).

Table 2.11 *NORM template for vowel formant normalization*

Speaker	Vowel	Context	F1	F2	F3	gl F1	gl F2	gl F3

Table 2.12 *NORM data: non-normalized (input) and normalized (output) values*

Speaker	Vowel	Context	F1	F*1	F2	F*2	F3	F*3
1	fair	NA	618	513	2137	1883	2954	NA
1	fair	NA	610	508	2187	1918	2760	NA
1	fair	NA	621	515	2161	1900	2895	NA
1	fair	NA	592	496	2250	1962	2934	NA
1	fair	NA	605	504	2295	1993	2974	NA
1	fair	NA	597	499	2385	2056	3168	NA
1	fair	NA	601	502	2342	2056	3148	NA
1	fair	NA	575	485	2223	1943	3028	NA
1	fair	NA	597	499	2389	2059	3036	NA
1	fair	NA	593	497	2319	2010	3040	NA
1	fear	NA	413	379	2505	2140	2941	NA
1	...	...	...	...	...	...	...	...
1	hire	NA	700	566	1964	1763	2616	NA
1	...	...	...	...	...	...	...	...
1	par	NA	764	608	1153	1197	2674	NA
1	...	...	...	...	...	...	...	...
1	poor	NA	437	395	674	863	2833	NA
1	...	...	...	...	...	...	...	...
1	pore	NA	467	415	896	1017	2743	NA
1	...	...	...	...	...	...	...	...
1	power	NA	587	493	918	1033	2454	NA
1	...	...	...	...	...	...	...	...
2	fair	NA	519	511	2145	1975	2862	NA
2	fair	NA	517	509	2143	1974	2840	NA
2	...	...	...	...	...	...	...	...
2	fear	NA	269	269	2317	2096	3073	NA
2	...	...	...	...	...	...	...	...
2	hire	NA	549	540	2156	1983	2858	NA
2	...	...	...	...	...	...	...	...
3	fair	NA	565	516	1923	1819	2553	NA
3	fair	NA	575	522	1974	1855	2600	NA
3	...	...	...	...	...	...	...	...
3	fear	NA	239	339	2417	2178	2910	NA
3	...	...	...	...	...	...	...	...
4	fair	NA	464	470	1922	2013	2294	NA
4	...	...	...	...	...	...	...	...
4	fear	NA	319	296	2100	2162	2872	NA
4	...	...	...	...	...	...	...	...
5	fair	NA	559	485	1793	1804	2397	NA
5	...	...	...	...	...	...	...	...
6	fair	NA	479	482	2232	1981	2693	NA
6	...	...	...	...	...	...	...	...

2.8 Inferential statistical analyses

The *Statistical Package for the Social Sciences (SPSS)*, version 21, for Macintosh was used to perform the inferential statistical analyses. The research design involved having the same subjects measured on the same dependent variables and serving under more than one independent variable (i.e., factor, treatment or condition) and in all the levels of each of them in the same way. Therefore, in order to test the effects of the independent variables on the dependent ones, and at the same time the hypotheses of the present study, the data were analyzed using two-way repeated measures (i.e., within-subjects) ANOVAs.

There were two categorical independent variables: rate and context. Rate had two levels: slow and fast, for the V+/l/ and V+/r/ sequences alike. Context had 14 levels for the V+/l/ sequences (i.e., one for each vowel: /il/, /ɪl/, /el/, /ɛl/, /æl/, /ɔl/, /ol/, /ʊl/, /ul/, /ʌl/, /ɝl/, /aɪl/, /ɔɪl/ and /aʊl/) and seven levels for the V+/r/ sequences (i.e., one for each vowel: /ir/, /ɛr/, /ɑr/, /ɔr/, /ʊr/, /aɪr/ and /aʊr/). There were three continuous dependent variables: duration, F1 and F2. For the duration variable, vowel and transition measurements were considered, while for the F1 and F2 variables, it was vowel, transition and vowel-transition differences that were considered. As Table 2.13 shows, there were 16 ANOVAs in total (i.e., eight for the V+/l/ sequences and eight for the V+/r/ sequences), one for each combination of dependent variable and measurement.

Table 2.13 *Overview of repeated measures ANOVAs performed*

	Dependent variables		
	Duration	F1	F2
V+/l/ sequences	Vowel Transition	Vowel Transition Vowel-transition differences	Vowel Transition Vowel-transition differences
V+/r/ sequences	Vowel Transition	Vowel Transition Vowel-transition differences	Vowel Transition Vowel-transition differences

Each two-way repeated measures ANOVA was performed with the six subjects pooled together, with the two independent variables (i.e., rate and context) and with 60 trials (i.e., six subjects x 10 trials per subject = 60 trials) per combination of each level of the independent variable context and each level of the independent variable rate (e.g., *bill slow*, *fell slow*, *pull fast* and *howl fast*, for the V+/l/ sequences, or *fear slow*, *par slow*, *poor fast* and *hire fast*, for the V+/r/ sequences). In those cases where the ANOVA yielded a significant interaction, simple main effects were analyzed separately for each independent variable.

Running simple main effects made it possible to investigate the effect of the two rate levels (i.e., slow vs. fast) on each dependent variable (e.g., vowel duration, transition F1, vowel-transition F2 differences, etc.) at every context level separately (e.g., *feel*, *pool*, *fair*, *par*, etc.). Paired-samples t-tests, which are equivalent to one-way repeated measures ANOVAs, were performed for this purpose. Because the rate variable consists of only two levels (i.e., slow vs. fast), t-tests were considered preferable to ANOVAs: the procedure is simpler and no post-hoc tests showing pairwise comparisons are necessary because the t-tests already show them. The results of these tests produced comparisons such as *bill slow* vs. *bill fast* for vowel duration, *fell slow* vs. *fell fast* for transition F1, or *poor slow* vs. *poor fast* for vowel-transition F2 differences, providing information about where rate differences lay.

Running simple main effects also made it possible to investigate the effect of context (e.g., *pal*, *hole*, *fear*, *pore*, etc.) on each dependent variable (e.g., vowel duration, transition F1, vowel-transition F2 differences, etc.) at every rate level separately (i.e., slow vs. fast). Because the context variable consists of more than two levels (i.e., 14 for /l/ and seven for /r/), t-tests were ruled out and one-way repeated measures ANOVAs were performed instead. In those cases where the ANOVA yielded significant results, Bonferroni post-hoc tests were run to obtain pairwise comparisons and thus determine where context differences were present. The results of these tests produced comparisons such as *pale slow* vs. *Paul slow* for vowel duration, *hull fast* vs. *furl fast* for transition F1, or *hire fast* vs. *power fast* for vowel-transition F2 differences.

The two-way repeated measures ANOVA design was considered the most appropriate on the basis of the kind of data to be analyzed. It met the two basic requirements as regards type and number of variables: three continuous dependent variables (i.e., duration, F1 and F2) and two categorical independent variables (i.e., rate and context) consisting of two or more levels (i.e., two for rate; 14 for the V+/l/ context and seven for the V+/r/ context). This type of design has two more requirements, which are related to the nature of the data: the non-existence of outliers and the assumption of normality. These were already dealt with when performing the descriptive statistical analyses described in Chapter 2 (section 2.6) but before the data had been normalized. As part of the repeated measures ANOVA procedure, SPSS generated data on studentized residuals which allowed for the identification of significant outliers and non-approximately normally distributed data. As assessed by examination of these residuals, there were no outliers for values greater than ±3 standard deviations. Similarly, as assessed by Shapiro-Wilk's test of normality on these residuals, the data were found to be approximately normally distributed and, since two-way repeated measures ANOVAs are considered to be quite robust to violations of normality, no further consideration was given to any data that might slightly deviate from this trend. Finally, the last requirement to be met for any repeated measures ANOVA design concerns the sphericity assumption, which is similar to the assumption of homogeneity of variances but which refers to the equality of variances of the differences between all combinations of levels of each independent variable instead of the variances within each level. Because this assumption is intimately related to the results of repeated measures ANOVAs, it is more extensively dealt with in Chapter 3 (section 3.1).

Chapter 3 Results

This chapter presents the results of the inferential statistical analyses described in Chapter 2 (section 2.8) in order to test the hypotheses formulated in Chapter 1 (section 1.5) and thus determine the effects of the independent variables (i.e., rate and context) on the dependent ones (i.e., duration, for the vowel and the transition; and F1 and F2, for the vowel, the transition and the vowel-transition differences).

Section 3.1 explains how the presentation of the results is organized. The results for the V+/l/ and V+/r/ sequences are reported in sections 3.2 and 3.3, respectively. These two sections are structured in the same manner, consisting of the same type of subsections with the same kind of information. In them, the results for duration (i.e., vowel duration and transition duration) are presented firstly; the results for F1 (i.e., vowel F1, transition F1 and vowel-transition F1 differences) are presented secondly; and the results for F2 (i.e., vowel F2, transition F2 and vowel-transition F2 differences) are presented lastly.

3.1 Organization

Given the considerable amount of data, for ease of presentation and comparison across the different subsections, the results of the statistical tests are reported in tables and figures instead of in running text. Reference to the most relevant aspects of these results (e.g., norms and trends, deviations from norms and trends, exceptions, special cases and comparisons) is then made in running text whenever appropriate. To avoid unnecessary repetition throughout the different subsections, an overview of the type of data provided and its organization in the tables and figures is offered in the following paragraphs.

The first table in each subsection shows the results of Mauchly's Test of Sphericity and the two-way repeated measures ANOVAs. These are presented together because the choice of the ANOVA results (i.e., *Sphericity Assumed*, *Greenhouse-Geisser*, *Huynh-Feldt* or *Lower-bound*, as presented in the SPSS output table) depends on the results of Mauchly's Test of Sphericity. This test is a necessary requirement for the correct interpretation of repeated measures ANOVA results given the importance of the sphericity assumption (Max & Onghena, 1999). It determines whether the variances of the differences between all combinations of levels of each independent variable are equal (i.e., homogeneous) or not and it is to be applied only in the case of variables with three or more treatment levels (i.e., context and rate*context in the present study) for any type of repeated measures ANOVA design (i.e., one-way and two-way in the present study). The test is therefore not applied in the case of the independent variable rate, which consists of only two levels (i.e., slow and fast).

The degree (i.e., size and strength of the effect) to which the sphericity assumption is or is not violated is shown by the estimated epsilon (ε) value. When Mauchly's Test of Sphericity is not statistically significant, and thus the estimated epsilon (ε) value is relatively high, the sphericity assumption is met (i.e., the variances are equal). In such cases, no correction to the test is needed and the ANOVA results to report are those provided in the *Sphericity Assumed* rows of the SPSS output table. These are the results to report in the case of the two-level independent variable rate as well. On the other hand, when the test is statistically significant, and thus the estimated epsilon (ε) value is relatively low, the sphericity assumption is violated (i.e., the variances are not equal). In these cases, one of *Greenhouse-Geisser*, *Huynh-Feldt* or *Lower-bound* results must be chosen. These are provided in the second, third and fourth rows, respectively, of the SPSS output table, and they are the outcome of applying the necessary correction to the test (i.e., adjustments, which take the form of reductions, in the degrees of freedom). An epsilon (ε) value of 1 implies that the sphericity assumption is exactly met and that there is no adjustment in the degrees of freedom. On the other hand, an epsilon (ε) value of 0 implies total violation of the sphericity assumption and requires the biggest possible adjustment in the degrees of freedom. The further the value of epsilon (ε) decreases below 1, the greater the violation. Intermediate values such as those close to 1 imply little violation and require small adjustment in the degrees of freedom, whereas intermediate values like those close to 0 imply great violation and require big adjustment in the degrees of freedom. In accordance with most common use, the *Greenhouse-Geisser* correction method was the one chosen for the cases of violation of the sphericity assumption in the present study. As a result of applying the corrections, and because these affect only the degrees of freedom, the actual value of the sum of squares (not provided in the results) and the *F* ratio remain the same.

For Mauchly's Test of Sphericity, the approximate chi-square value (χ^2), the degrees of freedom (*df*), the *p* value (*p*) and the *Greenhouse-Geisser* estimated epsilon correction value (ε) are provided in the tables. For the two-way repeated measures ANOVAs, the degrees of freedom (i.e., non-adjusted for rate and adjusted whenever necessary for context and rate*context), the *F* ratio, the *p* value and the partial eta squared value (η^2) for effect size and strength are provided.

The second table in each subsection shows the results of the paired-samples t-tests carried out to test for simple main effects between the two levels (i.e., slow vs. fast) of the rate variable on each dependent variable at every context level separately (i.e., each of the 14 contexts for /l/ and each of the seven contexts for /r/). For ease of identification, the tokens are presented in alphabetical order, with the phonemic symbol for the vowel in each of them provided to their right. Mean and standard deviation values for the slow and fast tokens are given next. These are followed by the *t* value, with the degrees of freedom in parentheses next to the *t* in the column head, the *p* value and, finally, Cohen's *d* value for effect size and strength.

The bar graphs that come in third place in each subsection illustrate the mean values for pairwise comparisons between the slow (shown by dark gray bars) and fast (shown by light gray bars) rates. These bar graphs are described in terms of, first, which of the two rates exhibits higher and lower values; and, second, which tokens show greater or smaller rate differences. The mean values represented by the bars correspond to the values reported in the tables that present the paired-samples t-test results. Standard error bars, indicating variability, above the bars are also provided. As shown in the *y*-axis titles, for duration, the values are in milliseconds (ms); for F1 and F2, they represent frequency and are shown in Hertz (Hz); and for vowel-transition differences, they are the numbers that result from subtracting the transition Hertz values from the vowel Hertz values, labeled as *difference*. The tokens are presented alphabetically with the phonemic symbol for the vowel provided below them in the *x*-axis labels. In the case of the V+/l/ sequences, due to the large number of tokens involved (i.e., 14), the figure consists of two bar graphs, while the number of tokens involved in the V+/r/ sequences (i.e., seven) allows for the presentation of the data in one single graph. The scale on the *y*-axis is the same for all the duration graphs (i.e., 0-220 ms), for all the vowel and transition F1 graphs (i.e., 0-800 Hz) and for all the vowel and transition F2 graphs (i.e., 0-2500 Hz). Because the range for the F2 values is wider than for the F1 values (e.g., the values for F1 are lower than 800 Hz but those for F2 may reach up to 2500 Hz), the scales for vowel-transition differences run from 0 to 200 for F1 but from 0 to 400 for F2.

The third table in each subsection shows the results of the one-way repeated measures ANOVAs performed to test for simple main effects between the different levels (i.e., 14 for V+/l/ and seven for V+/r/) of the context variable on each dependent variable at every rate level separately (i.e., slow vs. fast). The results for the slow and fast rates are provided in the same table. As in the case of the two-way repeated measures ANOVAs, the table reports the degrees of freedom, adjusted whenever necessary, the *F* ratio, the *p* value and the partial eta squared value (η^2) for effect size and strength.

The last table in each subsection shows the results of the Bonferroni post-hoc tests that were run to determine context differences from pairwise comparisons. The analysis of the results revolves around the non-significant differences reported in the tables and focuses on determining the overall quantity of differences as well as differences among contexts and between rates. The tokens are presented alphabetically with the phonemic symbol for the vowel next to them. The tables are formatted as 13x13 matrices for the V+/l/ sequences and as a 6x6 matrices for the V+/r/ sequences. Because pairwise comparisons involving the same tokens (e.g., *bill-bill*, *boil-boil*, *fair-fair*, *fear-fear*, etc.) are not possible, no cells for these are provided and thus the *y*-axis labels do not include *bill* (for V+/l/) and *fair* (for V+/r/) and the *x*-axis labels do not include *pull* (for V+/l/) and *power* (for V+/r/). Results for the two rate levels (i.e., slow vs. fast) are illustrated separately. Only information concerning statistical significance is provided, with non-significant values being specified in the cells and empty cells representing a significant value (i.e., $p < .01$).

The significance (i.e., alpha) level was set at .01 (i.e., 1%) for all the statistical tests. *P* values shown in the SPSS output as .000 are reported as $p < .001$, whereas in all other cases the actual *p* value is given. In order to help interpret the magnitude of the differences, the partial eta squared value (η^2) is provided as part of the two-way and one-way repeated measures ANOVA results. Likewise, Cohen's *d* value is provided as part of the results for the paired-samples t-tests. The larger the effect size, the greater the strength of the effect and, therefore, the bigger the differences.

For the partial eta squared value (η^2), effect sizes may run from .00 to 1. Effect sizes of .01, .06 and .14 are conventionally considered to have small, medium and large strength, respectively. These values can be interpreted as percentages of variance (in each of the effects, and the interaction) plus its associated error which are accounted for by the effects or the interaction, and they are equivalent to 1%, 6% and 14%. (Brown, 2008; Watson, 2015) For an easier interpretation of the results, and because the conversion is quite straightforward, the effect sizes provided by the partial eta squared value (η^2) will be presented, when in running text, in terms of their strength (i.e., whether they are small, medium or large) as well as in terms of the percentages of variance that they account for. Therefore, the partial eta squared value (η^2) will be transformed into a percentage in each case.

For Cohen's *d* value, effect sizes typically run from 0.00 to 3.00, but they may even reach up to almost 5.00 in very special cases. Effect sizes of 0.20, 0.50 and 0.80 are conventionally considered to have small, medium and large strength, respectively. These values can be interpreted in a variety of ways, depending on the type of data being analyzed and the kind of study conducted as, for example, in terms of standard deviations, percentiles, percentages of (non)-overlap, rankings or probabilities (Becker, 2000; Coe, 2002; Sullivan & Feinn, 2012; Watson, 2015). However, because it is not possible to apply a direct transformation, Cohen's *d* value will simply be interpreted, when in running text, in terms of the strength of the effect: small (approx. < .020), small-to-medium (approx. .020-.050), medium (approx. .050-.080), large (approx. .080-2.00), very large (approx. 2.00-3.00) or extremely large (> 3.00). Finally, since Cohen's *d* value is the result of dividing the mean difference by the standard deviation of the difference, the Cohen's *d* values provided in the tables must not be considered as equivalent to the values represented in the bar graphs, which are simply means and correspond to the values under *M* in the tables.

3.2 V+/l/ sequences

3.2.1 Duration in V+/l/ sequences

3.2.1.1 Vowel duration in V+/l/ sequences

Table 3.1 shows that the two-way repeated measures ANOVA performed on vowel duration in the V+/l/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 58.7% of the variance, which is noticeably lower than the variances for the main effects of rate (93.3%) and context (81.8%).

Table 3.1 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel duration in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	827.086	<.001	.933
Context	523.310	90	<.001	.323	4.20, 247.91	265.023	<.001	.818
Rate*Context	373.787	90	<.001	.448	5.83, 343.72	83.704	<.001	.587

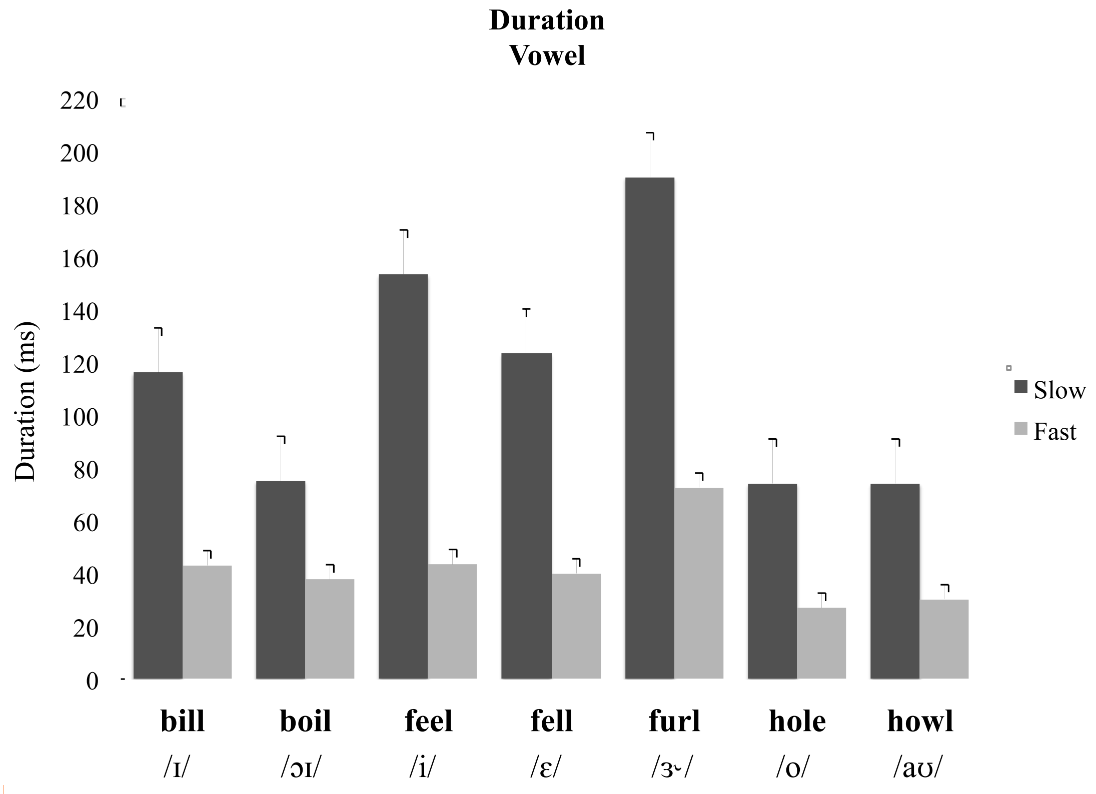
[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.2 shows that the t-tests performed for simple main effects of rate on vowel duration in the V+/l/ sequences elicited highly significant differences for all pairwise comparisons with large effect sizes (i.e., > 0.80), which are extremely large (i.e., > 3.00) for *hole*, *howl* and *pile* and very large for the rest of the cases.

Table 3.2 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel duration in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	116.07	25.94	43.06	6.70	22.44	<.001	2.90
boil	/ɔɪ/	75.09	10.48	37.73	5.74	22.77	<.001	2.94
feel	/i/	153.18	53.15	43.49	12.20	18.99	<.001	2.45
fell	/ɛ/	123.25	31.66	39.96	7.05	20.39	<.001	2.63
furl	/ɝ/	190.14	38.99	72.56	12.94	21.99	<.001	2.84
hole	/o/	74.04	13.59	26.96	3.74	29.82	<.001	3.85
howl	/aʊ/	74.11	9.85	30.33	5.30	32.41	<.001	4.18
hull	/ʌ/	148.44	31.77	57.60	8.51	20.88	<.001	2.70
pal	/æ/	137.90	36.43	54.71	8.23	17.70	<.001	2.29
pale	/e/	81.86	20.30	27.86	8.38	20.71	<.001	2.67
Paul	/ɔ/	158.08	32.60	61.04	11.52	22.71	<.001	2.93
pile	/aɪ/	80.53	11.69	34.55	4.51	28.98	<.001	3.74
pool	/u/	161.17	38.94	55.22	10.94	20.92	<.001	2.70
pull	/ʊ/	141.54	36.37	49.84	9.18	18.69	<.001	2.41

Figure 3.1 illustrates that the mean vowel duration values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens than for the fast ones in all cases. The most remarkable differences can be observed for *feel*, *furl*, *hull*, *pal*, *Paul*, *pool* and *pull*. The differences are not so prominent for *bill* and *fell*, and they are even less notable for *boil*, *hole*, *howl*, *pale* and *pile*, all of which contain diphthongized vowels or diphthongs.



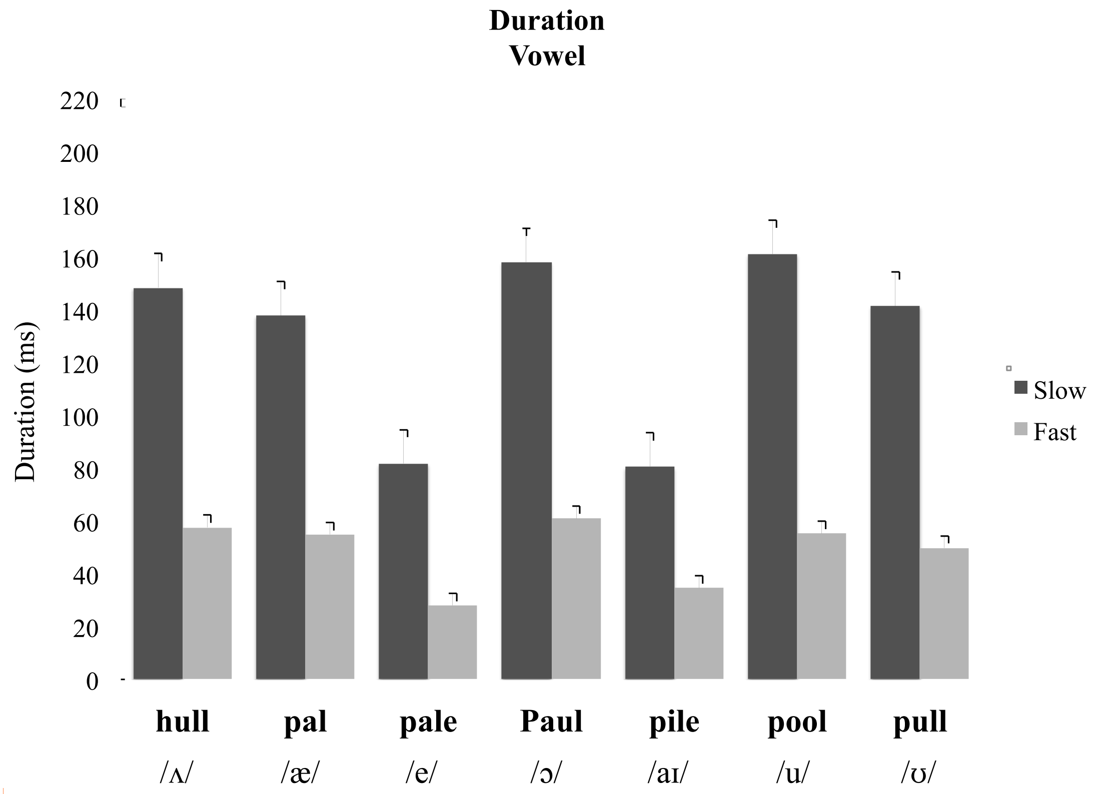


Figure 3.1 Mean vowel duration values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.3 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel duration in the V+/l/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 75.3% and 76.6% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have very similar strength.

Table 3.3 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel duration in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	486.563	90	<.001	.359	4.67, 275.43	180.126	<.001	.753
Context (fast)	301.634	90	<.001	.558	7.26, 428.23	192.769	<.001	.766

[a] *df* = Greenhouse-Geisser correction

Table 3.4 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for vowel duration. There is a larger number of non-significant pairs for the slow tokens ($^{23}/_{91}$ = 25.27%) than for the fast ones ($^{17}/_{91}$ = 18.68%). There are considerable coincidences between rates (i.e., *bill-fell*, *boil-pile*, *feel-pull*, *hole-pale*, *howl-pale*, *hull-pal*, *hull-Paul*, *hull-pool*, *pal-pull* and *Paul-pool*), with no exact correspondence between *p* values in any case.

Some of the non-significant pairs have similar vowels according to phonological parameters like backness, height or tenseness, which are conventionally used to classify vowels (henceforth *similar vowels* for short). For front vowels, examples are *bill-feel* (fast), with high vowels, despite the vowel in *bill* being lax and in *feel* tense; *bill-fell* (slow and fast), with lax vowels, despite the vowel in *bill* being high and in *fell* mid; or *pale-pile* (slow), with high lax vowels (i.e., the second element of the diphthongized vowel in *pale* and of the diphthong in *pile*). For back vowels, examples are *hole-howl* (slow), with high lax vowels (i.e., the second element of the diphthongized vowel in *hole* and of the diphthong in *howl*); or *pool-pull* (fast), with high vowels, despite the vowel in *pool* being tense and in *pull* lax.

Other pairs, however, contain vowels which are somehow different, like *boil-hole* (slow), *boil-howl* (slow), *hole-pale* (slow and fast) or *howl-pile* (slow). The vowels in these pairs differ in backness, with those in *boil*, *pale* and *pile* being front, and those in *hole* and *howl* back. Yet, they are all high and constitute the second elements of diphthongized vowels or diphthongs. Similar examples are *feel*-*pool* (slow) or *feel-pull* (slow and fast), with the vowel in *feel* being front and in *pool* and *pull* back, despite all of them being high. Also, the vowels in *feel* and *pool* are tense, whereas the vowel in *pull* is lax. Further examples are *hull*-*Paul* (slow and fast) or *hull*-*pull* (slow), whose first and second words in each pair contain central and back vowels, respectively. Although the vowels in *hull* and *Paul* are mid, the one in *pull* is high, and although those in *hull* and *pull* are lax, that in *Paul* is tense.

Table 3.4 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for vowel duration*

Slow		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/													
fell	/ɛ/	1.000												
furl	/ɝ/													
hole	/o/		1.000											
howl	/aʊ/		1.000				1.000							
hull	/ʌ/			1.000										
pal	/æ/			.614	.010				.094					
pale	/e/		1.000				.196	.377						
Paul	/ɔ/			1.000					.596					
pile	/aɪ/		.414				.094	.035			1.000			
pool	/u/			1.000					.115			1.000		
pull	/ʊ/			1.000					1.000	1.000				

Fast		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/	1.000	.042											
fell	/ɛ/	.253	1.000	1.000										
furl	/ɝ/													
hole	/o/													
howl	/aʊ/													
hull	/ʌ/													
pal	/æ/								1.000					
pale	/e/						1.000	1.000						
Paul	/ɔ/								1.000	.013				
pile	/aɪ/		.027											
pool	/u/								1.000	1.000		.081		
pull	/ʊ/			.290						.202				.016

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

Other contrasts involve words that consist of rather dissimilar vowels, such as *feel-pal* (slow), despite the vowels in them being front; *feel-Paul* (slow), despite the vowels in them being tense; or *pal-pull* (slow and fast), despite the vowels in them being lax. Similarly, a few contrasts involve words whose vowels have nothing in common, like *hull-pool* (slow and fast) or *pal-pool* (fast).

The highest possible p value (i.e., p = 1.000) is exhibited in slightly more than half of the cases by pairs with and without similar vowels.

3.2.1.2 Transition duration in V+/l/ sequences

Table 3.5 shows that the two-way repeated measures ANOVA performed on transition duration in the V+/l/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 44.6% of the variance, which is noticeably lower than the variance for the main effect of rate (94.9%) but moderately lower than the variance for the main effect of context (68.8%).

Table 3.5 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for transition duration in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	1101.295	<.001	.949
Context	355.295	90	<.001	.424	5.51, 325.14	130.140	<.001	.688
Rate*Context	325.162	90	<.001	.432	5.62, 331.55	47.410	<.001	.446

[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.6 shows that the t-tests performed for simple main effects of rate on transition duration in the V+/l/ sequences elicited highly significant differences for all pairwise comparisons with large effect sizes (i.e., > 0.80), which are very large for *bill*, *feel*, *pale* and *pile* and extremely large (i.e., > 3.00) for the rest of the cases.

Table 3.6 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for transition duration in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	123.23	30.77	39.86	6.70	20.25	<.001	2.61
boil	/ɔɪ/	79.51	15.52	29.37	4.67	23.25	<.001	3.00
feel	/i/	120.71	30.70	41.19	8.39	19.87	<.001	2.56
fell	/ɛ/	109.33	22.37	37.85	4.51	24.00	<.001	3.10
furl	/ɝ/	110.94	21.10	40.37	8.99	27.48	<.001	3.55
hole	/o/	71.08	14.04	25.71	3.53	27.12	<.001	3.50
howl	/aʊ/	73.16	9.47	27.51	4.78	35.04	<.001	4.52
hull	/ʌ/	86.46	13.18	28.48	4.37	32.70	<.001	4.22
pal	/æ/	107.90	18.60	38.20	4.80	28.74	<.001	3.71
pale	/e/	91.61	16.62	38.78	5.14	23.16	<.001	2.99
Paul	/ɔ/	95.87	14.68	35.12	4.84	30.84	<.001	3.98
pile	/aɪ/	78.66	16.17	32.70	3.83	20.20	<.001	2.61
pool	/u/	96.61	18.70	30.95	4.61	27.83	<.001	3.59
pull	/ʊ/	87.54	15.67	28.76	4.07	27.88	<.001	3.60

Figure 3.2 illustrates that the mean transition duration values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens than for the fast ones in all cases, as was the case for vowel duration. The most remarkable differences can be observed for *bill*, *feel*, *fell*, *furl* and *pal*. The differences are not so prominent for *hull*, *pale*, *Paul*, *pool* and *pull*, and they are even less notable for *boil*, *hole*, *howl* and *pile*. As with vowel duration, these are all diphthongized vowels and diphthongs. The exception in this case is *pile*.

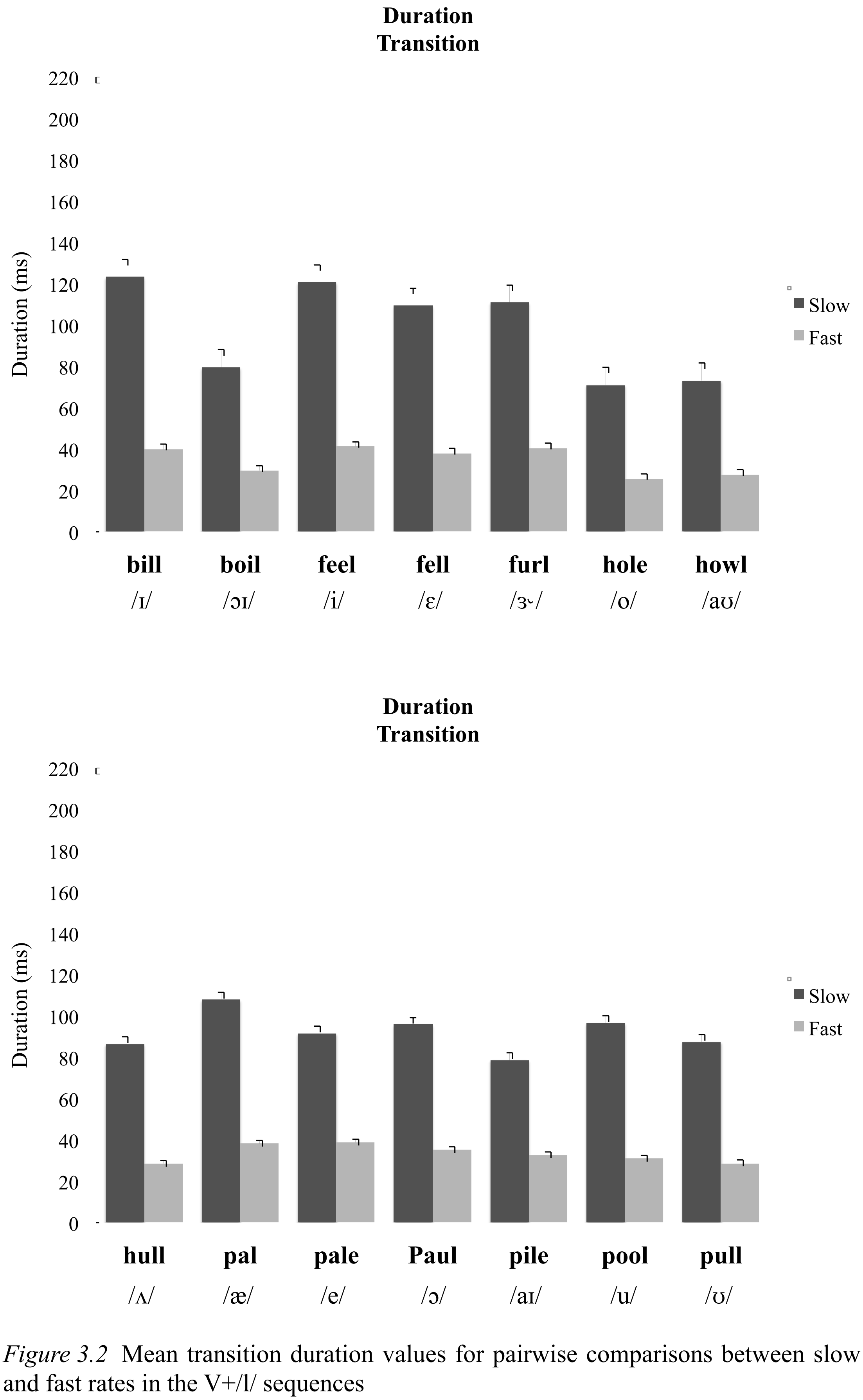


Figure 3.2 Mean transition duration values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.7 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on transition duration in the V+/l/ sequences yielded significant effects with large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 60.9% and 58.6% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have very similar strength.

Table 3.7 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for transition duration in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	357.608	90	<.001	.409	5.32, 313.90	91.957	<.001	.609
Context (fast)	250.236	90	<.001	.546	7.09, 418.56	83.530	<.001	.586

[a] *df* = Greenhouse-Geisser correction

Table 3.8 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for transition duration. There is a larger number of non-significant pairs for the fast tokens ($^{27}/_{91}$ = 29.67%) than for the slow ones ($^{20}/_{91}$ = 21.98%). There are considerable coincidences between rates (i.e., *bill-feel*, *bill-furl*, *boil-howl*, *boil-hull*, *feel-furl*, *fell-furl*, *fell-pal*, *furl-pal*, *hole-howl* and *hull-pull*), with an exact correspondence between *p* values (i.e., *p* = 1.000) in the case of *bill-feel*, *fell-furl*, *fell-pal*, *furl-pal* and *hull-pull*.

Some of the non-significant pairs have similar vowels. For front vowels, examples are *bill-feel* (slow and fast), with high vowels, despite the vowel in *bill* being lax and in *feel* tense; *bill-fell* (fast), with lax vowels, despite the vowel in *bill* being high and in *fell* mid; *boil-pile* (slow), with the second element of the diphthongs being high lax, despite the first element in *boil* being mid back and in *pile* high front; or *fell-pal* (slow and fast), with lax vowels, despite the vowel in *fell* being mid and in *pal* low.

For back vowels, examples are *hole-howl* (slow and fast), with high lax vowels (i.e., the second element of the diphthongized vowel in *hole* and of the diphthong in *howl*); or *howl-pull* (fast), with the second element of the diphthong in *howl* and the vowel in *pull* being the same vowel (i.e., high lax), despite the coarticulatory influence that the first element of the diphthong may exert on the second.

Other pairs, however, contain vowels which are somehow different, like *boil-hole* (slow), *boil-howl* (slow and fast), *hole-pile* (slow) or *howl-pile* (slow). The vowels in these pairs differ in backness, with those in *boil* and *pile* being front, and those in *howl* and *hole* back. Still, they are all high and constitute the second elements of diphthongized vowels and diphthongs.

Table 3.8 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for transition duration*

Slow		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/	1.000												
fell	/ɛ/													
furl	/ɝ/	.020		.237	1.000									
hole	/o/		.106											
howl	/aʊ/		.531				1.000							
hull	/ʌ/		.079											
pal	/æ/				1.000	1.000								
pale	/e/								.380					
Paul	/ɔ/										1.000			
pile	/aɪ/		1.000				.482	1.000	.040					
pool	/u/										1.000	1.000		
pull	/ʊ/								1.000		.979			

Fast		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/	1.000												
fell	/ɛ/	1.000		.367										
furl	/ɝ/	1.000		1.000	1.000									
hole	/o/													
howl	/aʊ/		.903				.797							
hull	/ʌ/		1.000					1.000						
pal	/æ/	1.000		.581	1.000	1.000								
pale	/e/	1.000		1.000	1.000	1.000				1.000				
Paul	/ɔ/				.070									
pile	/aɪ/											.195		
pool	/u/		1.000						.024					
pull	/ʊ/		1.000					1.000	1.000				1.000	

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

Other contrasts involve words that consist of rather dissimilar vowels, such as *feel-furl* (slow and fast), despite the vowels in them being tense; *fell-Paul* (fast), despite the vowels in them being mid; or *pale-pool* (slow), despite the vowels in them being high. Similarly, a few contrasts involve words whose vowels have nothing in common, like *furl-pale* (fast), *hull-pale* (slow), *hull-pile* (slow and fast), *pale-Paul* (slow) or *Paul-pile* (fast).

The highest possible *p* value (i.e., $p = 1.000$) is exhibited in more than half of the cases by pairs with and without similar vowels and is particularly common for the fast rate.

3.2.2 F1 in V+/l/ sequences

3.2.2.1 Vowel F1 in V+/l/ sequences

Table 3.9 shows that the two-way repeated measures ANOVA performed on vowel F1 in the V+/l/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 44.1% of the variance, which is noticeably lower than the variances for the main effects of rate (84.9%) and context (86.9%).

Table 3.9 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel F1 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	331.162	<.001	.849
Context	490.995	90	<.001	.396	5.15, 303.56	392.092	<.001	.869
Rate*Context	275.918	90	<.001	.526	6.84, 403.47	46.522	<.001	.441

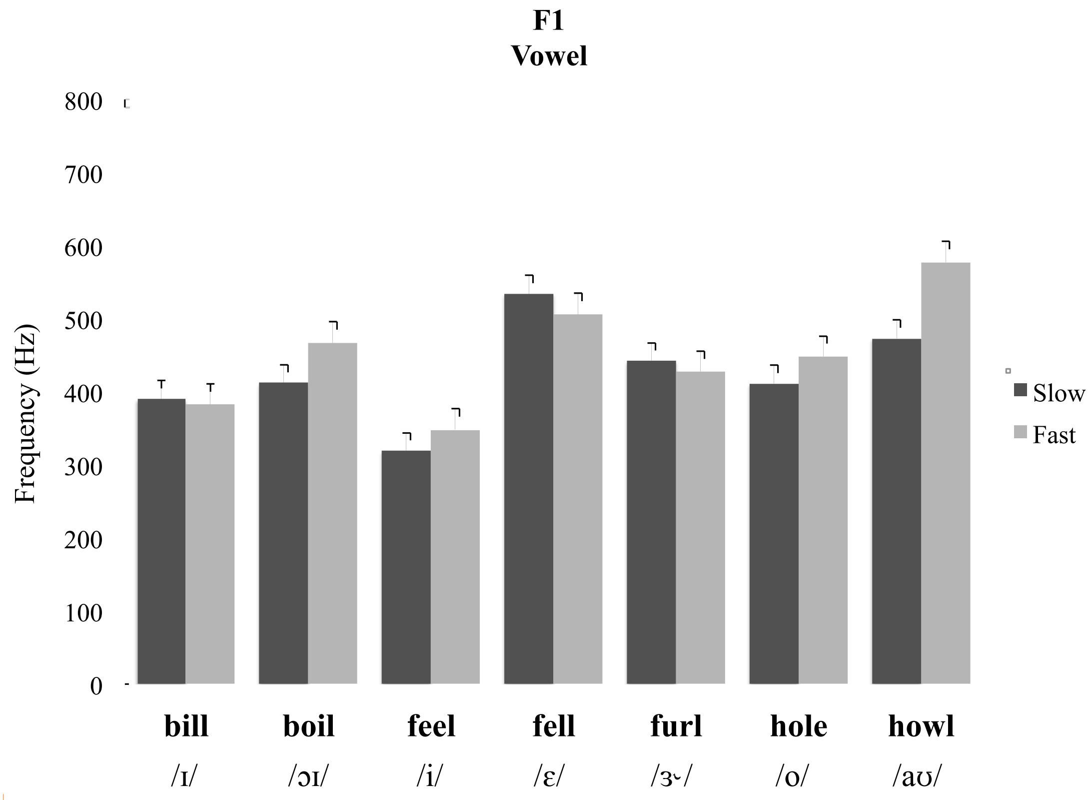
[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.10 shows that the t-tests performed for simple main effects of rate on vowel F1 in the V+/l/ sequences elicited non-significant differences for *bill*, *pal*, *pool* and *pull*, with small effect sizes (i.e., < .020) for *bill*, *pool* and *pull*, and a small-to-medium effect size for *pal*. However, they yielded significant differences for the rest of the pairwise comparisons, with small-to-medium effect sizes for *furl* and *hull*, medium effect sizes for *feel*, *fell* and *Paul*, and large effect sizes (i.e., > 0.80) for *boil*, *hole*, *howl*, *pale* and *pile*.

Table 3.10 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel F1 in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	390	29.90	382	37.98	1.31	.195	0.17
boil	/ɔɪ/	412	44.43	467	36.11	−8.51	<.001	−1.10
feel	/i/	319	37.12	348	61.10	−4.41	<.001	−0.57
fell	/ɛ/	534	39.84	506	40.49	5.08	<.001	0.66
furl	/ɝ/	442	30.49	427	43.82	3.50	.001	0.45
hole	/o/	411	40.90	448	37.15	−7.11	<.001	−0.92
howl	/aʊ/	473	74.18	577	53.07	−10.40	<.001	−1.34
hull	/ʌ/	475	60.60	497	51.93	−3.14	.003	−0.41
pal	/æ/	679	45.64	661	54.93	2.09	.041	0.27
pale	/e/	441	39.09	502	47.81	−8.78	<.001	−1.13
Paul	/ɔ/	551	33.94	571	35.06	−4.25	<.001	−0.55
pile	/aɪ/	508	47.53	632	30.80	−16.53	<.001	−2.13
pool	/u/	324	39.03	329	37.43	−1.15	.254	−0.15
pull	/ʊ/	413	37.48	413	49.45	−0.04	.970	0.00

Figure 3.3 illustrates that the mean vowel F1 values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens of *bill*, *fell*, *furl* and *pal* as well as for the fast tokens of *boil*, *feel*, *hole*, *howl*, *hull*, *pale*, *Paul*, *pile* and *pool*. The greatest differences are exhibited by *boil*, *howl*, *pale* and *pile* and, to a smaller degree, for *hole*, all of which coincide in having higher values for the fast tokens than for the slow ones. Moreover, as with the vowel duration and transition duration cases, they all contain diphthongized vowels or diphthongs. Appreciable smaller differences are displayed by *feel*, *fell*, *furl*, *hull*, *Paul* and *pal*. *Bill* and *pool* have very similar values, and those for *pull* are exactly the same.



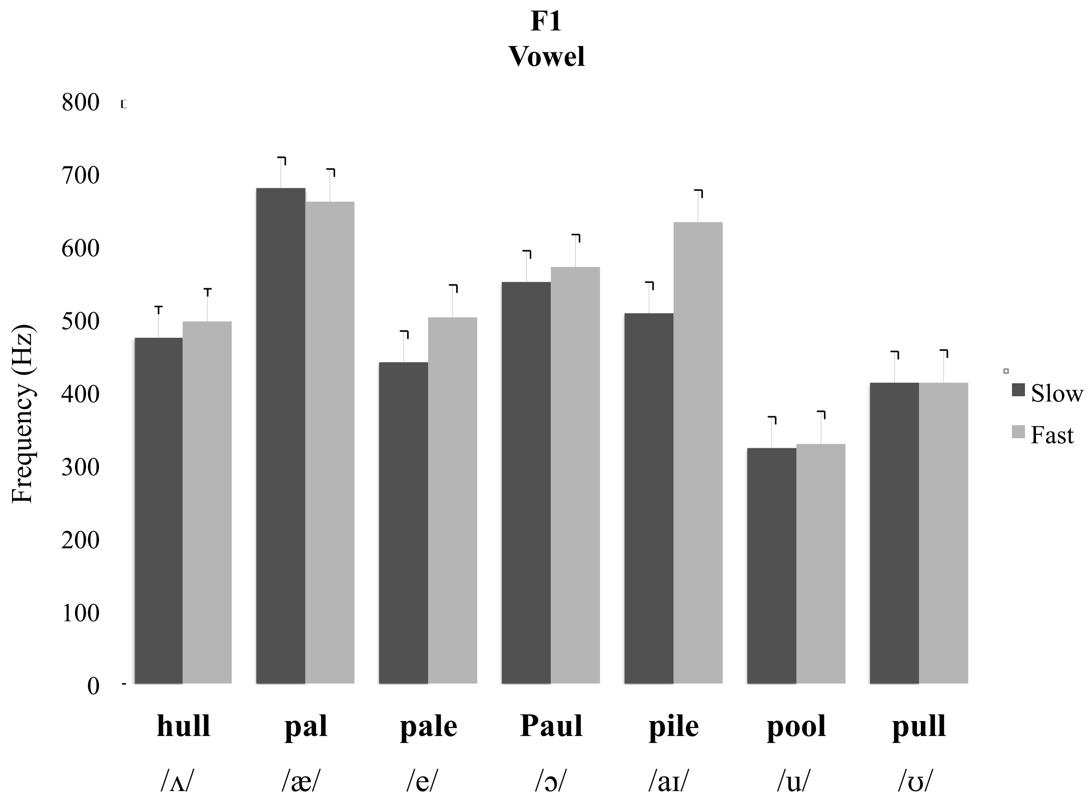


Figure 3.3 Mean vowel F1 values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.11 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel F1 in the V+/l/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 81.7% and 83.5% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have very similar strength.

Table 3.11 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel F1 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	544.461	90	<.001	.344	4.48, 263.75	262.768	<.001	.817
Context (fast)	302.199	90	<.001	.543	7.06, 416.29	297.749	<.001	.835

[a] *df* = Greenhouse-Geisser correction

Table 3.12 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for vowel F1. There is a larger number of non-significant pairs for the slow tokens ($^{18}/_{91}$ = 19.78%) than for the fast ones ($^{11}/_{91}$ = 12.09%). There are a few coincidences between rates (i.e., *boil-hole*, *feel-pool*, *furl-hole* and *hull-pale*), with an exact correspondence between *p* values (i.e., *p* = 1.000) in the case of *feel-pool*. Some of the non-significant pairs have similar vowels. For example, *bill-boil* (slow) and *bill-feel* (fast) have high front vowels; the vowels in *furl-hull* are mid central; and those in *hole-pull* are high back. Other pairs, however, contain vowels which are somehow different, like *boil-hole* (slow and fast), *hole-pale* (slow) or *howl-pale* (slow). The vowels in these pairs differ in backness, despite all being high and the second elements of diphthongized vowels or diphthongs. Similar examples are the vowels in *bill-pull* (fast) or *feel-pool* (slow and fast), which, despite all being high, are front for *bill* and *feel*, and back for *pull* and *pool*. Also, *bill* and *pull* are lax, whereas *feel* and *pool* are tense. Finally, other contrasts involve words that consist of rather dissimilar vowels, such as *bill-hole* (slow), *boil-pull* (slow), *fell-hull* (fast), *furl-hole* (slow) or *hull-pile* (slow). The highest possible *p* value (i.e., *p* = 1.000) is exhibited in about half of the cases by pairs with and without similar vowels and is more common for the fast rate.

Table 3.12 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for vowel F1*

Slow	bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil /ɔɪ/	.395												
feel /i/													
fell /ɛ/													
furl /ɝ/													
hole /o/	.166	1.000			.021								
howl /aʊ/					.073								
hull /ʌ/					.093		1.000						
pal /æ/													
pale /e/					1.000	.023	.067	.224					
Paul /ɔ/				1.000									
pile /aɪ/				.874			.090	.300					
pool /u/			1.000										
pull /ʊ/		1.000				1.000							

Fast	bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil /ɔɪ/													
feel /i/	.056												
fell /ɛ/													
furl /ɝ/													
hole /o/		.316			1.000								
howl /aʊ/													
hull /ʌ/				1.000									
pal /æ/													
pale /e/				1.000				1.000					
Paul /ɔ/							1.000						
pile /aɪ/									.038				
pool /u/			1.000										
pull /ʊ/	.164				1.000								

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.2.2.2 Transition F1 in V+/l/ sequences

Table 3.13 shows that the two-way repeated measures ANOVA performed on transition F1 in the V+/l/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 42.1% of the variance, which is noticeably lower than the variances for the main effects of rate (87.3%) and context (87.5%).

Table 3.13 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for transition F1 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	405.372	<.001	.873
Context	472.900	90	<.001	.410	5.33, 314.71	412.216	<.001	.875
Rate*Context	236.022	90	<.001	.589	7.66, 451.74	42.902	<.001	.421

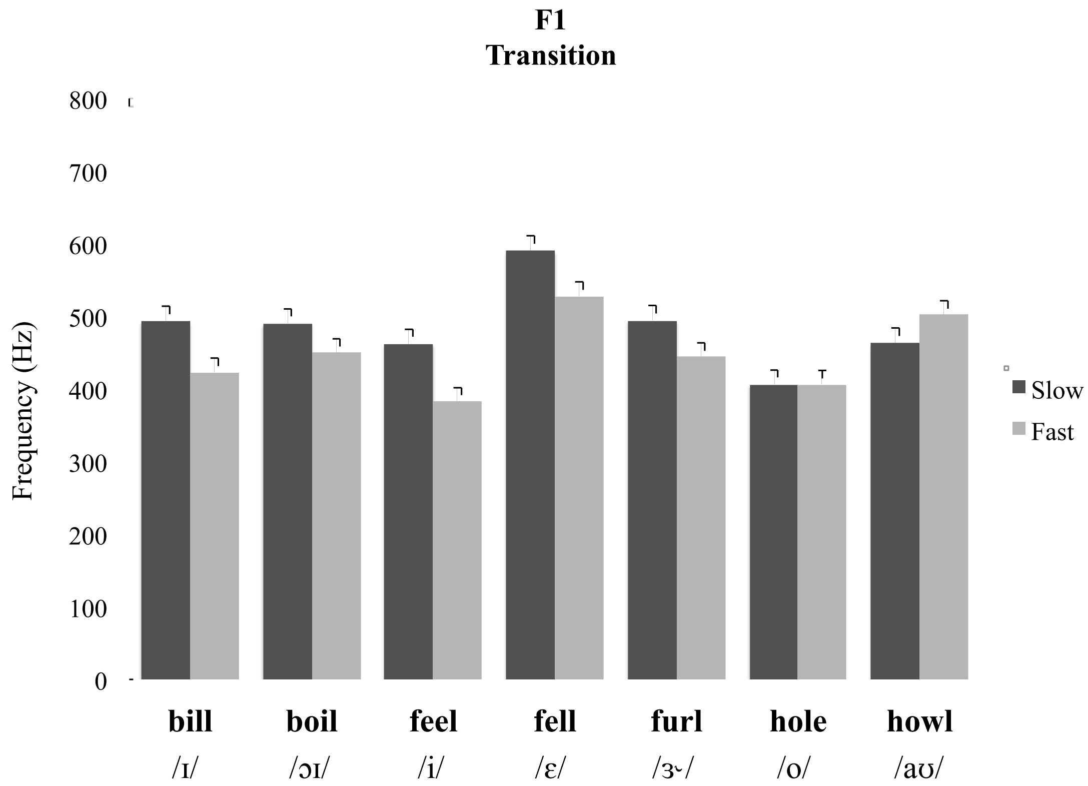
[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.14 shows that the t-tests performed for simple main effects of rate on transition F1 in the V+/l/ sequences elicited non-significant differences for *hole* with a very small effect size (i.e., < .020). However, they yielded significant differences for the rest of the pairwise comparisons, with small-to-medium effect sizes for *hull* and *pale*, medium effect sizes for *howl* and *pull*, and large effect sizes (i.e., > 0.80) for *bill*, *boil*, *feel*, *fell*, *furl*, *pal*, *Paul*, *pile* and *pool*.

Table 3.14 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for transition F1 in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	493	19.42	423	23.50	16.28	<.001	2.10
boil	/ɔɪ/	490	25.33	450	33.19	9.27	<.001	1.20
feel	/i/	462	38.75	383	33.13	14.68	<.001	1.89
fell	/ɛ/	590	27.95	528	29.22	13.55	<.001	1.75
furl	/ɝ/	494	21.39	444	38.06	9.82	<.001	1.27
hole	/o/	406	44.47	406	36.32	−0.03	.979	0.00
howl	/aʊ/	463	62.93	502	41.57	−4.65	<.001	−0.60
hull	/ʌ/	460	45.63	444	40.62	2.78	.007	0.36
pal	/æ/	679	40.54	629	57.72	6.35	<.001	0.82
pale	/e/	514	23.30	501	32.39	3.19	.002	0.41
Paul	/ɔ/	556	29.59	523	28.58	7.34	<.001	0.95
pile	/aɪ/	541	36.22	587	35.46	−8.22	<.001	−1.06
pool	/u/	375	43.72	324	41.91	10.03	<.001	1.29
pull	/ʊ/	412	34.00	374	42.34	5.34	<.001	0.69

Figure 3.4 illustrates that the mean transition F1 values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens in all cases except for *pile*. The greatest differences are exhibited by *bill*, *feel*, *fell*, *furl*, *pal*, *pile* and *pool*. Appreciable smaller differences are displayed by *boil*, *howl*, *Paul* and *pull*. *Hull* and *pale* have very similar values, and those for *hole* are exactly the same.



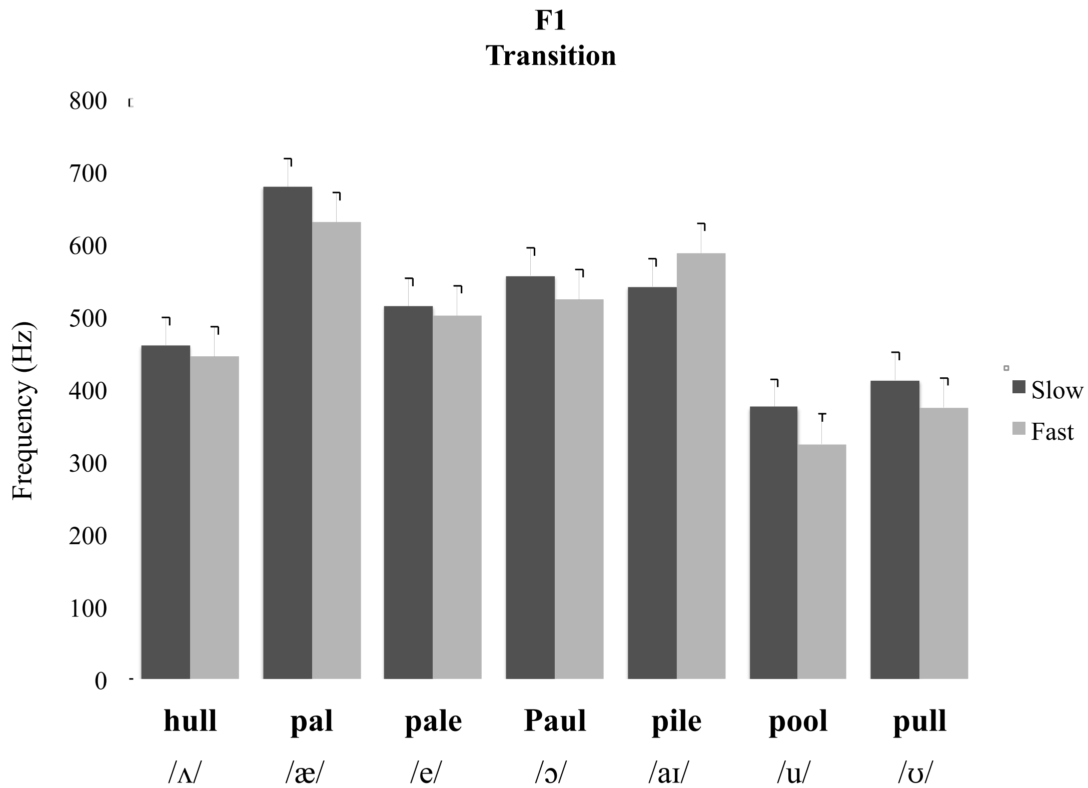


Figure 3.4 Mean transition F1 values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.15 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on transition F1 in the V+/l/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 82.1% and 83.4% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have very similar strength.

Table 3.15 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for transition F1 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	438.132	90	<.001	.429	5.57, 328.81	271.087	<.001	.821
Context (fast)	276.443	90	<.001	.508	6.60, 389.48	296.476	<.001	.834

[a] *df* = Greenhouse-Geisser correction

Table 3.16 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for transition F1. There is exactly the same number of non-significant pairs for the slow tokens as for the fast ones ($^{12}/_{91}$ = 13.19%). There is only one coincidence between rates (i.e., *boil-furl*), with the same *p* value (i.e., *p* = 1.000). Some of the non-significant pairs have similar vowels. Examples are *bill-boil* (slow), *furl-hull* (slow) or *hole-pull* (slow), with high front, mid central and high back vowels, respectively. Other pairs, however, contain vowels which are somehow different, like *boil-howl* (slow) or *howl-pale* (fast), which differ in backness, despite all being high and the second elements of diphthongized vowels or diphthongs. A similar example is *feel-pull* (fast), whose vowels, despite being high, are front and tense for *feel* and back and lax for *pull*. Finally, contrasts involve words that consist of rather dissimilar vowels, such as *bill-furl* (slow), *bill-howl* (slow), *bill-hull* (fast), *boil-furl* (fast), *feel-hole* (fast) or *pale-Paul* (fast). The three similar pairs exhibit the highest possible *p* value (i.e., *p* = 1.000), but some of the different pairs also exhibit this value.

Table 3.16 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for transition F1*

Slow		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/	1.000												
feel	/i/													
fell	/ɛ/													
furl	/ɝ/	1.000	1.000											
hole	/o/													
howl	/aʊ/	.087	.225	1.000		.025								
hull	/ʌ/			1.000				1.000						
pal	/æ/													
pale	/e/													
Paul	/ɔ/													
pile	/aɪ/											1.000		
pool	/u/						.018							
pull	/ʊ/						1.000							

Fast		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/													
fell	/ɛ/													
furl	/ɝ/		1.000											
hole	/o/	.398		.367										
howl	/aʊ/				.073									
hull	/ʌ/	.140	1.000			1.000								
pal	/æ/													
pale	/e/							1.000						
Paul	/ɔ/				1.000			.634			.063			
pile	/aɪ/													
pool	/u/													
pull	/ʊ/			1.000										

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.2.2.3 Vowel-Transition F1 differences in V+/l/ sequences

Table 3.17 shows that the two-way repeated measures ANOVA performed on vowel-transition F1 differences in the V+/l/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 48.6% of the variance, which is moderately lower than the variance for the main effect of rate (65.8%) but marginally higher than the variance for the main effect of context (42.6%).

Table 3.17 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel-transition F1 differences in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	113.403	<.001	.658
Context	304.468	90	<.001	.476	6.19, 364.92	43.752	<.001	.426
Rate*Context	179.091	90	<.001	.633	8.23, 485.59	55.702	<.001	.486

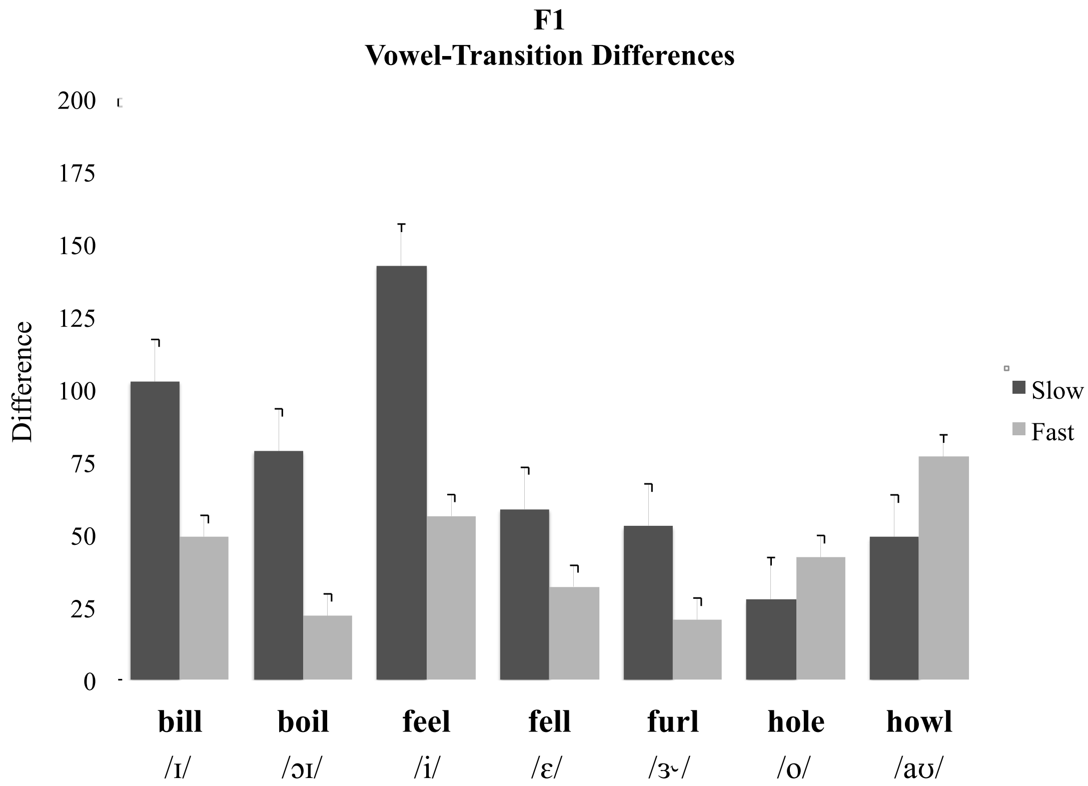
[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.18 shows that the t-tests performed for simple main effects of rate on vowel-transition F1 differences in the V+/l/ sequences elicited non-significant differences for *pal* and *pile*, with a small effect size (i.e., < .020) for *pal*, and a small-to-medium effect size for *pile*. However, they yielded significant differences for the rest of the pairwise comparisons, with medium effect sizes for *fell*, *hole*, *howl*, *hull*, *Paul* and *pull*, and large effect sizes (i.e., > 0.80) for *bill*, *boil*, *feel*, *furl*, *pale* and *pool*.

Table 3.18 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel-transition F1 differences in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	102.67	30.64	48.97	31.15	9.89	<.001	1.28
boil	/ɔɪ/	78.68	44.13	22.07	16.17	8.69	<.001	1.12
feel	/i/	142.18	45.69	56.28	38.45	14.50	<.001	1.87
fell	/ɛ/	58.70	35.09	32.02	22.50	5.54	<.001	0.71
furl	/ɝ/	52.77	25.80	20.53	21.49	8.49	<.001	1.10
hole	/o/	27.43	24.94	42.05	20.63	−3.86	<.001	−0.50
howl	/aʊ/	48.98	33.58	76.68	25.21	−5.30	<.001	−0.68
hull	/ʌ/	32.93	33.58	52.90	31.07	−4.36	<.001	−0.56
pal	/æ/	35.80	26.34	43.25	31.30	−1.41	.163	−0.18
pale	/e/	73.37	37.21	24.33	15.85	8.67	<.001	1.12
Paul	/ɔ/	24.50	21.72	49.32	30.11	−5.44	<.001	−0.70
pile	/aɪ/	35.27	29.53	45.53	18.53	−2.41	.019	−0.31
pool	/u/	53.77	38.31	18.87	19.33	6.36	<.001	0.82
pull	/ʊ/	22.97	15.39	44.47	32.14	−4.87	<.001	−0.63

Figure 3.5 illustrates that the mean vowel-transition-difference F1 values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens of *bill*, *boil*, *feel*, *fell*, *furl*, *pale* and *pool* as well as for the fast tokens of *hole*, *howl*, *hull*, *pal*, *Paul*, *pile* and *pull*. The greatest, and at the same time very prominent, differences are shown for *bill*, *boil*, *feel* and *pale*. Also clearly appreciable, though not so large, differences can be found for *fell*, *furl*, *howl*, *hull*, *Paul*, *pool* and *pull*. Smaller, despite still easily identifiable, differences can be discerned for *hole*, *pal* and *pile*.



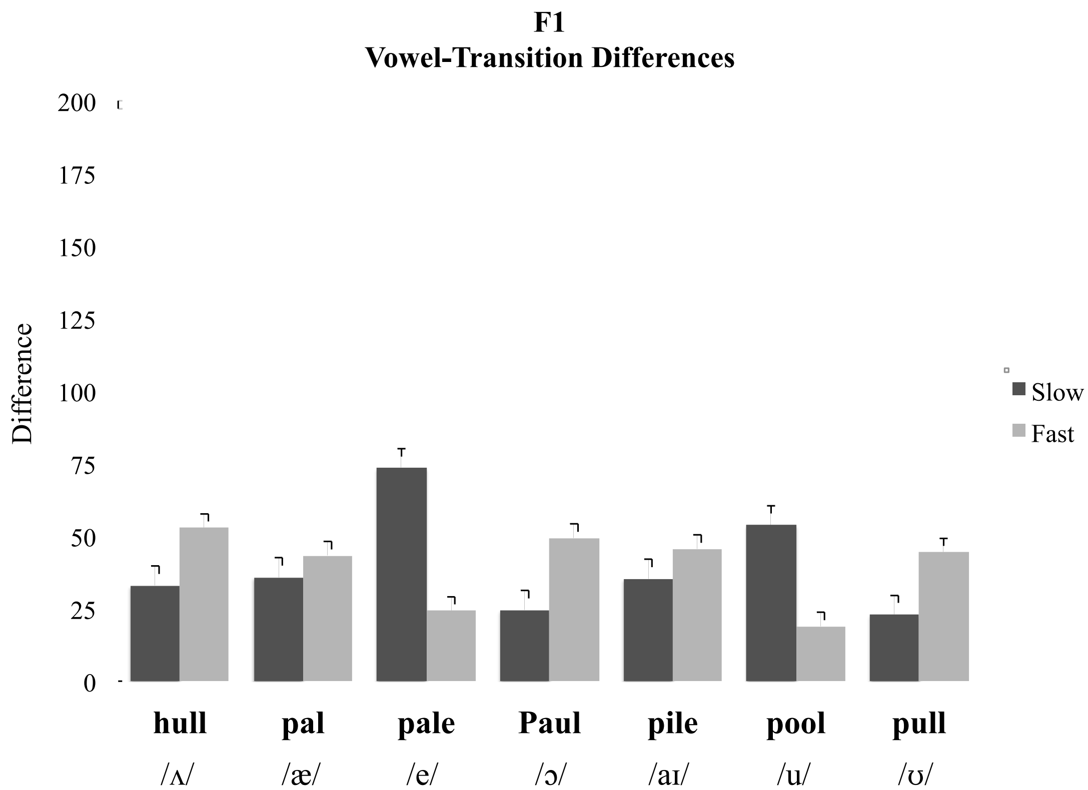


Figure 3.5 Mean vowel-transition-difference F1 values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.19 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel-transition F1 differences in the V+/l/ sequences yielded significant effects with large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 52.4% and 28.8% of the variance in the slow and fast tokens, respectively. Thus, the effect size for context (slow) is relatively larger than for context (fast).

Table 3.19 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel-transition F1 differences in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	336.068	90	<.001	.428	5.57, 328.50	65.029	<.001	.524
Context (fast)	261.375	90	<.001	.588	7.65, 451.10	23.851	<.001	.288

[a] *df* = Greenhouse-Geisser correction

Table 3.20 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for vowel-transition F1 differences. There is a very large number of non-significant pairs. The fast pairs are more numerous ($^{47}/_{91}$ = 51.65) than the slow ones ($^{39}/_{91}$ = 42.86%). There are a lot of coincidences between rates involving combinations with *fell*, *hole*, *hull*, *pal*, *Paul*, *pile* and *pull*. Pairs with *boil*, *furl*, *pale* and *pool* show fewer coincidences, and pairs with *bill*, *feel* and *howl* show none. Most of the pairs exhibit highly non-significant *p* values (i.e., *p* = 1.000, or close to it).

Table 3.20 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for vowel-transition F1 differences*

Slow		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/	.102												
feel	/i/													
fell	/ɛ/		1.000											
furl	/ɝ/				1.000									
hole	/o/													
howl	/aʊ/				1.000	1.000	.035							
hull	/ʌ/					.024	1.000	.072						
pal	/æ/					.093	1.000	1.000	1.000					
pale	/e/		1.000		1.000			.045						
Paul	/ɔ/						1.000		1.000	1.000				
pile	/aɪ/				.158	.158	1.000	1.000	1.000	1.000		1.000		
pool	/u/		.950		1.000	1.000		1.000	.013	.537	1.000		.214	
pull	/ʊ/						1.000		1.000	.370		1.000	.346	

Fast		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/	1.000												
fell	/ɛ/	.085	.093	.012										
furl	/ɝ/		1.000		.559									
hole	/o/	1.000		1.000	.814									
howl	/aʊ/			.078										
hull	/ʌ/	1.000		1.000			1.000							
pal	/æ/	1.000		1.000	1.000		1.000		1.000					
pale	/e/		1.000		1.000	1.000								
Paul	/ɔ/	1.000		1.000	.010		1.000		1.000	1.000				
pile	/aɪ/	1.000		1.000	.070		1.000		1.000	1.000		1.000		
pool	/u/		1.000		.058	1.000					1.000			
pull	/ʊ/	1.000		1.000	1.000		1.000		1.000	1.000	.017	1.000	1.000	

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.2.3 F2 in V+/l/ sequences

3.2.3.1 Vowel F2 in V+/l/ sequences

Table 3.21 shows that the two-way repeated measures ANOVA performed on vowel F2 in the V+/l/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 54.3% of the variance, which is noticeably lower than the variances for the main effects of rate (86.4%) and context (95.4%).

Table 3.21 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel F2 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	375.734	<.001	.864
Context	704.893	90	<.001	.243	3.16, 186.67	1213.954	<.001	.954
Rate*Context	306.327	90	<.001	.559	7.27, 428.63	69.972	<.001	.543

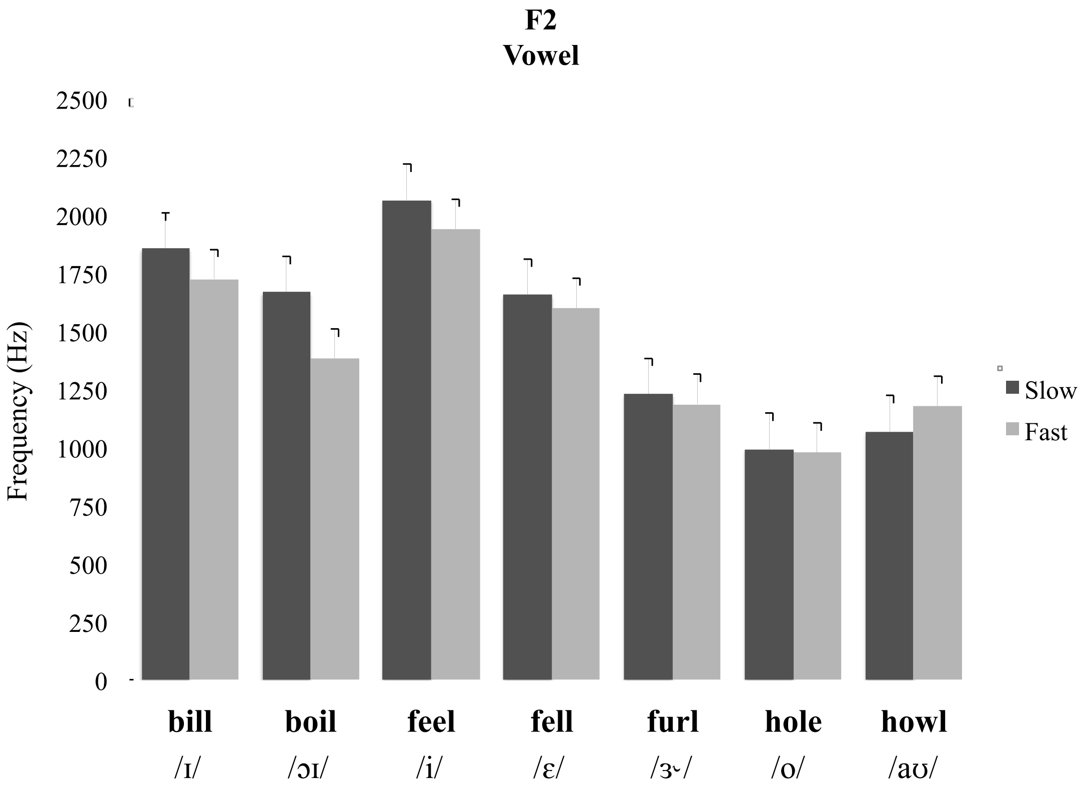
[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.22 shows that the t-tests performed for simple main effects of rate on vowel F2 in the V+/l/ sequences elicited non-significant differences for *hole*, *hull*, *pal*, *pool* and *pull*, with small effect sizes (i.e., < .020) for *hull*, *pal*, *pool* and *pull*, and a small-to-medium effect size for *hole*. However, they yielded significant differences for the rest of the pairwise comparisons, with small-to-medium effect sizes for *furl* and *Paul*, a medium effect size for *pale*, and large effect sizes (i.e., > 0.80) for *bill*, *boil*, *feel*, *fell*, *howl* and *pile*.

Table 3.22 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel F2 in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	1853	68.58	1723	115.17	9.12	<.001	1.18
boil	/ɔɪ/	1666	147.78	1379	164.91	16.18	<.001	2.09
feel	/i/	2063	101.56	1939	132.99	7.80	<.001	1.01
fell	/ɛ/	1655	77.06	1600	85.29	6.87	<.001	0.89
furl	/ɝ/	1229	75.35	1185	79.71	3.59	.001	0.46
hole	/o/	992	32.93	975	49.17	2.66	.010	0.34
howl	/aʊ/	1068	125.33	1178	97.77	−8.02	<.001	−1.04
hull	/ʌ/	1092	80.83	1086	80.45	0.73	.471	0.09
pal	/æ/	1513	110.37	1517	131.29	−0.20	.846	−0.03
pale	/e/	1935	81.67	1847	142.63	4.68	<.001	0.60
Paul	/ɔ/	1123	38.92	1142	50.74	−2.72	.009	−0.35
pile	/aɪ/	1782	78.34	1514	74.44	18.20	<.001	2.35
pool	/u/	973	50.64	977	36.42	−0.43	.667	−0.06
pull	/ʊ/	1031	40.79	1017	62.25	1.66	.104	0.21

Figure 3.6 illustrates that the mean vowel F2 values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens of *bill*, *boil*, *feel*, *fell*, *furl*, *hole*, *hull*, *pale*, *pile* and *pull* as well as for the fast tokens of *howl*, *pal*, *Paul* and *pool*. The biggest differences can be observed for *boil* and *pile* and, to a smaller degree, for *bill, feel, howl* and *pale*. Smaller differences can be distinguished for *fell* and *furl*, while *hole*, *hull*, *pal*, *Paul*, *pool* and *pull* have close values. The tokens showing the biggest differences contain high front vowels, with the exception of *howl*, whose vowel is high but back. In addition, *boil*, *pile* and *howl* contain diphthongs, and *pale* contains a diphthongized vowel. This corroborates what had already been evinced by vowel duration and vowel F1: that diphthongs and diphthongized vowels tend to exhibit a common pattern, although in this case the exception is *hole*. High front vowels can now be added to this group.



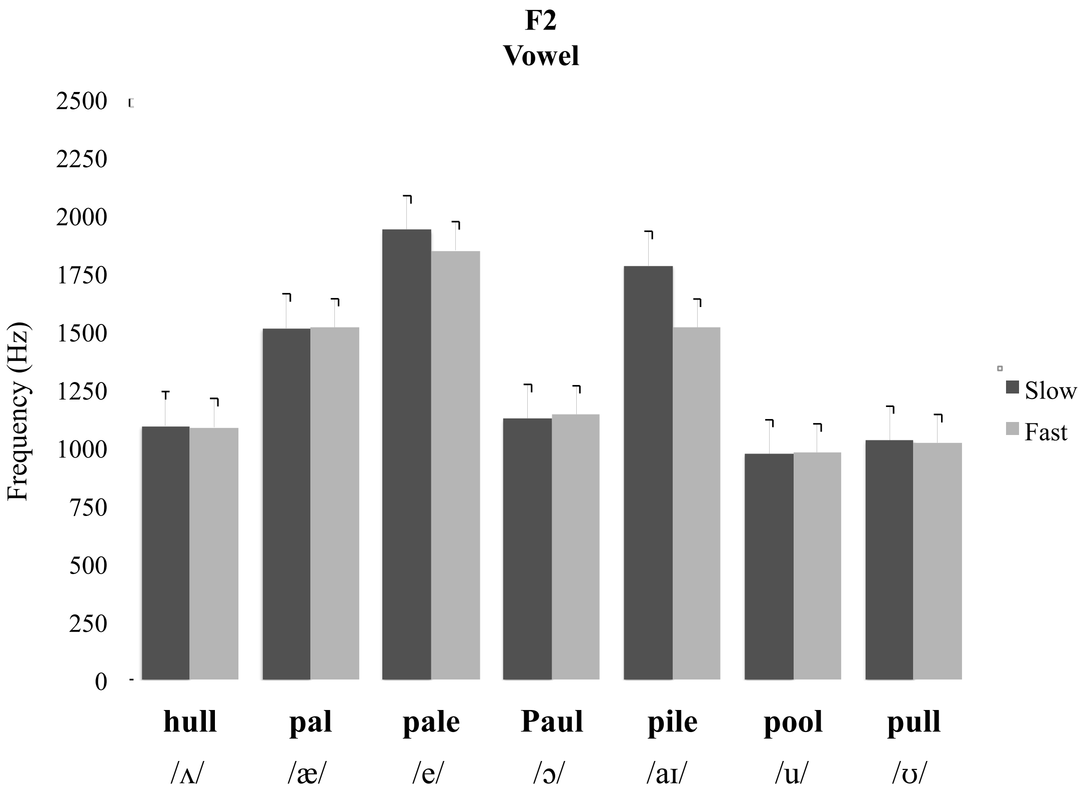


Figure 3.6 Mean vowel F2 values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.23 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel F2 in the V+/l/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 95.5% and 91.4% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have similar strength.

Table 3.23 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel F2 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	587.342	90	<.001	.281	3.65, 215.35	1241.137	<.001	.955
Context (fast)	532.142	90	<.001	.330	4.29, 253.29	629.340	<.001	.914

[a] *df* = Greenhouse-Geisser correction

Table 3.24 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for vowel F2. There are only six non-significant pairs for each rate ($\%_1$ = 6.59%), and of these only *hole-pool* and *howl-Paul*, which contain back vowels, coincide between rates. Only *hole-pool* shows an exact correspondence between *p* values (i.e., *p* = 1.000). Some of the non-significant pairs have similar vowels: *feel-pale* (fast), with high front vowels; and *hole-pool* (fast) and *howl-pull* (slow), with high back vowels. The other pairs, however, contain dissimilar vowels: *boil-fell* (slow), *boil-pal* (fast), *furl-howl* (fast), *howl-hull* (slow), *howl-Paul* (slow), *hull-Paul* (slow) and *pal-pile* (fast). The highest possible *p* value (i.e., *p* = 1.000) is exhibited in more than half of the cases by pairs with and without similar vowels.

Table 3.24 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for vowel F2*

Slow		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/													
fell	/ɛ/		1.000											
furl	/ɝ/													
hole	/o/													
howl	/aʊ/													
hull	/ʌ/							1.000						
pal	/æ/													
pale	/e/													
Paul	/ɔ/							.074	.947					
pile	/aɪ/													
pool	/u/						1.000							
pull	/ʊ/							1.000						

Fast		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/													
fell	/ɛ/													
furl	/ɝ/													
hole	/o/													
howl	/aʊ/					1.000								
hull	/ʌ/													
pal	/æ/		.019											
pale	/e/			.012										
Paul	/ɔ/							1.000						
pile	/aɪ/									1.000				
pool	/u/						1.000							
pull	/ʊ/													

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.2.3.2 Transition F2 in V+/l/ sequences

Table 3.25 shows that the two-way repeated measures ANOVA performed on transition F2 in the V+/l/ sequences yielded a significant rate*context interaction with a marginally large effect size (i.e., > .14) implying considerable differences and accounting for 26.5% of the variance, which is noticeably lower than the variances for the main effects of rate (92.6%) and context (92.3%).

Table 3.25 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for transition F2 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	741.844	<.001	.926
Context	552.556	90	<.001	.310	4.04, 238.08	711.958	<.001	.923
Rate*Context	267.526	90	<.001	.578	7.52, 443.64	21.254	<.001	.265

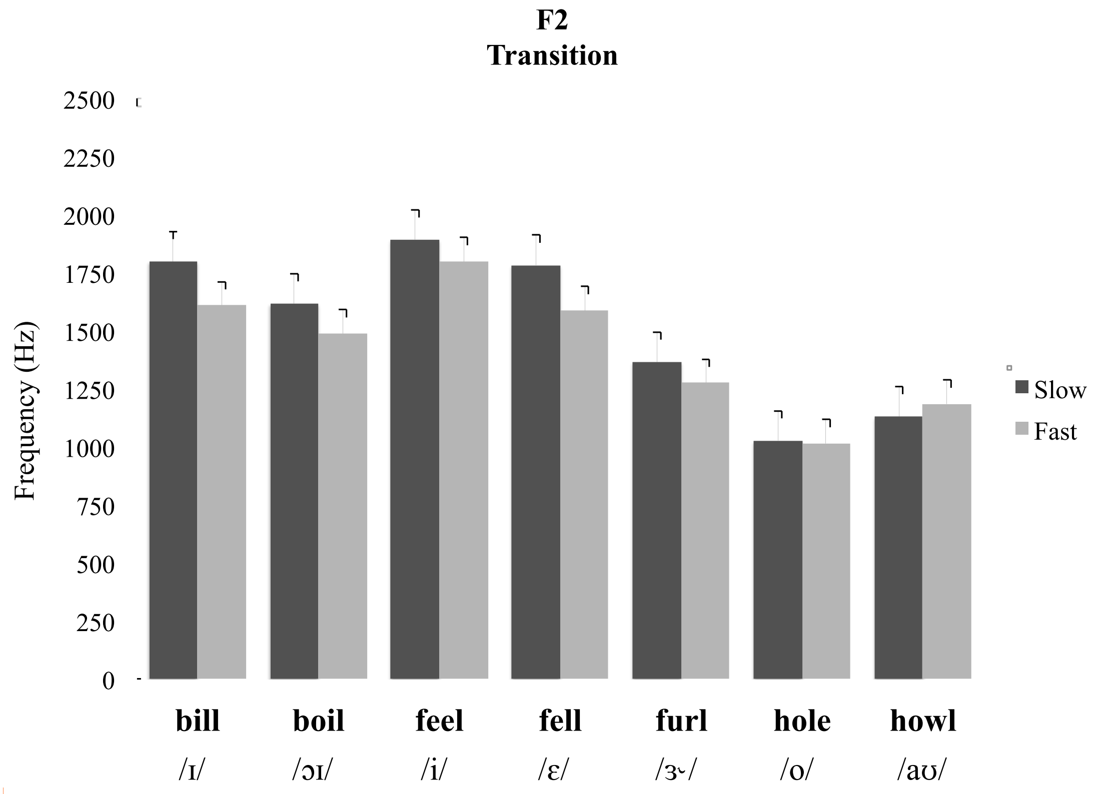
[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.26 shows that the t-tests performed for simple main effects of rate on transition F2 in the V+/l/ sequences elicited non-significant differences for *howl* with a medium effect size. However, they yielded significant differences for the rest of the pairwise comparisons, with a small effect size (i.e., < .020) for *hole*, medium effect sizes for *feel*, *furl* and *hull*, and large effect sizes (i.e., > 0.80) for *bill*, *boil*, *fell*, *pal*, *pale*, *Paul*, *pile*, *pool* and *pull*.

Table 3.26 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for transition F2 in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	1798	138.73	1608	121.21	8.72	<.001	1.13
boil	/ɔɪ/	1616	156.64	1487	180.43	6.91	<.001	0.89
feel	/i/	1891	143.91	1798	160.00	4.85	<.001	0.63
fell	/ɛ/	1782	107.84	1587	110.19	12.41	<.001	1.60
furl	/ɝ/	1365	99.16	1274	99.34	5.36	<.001	0.69
hole	/o/	1026	79.71	1014	53.21	0.98	<.001	0.13
howl	/aʊ/	1130	120.15	1184	106.73	−4.69	.329	−0.61
hull	/ʌ/	1145	89.54	1082	85.48	5.93	<.001	0.77
pal	/æ/	1696	109.84	1522	103.31	10.48	<.001	1.35
pale	/e/	1933	125.11	1778	133.73	6.20	<.001	0.80
Paul	/ɔ/	1238	74.86	1174	68.86	7.03	<.001	0.91
pile	/aɪ/	1804	123.76	1587	100.67	10.05	<.001	1.30
pool	/u/	1092	37.77	1025	51.73	9.02	<.001	1.16
pull	/ʊ/	1116	63.53	1022	63.41	9.95	<.001	1.28

Figure 3.7 illustrates that the mean transition F2 values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens in all cases except for *howl*, which is a pattern that was already observed for transition F1 values, although in that case the exception was *pile*. The biggest differences can be observed for *bill*, *fell*, *pal*, *pale* and *pile* and, to a smaller degree, for *boil*, *feel*, *furl* and *pull*. Smaller differences can be distinguished for *howl*, *hull*, *Paul* and *pool*, while *hole* has close values.



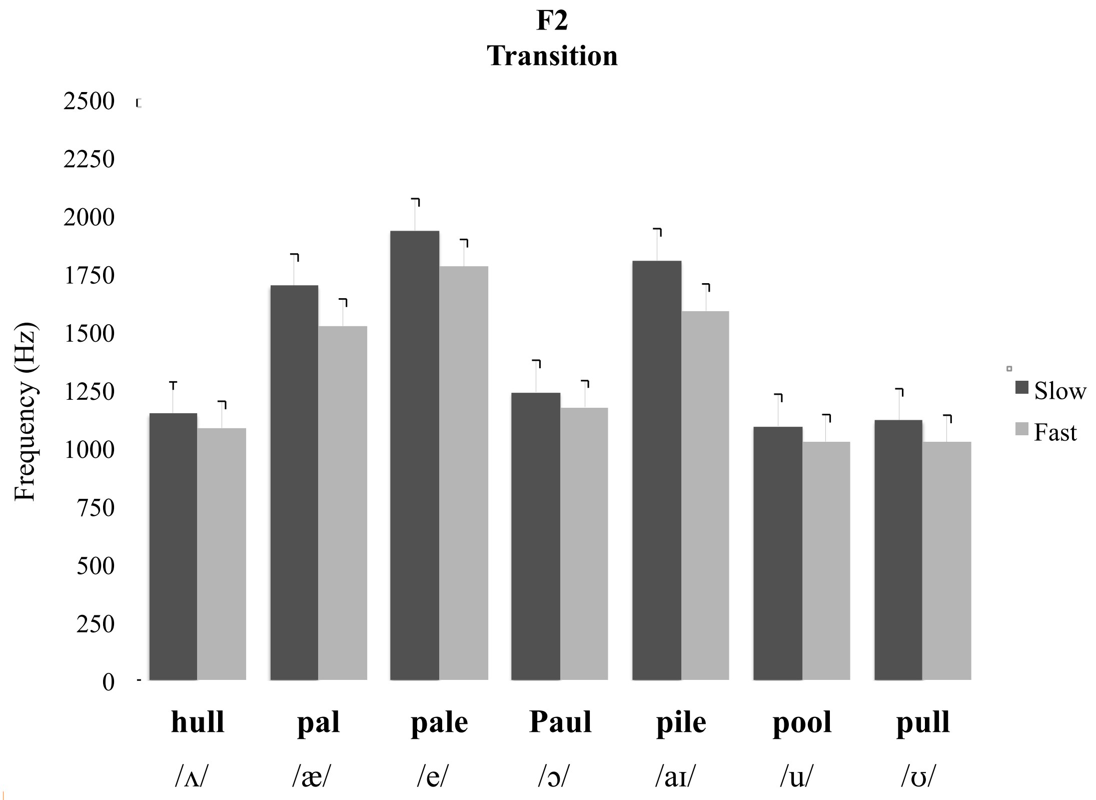


Figure 3.7 Mean transition F2 values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.27 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on transition F2 in the V+/l/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 90.6% and 87.2% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have similar strength.

Table 3.27 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for transition F2 in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	436.544	90	<.001	.432	5.61, 331.02	569.680	<.001	.906
Context (fast)	482.311	90	<.001	.357	4.64, 273.99	400.893	<.001	.872

[a] *df* = Greenhouse-Geisser correction

Table 3.28 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for transition F2. There is a slightly larger number of non-significant pairs for the fast tokens ($^{14}/_{91}$ = 15.38%) than for the slow ones ($^{13}/_{91}$ = 14.29%). There are some coincidences between rates (i.e., *bill-fell*, *bill-pile*, *boil-pal*, *feel-pale*, *fell-pile*, *hull-pool* and *pool-pull*), with an exact correspondence between *p* values (i.e., p = 1.000) in all cases except for *boil-pal* and *hull-pool*. Some of the non-significant pairs have similar vowels. The pairs with high front vowels are *bill-feel* (slow), *bill-pile* (slow and fast), *boil-pile* (fast), *feel-pale* (slow and fast) and *feel-pile* (slow). Similarly, the pairs with high back vowels are *hole-pool* (fast), *hole-pull* (fast), *howl-pool* (slow), *howl-pull* (fast) and *pool-pull* (slow and fast). Other pairs, however, contain vowels which are somehow different, like *bill-fell* (slow and fast), *boil-fell* (fast) and *fell-pile* (slow and fast). Despite all the vowels in these pairs being front, while the vowels in *bill*, *boil* and *pile* are high, the vowel in *fell* is mid. Finally, other contrasts involve words that consist of rather dissimilar vowels, such as *bill-pal* (fast), *boil-pal* (slow and fast) or *hull-pool* (slow and fast). The highest possible *p* value (i.e., p = 1.000) is exhibited in more than half of the cases by pairs with and without similar vowels.

Table 3.28 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for transition F2*

Slow		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/	.338												
fell	/ɛ/	1.000												
furl	/ɝ/													
hole	/o/													
howl	/aʊ/													
hull	/ʌ/							1.000						
pal	/æ/		.366											
pale	/e/			1.000										
Paul	/ɔ/													
pile	/aɪ/	1.000		.093	1.000									
pool	/u/							1.000	.041					
pull	/ʊ/							1.000	1.000					1.000

Fast		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/													
feel	/i/													
fell	/ɛ/	1.000	.437											
furl	/ɝ/													
hole	/o/													
howl	/aʊ/													
hull	/ʌ/													
pal	/æ/	.053	1.000											
pale	/e/			1.000										
Paul	/ɔ/							1.000						
pile	/aɪ/	1.000	.080		1.000					.012				
pool	/u/						1.000		.018					
pull	/ʊ/						1.000							1.000

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.2.3.3 Vowel-transition F2 differences in V+/l/ sequences

Table 3.29 shows that the two-way repeated measures ANOVA performed on vowel-transition F2 differences in the V+/l/ sequences yielded a significant rate*context interaction with a marginally large effect size (i.e., > .14) implying considerable differences and accounting for 14.5% of the variance, which is noticeably lower than the variance for the main effect of rate (70.6%) but moderately lower than the variance for the main effect of context (31.0%).

Table 3.29 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel-transition F2 differences in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	141.548	<.001	.706
Context	217.404	90	<.001	.663	8.62, 508.53	26.544	<.001	.310
Rate*Context	217.014	90	<.001	.668	8.68, 512.26	9.971	<.001	.145

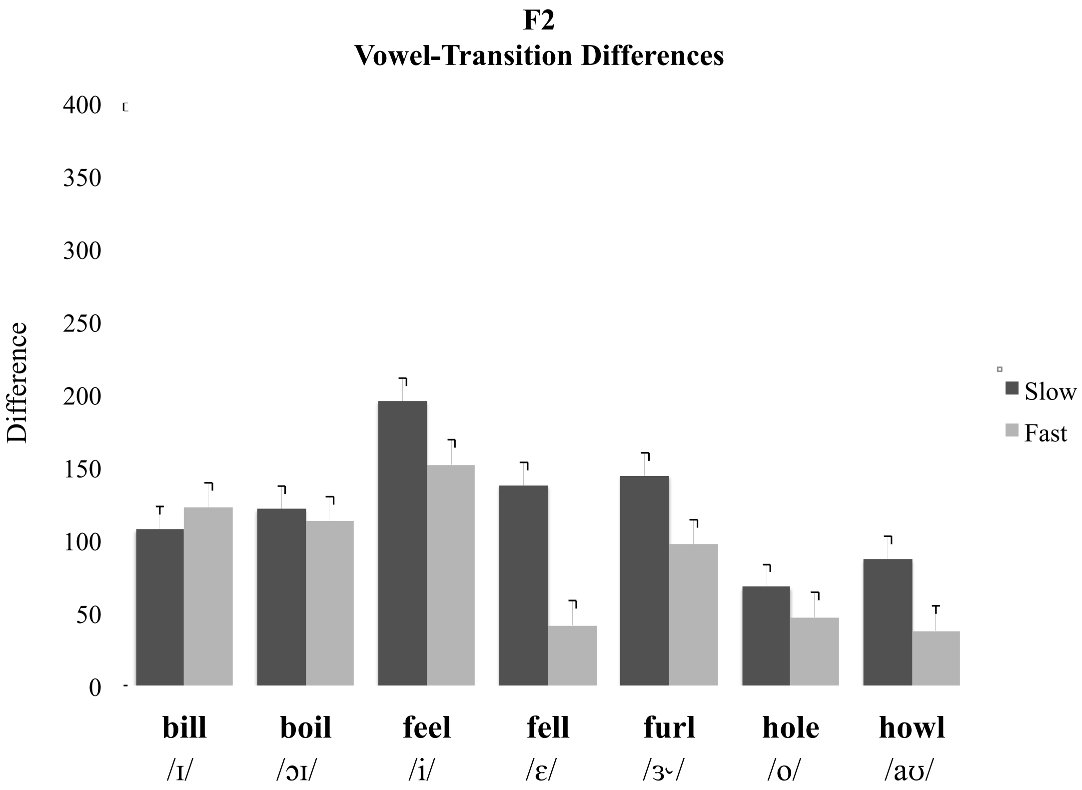
[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.30 shows that the t-tests performed for simple main effects of rate on vowel-transition F2 differences in the V+/l/ sequences elicited non-significant differences for *bill*, *boil*, *feel*, *pale* and *pile*, with small effect sizes for *bill*, *boil*, *pale* and *pile* (i.e., < .020), and a medium-to-high effect size for *feel*. However, they yielded significant differences for the rest of the pairwise comparisons, with small-to-medium effect sizes for *furl*, *hole* and *hull*, medium effect sizes for *howl* and *pull*, and large effect sizes (i.e., > 0.80) for *fell*, *pal*, *Paul* and *pool*.

Table 3.30 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel-transition F2 differences in the V+/l/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
bill	/ɪ/	107.08	73.68	122.17	88.63	−1.02	.314	−0.13
boil	/ɔɪ/	121.10	96.38	112.53	58.58	0.58	.567	0.07
feel	/i/	195.22	109.94	151.67	86.60	2.42	.019	0.31
fell	/ɛ/	137.42	78.57	41.22	39.80	8.80	<.001	1.14
furl	/ɝ/	143.92	97.91	96.70	76.87	3.36	.001	0.43
hole	/o/	67.65	47.33	46.93	32.26	2.93	.005	0.38
howl	/aʊ/	86.70	71.91	37.58	25.41	4.68	<.001	0.60
hull	/ʌ/	69.45	47.83	49.00	42.56	2.69	.009	0.35
pal	/æ/	191.37	106.22	59.20	50.94	8.70	<.001	1.12
pale	/e/	109.82	75.50	87.18	71.42	1.50	.140	0.19
Paul	/ɔ/	114.88	52.16	48.42	37.55	10.03	<.001	1.29
pile	/aɪ/	101.90	74.08	85.60	54.94	1.39	.168	0.18
pool	/u/	119.25	60.38	51.93	34.74	8.28	<.001	1.07
pull	/ʊ/	87.73	51.66	41.97	36.92	6.01	<.001	0.78

Figure 3.8 illustrates that the mean vowel-transition-difference F2 values for pairwise comparisons between the slow and fast rates in the V+/l/ sequences are higher for the slow tokens in all cases except for *bill*. By far the greatest differences are exhibited by *fell* and *pal*. Highly prominent differences are shown for *feel*, *furl*, *howl*, *Paul*, *pool* and *pull*. Smaller differences can be discerned for *hole*, *hull*, *pale* and *pile*, while *bill* and *boil* present the smallest.



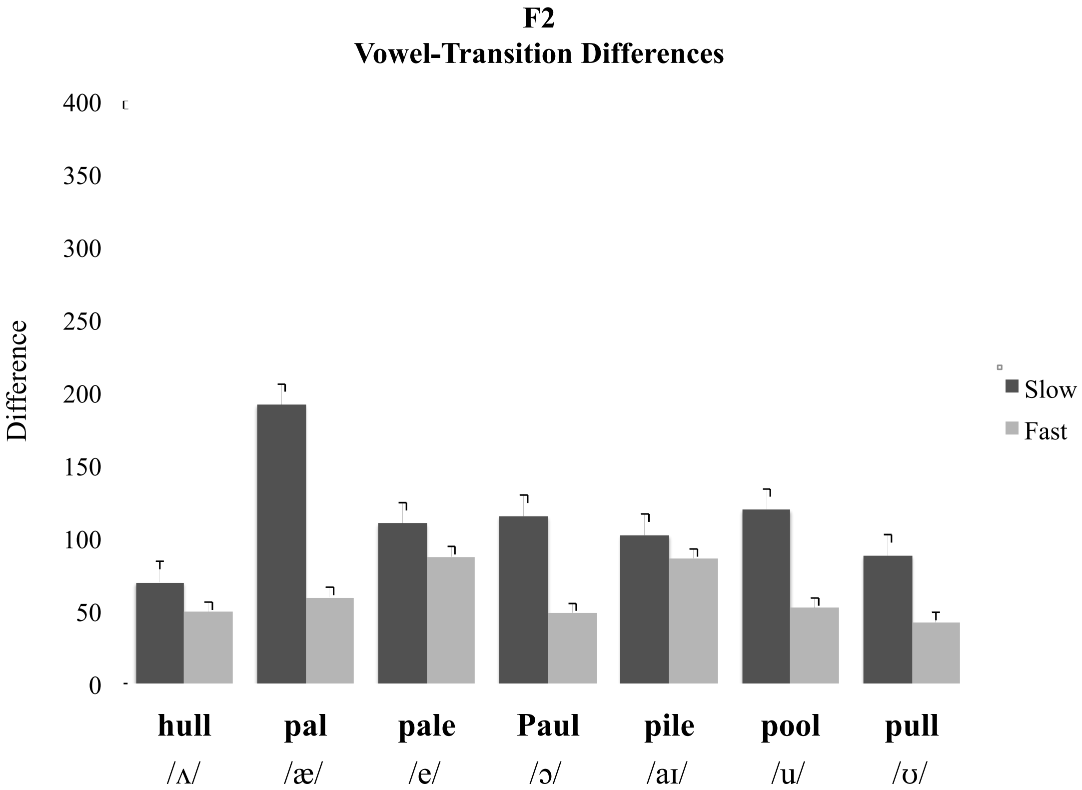


Figure 3.8 Mean vowel-transition-difference F2 values for pairwise comparisons between slow and fast rates in the V+/l/ sequences

Table 3.31 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel-transition F2 differences in the V+/l/ sequences yielded significant effects with large effect sizes (i.e., slightly > .14) suggesting substantial differences among contexts and accounting for 20.6% and 29.8% of the variance in the slow and fast tokens, respectively. Thus, the effect size for context (slow) is relatively smaller than for context (fast).

Table 3.31 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel-transition F2 differences in the V+/l/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	223.685	90	<.001	.662	8.61, 507.69	15.291	<.001	.206
Context (fast)	281.023	90	<.001	.577	7.50, 442.20	24.996	<.001	.298

[a] *df* = Greenhouse-Geisser correction

Table 3.32 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/l/ contexts for vowel-transition F2 differences. There is a very large number of non-significant pairs. The slow pairs are more numerous ($^{63}/_{91}$ = 69.23%) than the fast ones ($^{50}/_{91}$ = 54.95%). There are a lot of coincidences between rates involving combinations with *furl*, *howl*, *hull*, *pale*, *Paul*, *pile* and *pool*. Pairs with *boil*, *fell* and *pull* show fewer coincidences, and pairs with *feel*, *hole* and *pal* show even fewer. Most of the pairs exhibit highly non- significant *p* values (i.e., *p* = 1.000, or close to it).

Table 3.32 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/l/ contexts for vowel-transition F2 differences*

Slow		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/	1.000												
feel	/i/		.027											
fell	/ɛ/	1.000	1.000	.205										
furl	/ɝ/	.967	1.000	.830	1.000									
hole	/o/	.065	.080											
howl	/aʊ/	1.000	.700		.117	.013	1.000							
hull	/ʌ/	.220	.071				1.000	1.000						
pal	/æ/		.035	1.000	.300	.423								
pale	/e/	1.000	1.000		1.000	1.000	.083	1.000	.112					
Paul	/ɔ/	1.000	1.000		1.000	1.000		.605			1.000			
pile	/aɪ/	1.000	1.000		1.000	1.000	.197	1.000	.573		1.000	1.000		
pool	/u/	1.000	1.000		1.000	1.000		.587			1.000	1.000	1.000	
pull	/ʊ/	1.000	1.000				1.000	1.000	1.000		1.000	1.000	1.000	.553

Fast		bill /ɪ/	boil /ɔɪ/	feel /i/	fell /ɛ/	furl /ɝ/	hole /o/	howl /aʊ/	hull /ʌ/	pal /æ/	pale /e/	Paul /ɔ/	pile /aɪ/	pool /u/
boil	/ɔɪ/	1.000												
feel	/i/	1.000	.570											
fell	/ɛ/													
furl	/ɝ/	1.000	1.000											
hole	/o/				1.000									
howl	/aʊ/				1.000		1.000							
hull	/ʌ/				1.000		1.000	1.000						
pal	/æ/				1.000	.531	1.000	.499	1.000					
pale	/e/	1.000	1.000			1.000	.026		.069	.629				
Paul	/ɔ/				1.000		1.000	1.000	1.000	1.000	.045			
pile	/aɪ/	1.000	1.000			1.000			.026	.344	1.000	.036		
pool	/u/				1.000	.016	1.000	.858	1.000	1.000	.189	1.000		
pull	/ʊ/				1.000		1.000	1.000	1.000	1.000		1.000		1.000

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.3 V+/r/ sequences

3.3.1 Duration in V+/r/ sequences

3.3.1.1 Vowel Duration in V+/r/ sequences

Table 3.33 shows that the two-way repeated measures ANOVA performed on vowel duration in the V+/r/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 53.8% of the variance, which is noticeably lower than the variance for the main effect of rate (92.5%) but moderately lower than the variance for the main effect of context (74.0%).

Table 3.33 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel duration in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	726.031	<.001	.925
Context	112.372	20	<.001	.577	3.46, 204.23	167.973	<.001	.740
Rate*Context	109.310	20	<.001	.602	3.61, 213.05	68.706	<.001	.538

[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.34 shows that the t-tests performed for simple main effects of rate on vowel duration in the V+/r/ sequences elicited highly significant differences for all pairwise comparisons with large effect sizes (i.e., > 0.80), which are extremely large (i.e., > 3.00) for *hire*, *poor*, *pore* and *power* and very large for *fair*, *fear* and *par*.

Table 3.34 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel duration in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	166.47	46.38	54.16	10.84	20.99	<.001	2.71
fear	/i/	155.61	41.09	47.25	8.48	21.15	<.001	2.73
hire	/aɪ/	89.80	13.95	33.97	6.24	31.89	<.001	4.12
par	/ɑ/	141.86	51.03	48.53	9.58	14.59	<.001	1.88
poor	/ʊ/	154.41	32.27	45.22	10.74	25.93	<.001	3.35
pore	/ɔ/	153.97	33.52	45.19	9.65	26.20	<.001	3.38
power	/aʊ/	88.17	18.63	33.49	5.84	24.39	<.001	3.15

Figure 3.9 illustrates that the mean vowel duration values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are extremely higher for the slow tokens than for the fast ones in all cases. The most remarkable differences can be observed for *fair*, *fear*, *par*, *poor* and *pore*. The differences are not so prominent for *hire* and *power*, which contain diphthongs. The pattern observed for vowel duration and transition duration in the V+/l/ sequences is thus repeated for vowel duration in the V+/r/ sequences.

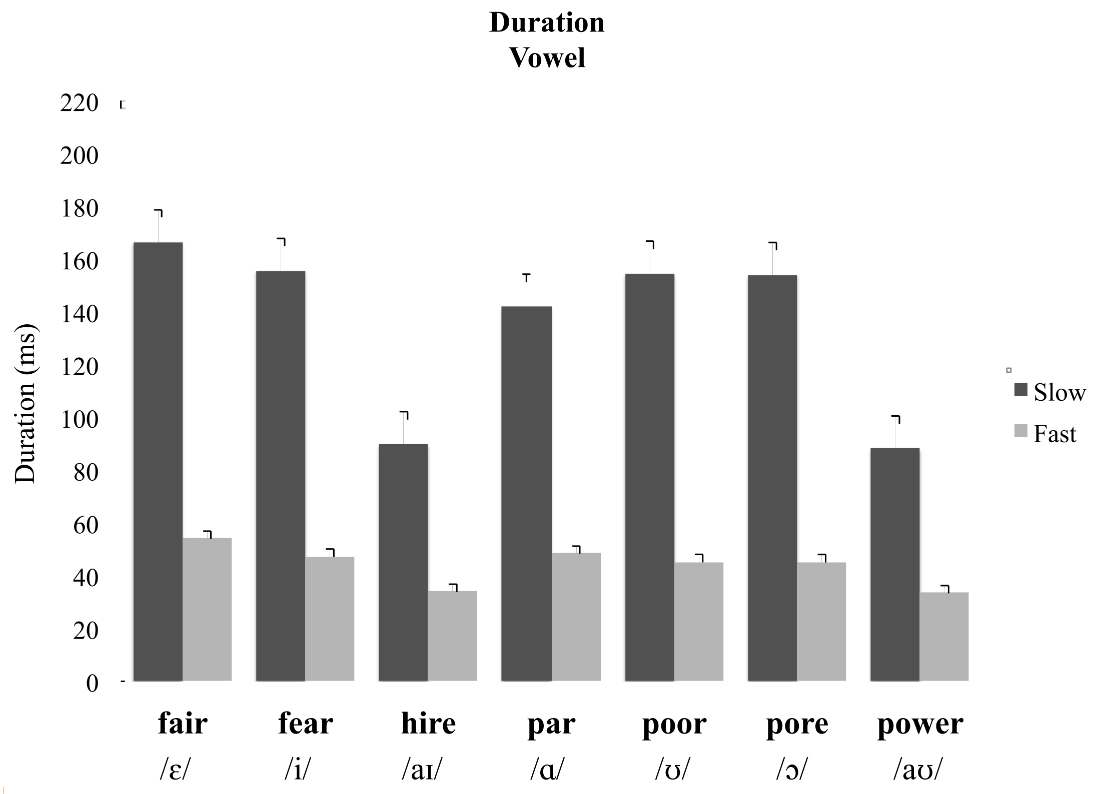


Figure 3.9 Mean vowel duration values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.35 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel duration in the V+/r/ sequences yielded significant effects with large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 67.6% and 52.9% of the variance in the slow and fast tokens, respectively. Thus, the effect size for context (slow) is relatively larger than for context (fast).

Table 3.35 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel duration in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	120.894	20	<.001	.560	3.36, 198.28	123.324	<.001	.676
Context (fast)	38.071	20	.009	.845	5.07, 299.21	66.398	<.001	.529

[a] *df* = Greenhouse-Geisser correction

Table 3.36 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for vowel duration. There is a larger number of non-significant pairs for the slow tokens ($\frac{9}{21}$ = 42.86%) than for the fast ones ($\frac{7}{21}$ = 33.33%). There are a few coincidences between rates (i.e., *fear-par*, *fear-poor*, *fear-pore*, *hire-power* and *par-pore*), with an exact correspondence between *p* values (i.e., *p* = 1.000) in the case of *fear-poor*, *fear-pore* and *hire-power*. The non-significant pairs with similar vowels are *poor-pore* (fast) and *poor-power* (slow), both of which exhibit the highest possible *p* value (i.e., *p* = 1.000). However, many of the pairs with dissimilar vowels also exhibit this value.

Table 3.36 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for vowel duration*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/						
par	/ɑ/		.025				
poor	/ʊ/	.358	1.000		.101		
pore	/ɔ/	.099	1.000		.076		
power	/aʊ/			1.000		1.000	

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/						
par	/ɑ/		1.000				
poor	/ʊ/		1.000				
pore	/ɔ/		1.000		.490	1.000	
power	/aʊ/			1.000	.228		

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.3.1.2 Transition duration in V+/r/ sequences

Table 3.37 shows that the two-way repeated measures ANOVA performed on transition duration in the V+/r/ sequences yielded a significant rate*context interaction with a relatively large effect size (i.e., > .14) implying considerable differences and accounting for 33.4% of the variance, which is noticeably lower than the variance for the main effect of rate (95.4%) but moderately lower than the variance for the main effect of context (56.0%).

Table 3.37 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for transition duration in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	1225.354	<.001	.954
Context	38.374	20	.008	.808	4.85, 285.88	75.144	<.001	.560
Rate*Context	45.574	20	.001	.792	4.75, 280.41	29.563	<.001	.334

[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.38 shows that the t-tests performed for simple main effects of rate on transition duration in the V+/r/ sequences elicited highly significant differences for all pairwise comparisons with extremely large effect sizes (i.e., > 3.00) in all cases.

Table 3.38 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for transition duration in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	112.78	23.80	38.85	5.47	23.48	<.001	3.03
fear	/i/	113.30	23.87	38.54	7.01	26.12	<.001	3.37
hire	/aɪ/	81.05	14.31	30.51	6.05	23.75	<.001	3.07
par	/ɑ/	102.20	18.78	34.65	4.44	26.36	<.001	3.40
poor	/ʊ/	105.75	18.12	35.02	5.00	30.52	<.001	3.94
pore	/ɔ/	103.47	16.80	34.63	4.20	33.30	<.001	4.30
power	/aʊ/	86.04	16.60	32.79	4.85	23.42	<.001	3.02

Figure 3.10 illustrates that the mean transition duration values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are higher for the slow tokens than for the fast ones in all cases. The difference, however, is not as marked as for vowel duration. The most remarkable differences can be observed for *fair*, *fear*, *par*, *poor* and *pore*. The differences are not so prominent for *hire* and *power*, which contain diphthongs. Once again, the pattern observed for vowel duration and transition duration in the V+/l/ sequences, and repeated for vowel duration in the V+/r/ sequences, is found here.

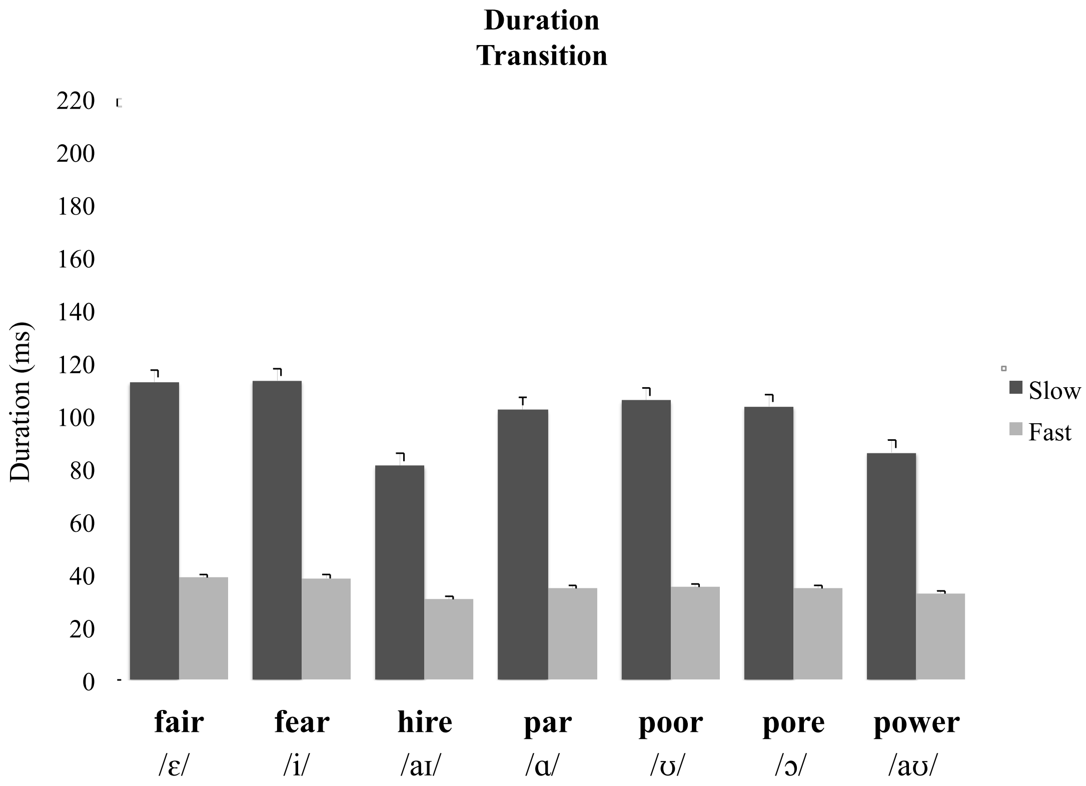


Figure 3.10 Mean transition duration values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.39 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on transition duration in the V+/r/ sequences yielded significant effects with large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 48.3% and 30.8% of the variance in the slow and fast tokens, respectively. Thus, the effect size for context (slow) is relatively larger than for context (fast). There was no adjustment required in the degrees of freedom for context (fast) because the sphericity assumption was not violated (i.e., $p > .01$). This outcome is a clear deviation for the general norm.

Table 3.39 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for transition duration in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	45.464	20	.001	.786	4.72, 278.29	55.036	<.001	.483
Context (fast)	30.412	20	.064	.838	6, 354	26.269	<.001	.308

[a] *df* for context (slow) = sphericity assumed; *df* for context (fast) = Greenhouse-Geisser correction

Table 3.40 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for transition duration. There is a slightly larger number of non-significant pairs for the fast tokens ($8/21$ = 38.10%) than for the slow ones ($7/21$ = 33.33%). There are a few coincidences between rates (i.e., *fair-fear*, *hire-power*, *par-poor*, *par-pore* and *poor-pore*), with an exact correspondence between *p* values (i.e., p = 1.000) in all cases except for *hire-power*. The non-significant pairs with similar vowels are *poor-pore* (slow and fast) and *poor-power* (fast). Also, *fair-fear* (slow and fast) and *poor-power* (fast) have somewhat similar vowels. The highest possible *p* value (i.e., p = 1.000) is exhibited in half of the cases, by pairs with and without similar vowels.

Table 3.40 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for transition duration*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/	1.000					
hire	/aɪ/						
par	/ɑ/						
poor	/ʊ/	.143	.019		1.000		
pore	/ɔ/				1.000	1.000	
power	/aʊ/			.419			

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/	1.000					
hire	/aɪ/						
par	/ɑ/						
poor	/ʊ/				1.000		
pore	/ɔ/				1.000	1.000	
power	/aʊ/			.379	.201	.032	.347

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.3.2 F1 in V+/r/ sequences

3.3.2.1 Vowel F1 in V+/r/ sequences

Table 3.41 shows that the two-way repeated measures ANOVA performed on vowel F1 in the V+/r/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 65.1% of the variance, which is noticeably lower than the variances for the main effects of rate (92.3%) and context (91.7%).

Table 3.41 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel F1 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	702.621	<.001	.923
Context	131.038	20	<.001	.487	2.92, 172.41	651.309	<.001	.917
Rate*Context	56.454	20	<.001	.760	4.56, 268.94	110.239	<.001	.651

[a] *df* = Greenhouse-Geisser correction

Table 3.42 shows that the t-tests performed for simple main effects of rate on vowel F1 in the V+/r/ sequences elicited non-significant differences for *fair* and *fear* with a small effect size (i.e., < .020) for *fear*, and a small-to-medium effect size for *fair*. However, they yielded significant differences for the rest of the pairwise comparisons, with a medium effect size for *par*, large effect sizes (i.e., > 0.80) for *poor* and *pore*, a very large effect size for *hire*, and an extremely large effect size (i.e., > 3.00) for *power*.

Table 3.42 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel F1 in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	499	21.20	489	36.02	1.85	.070	0.24
fear	/i/	314	28.98	320	28.93	−1.24	.220	−0.16
hire	/aɪ/	474	58.68	615	57.28	−16.11	<.001	−2.08
par	/ɑ/	611	47.58	645	42.26	−4.32	<.001	−0.56
poor	/ʊ/	366	40.82	413	46.56	−6.57	<.001	−0.85
pore	/ɔ/	382	37.98	425	38.31	−6.57	<.001	−0.85
power	/aʊ/	435	39.04	631	45.50	−24.76	<.001	−3.20

Figure 3.11 illustrates that the mean vowel F1 values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are higher for the fast tokens in all cases except for *fair*. This pattern is in accordance with the one observed for vowel F1 in the V+/l/ sequences, where most of the higher values corresponded to the fast tokens. The greatest differences are exhibited by *hire* and *power*, which are diphthongs. Appreciable smaller differences are displayed by *par*, *poor* and *pore*, while *fair* and *fear* have very similar values.

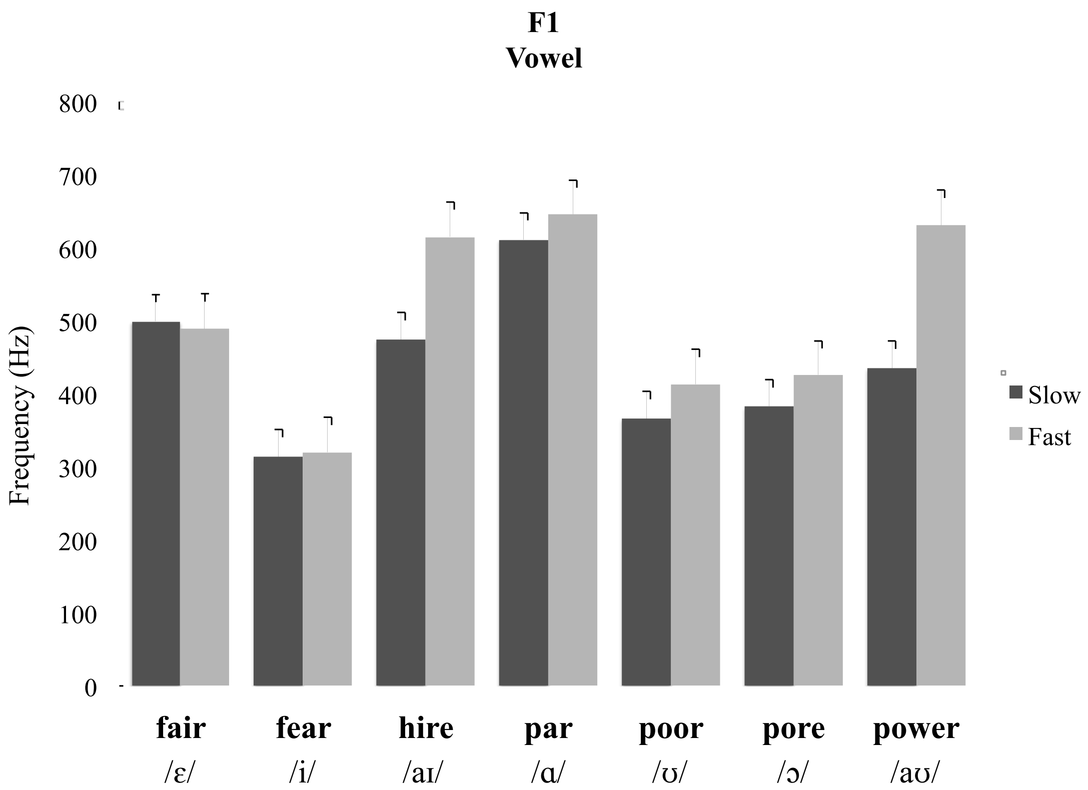


Figure 3.11 Mean vowel F1 values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.43 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel F1 in the V+/r/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 85.3% and 89.4% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have similar strength.

Table 3.43 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel F1 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	146.685	20	<.001	.477	2.86, 168.85	342.519	<.001	.853
Context (fast)	66.639	20	<.001	.684	4.10, 242.10	497.674	<.001	.894

[a] *df* = Greenhouse-Geisser correction

Table 3.44 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for vowel F1. There is a very small number of non-significant pairs, which is slightly larger for the fast tokens ($^4/_{21}$ = 19.05%) than for the slow ones ($^2/_{21}$ = 9.52%). There is only one coincidence between rates (i.e., *poor-pore*), with no exact correspondence between *p* values. This is the only non-significant pair with similar vowels. Also, the vowels in *fair-hire* (slow) are somewhat similar. The highest possible *p* value (i.e., *p* = 1.000) is exhibited in half of the cases, by pairs with and without similar vowels.

Table 3.44 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for vowel F1*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/	.025					
par	/ɑ/						
poor	/ʊ/						
pore	/ɔ/					.063	
power	/aʊ/						

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/						
par	/ɑ/			.166			
poor	/ʊ/						
pore	/ɔ/					1.000	
power	/aʊ/			1.000	1.000		

Note. Only non-significant values are provided in the cells. Empty cells represent a value of *p* < .01.

3.3.2.2 Transition F1 in V+/r/ sequences

Table 3.45 shows that the two-way repeated measures ANOVA performed on transition F1 in the V+/r/ sequences yielded a significant rate*context interaction with a relatively large effect size (i.e., > .14) implying considerable differences and accounting for 37.9% of the variance, which is noticeably lower than the variances for the main effects of rate (81.4%) and context (88.2%).

Table 3.45 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for transition F1 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	257.657	<.001	.814
Context	89.009	20	<.001	.620	3.72, 219.31	440.889	<.001	.882
Rate*Context	41.273	20	.003	.812	4.87, 287.55	36.052	<.001	.379

[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.46 shows that the t-tests performed for simple main effects of rate on transition F1 in the V+/r/ sequences elicited non-significant differences for *fear* with a small-to-medium effect size. However, they yielded significant differences for the rest of the pairwise comparisons, with medium effect sizes for *fair*, *par*, *poor* and *pore*, and large effect sizes (i.e., > 0.80) for *hire* and *power*.

Table 3.46 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for transition F1 in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	473	39.04	499	28.79	−3.95	<.001	−0.51
fear	/i/	329	38.04	341	38.06	−1.80	.078	−0.23
hire	/aɪ/	459	54.40	536	60.42	−9.83	<.001	−1.27
par	/ɑ/	677	41.55	647	41.61	4.07	<.001	0.52
poor	/ʊ/	414	55.31	446	43.01	−4.56	<.001	−0.59
pore	/ɔ/	434	54.28	470	37.41	−4.28	<.001	−0.55
power	/aʊ/	447	52.78	567	57.44	−12.14	<.001	−1.57

Figure 3.12 illustrates that the mean transition F1 values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are higher for the fast tokens in all cases except for *par*. This pattern is the same as that for vowel F1. However, it is the reverse of the one for transition F1 in the V+/l/ sequences, where the higher values were shown for most of the slow tokens. The greatest differences are exhibited by *hire* and *power*, which contain diphthongs. Appreciable smaller differences are displayed by *fair*, *par*, *poor* and *pore*, while *fear* has very similar values.

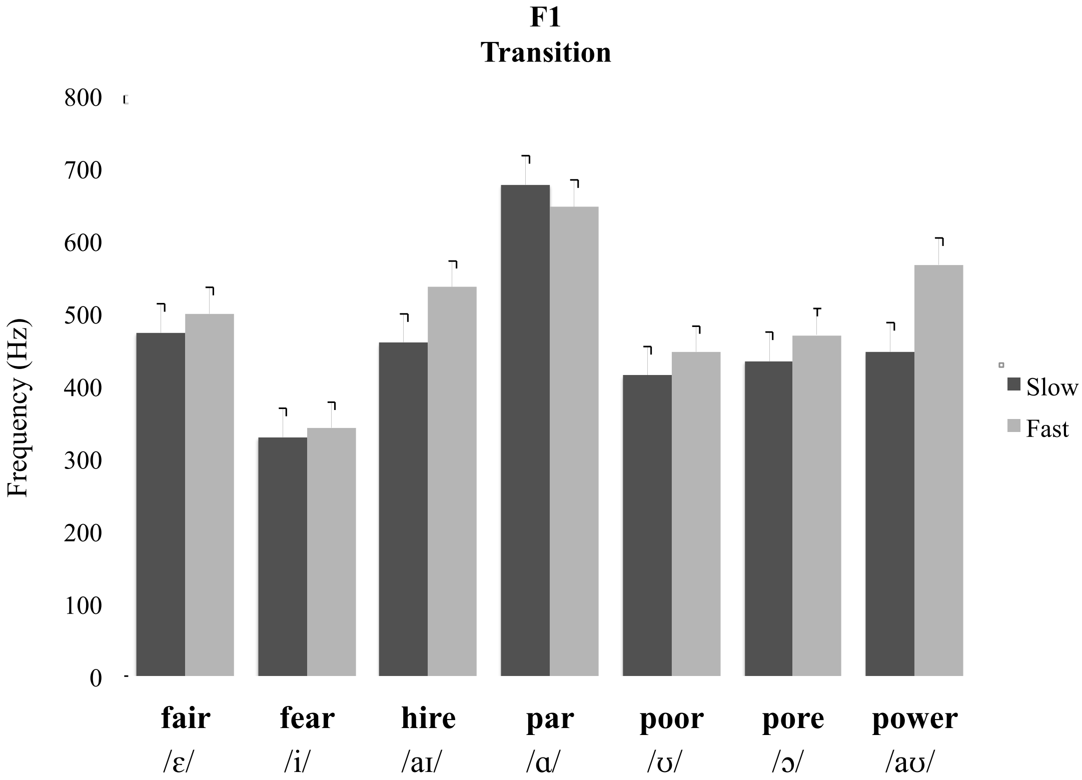


Figure 3.12 Mean transition F1 values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.47 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on transition F1 in the V+/r/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 82.8% and 81.5% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have very similar strength.

Table 3.47 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for transition F1 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	80.007	20	<.001	.635	3.81, 224.85	284.524	<.001	.828
Context (fast)	79.738	20	<.001	.715	4.29, 253.04	260.168	<.001	.815

[a] *df* = Greenhouse-Geisser correction

Table 3.48 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for transition F1. There is a relatively small number of non-significant pairs, which is considerably larger for the slow tokens ($^7/_{21}$ = 33.33%) than for the fast ones ($^1/_{21}$ = 4.76%). There is only one coincidence between rates (i.e., *hire-power*), with no exact correspondence between *p* values. The non-significant pairs with similar vowels are *poor-pore* (slow) and *poor-power* (slow). Also, *fair-hire* (slow) and *pore-power* (slow) have somewhat similar vowels. The highest possible *p* value (i.e., *p* = 1.000) is exhibited in less than half of the cases, by pairs with and without similar vowels.

Table 3.48 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for transition F1*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/	1.000					
par	/ɑ/						
poor	/ʊ/						
pore	/ɔ/			.445		.691	
power	/aʊ/	.077		1.000		.072	1.000

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/						
par	/ɑ/						
poor	/ʊ/						
pore	/ɔ/						
power	/aʊ/			.266			

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.3.2.3 Vowel-transition F1 differences in V+/r/ sequences

Table 3.49 shows that the two-way repeated measures ANOVA performed on vowel-transition F1 differences in the V+/r/ sequences yielded a significant rate*context interaction with a moderately large effect size (i.e., > .14) implying considerable differences and accounting for 22.2% of the variance, which is moderately higher than the variance for the main effect of rate (0.0%) and slightly higher than the variance for the main effect of context (12.7%).

There was no adjustment required in the degrees of freedom for context and rate*context because the sphericity assumption was not violated (i.e., $p > .01$). In addition, the main effect of rate yielded highly non-significant differences (i.e., $p = .967$). Both these outcomes are clear deviations from the general norm.

Table 3.49 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel-transition F1 differences in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	.002	.967	.000
Context	23.009	20	.289	.886	6, 354	8.602	<.001	.127
Rate*Context	29.142	20	.085	.862	6, 354	16.869	<.001	.222

[a] *df* for rate, context and rate*context = sphericity assumed

Table 3.50 shows that the t-tests performed for simple main effects of rate on vowel-transition F1 differences in the V+/r/ sequences elicited non-significant differences for *fair*, *fear*, *poor* and *pore* with small-to-medium effect sizes. However, they yielded significant differences for the rest of the pairwise comparisons, with medium effect sizes for *par* and *power*, and a large effect size (i.e., > 0.80) for *hire*.

Table 3.50 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel-transition F1 differences in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	40.90	29.60	31.00	26.16	1.88	.065	0.24
fear	/i/	45.38	25.11	34.25	25.11	2.59	.012	0.33
hire	/aɪ/	39.08	30.98	80.40	37.28	−6.22	<.001	−0.80
par	/ɑ/	70.73	47.33	42.93	28.82	3.93	<.001	0.51
poor	/ʊ/	58.52	38.73	44.75	33.99	1.95	.056	0.25
pore	/ɔ/	61.32	41.51	50.93	30.15	1.51	.136	0.20
power	/aʊ/	35.33	29.85	67.70	43.26	−4.99	<.001	−0.64

Figure 3.13 illustrates that the mean vowel-transition-difference F1 values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are higher for all the slow tokens except for *hire* and *power*. The greatest, and at the same time quite prominent, differences are found for *hire*, *par* and *power*. Once more, this confirms the tendency for words containing diphthongs to show a recurrent pattern: the values of the fast tokens are higher than those of the slow ones, and these are the words that exhibit the greatest differences. *Par* is the exception this time. Considerably smaller differences can be discerned for *fair*, *fear*, *poor* and *pore*.

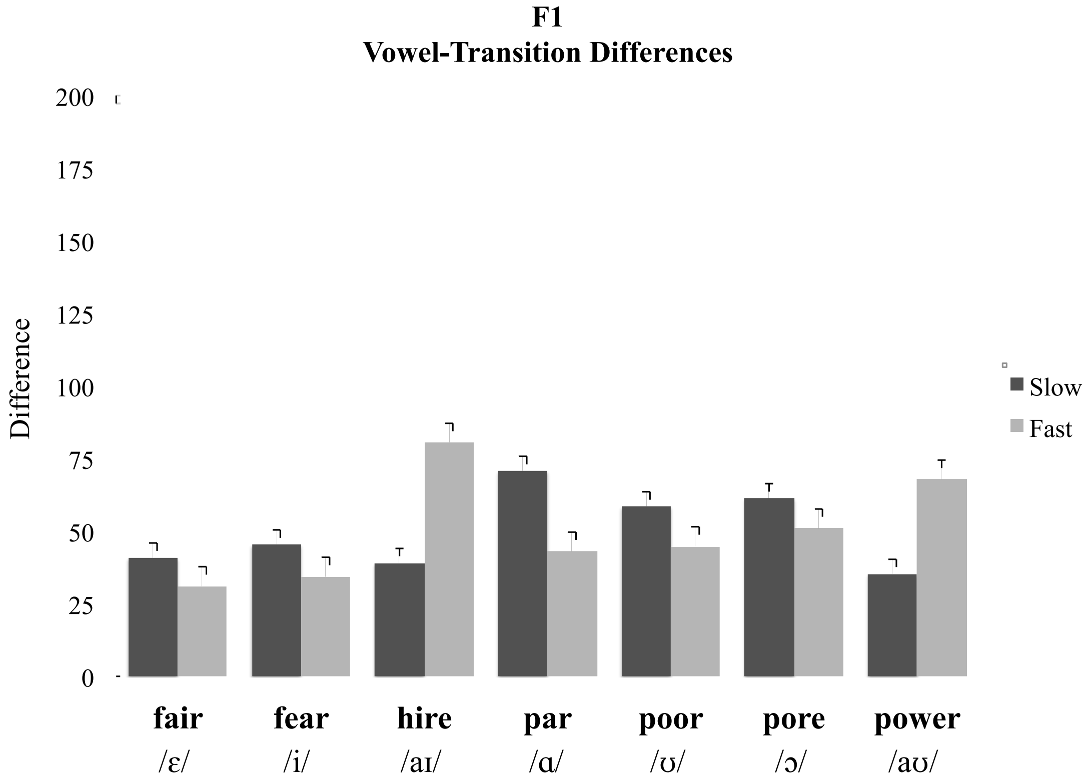


Figure 3.13 Mean vowel-transition-difference F1 values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.51 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel-transition F1 differences in the V+/r/ sequences yielded significant effects. The effect size for context (slow) was relatively smaller than for context (fast). For the slow rate, the effect size was of medium strength (i.e., > .06 but < .14), but still suggesting substantial differences among contexts, and accounted for 12.4% of the variance in the slow tokens. For the fast rate, there was a large effect size (i.e., slightly > .14) suggesting substantial differences among contexts which accounted for 23.8% of the variance in the fast tokens.

Table 3.51 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel-transition F1 differences in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	49.254	20	<.001	.756	4.53, 267.49	8.338	<.001	.124
Context (fast)	38.800	20	.007	.806	4.84, 285.34	18.415	<.001	.238

[a] *df* = Greenhouse-Geisser correction

Table 3.52 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for vowel-transition F1 differences. There is a very large number of non-significant pairs. The slow pairs are more numerous ($^{15}/_{21}$ = 71.43%) than the fast ones ($^{12}/_{21}$ = 57.14%). There are many coincidences between rates (i.e., *fair-fear*, *fair-poor*, *fear-poor*, *fear-pore*, *hire-power*, *par-poor*, *par-pore* and *poor-pore*), with an exact correspondence between *p* values (i.e., *p* = 1.000) in the case of *fair-fear*, *hire-power*, *par-poor* and *par-pore*. The non-significant pairs with similar vowels are *poor-pore* (slow and fast) and *poor-power* (fast). Also, *fair-fear* (slow and fast), *fair-hire* (slow) and *pore-power* (fast) have somewhat similar vowels. The highest possible *p* value (i.e., *p* = 1.000) is exhibited in more than half of the cases, by pairs with and without similar vowels.

Table 3.52 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for vowel-transition F1 differences*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/	1.000					
hire	/aɪ/	1.000	1.000				
par	/ɑ/						
poor	/ʊ/	.122	.998	.067	1.000		
pore	/ɔ/	.174	.375	.018	1.000	1.000	
power	/aʊ/	1.000	1.000	1.000			

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/	1.000					
hire	/aɪ/						
par	/ɑ/	.386	1.000				
poor	/ʊ/	.259	1.000		1.000		
pore	/ɔ/		.069		1.000	1.000	
power	/aʊ/			1.000		.106	.191

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.3.3 F2 in V+/r/ sequences

3.3.3.1 Vowel F2 in V+/r/ sequences

Table 3.53 shows that the two-way repeated measures ANOVA performed on vowel F2 in the V+/r/ sequences yielded a significant rate*context interaction with a large effect size (i.e., > .14) implying considerable differences and accounting for 76.3% of the variance, which is moderately lower than the variances for the main effects of rate (92.3%) and context (98.6%).

Table 3.53 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel F2 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	702.884	<.001	.923
Context	78.701	20	<.001	.690	4.14, 244.22	4254.982	<.001	.986
Rate*Context	49.123	20	<.001	.778	4.67, 275.45	190.120	<.001	.763

[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.54 shows that the t-tests performed for simple main effects of rate on vowel F2 in the V+/r/ sequences elicited non-significant differences for *fair* with a small effect size (i.e., < .020). However, they yielded significant differences for the rest of the pairwise comparisons, with a medium effect size for *fear*, large effect sizes (i.e., > 0.80) for *hire*, *poor* and *pore*, a very large effect size for *par*, and an extremely large effect size (i.e., > 3.00) for *power*.

Table 3.54 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel F2 in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	1913	80.87	1907	86.61	0.53	.596	0.07
fear	/i/	2142	50.64	2082	74.66	4.80	<.001	0.62
hire	/aɪ/	1957	77.53	1821	102.66	9.93	<.001	1.28
par	/ɑ/	1146	52.54	1342	55.28	−18.41	<.001	−2.38
poor	/ʊ/	927	30.86	1100	98.09	−13.39	<.001	−1.73
pore	/ɔ/	941	37.78	1102	82.68	−14.20	<.001	−1.83
power	/aʊ/	987	45.00	1341	73.80	−32.69	<.001	−4.22

Figure 3.14 illustrates that the mean vowel F2 values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are higher for the slow tokens of *fair*, *fear* and *hire*, which contain front vowels, as well as for the fast tokens of *par*, *poor*, *pore* and *power*, which contain back vowels. The biggest differences can be observed for the words containing back vowels, while the smallest ones can be distinguished for those containing front vowels, to the point that the values for *fair* are very similar. Therefore, there is a clear pattern here that reveals the different behavior of front and back vowels. In opposition to what happened with vowel F2 in the V+/l/ sequences, this time each of the diphthongs shows a different pattern. In addition, even though words containing front vowels in the V+/l/ sequences exhibited a common pattern for F2 as well, showing higher values for the slow tokens as is the case here, there they exhibited the biggest differences.

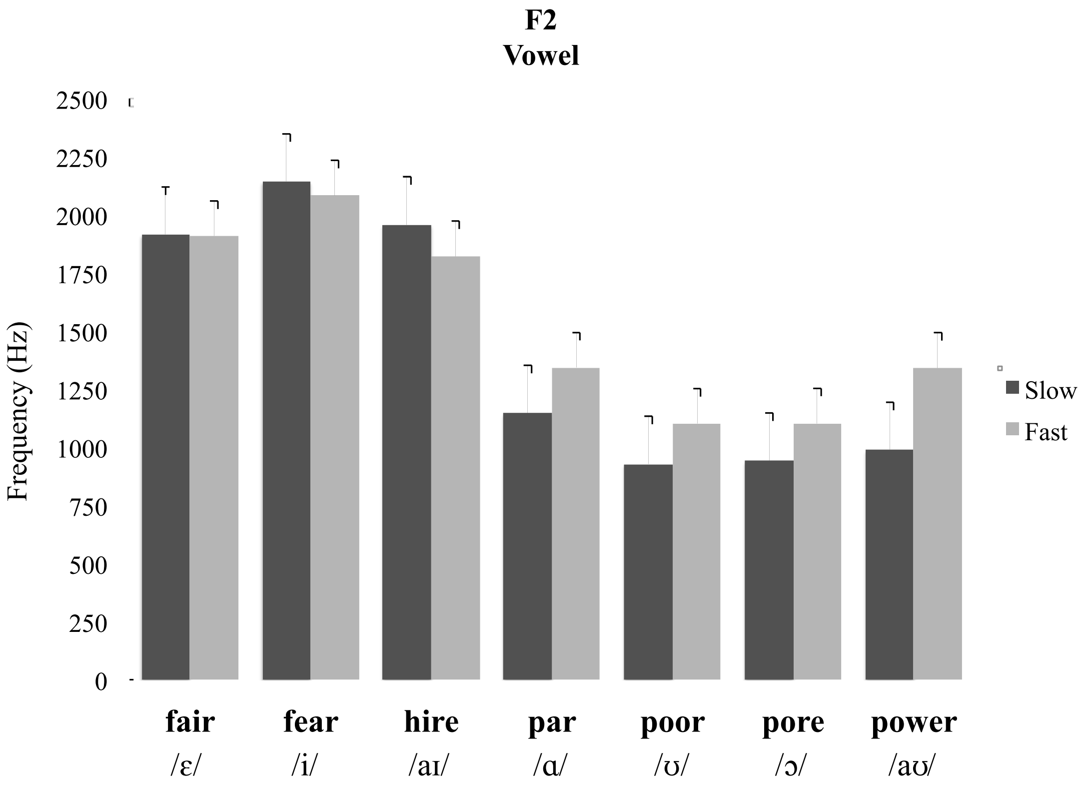


Figure 3.14 Mean vowel F2 values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.55 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel F2 in the V+/r/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 98.9% and 95.7% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have similar strength.

Table 3.55 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel F2 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	140.228	20	<.001	.591	3.55, 209.30	5119.185	<.001	.989
Context (fast)	58.714	20	<.001	.746	4.47, 263.97	1312.478	<.001	.957

[a] *df* = Greenhouse-Geisser correction

Table 3.56 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for vowel F2. There is a very small number of non-significant pairs, which is exactly the same for the fast tokens as for the slow ones ($^{2}/_{21}$ = 9.52%). There is only one coincidence between rates (i.e., *poor-pore*, which have similar vowels), with no exact correspondence between *p* values. The other two non-significant pairs are *fair-hire* (slow), with somewhat similar vowels, and *par-power* (fast), with dissimilar vowels. The highest possible *p* value (i.e., p = 1.000) is exhibited by the two fast-rate pairs (i.e., *par-power* and *poor-pore*).

Table 3.56 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for vowel F2*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/	.135					
par	/ɑ/						
poor	/ʊ/						
pore	/ɔ/					.664	
power	/aʊ/						

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/						
par	/ɑ/						
poor	/ʊ/						
pore	/ɔ/					1.000	
power	/aʊ/				1.000		

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

3.3.3.2 Transition F2 in V+/r/ sequences

Table 3.57 shows that the two-way repeated measures ANOVA performed on transition F2 in the V+/r/ sequences yielded a marginally significant rate*context interaction with a marginally medium effect size (i.e., > .01 but < .06), but still implying considerable differences and accounting for 5.4% of the variance, which is noticeably lower than the variance for the main effects of rate (70.6%) and context (97.1%). This *marginally* significant, though still significant, interaction (i.e., p = .007) constitutes a deviation from the general norm.

Table 3.57 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for transition F2 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	141.952	<.001	.706
Context	58.114	20	<.001	.739	4.44, 261.74	1993.083	<.001	.971
Rate*Context	54.597	20	<.001	.772	4.63, 273.186	3.375	.007	.054

[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.58 shows that the t-tests performed for simple main effects of rate on transition F2 in the V+/r/ sequences elicited non-significant differences for *fear* with a small-to-medium effect size. However, they yielded significant differences for the rest of the pairwise comparisons, with a small-to-medium effect size for *par*, medium effect sizes for *fair* and *hire*, and large effect sizes (i.e., > 0.80) for *poor*, *pore* and *power*.

Table 3.58 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for transition F2 in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	1931	111.85	1856	100.44	3.99	<.001	0.52
fear	/i/	1984	121.14	1946	96.40	1.70	.094	0.22
hire	/aɪ/	1888	85.79	1813	122.84	4.47	<.001	0.58
par	/ɑ/	1367	82.33	1327	57.73	2.89	.005	0.37
poor	/ʊ/	1111	72.17	1041	59.61	7.00	<.001	0.90
pore	/ɔ/	1135	86.52	1023	62.99	9.45	<.001	1.22
power	/aʊ/	1324	108.08	1212	86.25	6.59	<.001	0.85

Figure 3.15 illustrates that the mean transition F2 values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are higher for the slow tokens in all cases, which is a pattern that was already observed for transition F1 and F2 in the V+/l/ sequences, although in those cases the exceptions were *pile* for F1 and *howl* for F2. However, this pattern is the opposite of the one for transition F1 in the V+/r/ sequences, with the exception there being *par*. Likewise, it is different from that of vowel F2 in both the V+/l/ and V+/r/ sequences, where the values tended to be higher for the slow tokens that contained front vowels as well as for the fast tokens that contained back vowels. The differences are very similar in all cases, although they are slightly larger for *pore* and *power*.

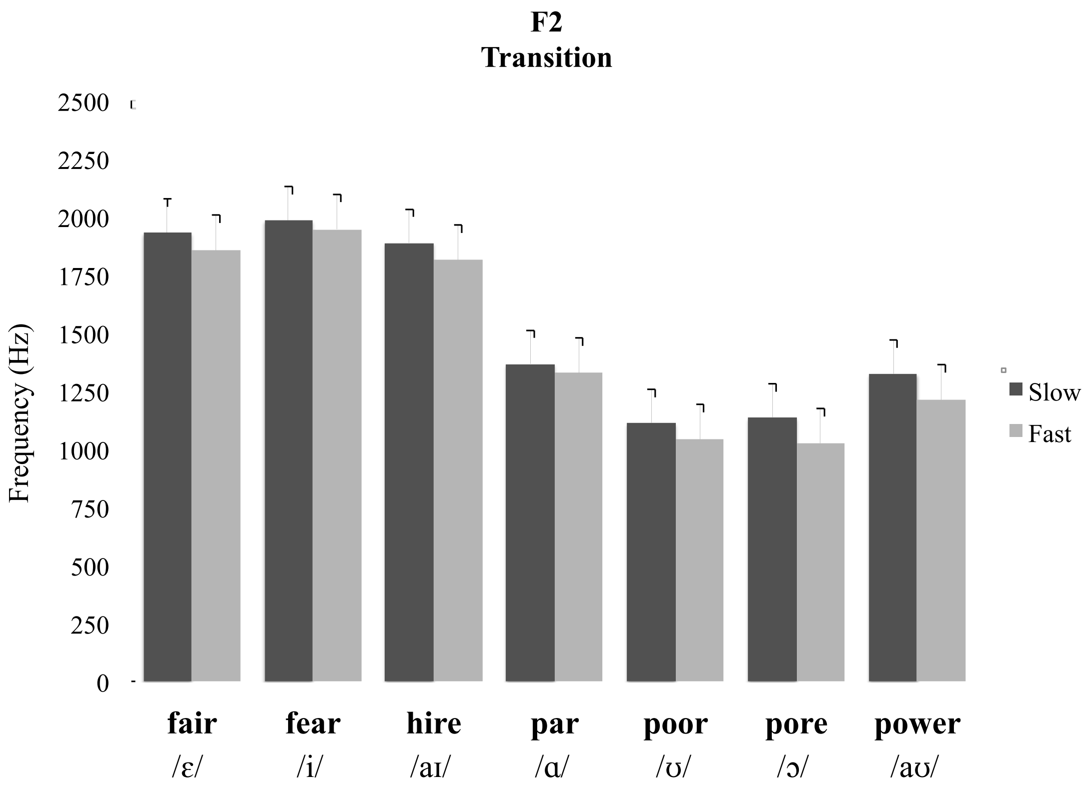


Figure 3.15 Mean transition F2 values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.59 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on transition F2 in the V+/r/ sequences yielded significant effects with very large effect sizes (i.e., > .14) suggesting substantial differences among contexts and accounting for 94.2% and 95.4% of the variance in the slow and fast tokens, respectively. Thus, the effect sizes for the two rates have very similar strength.

Table 3.59 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for transition F2 in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	37.792	20	.009	.833	5.00, 294.94	961.936	<.001	.942
Context (fast)	81.129	20	<.001	.665	3.99, 235.505	1225.534	<.001	.954

[a] *df* = Greenhouse-Geisser correction

Table 3.60 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for transition F2. There is a very small number of non-significant pairs, which is slightly larger for the slow tokens ($\frac{4}{21}$ = 19.05%) than for the fast ones ($\frac{2}{21}$ = 9.52%). There are only two coincidences between rates (i.e., *fair-hire* and *poor-pore*), with an exact correspondence between *p* values (i.e., *p* = 1.000) only in the case of *poor-pore*. The only non-significant pair with similar vowels is *poor-pore* (slow and fast). Also, *fair-fear* (slow) and *fair-hire* (slow and fast) have somewhat similar vowels. The highest possible *p* value (i.e., *p* = 1.000) is exhibited in half of the cases, by pairs with and without similar vowels.

Table 3.60 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for transition F2*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/	.332					
hire	/aɪ/	.375					
par	/ɑ/						
poor	/ʊ/						
pore	/ɔ/					1.000	
power	/aʊ/				.337		

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/	1.000					
par	/ɑ/						
poor	/ʊ/						
pore	/ɔ/					1.000	
power	/aʊ/						

Note. Only non-significant values are provided in the cells. Empty cells represent a value of *p* < .01.

3.3.3.3 Vowel-transition F2 differences in V+/r/ sequences

Table 3.61 shows that the two-way repeated measures ANOVA performed on vowel-transition F2 differences in the V+/r/ sequences yielded a significant rate*context interaction with a marginally large effect size (i.e., > .14) implying considerable differences and accounting for 26.1% of the variance, which is noticeably lower than the variance for the main effect of rate (88.0%) but moderately lower than the variance for the main effect of context (49.5%).

Table 3.61 *Mauchly's Test of Sphericity and two-way repeated measures ANOVA results for vowel-transition F2 differences in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Rate	0.000	0		1.000	1, 59	433.907	<.001	.880
Context	48.900	20	<.001	.801	4.80, 283.63	57.881	<.001	.495
Rate*Context	51.116	20	<.001	.771	4.63, 272.96	20.889	<.001	.261

[a] *df* for rate = sphericity assumed; *df* for context and rate*context = Greenhouse-Geisser correction

Table 3.62 shows that the t-tests performed for simple main effects of rate on vowel-transition F2 differences in the V+/r/ sequences elicited non-significant differences for *fear* with a small effect size (i.e., < .020). However, they yielded significant differences for the rest of the pairwise comparisons, with small-to-medium effect sizes for *fair* and *hire*, and large effect sizes (i.e., > 0.80) for *par*, *poor*, *pore* and *power*.

Table 3.62 *Means, standard deviations and t-test results for pairwise comparisons between slow and fast rates for vowel-transition F2 differences in the V+/r/ sequences*

		Slow		Fast				
		M	*SD*	*M*	*SD*	*t*(59)	*p*	Cohen's *d*
fair	/ɛ/	110.20	74.61	71.98	69.22	2.94	.005	0.38
fear	/i/	168.57	107.41	142.52	83.42	1.47	.146	0.19
hire	/aɪ/	94.93	60.64	56.23	53.55	3.43	.001	0.44
par	/ɑ/	221.38	96.67	51.92	39.68	13.26	<.001	1.71
poor	/ʊ/	187.13	65.30	84.38	88.94	7.35	<.001	0.95
pore	/ɔ/	195.90	76.91	92.70	77.95	7.21	<.001	0.93
power	/aʊ/	337.22	96.69	138.02	61.79	11.44	<.001	1.48

Figure 3.16 illustrates that the mean vowel-transition-difference F2 values for pairwise comparisons between the slow and fast rates in the V+/r/ sequences are higher for the slow tokens in all cases. By far the greatest differences are exhibited by *par* and *power*. Prominent differences are shown for *poor* and *pore*. These four words contain back vowels. Smaller differences can be discerned for *fair* and *hire*, while *fear* presents the smallest. These three words contain front vowels. This pattern is quite similar to the one for vowel-transition F2 differences in the V+/l/ sequences in that the slow tokens have higher values than the fast ones, and in that there are four clearly distinguished degrees of difference. However, there is no one-to-one correspondence between vowel and degree of difference for the V+/l/ and V+/r/ sequences. Moreover, words containing diphthongs do not pattern together as regards degree of difference, which is something that indeed happened for vowel-transition F1 differences in the V+/r/ sequences, with words containing diphthongs showing the smallest differences.

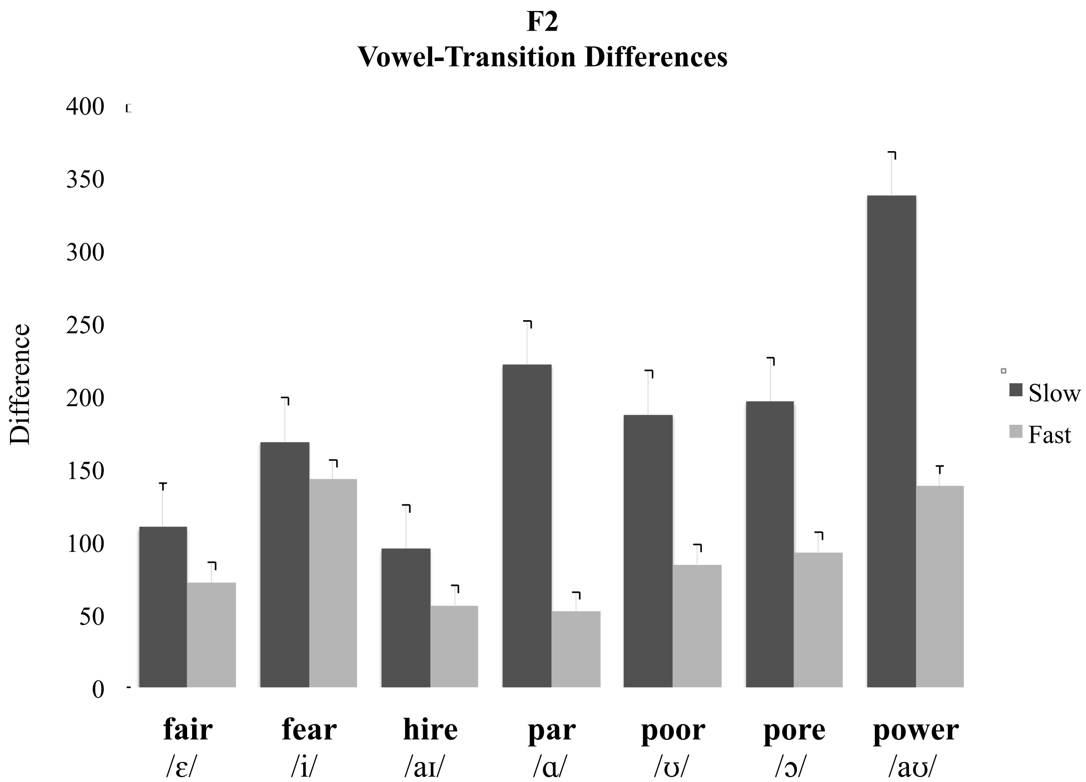


Figure 3.16 Mean vowel-transition-difference F2 values for pairwise comparisons between slow and fast rates in the V+/r/ sequences

Table 3.63 shows that the one-way repeated measures ANOVA to test for simple main effects of context at the two rate levels separately on vowel-transition F2 differences in the V+/r/ sequences yielded significant effects with large effect sizes (i.e., > .14 for the slow rate, but only slightly >.14 for the fast rate) suggesting substantial differences among contexts and accounting for 46.7% and 21.9% of the variance in the slow and fast tokens, respectively. Thus, the effect size for context (slow) is relatively larger than for context (fast).

Table 3.63 *Mauchly's Test of Sphericity and separate one-way repeated measures ANOVAs (slow and fast) results for vowel-transition F2 differences in the V+/r/ sequences*

	Mauchly's Test of Sphericity				Repeated Measures ANOVA			
	χ^2	*df*	*p*	ε	*df* [a]	*F*	*p*	η^2
Context (slow)	42.044	20	.003	.817	4.90, 289.13	51.764	<.001	.467
Context (fast)	48.073	20	<.001	.818	4.91, 289.64	16.590	<.001	.219

[a] *df* = Greenhouse-Geisser correction

Table 3.64 shows the non-significant *p* values yielded by the Bonferroni post-hoc test results for separate pairwise comparisons between the V+/r/ contexts for vowel-transition F2 differences. There is a very large number of non-significant pairs. The fast pairs are considerably more numerous ($^{13}/_{21}$ = 61.90%) than the slow ones ($^{8}/_{21}$ = 38.10%). There are only a few coincidences between rates (i.e, *fair-hire*, *fear-pore*, *par-poor* and *poor-pore*), with an exact correspondence between *p* values (i.e., *p* = 1.000) in the case of *fair-hire* and *poor-pore*, but not in the case of *fear-pore* or *par-poor*. The non-significant pairs with similar vowels are *poor-pore* (slow and fast) and *poor-power* (fast). Also, *fair-fear* (slow), *fair-hire* (slow and fast) and *pore-power* (fast) have somewhat similar vowels. The highest possible *p* value (i.e., *p* = 1.000) is exhibited in more than half of the cases, by pairs with and without similar vowels.

Table 3.64 *Bonferroni post-hoc test results for separate pairwise comparisons (slow and fast) between the V+/r/ contexts for vowel-transition F2 differences*

Slow		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/	.043					
hire	/aɪ/	1.000					
par	/ɑ/		.124				
poor	/ʊ/		1.000		.638		
pore	/ɔ/		1.000		1.000	1.000	
power	/aʊ/						

Fast		fair /ɛ/	fear /i/	hire /aɪ/	par /ɑ/	poor /ʊ/	pore /ɔ/
fear	/i/						
hire	/aɪ/	1.000					
par	/ɑ/	1.000		1.000			
poor	/ʊ/	1.000		.924	.367		
pore	/ɔ/	1.000	.014	.054		1.000	
power	/aʊ/		1.000			.023	.078

Note. Only non-significant values are provided in the cells. Empty cells represent a value of $p < .01$.

Chapter 4 Discussion and conclusions

This chapter is devoted to the discussion and conclusions of this dissertation. Section 4.1 presents an overview of the results and is organized according to the three inferential statistical tests carried out: two-way repeated measures ANOVAs, paired-samples t-tests for simple main effects of rate, and one-way repeated measures ANOVAs for simple main effects of context. The first and second hypotheses are the focus of discussion of sections 4.2 and 4.3, respectively. These sections provide answers to the research questions and hypotheses formulated in Chapter 1 by means of discussion of the results reported in Chapter 3, with references to the theoretical background presented in Chapter 1. Finally, section 4.4 details the contributions of this dissertation, sets its limitations and provides suggestions for further research.

4.1 Overview of results

4.1.1 Two-way repeated measures ANOVAs

The two-way repeated measures ANOVAs performed to test for the main effects of rate and context and the rate*context interaction yielded significant main effects and interactions for all tests with the exception of one case: the main effect of rate was highly significant for vowel-transition F1 differences in the V+/r/ sequences. Excluding this case, the main effects were thus disregarded and the presentation of the results focused on the interactions. There was only one instance in which the interaction was marginally significant: transition F2 in the V+/r/ sequences.

Mauchly's test of Sphericity had previously shown the violation of sphericity in all cases except for vowel-transition F1 differences in the V+/r/ sequences. Therefore, there had been an adjustment made in the degrees of freedom for both the main effect of context and the interaction in the form of a Greenhouse-Geisser correction in all cases but this one.

Partial eta squared (η^2) values provided a more straightforward interpretation of the magnitude of the differences implied by the significant results of the interaction and were interpreted in terms of their strength and as percentages of variance. Large effect sizes were the norm, implying considerable differences and accounting for varying degrees of variance. Effect sizes were larger for the vowels than for the transitions in all cases, and they were larger for the transitions than for the vowel-transition differences for F2 (V+/l/) and F1 (V+/r/) but smaller for F1 (V+/l/) and F2 (V+/r/).

Comparisons were made between the effect sizes of the interaction and those of the main effects only as a means to look for some kind of pattern that may help interpret the significant results of the interaction more accurately. Although no immediately detectable pattern was visible, some quite robust trends could be inferred. There was a tendency for the effect sizes of the interaction to be either noticeably or moderately lower than those of the main effects. Vowel-transition F1 differences, however, tended to show the reverse pattern: for the V+/l/ sequences, the effect size was marginally higher for the interaction than for the main effect of context; and for the V+/r/ sequences it was higher than for either of the main effects.

4.1.2 Paired-samples t-tests for simple main effects of rate

The paired-samples t-tests carried out to test for simple main effects between the slow and fast levels of the rate variable at every context level separately yielded significant differences for the majority of the pairwise comparisons. Differences were significant for vowel duration and transition duration in all cases. Vowel F1 yielded non-significant differences for *bill*, *pool*, *pull*, *fair* and *fear*; transition F1 for *hole* and *fear*; vowel-transition F1 differences for *pal*, *pile*, *fair*, *fear*, *poor* and *pore*; vowel F2 for *hole*, *hull*, *pal*, *pool*, *pull* and *fair*; transition F2 for *howl* and *fear*; and vowel-transition F2 differences for *bill*, *boil*, *feel*, *pale*, *pile* and *fear*.

In spite of the lack of a clear pattern, a series of trends may be said to apply for non-significant differences. First, high and high mid (front and back) vowels tended to show non-significant differences for the vowel and the transition, for F1 as well as for F2, in both the V+/l/ and V+/r/ sequences. However, *pal* and *fair* were exceptions. Second, for vowel-transition F2 differences, it was high front vowels that clearly showed this tendency. Finally, for vowel-transition F1 differences, it was high and mid (front and back) vowels that showed it, with *pal* being the exception.

Cohen's *d* revealed very large or extremely large effect sizes for vowel duration and transition duration in all cases. Non-significant differences tended to have small effect sizes, though there were a few cases of small-to-medium and medium effect sizes. For significant differences, effect sizes ranged from small to large through small-to-medium and medium, but large effect sizes seemed to be the most common norm, closely followed by effect sizes of a medium strength, whereas small-to-medium and small effect sizes were much less common.

The description of the bar graphs that illustrated the mean values for pairwise comparisons between the slow and fast rates was done on the basis of observation of the graphs only and no reference was made to the actual values shown in the tables which reported the results of the paired-samples t-tests. The aim was to determine common patterns related to two main areas of analysis: first, which of the two rates exhibited higher and lower values; and, second, which tokens showed greater or smaller rate differences. Given the large amount of data (i.e., two rates, plus 14 and seven contexts for the V+/l/ and V+/r/ sequences, respectively), and given the very diverse nature of the dependent variables (i.e., duration, F1 and F2) and measurements (i.e., vowel, transition and vowel-transition differences) under study, it was impossible to determine any distinct pattern that did not include exceptions. Therefore, as with the results of the paired-samples t-tests, any visible patterns should be understood as trends rather than as norms.

As regards duration, values were higher for the slow tokens than for the fast ones in all cases. This was expected because speaking rate had been well controlled for when the experiment had been designed and the speakers had produced the slow and fast versions at two clearly differentiated rates. In addition, the most common tendency was for tokens containing diphthongized vowels and diphthongs to present the smallest duration differences. This is a logical outcome since the second element in these, which is the one that was considered for the analysis, is already relatively short and weak, compared to the first element. Finally, in very general terms and as a weak tendency only, tokens that contained high front vowels (diphthongized vowels and diphthongs excluded) tended to show greater duration differences than those containing other types of vowels, but exceptions abounded. All this applies to duration in the vowel and the transition alike.

As far as F1 is concerned, there was a tendency for the fast tokens to exhibit higher values than the slow ones for the vowel in both the V+/l/ and V+/r/ sequences and for the transition in only the V+/r/ sequences. Diphthongized vowels and diphthongs displayed the clearest pattern. Similarly, the tendency was for the slow tokens to exhibit higher values than the fast ones for the transition in the V+/l/ sequences and for vowel-transition differences in the V+/r/ sequences. Vowel-transition differences in the V+/l/ sequences did not adhere to any of these trends, with half of the cases showing higher values for the fast tokens and the other half showing higher values for the slow ones. In addition, there seemed to be a tendency for diphthongized vowels and diphthongs to show the greatest rate differences for the vowel in both the V+/l/ and V+/r/ sequences, but for the transition and vowel-transition differences in only the V+/r/ sequences. This evinced a correlation between smaller duration differences and greater F1 differences for diphthongized vowels and diphthongs. The transition and vowel-transition differences in the V+/l/ sequences deviated from this trend.

Concerning F2, there was an overall tendency for the slow tokens to exhibit higher values than the fast ones for the vowel, the transition and vowel-transition differences. Tokens containing back vowels revealed the greatest differences for the vowel and vowel-transition differences in the V+/r/ sequences. The transition in these sequences showed very similar differences for all tokens. There did not seem to be any logical pattern that could explain the distribution of tokens for vowel-transition differences in the V+/l/ sequences in terms of degree of differences. However, for the vowel and transition in the V+/l/ sequences, it was high vowels, with a preference for front over back ones, that tended to reveal the greatest differences. Diphthongized vowels and diphthongs are included within this classification. The whole pattern was stronger for the vowel than for the transition. Finally, a pattern shared by vowel-transition differences in the V+/l/ and V+/r/ sequences was the existence of four clearly distinguished degrees of difference with no one-to-one correspondence between vowel and degree of difference for the two types of sequences, however.

As conveyed by these results, V+/l/ and V+/r/ sequences can be said to behave quite similarly although, probably due to the reduced number of V+/r/ tokens, these tend to show greater homogeneity. On the whole, despite the significant rate*context interactions revealed by the results of the two-way repeated measures ANOVAs, looking into simple main effects of rate made it possible to corroborate the significant main effect of rate that these ANOVAs had also yielded. The results of the paired-samples t-tests disclosed many more significant differences than non-significant ones, Cohen's *d* large effect sizes for significant differences outnumbered those that were medium or small, and observation of the bar graphs evidenced the high degree of existing variability between rates. All in all, this showed significant rate differences independently of context, but any attempt to unveil which contexts were responsible for the rate*context interaction proved successful at indicating very general trends among contexts but unsuccessful at determining clear-cut patterns. In addition, straightforward patterns accounting for the characteristics of the vowel, transition or vowel-transition differences were almost inexistent and only trends could be suggested, which at the same time illustrated dissimilarities among vowel, transition and vowel-transition differences as well as between the V+/l/ and V+/r/ sequences. The lack of well-defined patterns in favor of the existence of general trends can be interpreted as further confirmation of the high degree of variability exhibited by the vowels and transitions of the V+/l/ and V+/r/ sequences under study.

4.1.3 One-way repeated measures ANOVAs for simple main effects of context

The one-way repeated measures ANOVAs performed to test for simple main effects of context at the two rate levels separately yielded significant results in all cases, so Bonferroni post-hoc tests were subsequently performed to determine context differences from pairwise comparisons.

Mauchly's test of Sphericity had previously shown the violation of sphericity in all cases except for the simple main effect of context (fast) for transition duration in the V+/r/ sequences. A Greenhouse-Geisser correction had therefore been applied to adjust the degrees of freedom in all cases but this one.

Partial eta squared (η^2) values were provided and reported in terms of their strength and as percentages of variance. Effect sizes were large in slightly below 50% of the cases and very large in slightly over 50%. Such effect sizes suggested substantial differences among contexts and accounted for varying degrees of variance. There was only one occurrence of a marginally medium-strength effect size: context (slow) for vowel-transition F1 differences in the V+/r/ sequences.

Effect sizes were much larger for the vowels and the transitions than for vowel-transition differences in all cases: for all the dependent variables (i.e., duration, F1 and F2) and for the V+/l/ and V+/r/ sequences alike. There was a strong tendency for effect sizes to have similar values for the slow and fast contexts of the same dependent variable in the case of the vowels and the transitions. This was specifically the case for duration, F1 and F2 in the V+/l/ sequences as well as for F1 and F2 in the V+/r/ sequences. The tendency was for effect sizes to be larger, though only very slightly so, for the vowel than for the transition in these cases. However, the effect sizes for duration for both the vowel and the transition in the V+/r/ sequences were larger for the slow contexts than for the fast ones, implying greater differences in the slow tokens than in the fast ones. Similarly, for vowel-transition F1 differences (V+/l/) and vowel-transition F2 differences (V+/r/), the effect sizes for context (slow) were relatively larger than for context (fast), implying greater differences in the slow tokens than in the fast ones. On the other hand, for vowel-transition F2 differences (V+/l/) and vowel-transition F1 differences (V+/r/), the effect sizes for context (slow) were relatively smaller than for context (fast), implying smaller differences in the slow tokens than in the fast ones.

The description of the Bonferroni post-hoc test results presented in the form of pairwise comparisons between contexts independently of rate was carried out by means of general observation and taking a series of aspects into consideration. The aim was to find regular patterns that could prove the existence of differences among contexts and, if possible, determine contrasts between rates. The higher the non-significant values, the smaller the differences between pairs.

First, reference was made to the number of non-significant pairs for the slow and fast tokens separately for comparative purposes. For the V+/l/ sequences, which had 14 contexts, there were 91 possible pairwise combinations; for the V+/r/ sequences, which had seven, there were 21. Even though there was no clearly discernible pattern, some trends could be detected. In some cases, the number was larger for the slow tokens, while in others it was so for the fast ones. This applies to the dependent variables (i.e., duration, F1 and F2) as well as to the measurements taken (i.e., vowel, transition and vowel-transition differences). However, F1 and F2 vowel-transition differences for both the V+/l/ and V+/r/ sequences showed the largest number of non-significant pairs, with over 50% of them in most cases. Likewise, vowel F2 showed the smallest number, with the same number for the slow and fast rates of the V+/l/ sequences as well as for the two rates of the V+/r/ sequences. Vowel F1 for both types of sequences also had relatively small instances of non-significant pairs, and for the V+/l/ sequences the number was the same for the slow and fast pairs. In general, there were more non-significant pairs for the transition than for the vowel. Table 4.1 presents the number (in percentages) of non-significant pairs for the two types of sequences, the two rates, the dependent variables and the measurements taken.

Second, reference was made to any coincidences between rates concerning which pairs showed non-significant differences. Despite considerable coincidences, no pattern arose. In all cases, there were common non-significant pairs to the two rates, but there was generally no exact correspondence between *p* values for the two rates. As may seem obvious, the more pairs involved and the more non-significant pairs, the more possibility for coincidences to exist. Therefore, there were more coincidences for the V+/l/ sequences than for the V+/r/ ones. By far, duration exhibited the greatest number of coincidences, followed by vowel-transition differences, although the latter outnumbered the former in the overall amount of non-significant pairs. Vowel and transition came in third place, with one or the other exhibiting more or fewer coincidences depending on the dependent variable and the rate being considered, but with no clear pattern to show that one exhibited more than the other.

Table 4.1 *Percentages of non-significant pairs yielded by Bonferroni post-hoc tests*

		V+/l/ Sequences		V+/r/ Sequences	
		Slow %	Fast %	Slow %	Fast %
Duration	Vowel	25.27	18.68	42.86	33.33
Duration	Transition	21.98	29.67	33.33	38.10
F1	Vowel	19.78	12.09	9.52	19.05
F1	Transition	13.19	13.19	33.33	4.76
F1	V-T Differences	42.86	51.65	71.43	57.14
F2	Vowel	6.59	6.59	9.52	9.52
F2	Transition	14.29	15.38	19.05	9.52
F2	V-T Differences	69.23	54.95	38.1	61.90

Third, reference was made to the relationship between non-significance and some of the phonological parameters for the classification of vowels to see whether it was possible to reach any conclusion as to why certain pairs were non-significant. The focus was on deciding how similar the vowels in each pair were, taking into consideration vowel height, backness and tenseness as well as whether the vowels were monophthongs, diphthongized vowels or diphthongs. Once again, it was impossible to find any clear-cut pattern. There seemed to be a very general tendency for some non-significant pairs to consist of similar vowels (e.g., /i/-/ɪ/, /ɪ/-/e/, /ɪ/-/aɪ/, /ɪ/-/ɔɪ/, /ɛ/-/æ/, /u/-/ʊ/, /ʊ/-/aʊ/ or /ʊ/-/o/), but exceptions disproved any slight hint of a pattern. Given the reduced number of vowels involved in the V+/r/ sequences, it was more difficult to establish relationships of this kind between V+/r/ tokens than between V+/l/ ones.

Finally, reference was made to the actual *p* values. Many pairs containing similar vowels showed *p* values equivalent or close to 1.000, but there were many which had lower values as well. It is also true that many of the pairs that had somehow different or rather dissimilar vowels also showed such high values, but many of these also had low ones. Most of the non-significant pairs for vowel-duration F1 and F2 differences for V+/l/ and V+/r/ sequences alike showed the highest possible p value (i.e., $p = 1.000$).

As was the case with the simple main effects of rate, results for the simple main effects of context elicited by the Bonferroni post-hoc tests demonstrated that V+/l/ and V+/r/ sequences behave quite similarly, despite the different number of contexts involved (i.e., 14 vs. seven). Overall, they also confirmed the significant main effect of context that the two-way repeated measures ANOVAs had yielded, despite the significant rate*context interactions. As with the paired-samples t-test results, the large amount of data and the diverse nature of the dependent variables and measurements made it very difficult to detect exception-free patterns, so it was therefore easier to establish only trends. None of the aspects considered for the analysis of the Bonferroni post-hoc test results were determinant to establish patterns either. Again, this illustrates the existing variability in the vowels and transitions of the V+/l/ and V+/r/ sequences under study.

4.2 The first hypothesis

The first hypothesis of this dissertation predicted that a transitional vocalic element of a mid central weak unstressed (i.e., schwa-like) type would be present in all the V+/l/ and V+/r/ sequences under study (i.e., in the 15 V+/l/ and the seven V+/r/ contexts, as well as in slow and fast speaking rates). A speech production experiment was designed for this purpose. Native speakers of American English who had similar accents were selected as participants. The CVC monosyllables that were used as stimuli included all the possible combinations of strong, stressed vowel plus /l/ or /r/ and were complemented with distracters. The data recording sessions were carefully devised to control for speaking rate. Initial auditory and visual acoustic signal inspection constituted the first steps in order to identify this transitional vocalic element. These were followed by an exhaustive procedure of speech signal segmentation that combined a thorough manual method dependent on spectrographic observation with a rigorous automatic method based on first derivative curve extraction. Durational and spectral measurements of each of the segmented parts were then taken. It was possible to finally determine, to a greater or lesser extent depending on the speaking rate and the contexts involved, the presence of such an element in all the sequences. This leads to the conclusion that the process at play in these sequences is a generalized one affecting all the contexts and the two rates. This conclusion has two closely related implications. It expands on previous, though limited in number, work by other authors which has not looked into all the possible contexts and has not taken speaking rate into consideration. At the same time, however, it could corroborate the reasons why such work might not have focused on all the possibilities.

The segmentation procedure required dividing the speech signal into one more part than the number of segments it consisted of. Therefore, in the case of monophthongs, it was divided into four parts (i.e., the initial consonant, the monophthong, the transitional vocalic element, and the final consonant), whereas in the case of diphthongized vowels and diphthongs, it was divided into five parts (i.e., the initial consonant, the first and second elements of diphthongized vowels and diphthongs, the transitional vocalic element, and the final consonant). The resulting segmented speech signal may thus lead to interpreting the presence of the transitional element as equivalent to that of an extra (i.e., 'inserted') segment. This is far from how it was intended to be considered at this initial stage. Because the analysis was exclusively acoustic, there was no other possible segmentation procedure to rely on. It was the results of the measurements taken and of the statistical analyses performed that were eventually to determine the nature of the element.

The paired-samples t-test results for duration provide further evidence that there is a distinct transitional vocalic element which is identifiable in all the sequences. These results revealed highly significant differences with very large effect sizes between the slow and fast rates for all the contexts of both the vowel and the transition. The fact that the behavior of the transition mirrors that of the vowel in this respect can be understood as an indication that the element present in it is of a vocalic type.

As regards this segmentation procedure, different patterns of vocalic transitional element behavior were detected depending of which the preceding vowel was. For example, VC transitions proved easier to identify after front vowels than after back ones, after high vowels than after low ones, after high front vowels than after high back ones, after low front vowels than after low back ones, and after tense vowels than after lax ones. Transitions after low back vowels by far turned out to be the most difficult to identify. According to this, those transitions which were more easily identifiable happened to be the ones that had been the object of study of previous experimental work as well as the ones that tend to be transcribed with schwa epenthesis in pronunciation dictionaries and manuals.

Differences concerning the ease of identification of the transitions can be explained in terms of the articulatory tongue dorsum movement required by the tongue in passing from the vowel to the consonant through the mid central area of the oral cavity. In doing so, the tongue traverses through a schwa-like configuration that is more easily distinguishable when vowels are high and front than when they are low or back. In the case of low back vowels, this movement is less prominent because the production of these vowels also requires a tongue dorsum movement. Therefore, the transitions are much less discernible and the auditory impression in some cases, instead of being that of a mid central weak unstressed (i.e., schwa-like) vowel, might be that of a longer vowel, typically in the case of slow productions, or even of nothing at all, especially in the case of fast productions. There is no gestural intent for a schwa target, but rather for an /l/ or /r/ target. The schwa-like configuration through which the tongue traverses is just an inevitable outcome previous to reaching the consonantal target. In addition, the differences can also be explained in terms of the extent of the transition. For example, at one extreme, when the preceding vowel is high front, the extent is the greatest and, in consequence, the auditory sensation of the transition can easily lead to the perception of a schwa-like vowel. On the other hand, and at the opposite extreme, when the preceding vowel is low back, the extent is the smallest, which may prevent the perception of a distinct schwa-like element.

The fact that VC transitions in the V+/l/ and V+/r/ sequences under study were also more easily identifiable (i.e., visually, auditorily and by peaks of formant change given by velocity maxima and minima in the first derivative curve) in slow than in fast productions can be reasonably attributed to duration differences. The longer the sequences, the longer and, therefore, the more easily identifiable the transitional elements. Also, the slower the speaking rate, the less overlap and blending there is in the transitions and the easier it is to determine their existence and their boundaries. As speaking rate increases, the time for articulatory gestures to attain their targets decreases and hence there is less formant movement in the waveform and spectrographic signals to be detected by the human eye, in the case of visual observation, by the human ear, in the case of auditory corroboration, or by automatic means such as that of first derivative curve extraction.

What may be inferred from the results of the segmentation procedure is in accordance with the continuous nature of speech production. Also, it agrees with the explanations given by authors of pronunciation manuals (Calvert, 1986; Prator and

Robinett, 1985), authors of manuals with provide detailed accounts of the acoustics of American English sounds (Olive et al., 1993), or authors that report on experimental studies (Gick & Wilson, 2001, 2006; Gick et al., 2002). These conclusions may lead to the claim that the term *epenthetic schwa* is not appropriate to refer to this transitional vocalic element. Despite resembling schwa, this element also has spectral values similar to those of its preceding vowel, to the point of being turned into a 'different' vocalic element in each of the different contexts, as a function of the vowel that precedes it and of the speaking rate at which the words are uttered. Other terms such as *targetless schwa* (Browman & Goldstein, 1992), *excrescent schwa* (Gick & Wilson, 2001, 2006) or *intrusive schwa* (Hall, 2003, 2004, 2006) seem more appropriate, since they imply the existence of an element which has differing spectral and duration values across contexts that are context-dependent and which can be better understood as the result of gestural timing rather than as an epenthetic segment. In fact, the vocalic transitional element that is the object of study of this dissertation may have some of the characteristics of intrusive vowels set forth by Hall (2003, 2004, 2006) as, for example, that it is neutral and schwa-like in quality and that it does not involve the addition of a vowel segment. Similarly, although its analysis has not been intended for like purposes, this element might be responsible for creating the *sesquisyllables* defined by Lavoie and Cohn (1999).

Finally, after considering the characteristics of the transitional vocalic element of this dissertation as presented in the above lines, it seems reasonable to conclude that a phonological/phonemic representation of this element, like the one found in some pronunciation dictionaries and manuals (i.e., /ə/ or /ᵊ/) does not seem very adequate. In the view presented in this dissertation, a representation of this element would only be appropriate in the case of a phonetic/allophonic transcription, although it would be justifiable, provided its usefulness is verified, as an aid in second/foreign language pronunciation learning. An epenthetic vocalic element should be characterized mainly by having a phonological target, with relatively stable, uniform duration and formant values regardless of context and speaking rate. It could thus be referred to as a *vowel*. In contrast, a coarticulatory vocalic element should be phonologically targetless, exhibiting relatively high variability as a function of both context and speaking rate, although some of its acoustic characteristics (e.g., durational and spectral) may resemble more those of a mid central unstressed vowel (i.e., schwa-like) than of any other vowel. Hence, it ought not to be termed *vowel*.

4.3 The second hypotheses

The second research question and objective of this dissertation directly addressed the issue of the coarticulatory nature of the vocalic element in the VC transitions and aimed to study the roles of speaking rate and context. Three hypotheses were formulated which sought to investigate speaking rate (Hypothesis 2a), context (Hypothesis 2b), and speaking rate together with context (Hypothesis 2c). Because the main object of study of this dissertation is the transitional vocalic element, the treatment of these hypotheses will focus on this element. References to the preceding vowel will be made only for comparative purposes and whenever relevant.

Hypothesis 2a predicted that the acoustic characteristics of the transitional vocalic element would vary as a function of speaking rate. This hypothesis is confirmed by the results of the paired-samples t-tests carried out to test for simple main effects between slow and fast rates at every context level separately for transition F1 and transition F2. These tests yielded significant results in most cases, and large effect sizes for significant differences were also the norm. The bar graphs which were intended to illustrate the mean values for pairwise comparisons between the slow and fast rates made it easy for differences to be identified as regards which of the two rates exhibited higher and lower values and which tokens showed greater or smaller rate differences. For transition F1, the tendency was for the slow tokens to exhibit higher values than for the fast ones in the V+/l/ sequences and for the fast tokens to exhibit higher values than for the slow ones in the V+/r/ sequences. Diphthongized vowels and diphthongs tended to show the greatest rate differences in only the V+/r/ sequences. For transition F2, the slow tokens tended to exhibit higher values than the fast ones. In the V+/l/ sequences, the greatest differences tended to be revealed by high vowels, and more so by front than back ones, but the differences were very similar for all the tokens of the V+/r/ sequences.

Despite similarities suggested by these tendencies, the significant results implying significant rate differences provide evidence of the high degree of variability that exists between slow and fast rates in the transitions. This variability can then be understood as an indication of the coarticulatory nature of the transitional vocalic element, which is characterized by not having a clearly defined target and can thus not be considered an epenthetic vowel. If this element had a clearly defined target, such variability would be less remarkable or even inexistent. This would in turn imply that this element would have similar F1 and F2 values independently of which the preceding vowel is. Therefore, it could be appropriately termed *schwa*, since these values are more similar to those of schwa than to those of any other vowel.

As the results of the paired-samples t-tests also show, the preceding vowels show a similar pattern of behavior to that of the transitions as regards significant differences that can be interpreted as a manifestation of the high variability existing in them. This is the expected outcome for the preceding vowels because they are all 'different vowels', each with its own specific target. In the case of the transitional vocalic elements, these should also be understood as being all "different", and this is so because they all come from a different preceding vowel and are thus the result of the coarticulatory process required to go from the preceding vowel to the following consonant.

Hypothesis 2b predicted that the acoustic characteristics of the transitional vocalic element would vary as a function of context. This hypothesis is confirmed by the results of the one-way repeated measures ANOVAs performed to test for simple main effects of context at the two rate levels separately for the transition. Because these ANOVAs considered all contexts together, though separated by rate, the subsequently performed Bonferroni post-hoc tests were the ones that determined the actual context differences for transition F1 and transition F2. The ANOVAs yielded significant results in all cases. Effect sizes were large, and the tendency was for them to have similar values for the slow and fast rates and to be slightly smaller than for the vowel. The results of the Bonferroni post-hoc tests revealed a very small number of non-significant pairwise comparisons. This was about the same for F1 and F2, for the slow and fast tokens in the V+/l/ sequences, but it was lower for the fast tokens than for the slow ones for F2, and especially for F1, in the V+/r/ sequences. Because the number was small, there were hardly any coincidences of non-significant pairs between the slow and fast rates. Moreover, it was impossible to classify them according to phonological parameters, despite the general tendency for some of the non-significant pairs to consist of similar vowels. Similarly, the actual p values differed from case to case.

These significant results offer further support for the view in favor of the coarticulatory and targetless nature of the transitional vocalic element. The existence of only a few non-significant differences between contexts, the lack of coincidences between rates, and the differing p values can all be taken as evidence of the variability to which this element is subject. As with the paired-samples t-tests, the results of the ANOVAs and Bonferroni post-hoc tests showed that the behavior of the transition was comparable to that of the preceding vowel. This is suggestive of a close relationship between the two and corroborates the influence exerted by the preceding vowel on the transitional vocalic element to the point that the former can be considered as responsible for the existing variability in the latter. Also, the fact that some of the non-significant pairs contained similar vowels helps validate this claim since, the more similar the preceding vowels are, the more similar the transitional elements can be expected to be.

Hypothesis 2c predicted that the faster the speaking rate, the more similar to the preceding vowel the acoustic characteristics of the transitional vocalic element would be. This hypothesis is confirmed by the overall results of the paired-samples t-tests performed to test for simple main effects between slow and fast rates at every context level separately for vowel-transition F1 and F2 differences. Although these tests yielded more significant results than non-significant ones, the latter were particularly numerous in the case of F1 differences for the V+/r/ sequences. In addition, compared to the vowel and the transition, vowel-transition differences tended to exhibit a greater number of non-significant cases for both F1 and F2. Despite the existence of non-significant results, some general trends could be observed that point to a resemblance between the acoustic characteristics of the transition and the preceding vowel, as well as to greater similarity between the values of the transition and the preceding vowel in fast tokens than in slow ones.

The bar graphs that illustrate mean values for pairwise comparisons reveal a tendency for the slow tokens to have higher values than the fast ones. The higher these values, the greater the differences between the vowel and the transition. Conversely, the lower the values, the smaller the differences. This can also be interpreted in terms of distance (i.e, how far from or close to each other the values of the transition and its preceding vowel are), with greater differences implying a longer distance and smaller ones implying a shorter one. According to these parameters, then, higher values are equivalent to greater differences, which are in turn equivalent to longer distances, and which is what the slow tokens tend to exhibit. On the other hand, lower values are equivalent to smaller differences, which are in turn equivalent to shorter distances, which is what the fast tokens tend to exhibit. Regardless of whether the differences are significant or non-significant, this pattern of behavior is particularly noticeable in the case of F2, for both the V+/r/ sequences, where there is no exception, and the V+/l/ sequences, where there is only one exception (i.e., *bill*), with no logical explanation to justify it. To a lesser degree, this pattern can also be observed in the case of F1 for the V+/r/ sequences, which has two exceptions (i.e., *hire* and *power*), which happen to be the two words that contain diphthongs. The case of F1 for the V+/l/ sequences, however, complies with this pattern in only half of the cases (i.e., *bill*, *boil*, *feel*, *fell*, *furl*, *pale* and *pool*), with the remaining half following the reverse pattern (i.e., *hole*, *howl*, *hull*, *pal*, *Paul*, *pile* and *pull*). If a tendency is to be found, it would be for front vowels and high back vowels to exhibit the pattern, but *furl*, *howl*, *hull*, *pal*, *pile* and *pull* would account for too many exceptions for this to be really considered a tendency.

This pattern of behavior can be interpreted as further evidence that the transitional vocalic element in the V+/l/ and V+/r/ sequences under study is the result of a dynamic phonetic process of coarticulation rather than of a discrete phonological one of epenthesis/insertion. As speech rate increases, the degree of gestural overlap and blending increases as well. Similarly, an increase in speech rate entails a decrease in time for articulatory gestures to attain their targets. Consequently, the acoustic characteristics of the transitional vocalic element in the sequences tend to resemble more those of its preceding vowel the faster the speaking rate. This view is in accordance with the dynamic, continuous and overlapping nature of synchronic speech production.

4.4 Contributions, limitations and further research

This dissertation provides new insights into the fields of the phonetics-phonology interface, acoustic phonetics and articulatory dynamics. It also sets the ground for future research in articulatory phonetics, speech perception, sound change and second language acquisition and learning.

One of the novel contributions of this dissertation is that it has considered all the possible V+/l/ and V+/r/ contexts instead of just a few, such as those consisting of high front and high back vowels. This limited number of contexts has been the object of study of the scant previous published work on the subject. Whether the phenomenon applies to more contexts than these cannot be clearly inferred from the results of previous studies. The phonological transcriptions of the sequences as they appear in pronunciation dictionaries and manuals point to restricted contexts as well, although in these a few more contexts are considered. Rather than take for granted that the transitional vocalic element is only present after the aforementioned vowels, or that it is simply more noticeable after these, and thus limit the object of study only to them, this dissertation has aimed to show that the process is a generalized one affecting all contexts, not without assuming, on the basis of available sources and published work, that it might do so to different degrees depending on context.

A second novel contribution of this dissertation is that it has taken speaking rate into consideration, something to which previous studies had paid little or no attention. Having a third, intermediate, speaking rate (i.e., between slow and fast) is a possibility to contemplate for future research. However, as pilot studies had already revealed, it might be quite impractical given the strong requirement to control for speaking rate and the difficulty to do so when three speaking rates are involved (see Chapter 2, section 2.3). The most probable outcome would thus be for many of the intermediate-rate tokens to have to be discarded for being too similar to either the slow or the fast ones. In any case, the combination of two speaking rates (i.e., slow and fast) and a total of 22 contexts (i.e., 15 and seven for the V+/l/ and V+/r/ sequences, respectively) has rendered this study an ambitious enough one.

A third novel contribution of this dissertation is that the segmentation procedure, apart from relying on a manual method based on spectrographic observation, has been complemented with an automatic one consisting of first derivative curve extraction. Delimiting speech signal boundaries on the sole basis of spectrographic observation would have proven too difficult and cumbersome a task. Doing so by means of first derivative curve extraction is still not problem-free, but it has certainly made the segmentation task easier and more reliable and has provided the necessary degree of objectivity expected of any experimental method. In addition, the formant vowel normalization procedure to which the data have been submitted has added robustness to the experimental method. On the other hand, the limitations posed by an acoustic analysis of the type reported here, based on segmentation as well as duration and spectral measurements, could be overcome by gathering articulatory data and conducting, in combination with an acoustic analysis, an articulatory analysis of the type offered, for example, by the Electromagnetic Midsagittal Articulometer (EMMA) or ultrasound techniques. Finally, this study has depended on production data only. A perception study would be necessary if a better understanding of the nature of the phonetic and phonological processes at play is to be achieved. A production and perception study of V+/l/ and V+/r/ sequences with implications for second or foreign language acquisition and learning with a focus on pronunciation is another possibility to contemplate.

The number of participants in this dissertation has been limited to six speakers of American English. Increasing the number would most probably not yield very different results. Alternatively, accent could be more carefully controlled for, although special care had already been taken before the experiments were performed to ensure that the speakers' accents were not marked by any strong idiolectal or dialectal traits (see Chapter 2, section 2.1). Part of the data inspection process was also meant for this purpose (see Chapter 2, section 2.4.3). Cautiously controlling for accent may not only help unveil context differences that have not been detected in the present study, but it may as well disclose that some of the differences detected may not actually be such. In addition, having speakers from different varieties of English might be too forceful an enterprise but it might as well provide unthought-of insights. Further, cross-language studies involving languages like Catalan or Dutch, which have a dark /l/ as part of their phonetic inventories, would highlight similarities and differences among the different languages that would probably offer a clearer picture of the characteristics of the V+/l/ sequences in each of them. Finally, part of the data gathered for this dissertation could be useful to explain how the analysis of final V+/r/ sequences in a rhotic variety such as 21st-century American English can be used to account for the process of /r/-vocalization that started taking place in British English during the transition from the 17th to the 18th centuries.

The present study was not designed to determine the role of context in terms of phonological parameters for the classification of vowels. Even though, at certain stages of the analysis of the results, it has been necessary to look for some type of explanation based on this type of classification, this has not been part of any of the research questions, objectives or hypotheses of this dissertation, and any attempt at doing so has in fact been rather unsuccessful. A different kind of study should be designed to look into this issue. Also, this study has not included any analysis of canonical schwa. Although previous work carried out by the author had looked into comparisons of the transitional vocalic element and what can be considered as the closest possible to a fully-licensed schwa (see Chapter 1, section 1.4), the non-existence of the exact same phonological contexts in English rules out any comparative study of a much different kind. Finally, despite having gathered the necessary data and having been considered in the initial experimental design and even in some parts of this dissertation, the final consonants in the VC sequences under study (i.e., /l/ and /r/) and the third formant have not formed part of the main analysis or the results. This has been so due to time and space constraints as much as to limitations posed by the vowel normalization method and the inferential statistical analyses performed (see Chapter 2, sections 2.7 and 2.8). Further research could thus be aimed at revealing the extent to which the final consonants influence the presence and magnitude of the transitional vocalic element, at showing how they are influenced by the variability of that element, and at determining the role of the third formant in both the transitional vocalic element and the final consonants.

Last of all, this dissertation has been centered around an entirely phonetic study and has not aimed at providing theoretical explanations for the process that has been the main focus of investigation. Still, given the conclusions presented in it regarding the coarticulatory nature of the transitional vocalic element in the V+/l/ and V+/r/ sequences, an analysis within the framework of Articulatory Phonology would seem pertinent. This, however, together with the rest of the suggestions made in this section, must remain for now the object of future work.

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Appendix A

Questionnaire

Appendix A presents the questionnaire that the six subjects were asked to fill out before they took part in the production experiment.

Subject: _______ Date: ________ ________ ________
year *month* *day*

First name: __________ Middle name: __________ Last name(s): ___________

E-mail address: ________________________ Phone #: _______________

Date of birth: ________ ________ ________ Age: ______ Sex: ______
day month year

Place of birth: _____________ _____________ _____________
town/city state/province country

Place of residency:

1. From ages ___ to ___ : _____________ _____________ _____________
   town/city state/province country
2. From ages ___ to ___ : _____________ _____________ _____________
   town/city state/province country
3. From ages ___ to ___ : _____________ _____________ _____________
   town/city state/province country
4. From ages ___ to ___ : _____________ _____________ _____________
   town/city state/province country
5. From ages ___ to ___ : _____________ _____________ _____________
   town/city state/province country
6. From ages ___ to ___ : _____________ _____________ _____________
   town/city state/province country

1st language(s): __________ __________ __________

2nd language(s): __________ __________ __________

Foreign language(s): __________ __________ __________

Father's 1st language(s): __________ __________ __________

Mother's 1st language: __________ __________ __________

Language(s) spoken at home: __________ __________ __________

Language(s) spoken with friends: __________ __________ __________

Language(s) spoken at school/in college: __________ __________ __________

Language(s) spoken at work: __________ __________ __________

Are you currently

studying? ______ Where? ______________________________

What? ______________________________

working? ______ Where? ______________________________

Doing what? ______________________________

Previous studies:

____ Secondary School: When? ______________________________

Where? ______________________________

____ College/university: What? ______________________________

When? ______________________________

Where? ______________________________

Which accent of American English would you say you have?

_____ North eastern	_____ Upper southern	_____ Midwestern
_____ Eastern	_____ Lower southern	_____ Western

Have you ever taken a phonetics and/or phonology course? _____

Course name: ______________________________

When? ____________ Where? ______________________________

Course name: ______________________________

When? ____________ Where? ______________________________

Course name: ______________________________

When? ____________ Where? ______________________________

Have you ever taken part in a phonetics experiment? _____

When? ____________ Where? ______________________________

What were you required to do? ______________________________

____

Do you have any

visual impairment? ______ Specify: ______________________________

hearing impairment? ______ Specify: ______________________________

speaking impairment? ______ Specify: ______________________________

Appendix B

Instructions

Appendix B presents the instructions that the six subjects were given before they performed the trial and experimental sessions .

Part 1 (55-60 min)	Break (30 min)	Part 2 (30-35 min)

Part 1 (55-60 min)

Instructions (10 min)
Trial: Slow (6 min 45 s)
Break (5-10 min)
Experiment: Slow (32 min)

Read sentences: **slow** speaking rate

78 sentences in **trial**
370 sentences in **experiment**

Slides presented in **blocks**
75 sentences in each block

4 s to read each sentence
1 s between slides

REST slide between blocks

THE END slide at the end

Break (30 min)

Part 2 (30-35 min)

Instructions (10 min)
Trial: Fast (2 min 35 s)
Break (5-10 min)
Experiment: Fast (12 min)

Read sentences: **fast** speaking rate

78 sentences in **trial**
370 sentences in **experiment**

Slides presented in **blocks**
75 sentences in each block

1 s to read each sentence
0 s between slides
54321 every 5 sentences

REST slide between blocks

THE END slide at the end

Keep the same **pace**.
Keep the same **rhythm**.
Keep the same **intonation**.

Go on even if you make **mistakes**.

Don't emphasize the target word.

Relax during *REST* periods.
Drink water during *REST* periods.
Save files during *REST* periods.

TRIAL: Slow


Say shop for me again.
Say cat for me again.
Say soup for me again.
Say height for me again.
Say house for me again.
Say phone for me again.
REST
Say love for me again.
Say shop for me again.
Say nurse for me again.
Say noise for me again.
Say mail for me again.
Say house for me again.
Say beach for me again.
Say ship for me again.
Say book for me again.
Say nurse for me again.
Say rain for me again.
Say loud for me again.
THE END

TRIAL: Fast

Say shop for me again.	1	2	3
Say house for me again.	Say soup for me again.	1	2
Say nurse for me again.	Say love for me again.	Say phone for me again.	1
Say beach for me again.	Say mail for me again.	Say noise for me again.	Say soul for me again.
Say rain for me again.	Say book for me again.	Say ship for me again.	REST
5	Say cat for me again.	Say loud for me again.	Say shop for me again.
4	5	Say height for me again.	Say house for me again.
3	4	5	Say nurse for me again.
2	3	4	THE END

Appendix C

Stimuli presentation

The following four lists contain all the stimuli presented in the order in which they were shown in the Power Point slide presentations used in the trial (Lists 1 and 2) and experimental (Lists 3 and 4) sessions for the slow (Lists 1 and 3) and fast (Lists 2 and 4) speaking rate readings performed by each subject.

Lists 1 and 2 (trial) consist of 78 sentences each, divided into three groups of 25 randomized sentences, plus the first three sentences of a fourth group. Lists 3 and 4 (experiment) contain 10 groups of 37 randomized sentences (22 with target words; 15 with distracters), yielding a total of 370 sentences for each list.

When appropriate, each list provides information regarding type of session and speaking rate (*Trial: Slow* and *Trial: Fast* or *Experiment: Slow* and *Experiment: Fast*), number of randomized repetition (from Group 1 to Group 4 or to Group 10), breaks (*REST* and *54321*), and end of presentation (*THE END*).

The trial, target and distracter words on these lists are shown in italics to facilitate identification. In the original presentations, however, these words were written in normal font type to prevent the speakers from saying them with too much emphasis.

List 1

Trial: Slow

Group 1
Say *shop* for me again.
Say *house* for me again.
Say *nurse* for me again.
Say *beach* for me again.
Say *rain* for me again.
Say *soup* for me again.
Say *love* for me again.
Say *mail* for me again.
Say *book* for me again.
Say *cat* for me again.
Say *phone* for me again.
Say *noise* for me again.
Say *ship* for me again.
Say *loud* for me again.
Say *height* for me again.
Say *soul* for me again.
Say *car* for me again.
Say *pen* for me again.
Say *seem* for me again.
Say *wood* for me again.
Say *course* for me again.
Say *fruit* for me again.
Say *sun* for me again.
Say *church* for me again.
Say *yes* for me again.

Group 2
Say *car* for me again.
Say *mail* for me again.
Say *wood* for me again.
Say *nurse* for me again.
Say *soul* for me again.
Say *yes* for me again.
Say *cat* for me again.
Say *height* for me again.
Say *sun* for me again.
Say *beach* for me again.
Say *course* for me again.
Say *seem* for me again.
Say *shop* for me again.
Say *rain* for me again.
Say *book* for me again.
Say *house* for me again.
Say *ship* for me again.
Say *phone* for me again.
Say *soup* for me again.
Say *fruit* for me again.
Say *pen* for me again.
Say *loud* for me again.
Say *noise* for me again.
Say *love* for me again.
Say *church* for me again.

Group 3
Say *loud* for me again.
Say *course* for me again.
Say *wood* for me again.
Say *ship* for me again.
Say *seem* for me again.
Say *height* for me again.
Say *book* for me again.
Say *car* for me again.
Say *pen* for me again.
Say *house* for me again.
Say *noise* for me again.
Say *shop* for me again.
Say *nurse* for me again.
Say *soul* for me again.
Say *beach* for me again.
Say *rain* for me again.
Say *yes* for me again.
Say *soup* for me again.
Say *love* for me again.
Say *mail* for me again.
Say *fruit* for me again.
Say *cat* for me again.
Say *church* for me again.
Say *sun* for me again.
Say *phone* for me again.

REST

Group 4
Say *shop* for me again.
Say *house* for me again.
Say *nurse* for me again.

THE END

List 2

Trial: Fast

Group 1
Say *shop* for me again.
Say *house* for me again.
Say *nurse* for me again.
Say *beach* for me again.
Say *rain* for me again.
54321
Say *soup* for me again.
Say *love* for me again.
Say *mail* for me again.
Say *book* for me again.
Say *cat* for me again.
54321
Say *phone* for me again.
Say *noise* for me again.
Say *ship* for me again.
Say *loud* for me again.
Say *height* for me again.
54321
Say *soul* for me again.
Say *car* for me again.
Say *pen* for me again.
Say *seem* for me again.
Say *wood* for me again.
54321
Say *course* for me again.
Say *fruit* for me again.
Say *sun* for me again.
Say *church* for me again.
Say *yes* for me again.
54321

Group 2
Say *car* for me again.
Say *mail* for me again.
Say *wood* for me again.
Say *nurse* for me again.
Say *soul* for me again.
54321
Say *yes* for me again.
Say *cat* for me again.
Say *height* for me again.
Say *sun* for me again.
Say *beach* for me again.
54321
Say *course* for me again.
Say *seem* for me again.
Say *shop* for me again.
Say *rain* for me again.
Say *book* for me again.
54321
Say *house* for me again.
Say *ship* for me again.
Say *phone* for me again.
Say *soup* for me again.
Say *fruit* for me again.
54321
Say *pen* for me again.
Say *loud* for me again.
Say *noise* for me again.
Say *love* for me again.
Say *church* for me again.
54321

Group 3
Say *loud* for me again.
Say *course* for me again.
Say *wood* for me again.
Say *ship* for me again.
Say *seem* for me again.
54321
Say *height* for me again.
Say *book* for me again.
Say *car* for me again.
Say *pen* for me again.
Say *house* for me again.
54321
Say *noise* for me again.
Say *shop* for me again.
Say *nurse* for me again.
Say *soul* for me again.
Say *beach* for me again.
54321
Say *rain* for me again.
Say *yes* for me again.
Say *soup* for me again.
Say *love* for me again.
Say *mail* for me again.
54321
Say *fruit* for me again.
Say *cat* for me again.
Say *church* for me again.
Say *sun* for me again.
Say *phone* for me again.
REST

Group 4
Say *shop* for me again.
Say *house* for me again.
Say *nurse* for me again.
THE END

List 3

Experiment: Slow

Group 1
Say *feel* for me again.
Say *hate* for me again.
Say *pore* for me again.
Say *hood* for me again.
Say *pool* for me again.
Say *heard* for me again.
Say *fell* for me again.
Say *vote* for me again.
Say *fit* for me again.
Say *par* for me again.
Say *power* for me again.
Say *fat* for me again.
Say *fear* for me again.
Say *hut* for me again.
Say *furl* for me again.
Say *pal* for me again.
Say *pile* for me again.
Say *hire* for me again.
Say *Paul* for me again.
Say *fought* for me again.
Say *boil* for me again.
Say *hole* for me again.
Say *food* for me again.
Say *pale* for me again.
Say *vet* for me again.
Say *howl* for me again.
Say *void* for me again.
Say *Poll* for me again.
Say *hull* for me again.
Say *hide* for me again.
Say *bill* for me again.
Say *heat* for me again.
Say *pull* for me again.
Say *vowed* for me again.
Say *hot* for me again.
Say *fair* for me again.
Say *poor* for me again.

Group 2
Say *boil* for me again.
Say *fell* for me again.
Say *poor* for me again.
Say *fat* for me again.
Say *pore* for me again.
Say *hood* for me again.
Say *feel* for me again.
Say *hire* for me again.
Say *par* for me again.
Say *howl* for me again.
Say *void* for me again.
Say *pale* for me again.
Say *hate* for me again.
Say *vowed* for me again.
Say *hull* for me again.
Say *fought* for me again.
Say *pal* for me again.
Say *hut* for me again.
Say *power* for me again.
Say *heard* for me again.
Say *pull* for me again.
Say *hot* for me again.
Say *fear* for me again.
Say *vet* for me again.
Say *Poll* for me again.
Say *hole* for me again.
Say *fair* for me again.
Say *heat* for me again.
Say *hide* for me again.
Say *pile* for me again.
Say *pool* for me again.
Say *vote* for me again.
Say *bill* for me again.
Say *food* for me again.
Say *fit* for me again.
Say *Paul* for me again.
Say *furl* for me again.

Group 3
Say *pile* for me again.
REST
Say *vet* for me again.
Say *fit* for me again.
Say *pale* for me again.
Say *heard* for me again.
Say *bill* for me again.
Say *hood* for me again.
Say *par* for me again.
Say *hull* for me again.
Say *pal* for me again.
Say *hire* for me again.
Say *fear* for me again.
Say *hole* for me again.
Say *furl* for me again.
Say *vote* for me again.
Say *fell* for me again.
Say *hide* for me again.
Say *Paul* for me again.
Say *howl* for me again.
Say *fat* for me again.
Say *hate* for me again.
Say *Poll* for me again.
Say *hot* for me again.
Say *poor* for me again.
Say *heat* for me again.
Say *hut* for me again.
Say *vowed* for me again.
Say *pool* for me again.
Say *void* for me again.
Say *feel* for me again.
Say *pull* for me again.
Say *fought* for me again.
Say *power* for me again.
Say *fair* for me again.
Say *food* for me again.
Say *boil* for me again.
Say *pore* for me again.

Group 4
Say *hot* for me again.
Say *Poll* for me again.
Say *hire* for me again.
Say *vowed* for me again.
Say *par* for me again.
Say *heat* for me again.
Say *poor* for me again.

Say *fat* for me again.
Say *boil* for me again.
Say *feel* for me again.
Say *hull* for me again.
Say *heard* for me again.
Say *fear* for me again.
Say *void* for me again.
Say hut for me again.
Say *fought* for me again.
Say *bill* for me again.
Say *power* for me again.
Say *pale* for me again.
Say *hide* for me again.
Say *pile* for me again.
Say *pal* for me again.
Say *hood* for me again.
Say *furl* for me again.
Say *fair* for me again.
Say *food* for me again.
Say *hole* for me again.
Say *fit* for me again.
Say *vote* for me again.
Say *Paul* for me again.
Say *fell* for me again.
Say *howl* for me again.
Say *pull* for me again.
Say *hate* for me again.
Say *pore* for me again.
Say *vet* for me again.
Say *pool* for me again.

Group 5
Say *fit* for me again.
Say *hut* for me again.
REST
Say *Poll* for me again.
Say *fought* for me again.
Say *pull* for me again.
Say *food* for me again.
Say *fear* for me again.
Say *hire* for me again.
Say *furl* for me again.
Say *pal* for me again.
Say *heat* for me again.
Say *void* for me again.
Say *pale* for me again.
Say *hide* for me again.
Say *pool* for me again.
Say *heard* for me again.
Say *power* for me again.
Say *vet* for me again.
Say *Paul* for me again.
Say *fat* for me again.
Say *par* for me again.
Say *vote* for me again.
Say *poor* for me again.
Say *hot* for me again.
Say *feel* for me again.
Say *hole* for me again.
Say *pile* for me again.
Say *hood* for me again.
Say *fell* for me again.
Say *boil* for me again.
Say *bill* for me again.
Say *hull* for me again.
Say *pore* for me again.
Say *hate* for me again.
Say *fair* for me again.
Say *howl* for me again.
Say *vowed* for me again.

Group 6
Say *hire* for me again.
Say *void* for me again.
Say *Paul* for me again.
Say *vet* for me again.
Say *feel* for me again.
Say *hide* for me again.
Say *hull* for me again.
Say *fit* for me again.
Say *pal* for me again.
Say *hole* for me again.
Say *bill* for me again.
Say *hood* for me again.
Say *par* for me again.
Say *fought* for me again.
Say *pool* for me again.
Say *hut* for me again.
Say *fair* for me again.
Say *vowed* for me again.
Say *pile* for me again.
Say *power* for me again.
Say *poor* for me again.
Say *fat* for me again.
Say *Poll* for me again.
Say *hate* for me again.
Say *pull* for me again.
Say *food* for me again.
Say *fell* for me again.
Say *vote* for me again.
Say *pale* for me again.
Say *howl* for me again.
Say *pore* for me again.
Say *furl* for me again.
Say *hot* for me again.
Say *fear* for me again.
Say *heard* for me again.
Say *boil* for me again.
Say *heat* for me again.

Group 7
Say *pile* for me again.
Say *heard* for me again.
Say *Poll* for me again.
REST
Say *hide* for me again.
Say *feel* for me again.
Say *hot* for me again.
Say *bill* for me again.
Say *hood* for me again.
Say *pale* for me again.
Say *howl* for me again.
Say *fear* for me again.
Say *vote* for me again.
Say *hole* for me again.
Say *power* for me again.
Say *fell* for me again.
Say *fought* for me again.
Say *fair* for me again.
Say *poor* for me again.
Say *hut* for me again.
Say *vowed* for me again.
Say *fat* for me again.
Say *furl* for me again.
Say *void* for me again.
Say *hire* for me again.
Say *boil* for me again.
Say *pal* for me again.

Say *hull* for me again.
Say *hate* for me again.
Say *vet* for me again.
Say *pull* for me again.
Say *Paul* for me again.
Say *heat* for me again.
Say *par* for me again.
Say *fit* for me again.
Say *pore* for me again.
Say *food* for me again.
Say *pool* for me again.

Group 8

Say *vote* for me again.
Say *furl* for me again.
Say *heat* for me again.
Say *void* for me again.
Say *feel* for me again.
Say *pile* for me again.
Say *hut* for me again.
Say *bill* for me again.
Say *hate* for me again.
Say *Poll* for me again.
Say *howl* for me again.
Say *pale* for me again.
Say *fat* for me again.
Say *Paul* for me again.
Say *fought* for me again.
Say *fair* for me again.
Say *vowed* for me again.
Say *power* for me again.
Say *poor* for me again.
Say *heard* for me again.
Say *food* for me again.
Say *hole* for me again.
Say *fit* for me again.
Say *pal* for me again.
Say *hull* for me again.
Say *vet* for me again.
Say *pore* for me again.
Say *hood* for me again.
Say *pull* for me again.
Say *boil* for me again.
Say *fear* for me again.
Say *hide* for me again.
Say *fell* for me again.
Say *pool* for me again.
Say *hot* for me again.
Say *par* for me again.
Say *hire* for me again.

Group 9

Say *heat* for me again.
Say *fair* for me again.
Say *pile* for me again.
Say *fat* for me again.

REST

Say *pale* for me again.
Say *hull* for me again.
Say *power* for me again.
Say *fear* for me again.
Say *hire* for me again.
Say *hole* for me again.
Say *pool* for me again.
Say *vet* for me again.
Say *pal* for me again.
Say *fought* for me again.
Say *pore* for me again.
Say *food* for me again.
Say *howl* for me again.
Say *poor* for me again.
Say *hide* for me again.
Say *vowed* for me again.
Say *boil* for me again.
Say *fell* for me again.
Say *heard* for me again.
Say *par* for me again.
Say *fit* for me again.
Say *feel* for me again.
Say *vote* for me again.
Say *Paul* for me again.
Say *hut* for me again.
Say *hate* for me again.
Say *bill* for me again.
Say *furl* for me again.
Say *hot* for me again.
Say *Poll* for me again.
Say *hood* for me again.
Say *pull* for me again.
Say *void* for me again.

Group 10

Say *bill* for me again.
Say *power* for me again.
Say *par* for me again.
Say *fit* for me again.
Say *poor* for me again.
Say *pale* for me again.
Say *hide* for me again.
Say *pal* for me again.
Say *vet* for me again.
Say *howl* for me again.
Say *feel* for me again.
Say *pore* for me again.
Say *hot* for me again.
Say *hull* for me again.
Say *heard* for me again.
Say *furl* for me again.
Say *hood* for me again.
Say *vowed* for me again.
Say *hire* for me again.
Say *food* for me again.
Say *heat* for me again.
Say *fell* for me again.
Say *pull* for me again.
Say *fought* for me again.
Say *fear* for me again.
Say *hate* for me again.
Say *Paul* for me again.
Say *hut* for me again.
Say *hole* for me again.
Say *void* for me again.
Say *pool* for me again.
Say *fair* for me again.
Say *boil* for me again.
Say *fat* for me again.
Say *Poll* for me again.
Say *vote* for me again.
Say *pile* for me again.

THE END

List 4

Experiment: Fast

Group 1
Say *feel* for me again.
Say *hate* for me again.
Say *pore* for me again.
Say *hood* for me again.
Say *pool* for me again.
54321
Say *heard* for me again.
Say *fell* for me again.
Say *vote* for me again.
Say *fit* for me again.
Say *par* for me again.
54321
Say *power* for me again.
Say *fat* for me again.
Say *fear* for me again.
Say *hut* for me again.
Say *furl* for me again.
54321
Say *pal* for me again.
Say *pile* for me again.
Say *hire* for me again.
Say *Paul* for me again.
Say *fought* for me again.
54321
Say *boil* for me again.
Say *hole* for me again.
Say *food* for me again.
Say *pale* for me again.
Say *vet* for me again.
54321
Say *howl* for me again.
Say *void* for me again.
Say *Poll* for me again.
Say *hull* for me again.
Say *hide* for me again.
54321
Say *bill* for me again.
Say *heat* for me again.
Say *pull* for me again.
Say *vowed* for me again.
Say *hot* for me again.
54321
Say *fair* for me again.
Say *poor* for me again.

Group 2
Say *boil* for me again.
Say *fell* for me again.
Say *poor* for me again.
54321
Say *fat* for me again.
Say *pore* for me again.
Say *hood* for me again.
Say *feel* for me again.
Say *hire* for me again.
54321
Say *par* for me again.
Say *howl* for me again.
Say *void* for me again.
Say *pale* for me again.
Say *hate* for me again.
54321
Say *vowed* for me again.
Say *hull* for me again.
Say *fought* for me again.
Say *pal* for me again.
Say *hut* for me again.
54321
Say *power* for me again.
Say *heard* for me again.
Say *pull* for me again.
Say *hot* for me again.
Say *fear* for me again.
54321
Say *vet* for me again.
Say *Poll* for me again.
Say *hole* for me again.
Say *fair* for me again.
Say *heat* for me again.
54321
Say *hide* for me again.
Say *pile* for me again.
Say *pool* for me again.
Say *vote* for me again.
Say *bill* for me again.
54321
Say *food* for me again.
Say *fit* for me again.
Say *Paul* for me again.
Say *furl* for me again.

Group 3
Say *pile* for me again.
REST
Say *vet* for me again.
Say *fit* for me again.
Say *pale* for me again.
Say *heard* for me again.
Say *bill* for me again.
54321
Say *hood* for me again.
Say *par* for me again.
Say *hull* for me again.
Say *pal* for me again.
Say *hire* for me again.
54321
Say *fear* for me again.
Say *hole* for me again.
Say *furl* for me again.
Say *vote* for me again.
Say *fell* for me again.
54321
Say *hide* for me again.
Say *Paul* for me again.
Say *howl* for me again.
Say *fat* for me again.
Say *hate* for me again.
54321
Say *Poll* for me again.
Say *hot* for me again.
Say *poor* for me again.
Say *heat* for me again.
Say *hut* for me again.
54321
Say *vowed* for me again.

Say *pool* for me again.
Say *void* for me again.
Say *feel* for me again.
Say *pull* for me again.
54321
Say *fought* for me again.
Say *power* for me again.
Say *fair* for me again.
Say *food* for me again.
Say *boil* for me again.
54321
Say *pore* for me again.

Say *fit* for me again.
Say *vote* for me again.
54321
Say *Paul* for me again.
Say *fell* for me again.
Say *howl* for me again.
Say *pull* for me again.
Say *hate* for me again.
54321
Say *pore* for me again.
Say *vet* for me again.
Say *pool* for me again.

54321
Say *hood* for me again.
Say *fell* for me again.
Say *boil* for me again.
Say *bill* for me again.
Say *hull* for me again.
54321
Say *pore* for me again.
Say *hate* for me again.
Say *fair* for me again.
Say *howl* for me again.
Say *vowed* for me again.
54321

Group 4
Say *hot* for me again.
Say *Poll* for me again.
Say *hire* for me again.
Say *vowed* for me again.
54321
Say *par* for me again.
Say *heat* for me again.
Say *poor* for me again.
Say *fat* for me again.
Say *boil* for me again.
54321
Say *feel* for me again.
Say *hull* for me again.
Say *heard* for me again.
Say *fear* for me again.
Say *void* for me again.
54321
Say *hut* for me again.
Say *fought* for me again.
Say *bill* for me again.
Say *power* for me again.
Say *pale* for me again.
54321
Say *hide* for me again.
Say *pile* for me again.
Say *pal* for me again.
Say *hood* for me again.
Say *furl* for me again.
54321
Say *fair* for me again.
Say *food* for me again.
Say *hole* for me again.

Group 5
Say *fit* for me again.
Say *hut* for me again.
REST
Say *Poll* for me again.
Say *fought* for me again.
Say *pull* for me again.
Say *food* for me again.
Say *fear* for me again.
54321
Say *hire* for me again.
Say *furl* for me again.
Say *pal* for me again.
Say *heat* for me again.
Say *void* for me again.
54321
Say *pale* for me again.
Say *hide* for me again.
Say *pool* for me again.
Say *heard* for me again.
Say *power* for me again.
54321
Say *vet* for me again.
Say *Paul* for me again.
Say *fat* for me again.
Say *par* for me again.
Say *vote* for me again.
54321
Say *poor* for me again.
Say *hot* for me again.
Say *feel* for me again.
Say *hole* for me again.
Say *pile* for me again.

Group 6
Say *hire* for me again.
Say *void* for me again.
Say *Paul* for me again.
Say *vet* for me again.
Say *feel* for me again.
54321
Say *hide* for me again.
Say *hull* for me again.
Say *fit* for me again.
Say *pal* for me again.
Say *hole* for me again.
54321
Say *bill* for me again.
Say *hood* for me again.
Say *par* for me again.
Say *fought* for me again.
Say *pool* for me again.
54321
Say *hut* for me again.
Say *fair* for me again.
Say *vowed* for me again.
Say *pile* for me again.
Say *power* for me again.
54321
Say *poor* for me again.
Say *fat* for me again.
Say *Poll* for me again.
Say *hate* for me again.
Say *pull* for me again.
54321
Say *food* for me again.

Say *fell* for me again.
Say *vote* for me again.
Say *pale* for me again.
Say *howl* for me again.
54321
Say *pore* for me again.
Say *furl* for me again.
Say *hot* for me again.
Say *fear* for me again.
Say *heard* for me again.
54321
Say *boil* for me again.
Say *heat* for me again.

Say *hull* for me again.
Say *hate* for me again.
54321
Say *vet* for me again.
Say *pull* for me again.
Say *Paul* for me again.
Say *heat* for me again.
Say *par* for me again.
54321
Say *fit* for me again.
Say *pore* for me again.
Say *food* for me again.
Say *pool* for me again.

54321
Say *pore* for me again.
Say *hood* for me again.
Say *pull* for me again.
Say *boil* for me again.
Say *fear* for me again.
54321
Say *hide* for me again.
Say *fell* for me again.
Say *pool* for me again.
Say *hot* for me again.
Say *par* for me again.
54321
Say *hire* for me again.

Group 7
Say *pile* for me again.
Say *heard* for me again.
Say *Poll* for me again.
REST
Say *hide* for me again.
Say *feel* for me again.
Say *hot* for me again.
Say *bill* for me again.
Say *hood* for me again.
54321
Say *pale* for me again.
Say *howl* for me again.
Say *fear* for me again.
Say *vote* for me again.
Say *hole* for me again.
54321
Say *power* for me again.
Say *fell* for me again.
Say *fought* for me again.
Say *fair* for me again.
Say *poor* for me again.
54321
Say *hut* for me again.
Say *vowed* for me again.
Say *fat* for me again.
Say *furl* for me again.
Say *void* for me again.
54321
Say *hire* for me again.
Say *boil* for me again.
Say *pal* for me again.

Group 8
Say *vote* for me again.
54321
Say *furl* for me again.
Say *heat* for me again.
Say *void* for me again.
Say *feel* for me again.
Say *pile* for me again.
54321
Say *hut* for me again.
Say *bill* for me again.
Say *hate* for me again.
Say *Poll* for me again.
Say *howl* for me again.
54321
Say *pale* for me again.
Say *fat* for me again.
Say *Paul* for me again.
Say *fought* for me again.
Say *fair* for me again.
54321
Say *vowed* for me again.
Say *power* for me again.
Say *poor* for me again.
Say *heard* for me again.
Say *food* for me again.
54321
Say *hole* for me again.
Say *fit* for me again.
Say *pal* for me again.
Say *hull* for me again.
Say *vet* for me again.

Group 9
Say *heat* for me again.
Say *fair* for me again.
Say *pile* for me again.
Say *fat* for me again.
REST
Say *pale* for me again.
Say *hull* for me again.
Say *power* for me again.
Say *fear* for me again.
Say *hire* for me again.
54321
Say *hole* for me again.
Say *pool* for me again.
Say *vet* for me again.
Say *pal* for me again.
Say fought for me again.
54321
Say *pore* for me again.
Say *food* for me again.
Say *howl* for me again.
Say *poor* for me again.
Say *hide* for me again.
54321
Say *vowed* for me again.
Say *boil* for me again.
Say *fell* for me again.
Say *heard* for me again.
Say *par* for me again.
54321
Say *fit* for me again.

Say *feel* for me again.
Say *vote* for me again.
Say *Paul* for me again.
Say *hut* for me again.
54321
Say *hate* for me again.
Say *bill* for me again.
Say *furl* for me again.
Say *hot* for me again.
Say *Poll* for me again.
54321
Say *hood* for me again.
Say *pull* for me again.
Say *void* for me again.

Group 10
Say *bill* for me again.
Say *power* for me again.
54321
Say *par* for me again.
Say *fit* for me again.
Say *poor* for me again.
Say *pale* for me again.
Say *hide* for me again.
54321
Say *pal* for me again.
Say *vet* for me again.
Say *howl* for me again.
Say *feel* for me again.
Say *pore* for me again.
54321
Say *hot* for me again.
Say *hull* for me again.
Say *heard* for me again.
Say *furl* for me again.
Say *hood* for me again.
54321
Say *vowed* for me again.
Say *hire* for me again.
Say *food* for me again.
Say *heat* for me again.
Say *fell* for me again.
54321
Say *pull* for me again.
Say *fought* for me again.
Say *fear* for me again.
Say *hate* for me again.
Say *Paul* for me again.
54321
Say *hut* for me again.
Say *hole* for me again.
Say *void* for me again.
Say *pool* for me again.
Say *fair* for me again.
54321
Say *boil* for me again.
Say *fat* for me again.
Say *Poll* for me again.
Say *vote* for me again.
Say *pile* for me again.
THE END

Appendix D

Maximum formant (Hz) values

The following tables show the *maximum formant (Hz)* values that were recorded for each token (from T1 to T10) of each subject's slow and fast productions. The tokens are presented in alphabetical order for ease of identification. Mean (M), mode (Mo), median (Mdn) and standard deviation (SD) values are also provided. As stated in Chapter 2 (section 2.4.2), a rounded-up value between those of the mean and the mode was chosen as the *maximum formant (Hz)* value to be used for all the tokens of a given subject.

Table D1 *Maximum formant (Hz) values for Subject 1's slow tokens*

Slow	Subject 1												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	55	55	55	50	50	50	50	50	53	50	51.80	50.00	50.00	2.39
boil	50	55	50	53	53	55	50	55	55	55	53.10	55.00	54.00	2.28
fair	50	50	50	53	50	50	50	50	50	50	50.30	50.00	50.00	0.95
fear	55	50	50	50	55	55	50	55	55	50	52.50	55.00	52.50	2.64
feel	55	55	—	50	50	50	50	50	50	50	51.11	50.00	50.00	2.20
fell	55	55	55	55	53	53	53	50	53	53	53.50	53.00	53.00	1.58
furl	55	53	50	50	50	55	55	55	55	55	53.30	55.00	55.00	2.36
hire	55	53	55	53	53	50	50	50	50	50	51.90	50.00	51.50	2.13
hole	55	55	55	53	50	55	55	55	50	55	53.80	55.00	55.00	2.10
howl	55	55	55	55	53	53	53	50	50	53	53.20	55.00	53.00	1.93
hull	55	53	53	53	55	55	53	53	55	53	53.80	53.00	53.00	1.03
pal	55	55	55	55	55	55	55	55	50	53	54.30	55.00	55.00	1.64
pale	55	55	55	50	55	50	50	53	53	50	52.60	55.00	53.00	2.37
par	53	55	53	53	55	50	50	55	55	50	52.90	55.00	53.00	2.18
Paul	55	55	55	55	53	55	50	50	50	50	52.80	55.00	54.00	2.49
pile	55	55	55	55	53	50	50	55	50	50	52.80	55.00	54.00	2.49
Poll	55	55	53	53	53	53	50	53	53	55	53.30	53.00	53.00	1.49
pool	55	55	50	55	53	53	53	53	55	53	53.50	53.00	53.00	1.58
poor	55	50	53	55	55	55	55	55	55	55	54.30	55.00	55.00	1.64
pore	55	55	55	50	55	55	55	55	53	55	54.30	55.00	55.00	1.64
power	55	55	55	55	55	55	55	53	53	53	54.40	55.00	55.00	0.97
pull	55	55	55	55	55	55	53	55	55	55	54.80	55.00	55.00	0.63
										M	53.11	53.73	53.27	1.85

Table D2 *Maximum formant (Hz) values for Subject 1's fast tokens*

Fast	Subject 1												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	55	50	50	50	50	53	50	50	50	50	50.80	50.00	50.00	1.75
boil	53	53	55	55	55	53	53	53	55	55	54.00	53.00	54.00	1.05
fair	50	50	50	50	55	55	50	50	50	50	51.00	50.00	50.00	2.11
fear	55	55	53	55	—	50	55	55	55	—	54.13	55.00	55.00	1.81
feel	55	55	55	55	55	55	55	50	55	55	54.50	55.00	55.00	1.58
fell	53	53	53	53	53	53	53	53	53	53	53.00	53.00	53.00	0.00
furl	53	53	53	53	50	53	55	55	53	53	53.10	53.00	53.00	1.37
hire	50	50	50	50	55	53	55	55	55	55	52.80	55.00	54.00	2.49
hole	55	53	55	55	53	53	53	53	55	55	54.00	55.00	54.00	1.05
howl	50	53	55	55	55	55	55	55	55	55	54.30	55.00	55.00	1.64
hull	53	53	55	55	55	55	55	55	55	55	54.60	55.00	55.00	0.84
pal	53	50	55	55	55	53	55	53	55	55	53.90	55.00	55.00	1.66
pale	—	53	50	50	50	53	50	50	50	50	50.67	50.00	50.00	1.32
par	55	55	53	53	50	53	55	55	50	53	53.20	55.00	53.00	1.93
Paul	55	53	53	55	53	55	55	55	55	55	54.40	55.00	55.00	0.97
pile	55	53	53	53	53	55	55	55	53	55	54.00	55.00	54.00	1.05
Poll	53	50	50	55	50	55	55	50	53	55	52.60	50.00	53.00	2.37
pool	53	53	50	53	55	53	55	53	55	50	53.00	53.00	53.00	1.83
poor	55	55	55	55	55	55	50	55	55	55	54.50	55.00	55.00	1.58
pore	53	53	55	50	53	53	53	55	55	55	53.50	53.00	53.00	1.58
power	55	55	55	55	55	55	55	55	55	55	55.00	55.00	55.00	0.00
pull	55	55	55	55	55	55	55	55	55	—	55.00	55.00	55.00	0.00
										M	53.45	53.64	53.59	1.36

Table D3 *Maximum formant (Hz) values for Subject 2's slow tokens*

Slow	Subject 2												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	45	45	45	45	46	46	47	47	45	47	45.80	45.00	45.50	0.92
boil	43	43	41	45	46	42	43	42	46	41	43.20	43.00	43.00	1.87
fair	45	44	44	45	45	45	46	45	45	43	44.70	45.00	45.00	0.82
fear	45	45	43	43	43	43	45	44	43	42	43.60	43.00	43.00	1.07
feel	43	43	44	45	47	47	49	55	49	47	46.90	47.00	47.00	3.60
fell	50	45	47	48	48	45	47	46	48	46	47.00	48.00	47.00	1.56
furl	41	40	40	40	43	41	41	40	40	40	40.60	40.00	40.00	0.97
hire	45	42	53	42	46	55	45	55	47	43	47.30	45.00	45.50	5.14
hole	45	45	50	45	50	45	50	50	50	45	47.50	45.00	47.50	2.64
howl	52	45	50	45	43	46	48	50	55	50	48.40	50.00	49.00	3.69
hull	50	50	50	45	45	45	45	50	45	45	47.00	45.00	45.00	2.58
pal	50	45	—	50	50	50	40	45	50	50	47.78	50.00	50.00	3.63
pale	45	45	45	45	45	45	45	45	45	47	45.20	45.00	45.00	0.63
par	44	43	42	44	43	43	43	43	45	45	43.50	43.00	43.00	0.97
Paul	50	47	50	50	47	50	50	50	50	47	49.10	50.00	50.00	1.45
pile	44	44	45	45	55	55	50	45	45	45	47.30	45.00	45.00	4.40
Poll	55	55	55	53	55	55	50	55	45	55	53.30	55.00	55.00	3.33
pool	50	45	55	45	45	50	54	55	48	55	50.20	45.00	50.00	4.34
poor	43	42	50	40	43	43	43	42	43	42	43.10	43.00	43.00	2.60
pore	43	41	43	43	43	42	41	43	42	42	42.30	43.00	42.50	0.82
power	45	41	43	43	43	43	41	42	42	42	42.50	43.00	42.50	1.18
pull	50	53	45	46	52	45	42	48	50	46	47.70	50.00	47.00	3.50
										M	46.09	45.82	45.93	2.35

Table D4 *Maximum formant (Hz) values for Subject 2's fast tokens*

Fast	Subject 2												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	45	50	47	50	50	50	50	50	50	50	49.20	50.00	50.00	1.75
boil	53	47	47	48	50	50	50	50	45	50	49.00	50.00	50.00	2.26
fair	55	55	60	55	55	55	55	55	55	55	55.50	55.00	55.00	1.58
fear	55	55	55	53	55	55	55	55	53	55	54.60	55.00	55.00	0.84
feel	45	50	45	46	50	45	47	45	45	53	47.10	45.00	45.50	2.88
fell	45	50	50	50	50	50	50	50	50	49	49.40	50.00	50.00	1.58
furl	40	40	40	40	43	45	47	50	50	40	43.50	40.00	41.50	4.22
hire	55	55	56	55	53	50	53	53	53	55	53.80	55.00	54.00	1.75
hole	50	50	45	50	50	45	50	50	50	40	48.00	50.00	50.00	3.50
howl	52	50	50	50	50	50	50	50	55	50	50.70	50.00	50.00	1.64
hull	50	55	50	50	50	50	48	50	45	53	50.10	50.00	50.00	2.64
pal	50	50	50	55	50	52	52	52	53	55	51.90	50.00	52.00	1.97
pale	50	55	55	45	53	45	54	55	50	45	50.70	55.00	51.50	4.35
par	40	40	50	40	40	50	47	40	47	50	44.40	40.00	43.50	4.77
Paul	50	50	45	47	50	50	53	53	55	50	50.30	50.00	50.00	2.91
pile	50	50	50	55	50	53	53	52	53	53	51.90	50.00	52.50	1.79
Poll	52	51	50	52	50	51	—	46	52	52	50.67	52.00	51.00	1.94
pool	50	50	42	50	50	50	50	50	50	50	49.20	50.00	50.00	2.53
poor	40	40	40	45	42	43	40	45	45	40	42.00	40.00	41.00	2.31
pore	45	45	45	40	46	45	40	45	40	45	43.60	45.00	45.00	2.50
power	40	47	40	42	40	40	40	40	50	40	41.90	40.00	40.00	3.60
pull	52	51	50	45	50	50	50	50	48	48	49.40	50.00	50.00	1.96
										M	48.95	48.73	48.98	2.51

Table D5 *Maximum formant (Hz) values for Subject 3's slow tokens*

Slow	Subject 3												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	50	50	50	50	50	50	50	47	47	47	49.10	50.00	50.00	1.45
boil	50	50	53	53	53	50	53	53	45	45	50.50	53.00	51.50	3.21
fair	47	47	53	47	45	45	45	45	45	45	46.40	45.00	45.00	2.50
fear	47	45	45	53	50	47	50	50	47	53	48.70	47.00	48.50	2.95
feel	45	50	50	50	50	50	47	47	47	47	48.30	50.00	48.50	1.89
fell	50	53	45	45	53	47	47	47	47	45	47.90	47.00	47.00	3.07
furl	45	45	45	45	50	50	50	50	50	45	47.50	45.00	47.50	2.64
hire	47	45	45	45	47	45	45	45	45	45	45.40	45.00	45.00	0.84
hole	53	53	50	50	45	50	50	53	45	45	49.40	50.00	50.00	3.31
howl	50	50	45	50	50	45	45	45	50	50	48.00	50.00	50.00	2.58
hull	50	47	50	50	47	50	47	55	47	47	49.00	47.00	48.50	2.58
pal	50	50	47	47	47	45	47	47	47	47	47.40	47.00	47.00	1.51
pale	53	50	50	53	50	53	50	47	47	45	49.80	50.00	50.00	2.78
par	50	45	45	45	45	45	45	45	45	45	45.50	45.00	45.00	1.58
Paul	50	50	50	45	45	45	47	47	45	45	46.90	45.00	46.00	2.28
pile	53	53	53	45	45	45	47	45	45	45	47.60	45.00	45.00	3.78
Poll	47	47	50	50	50	45	45	45	47	45	47.10	45.00	47.00	2.18
pool	50	50	53	50	53	50	50	50	50	50	50.60	50.00	50.00	1.26
poor	50	50	50	50	50	50	47	47	47	47	48.80	50.00	50.00	1.55
pore	47	50	47	53	50	50	50	47	45	45	48.40	50.00	48.50	2.59
power	45	45	50	53	45	50	50	45	47	45	47.50	45.00	46.00	2.99
pull	50	50	50	50	50	50	50	53	47	45	49.50	50.00	50.00	2.12
										M	48.15	47.77	48.00	2.35

Table D6 *Maximum formant (Hz) values for Subject 3's fast tokens*

Fast	Subject 3													
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	45	45	—	45	45	47	55	47	53	53	48.33	45.00	47.00	4.12
boil	45	45	45	50	50	47	47	45	45	45	46.40	45.00	45.00	2.07
fair	45	45	45	47	45	45	53	53	50	50	47.80	45.00	46.00	3.39
fear	50	53	50	47	53	55	55	50	55	55	52.30	55.00	53.00	2.87
feel	50	53	55	47	53	50	53	—	53	50	51.56	53.00	53.00	2.46
fell	50	47	47	47	45	47	45	—	45	45	46.44	47.00	47.00	1.67
furl	45	45	47	47	45	47	45	47	47	47	46.20	47.00	47.00	1.03
hire	45	45	45	45	45	45	45	45	45	45	45.00	45.00	45.00	0.00
hole	47	47	47	47	47	47	47	45	45	45	46.40	47.00	47.00	0.97
howl	47	45	47	45	45	47	45	45	50	47	46.30	45.00	46.00	1.64
hull	45	47	47	47	50	45	50	47	47	47	47.20	47.00	47.00	1.69
pal	50	50	53	47	45	47	53	47	45	50	48.70	50.00	48.50	2.95
pale	45	45	—	45	50	45	45	45	47	45	45.78	45.00	45.00	1.72
par	47	45	—	45	45	45	47	45	45	45	45.44	45.00	45.00	0.88
Paul	47	45	45	45	45	47	45	47	47	45	45.80	45.00	45.00	1.03
pile	47	45	47	47	45	47	45	47	45	47	46.20	47.00	47.00	1.03
Poll	50	53	50	45	47	47	47	47	50	47	48.30	47.00	47.00	2.36
pool	47	50	50	50	53	47	47	47	47	53	49.10	47.00	48.50	2.47
poor	45	47	45	45	50	45	50	47	50	47	47.10	45.00	47.00	2.18
pore	45	45	45	45	45	50	45	45	50	47	46.20	45.00	45.00	2.10
power	47	45	45	45	45	45	45	45	45	45	45.20	45.00	45.00	0.63
pull	45	45	47	47	47	45	45	45	45	45	45.60	45.00	45.00	0.97
										M	47.15	46.68	46.86	1.83

Table D7 *Maximum formant (Hz) values for Subject 4's slow tokens*

Slow	Subject 4													
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	40	43	43	43	43	43	43	43	43	43	42.70	43.00	43.00	0.95
boil	40	40	45	43	45	43	45	45	45	43	43.40	45.00	44.00	2.01
fair	40	40	43	43	43	43	43	43	43	43	42.40	43.00	43.00	1.26
fear	40	40	45	43	43	40	43	43	43	43	42.30	43.00	43.00	1.70
feel	43	43	45	45	43	43	43	43	43	43	43.40	43.00	43.00	0.84
fell	—	43	40	45	—	43	43	43	45	43	43.13	43.00	43.00	1.55
furl	40	40	40	43	43	40	43	40	43	43	41.50	40.00	41.50	1.58
hire	40	43	43	43	43	43	43	43	45	43	42.90	43.00	43.00	1.20
hole	43	50	43	43	43	43	50	43	43	43	44.40	43.00	43.00	2.95
howl	40	40	43	43	43	40	43	43	43	43	42.10	43.00	43.00	1.45
hull	43	43	43	43	43	43	43	43	43	43	43.00	43.00	43.00	0.00
pal	40	43	43	43	45	43	43	43	45	43	43.10	43.00	43.00	1.37
pale	43	43	43	40	45	45	47	43	43	43	43.50	43.00	43.00	1.84
par	40	40	40	40	40	40	40	40	43	47	41.00	40.00	40.00	2.31
Paul	53	55	53	53	53	55	55	53	45	47	52.20	53.00	53.00	3.43
pile	40	43	43	43	45	43	43	43	45	45	43.30	43.00	43.00	1.49
Poll	43	47	50	43	43	40	43	43	45	43	44.00	43.00	43.00	2.75
pool	40	40	43	45	45	53	43	43	43	43	43.80	43.00	43.00	3.65
poor	40	40	40	40	43	40	40	40	40	43	40.60	40.00	40.00	1.26
pore	40	40	40	40	40	40	40	40	43	43	40.60	40.00	40.00	1.26
power	40	40	40	40	40	40	40	40	43	43	40.60	40.00	40.00	1.26
pull	45	45	43	45	45	45	43	43	43	40	43.70	45.00	44.00	1.64
										M	43.07	42.95	42.93	1.72

Table D8 *Maximum formant (Hz) values for Subject 4's fast tokens*

Fast	Subject 4													
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	—	43	43	43	40	40	47	45	43	43	43.00	43.00	43.00	2.18
boil	43	43	43	43	43	43	43	43	43	43	43.00	43.00	43.00	0.00
fair	45	43	45	40	45	43	43	43	45	43	43.50	43.00	43.00	1.58
fear	40	43	47	45	43	40	45	43	43	43	43.20	43.00	43.00	2.15
feel	43	43	45	43	45	43	43	47	45	45	44.20	43.00	44.00	1.40
fell	40	43	43	—	43	43	—	—	43	43	42.57	43.00	43.00	1.13
furl	40	43	40	45	43	40	47	45	45	43	43.10	40.00	43.00	2.47
hire	43	43	43	43	47	45	45	43	47	40	43.90	43.00	43.00	2.13
hole	40	45	43	45	40	43	45	40	40	43	42.40	40.00	43.00	2.22
howl	40	43	47	43	43	45	43	45	45	45	43.90	43.00	44.00	1.91
hull	40	40	43	43	43	43	45	43	43	43	42.60	43.00	43.00	1.51
pal	43	45	50	45	47	43	43	47	45	45	45.30	45.00	45.00	2.21
pale	43	43	43	47	—	47	45	45	45	45	44.78	45.00	45.00	1.56
par	43	43	43	43	47	47	43	43	43	45	44.00	43.00	43.00	1.70
Paul	40	43	45	45	40	40	47	47	43	43	43.30	40.00	43.00	2.71
pile	43	45	43	43	47	45	43	47	45	45	44.60	43.00	45.00	1.58
Poll	43	43	40	43	45	43	43	45	45	40	43.00	43.00	43.00	1.83
pool	45	43	43	43	—	—	43	43	43	—	43.29	43.00	43.00	0.76
poor	40	40	43	43	43	43	45	—	43	43	42.56	43.00	43.00	1.59
pore	43	40	43	40	40	43	40	40	43	43	41.50	43.00	41.50	1.58
power	47	43	45	43	45	45	45	43	40	43	43.90	43.00	44.00	1.91
pull	45	43	40	43	43	43	43	43	43	43	42.90	43.00	43.00	1.20
										M	43.39	42.77	43.34	1.70

Table D9 *Maximum formant (Hz) values for Subject 5's slow tokens*

Slow	Subject 5													
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	53	53	53	53	53	53	53	55	55	55	53.60	53.00	53.00	0.97
boil	53	53	53	53	55	55	53	53	53	55	53.60	53.00	53.00	0.97
fair	55	53	53	53	53	53	55	53	55	53	53.60	53.00	53.00	0.97
fear	53	53	53	50	53	55	55	55	53	53	53.30	53.00	53.00	1.49
feel	50	53	55	55	53	55	55	55	53	53	53.70	55.00	54.00	1.64
fell	53	53	55	53	55	55	55	53	53	55	54.00	53.00	54.00	1.05
furl	53	53	53	53	50	53	55	50	50	55	52.50	53.00	53.00	1.90
hire	55	53	50	50	53	53	55	55	55	53	53.20	55.00	53.00	1.93
hole	53	53	53	50	50	53	53	50	53	50	51.80	53.00	53.00	1.55
howl	53	53	50	53	53	50	50	53	50	55	52.00	53.00	53.00	1.83
hull	50	53	53	50	50	50	53	50	50	53	51.20	50.00	50.00	1.55
pal	55	55	—	53	53	53	53	53	53	55	53.67	53.00	53.00	1.00
pale	55	55	55	—	55	55	53	55	55	55	54.78	55.00	55.00	0.67
par	53	53	55	53	55	50	53	55	50	50	52.70	53.00	53.00	2.06
Paul	53	53	53	50	50	50	53	50	53	50	51.50	53.00	51.50	1.58
pile	53	53	53	53	55	55	55	53	53	50	53.30	53.00	53.00	1.49
Poll	53	53	55	55	53	50	55	55	53	50	53.20	53.00	53.00	1.93
pool	50	53	53	53	50	53	50	53	50	53	51.80	53.00	53.00	1.55
poor	50	53	55	53	50	53	50	53	53	50	52.00	53.00	53.00	1.83
pore	53	55	53	50	53	53	55	53	53	50	52.80	53.00	53.00	1.69
power	50	53	53	53	53	50	50	50	50	53	51.50	50.00	51.50	1.58
pull	53	53	53	53	50	50	50	50	53	53	51.80	53.00	53.00	1.55
										M	52.80	53.00	52.91	1.49

Table D10 *Maximum formant (Hz) values for Subject 5's fast tokens*

Fast	Subject 5													
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	53	53	55	53	55	53	53	53	50	55	53.30	53.00	53.00	1.49
boil	53	50	55	53	53	53	53	55	53	53	53.10	53.00	53.00	1.37
fair	55	53	55	53	50	53	53	53	53	50	52.80	53.00	53.00	1.69
fear	53	50	55	53	55	50	55	55	55	53	53.40	55.00	54.00	2.01
feel	53	53	55	53	55	55	50	55	53	53	53.50	53.00	53.00	1.58
fell	53	55	53	55	53	55	53	55	55	53	54.00	53.00	54.00	1.05
furl	53	50	53	53	53	50	50	55	53	53	52.30	53.00	53.00	1.70
hire	50	53	53	53	55	55	55	53	50	53	53.00	53.00	53.00	1.83
hole	53	50	53	53	55	55	55	53	50	53	53.00	53.00	53.00	1.83
howl	53	53	55	53	55	55	53	55	55	53	54.00	53.00	54.00	1.05
hull	53	53	55	50	53	53	53	50	50	53	52.30	53.00	53.00	1.70
pal	53	55	53	—	55	55	53	50	53	53	53.33	53.00	53.00	1.58
pale	55	55	50	55	55	55	55	53	53	55	54.10	55.00	55.00	1.66
par	53	53	53	50	50	53	53	55	—	53	52.56	53.00	53.00	1.59
Paul	53	53	50	50	53	53	50	53	55	55	52.50	53.00	53.00	1.90
pile	53	53	53	53	53	53	53	50	53	50	52.40	53.00	53.00	1.26
Poll	53	53	53	55	50	—	53	53	53	53	52.89	53.00	53.00	1.27
pool	50	53	50	53	53	50	53	53	53	53	52.10	53.00	53.00	1.45
poor	50	50	50	53	53	53	53	53	53	53	52.10	53.00	53.00	1.45
pore	50	53	50	55	53	53	53	55	53	53	52.80	53.00	53.00	1.69
power	53	53	50	53	55	53	53	50	53	55	52.80	53.00	53.00	1.69
pull	53	53	50	53	55	50	53	—	50	53	52.22	53.00	53.00	1.79
										M	52.93	53.18	53.23	1.57

Table D11 *Maximum formant (Hz) values for Subject 6's slow tokens*

Slow	Subject 6												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	55	50	53	53	50	50	53	50	55	55	52.40	50.00	53.00	2.22
boil	55	55	55	55	55	55	53	53	53	55	54.40	55.00	55.00	0.97
fair	55	53	55	55	50	53	55	50	53	50	52.90	55.00	53.00	2.18
fear	50	53	55	50	50	53	53	53	53	50	52.00	53.00	53.00	1.83
feel	50	53	55	53	53	50	55	55	53	50	52.70	53.00	53.00	2.06
fell	53	53	53	55	53	55	53	55	53	53	53.60	53.00	53.00	0.97
furl	53	53	55	55	53	53	55	53	50	53	53.30	53.00	53.00	1.49
hire	53	55	55	53	55	50	53	50	50	53	52.70	53.00	53.00	2.06
hole	53	55	53	53	55	53	53	55	50	50	53.00	53.00	53.00	1.83
howl	50	55	53	50	53	55	50	53	50	53	52.20	50.00	53.00	2.04
hull	53	53	55	53	50	55	55	50	55	50	52.90	55.00	53.00	2.18
pal	53	50	53	53	50	—	50	55	53	50	51.89	53.00	53.00	1.90
pale	53	55	50	53	50	—	53	53	50	50	51.89	53.00	53.00	1.90
par	55	50	50	53	50	53	55	55	55	50	52.60	55.00	53.00	2.37
Paul	55	55	50	55	55	53	53	50	53	55	53.40	55.00	54.00	2.01
pile	55	55	55	53	50	53	50	55	53	55	53.40	55.00	54.00	2.01
Poll	53	53	55	55	53	55	50	53	53	55	53.50	53.00	53.00	1.58
pool	53	55	55	55	53	53	53	53	55	55	54.00	53.00	54.00	1.05
poor	50	50	50	53	53	53	50	53	53	53	51.80	53.00	53.00	1.55
pore	50	53	53	50	53	53	50	53	53	53	52.10	53.00	53.00	1.45
power	53	53	55	55	53	55	53	55	50	53	53.50	53.00	53.00	1.58
pull	50	53	55	55	53	50	50	53	53	53	52.50	53.00	53.00	1.90
										M	52.85	53.27	53.23	1.78

Table D12 *Maximum formant (Hz) values for Subject 6's fast tokens*

Fast	Subject 6												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	M	Mo	Mdn	SD
bill	50	53	—	—	53	53	53	50	55	55	52.75	53.00	53.00	1.91
boil	55	53	—	—	53	55	55	50	55	53	53.63	55.00	54.00	1.77
fair	50	55	—	—	53	53	53	53	55	55	53.38	53.00	53.00	1.69
fear	55	50	—	—	53	53	53	53	53	53	52.88	53.00	53.00	1.36
feel	53	—	—	—	55	50	53	55	53	50	52.71	53.00	53.00	2.06
fell	55	53	—	—	—	50	—	55	53	53	53.17	53.00	53.00	1.83
furl	55	53	—	—	55	53	55	53	53	55	54.00	55.00	54.00	1.07
hire	50	—	—	—	50	50	53	50	53	53	51.29	50.00	50.00	1.60
hole	53	50	—	—	53	—	53	53	55	55	53.14	53.00	53.00	1.68
howl	55	53	—	—	53	55	53	50	50	53	52.75	53.00	53.00	1.91
hull	53	55	—	—	55	53	55	53	55	55	54.25	55.00	55.00	1.04
pal	55	53	—	—	50	53	55	—	50	53	52.71	53.00	53.00	2.06
pale	53	53	—	—	50	50	53	55	53	53	52.50	53.00	53.00	1.69
par	55	53	—	—	53	50	55	53	55	53	53.38	53.00	53.00	1.69
Paul	55	53	—	—	—	53	53	50	55	53	53.14	53.00	53.00	1.68
pile	53	50	53	—	53	53	55	55	55	53	53.33	53.00	53.00	1.58
Poll	53	50	—	—	53	53	53	53	53	53	52.63	53.00	53.00	1.06
pool	53	55	—	—	53	53	53	50	53	50	52.50	53.00	53.00	1.69
poor	53	55	—	—	53	53	53	53	55	53	53.50	53.00	53.00	0.93
pore	53	55	—	—	53	50	53	50	53	53	52.50	53.00	53.00	1.69
power	53	53	—	—	53	55	53	50	53	53	52.88	53.00	53.00	1.36
pull	55	53	—	—	55	53	55	50	53	53	53.38	53.00	53.00	1.69
										M	53.02	53.14	53.05	1.59

Appendix E

Praat scripts for first derivative curve extraction

Appendix E presents the Praat scripts that generated the first derivative curves reported in Chapter 2 (section 2.5). Information that differs from script to script, from speaker to speaker or from token to token is shown in bold type and is shaded in gray.

1st Derivative for F1 Slow

Erase all

ini = 0
fin = 0

Times
12
Select outer viewport... 0 12 0 6
Text top... yes **F1 AFs BILL 01**

To Formant (burg)... 0 5 **5300** 0.012 50
Black
Speckle... 'ini' 'fin' 5000 30 yes
To Matrix... **1**
To Pitch
Smooth... **20**
Rename... smoothed
To Matrix
Solid line
Line width... 4
Lime
Draw rows... 'ini' 'fin' 0 5 0 5000
Copy... derivada
Formula... (self[col+**1**]-self[col])/dx
Solid line
Line width... 4
Red
Draw rows... 'ini' 'fin' 0 5 -50000 50000
To Sound (slice)... **1**
To PointProcess (extrema)... Left yes yes Sinc70
Dotted line
Line width... 1
Blue
Draw... 0 0 yes

Up to TextTier...
Into TextGrid

1st Derivative for F1 Fast

Erase all

ini = 0
fin = 0

Times
12
Select outer viewport... 0 12 0 6
Text top... yes **F1 AFs BILL 01**

To Formant (burg)... 0 5 **5300** 0.012 50
Black
Speckle... 'ini' 'fin' 5000 30 yes
To Matrix... **1**
To Pitch
Smooth... **30**
Rename... smoothed
To Matrix
Solid line
Line width... 4
Lime
Draw rows... 'ini' 'fin' 0 5 0 5000
Copy... derivada
Formula... (self[col+**1**]-self[col])/dx
Solid line
Line width... 4
Red
Draw rows... 'ini' 'fin' 0 5 -50000 50000
To Sound (slice)... **1**
To PointProcess (extrema)... Left yes yes Sinc70
Dotted line
Line width... 1
Blue
Draw... 0 0 yes

Up to TextTier...
Into TextGrid

1st Derivative for F2 Slow

Erase all

ini = 0
fin = 0

Times
12
Select outer viewport... 0 12 0 6
Text top... yes **F2 AFs BILL 01**

To Formant (burg)... 0 5 **5300** 0.012 50
Black
Speckle... 'ini' 'fin' 5000 30 yes
To Matrix... **2**
To Pitch
Smooth... **20**
Rename... smoothed
To Matrix
Solid line
Line width... 4
Lime
Draw rows... 'ini' 'fin' 0 5 0 5000
Copy... derivada
Formula... (self[col+2]-self[col])/dx
Solid line
Line width... 4
Red
Draw rows... 'ini' 'fin' 0 5 -50000 50000
To Sound (slice)... **2**
To PointProcess (extrema)... Left yes yes Sinc70
Dotted line
Line width... 1
Blue
Draw... 0 0 yes

Up to TextTier...
Into TextGrid

1st Derivative for F2 Fast

Erase all

ini = 0
fin = 0

Times
12
Select outer viewport... 0 12 0 6
Text top... yes **F2 AFs BILL 01**

To Formant (burg)... 0 5 **5300** 0.012 50
Black
Speckle... 'ini' 'fin' 5000 30 yes
To Matrix... **2**
To Pitch
Smooth... **30**
Rename... smoothed
To Matrix
Solid line
Line width... 4
Lime
Draw rows... 'ini' 'fin' 0 5 0 5000
Copy... derivada
Formula... (self[col+2]-self[col])/dx
Solid line
Line width... 4
Red
Draw rows... 'ini' 'fin' 0 5 -50000 50000
To Sound (slice)... **2**
To PointProcess (extrema)... Left yes yes Sinc70
Dotted line
Line width... 1
Blue
Draw... 0 0 yes

Up to TextTier...
Into TextGrid

1st Derivative for F3 Slow

```
Erase all

ini = 0
fin = 0

Times
12
Select outer viewport... 0 12 0 6
Text top... yes F3 AFs BILL 01

To Formant (burg)... 0 5 5300 0.012 50
Black
Speckle... 'ini' 'fin' 5000 30 yes
To Matrix... 3
To Pitch
Smooth... 20
Rename... smoothed
To Matrix
Solid line
Line width... 4
Lime
Draw rows... 'ini' 'fin' 0 5 0 5000
Copy... derivada
Formula... (self[col+3]-self[col])/dx
Solid line
Line width... 4
Red
Draw rows... 'ini' 'fin' 0 5 -50000 50000
To Sound (slice)... 3
To PointProcess (extrema)... Left yes
yes Sinc70
Dotted line
Line width... 1
Blue
Draw... 0 0 yes

Up to TextTier...
Into TextGrid
```

1st Derivative for F3 Fast

```
Erase all

ini = 0
fin = 0

Times
12
Select outer viewport... 0 12 0 6
Text top... yes F3 AFs BILL 01

To Formant (burg)... 0 5 5300 0.012 50
Black
Speckle... 'ini' 'fin' 5000 30 yes
To Matrix... 3
To Pitch
Smooth... 30
Rename... smoothed
To Matrix
Solid line
Line width... 4
Lime
Draw rows... 'ini' 'fin' 0 5 0 5000
Copy... derivada
Formula... (self[col+3]-self[col])/dx
Solid line
Line width... 4
Red
Draw rows... 'ini' 'fin' 0 5 -50000 50000
To Sound (slice)... 3
To PointProcess (extrema)... Left yes
yes Sinc70
Dotted line
Line width... 1
Blue
Draw... 0 0 yes

Up to TextTier...
Into TextGrid
```

Appendix F

Praat script for duration and midpoint formant values

Appendix F presents the Praat script that was written to extract the duration and midpoint F1, F2 and F3 values mentioned in Chapter 2 (section 2.6).

```
use_TextGrid$ = selected$ ("TextGrid")

editor TextGrid 'use_TextGrid$'

  begin = Get begin of selection
  end = Get end of selection
  duration = end-begin
  midpoint = begin + (duration/2)
  mid_start = midpoint-0.025
  mid_end = midpoint+0.025
  Select... mid_start mid_end
  f1mid = Get first formant
  f2mid = Get second formant
  f3mid = Get third formant
  Select... begin end

endeditor

printline 'use_TextGrid$' 'tab$' 'midpoint:6' 'tab$' 'begin:6' 'tab$' 'end:6' 'tab$'
'duration:4' 'tab$' 'f1mid:0' 'tab$' 'f2mid:0' 'tab$' 'f3mid:0' 'tab$'
```

Appendix G

Pearson correlation coefficients for midpoint vs. mean formant values

The following tables present the results of the Pearson correlation statistical analysis reported in Chapter 2 (section 2.6). As explained there, these results justify the methodological choice of midpoint over mean measurements of the constituent elements of the V+/l/ and V+/r/ sequences under study.

Each table shows data for one of the 22 target words. In order to facilitate identification, the target words are presented in alphabetical order and the phonemic transcription is shown below the spelled word on the top left-hand side of each table.

The Pearson correlation coefficient (*r*) showing the strength and direction of the linear relationship between the two variables (i.e., measurements taken at midpoint and mean measurements) is provided for F1, F2 and F3 measurements taken for the vowel (V), transition (T) and consonant (C) for each subject's slow and fast productions. The table cells corresponding to the discarded token *Poll* /pɑl/ for Subjects 4, 5 and 6 are left blank.

Significant correlations at $\alpha = .01$ (i.e., p = or <. 01) are shaded in light gray, while those at $\alpha = .05$ (i.e., p = or <.05) are shaded in dark gray. In all cases $n = 10$ and $df = 9$.

Table G1 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* bill

bill	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/bɪl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.993	.965	.903	.944	.977	.995	.994	.922	.878	.406	.955	.821
V F2	.738	.996	.584	.602	.973	.786	.961	.957	.987	.868	.900	.996
V F3	.581	.968	.867	.962	.948	.988	.970	.632	.910	.562	.346	.923
T F1	.754	.997	.928	.998	.894	.998	.986	.745	.739	.455	.934	.998
T F2	.945	.782	.923	.960	.981	.996	.988	.997	.981	.995	.988	.775
T F3	.686	.997	.977	.990	.972	.987	.668	.363	.950	.989	.429	.981
C F1	.681	.971	.822	.986	.762	.936	.820	.351	.935	.731	-.179	.951
C F2	.462	.953	.632	.675	.899	.816	.720	.990	.137	.490	.495	.905
C F3	.131	.976	.505	.985	.950	.960	.922	.962	.727	.859	.848	.992

Table G2 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* boil

boil	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/bɔɪl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.954	.998	.976	1.000	.990	.978	.563	.808	.963	.996	.989	.999
V F2	.990	.999	.986	.998	.994	.996	.939	.791	.969	.991	.978	.992
V F3	.967	.987	.986	.803	.952	.996	.927	.576	.992	.996	.949	.991
T F1	.780	.993	.957	.975	.458	.819	.960	.967	.979	.990	.611	.796
T F2	.996	.810	.980	.984	.995	.991	.839	.962	.987	.990	.968	.969
T F3	.801	.779	.991	.788	.974	.924	.962	.989	.772	.976	.955	.716
C F1	.935	.985	.645	.329	.968	.176	.418	.600	.913	.134	.393	.300
C F2	.614	.988	.017	.472	.688	.384	.349	.863	-.423	.906	.688	.800
C F3	.324	.787	.751	.847	.945	.884	.457	.945	.773	.549	.731	.655

Table G3 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* fair

fair	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/fɛr/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.638	.977	.799	.944	.945	.816	.726	.242	.924	.331	.970	.504
V F2	.921	.995	.575	.994	.725	.753	.977	.687	.924	.919	.450	.993
V F3	.786	.986	.742	.994	.782	.983	.987	.992	.739	.802	.451	.942
T F1	.955	.999	.548	.998	.870	.982	.814	.998	.989	.994	.973	.998
T F2	.870	.975	.895	.913	.830	.967	.992	.973	.951	.990	.765	.976
T F3	.720	.993	.885	.993	.961	.725	.992	.981	.940	.974	.975	.846
C F1	.754	.760	.441	.766	.953	.644	.794	.455	.872	.855	.382	.614
C F2	.723	.767	.580	.973	.684	.975	.816	.694	.781	.041	.886	.822
C F3	.394	.923	-.134	.746	.849	.923	.947	.566	.778	-.740	.546	.855

Table G4 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* fear

fear	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/fir/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.990	.986	.571	.994	.961	.496	.977	.925	.972	-.394	.712	.308
V F2	.803	.989	.822	.767	.696	.912	.930	.878	.932	.956	.723	.980
V F3	.925	.800	.740	.981	.850	.954	.976	.935	.931	.807	.322	.960
T F1	.928	.990	.555	.999	.976	.999	.990	.617	.952	.996	.926	.997
T F2	.927	.779	.941	.997	.520	.737	.971	.879	.933	.998	.972	.992
T F3	.805	.791	.653	.973	.965	.971	.983	.804	.486	.961	.846	.993
C F1	.881	.755	.937	.683	.813	.360	.984	.477	.818	-.057	.026	.827
C F2	.846	.350	.812	.830	.883	.937	.588	.708	.783	.304	.759	.518
C F3	.879	.955	.948	.613	.404	.972	.883	.435	.588	.862	.938	.003

Table G5 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* feel

feel	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/fil/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.990	.742	.541	.994	.964	.410	.673	.807	.941	.276	.907	.999
V F2	.775	.939	.433	.984	.789	.995	.731	.915	.661	.856	.892	.932
V F3	.959	.877	.961	.957	.919	.994	.770	.923	.976	.242	.740	.994
T F1	.938	.992	.806	.990	.977	.996	.975	.982	.682	.998	.510	.997
T F2	.628	.963	.950	.822	.951	1.000	.997	.679	.965	.996	.987	.995
T F3	.749	.596	.821	.774	.925	.995	.825	.947	.855	.997	.605	.794
C F1	.679	.984	.627	.960	.944	.952	.399	.747	.213	.600	.578	.786
C F2	.240	.580	.950	.806	.726	.416	.940	.880	.043	.343	.940	.467
C F3	-.005	.823	.167	.649	.471	.992	-.003	.970	.899	.779	.814	.883

Table G6 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* fell

fell	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/fɛl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.784	.833	.909	.905	.948	.625	.563	.808	.926	.450	.750	.067
V F2	.946	.927	.805	.923	.891	.681	.939	.791	.822	.492	.941	.926
V F3	.822	.885	.600	.993	.955	.982	.927	.576	.916	.472	.415	-.074
T F1	.762	.999	.877	.996	.972	.999	.960	.967	.830	.997	.995	.988
T F2	.851	.991	.881	.807	.997	.971	.839	.962	.969	.992	.981	.788
T F3	.677	.693	.613	.896	.952	.730	.962	.989	.758	.976	.790	.998
C F1	.728	.965	.801	.735	.550	.723	.418	.600	.750	.624	.673	.781
C F2	.697	.952	.825	.994	.920	.975	.349	.863	.001	.898	.718	.563
C F3	.871	.641	.746	.780	.760	.994	.457	.945	.879	.818	.765	.510

Table G7 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* furl

furl	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/fɝl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.960	.962	.708	.971	.922	.949	.829	.965	.943	.992	.974	.997
V F2	.582	.996	.895	.984	.986	.866	.839	.987	.936	.986	.897	.995
V F3	.911	.588	.605	.489	.955	.202	.937	.723	.946	.562	.965	.949
T F1	.984	1.000	.748	.996	.982	.997	.976	.725	.782	.996	.972	.997
T F2	.855	.854	.861	1.000	.993	.974	.899	.814	.992	.785	.982	.990
T F3	.997	.999	.978	.996	.996	.996	.923	.782	.988	.997	.992	.990
C F1	.895	.716	.973	.741	.735	.767	.989	.862	.706	.686	.803	.272
C F2	.799	.901	.640	.822	.828	.970	.799	.689	.396	.848	.821	.756
C F3	.809	.943	.742	.986	.724	.993	.685	.993	.772	.877	.922	.864

Table G8 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* hire

hire	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/haɪr/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.959	.986	.967	.995	.982	.965	.998	.995	.994	.969	.968	.998
V F2	.989	.977	.782	.990	.716	.977	.990	.990	.784	.984	.479	.997
V F3	.985	.626	.972	.981	.975	.986	.991	.986	.748	.982	.555	.999
T F1	.755	.998	.994	.819	.986	.780	.998	.957	.987	.995	.940	.981
T F2	.842	.971	.890	.988	.993	.733	.993	.990	.992	.986	.671	.997
T F3	.991	.744	.652	.992	.993	.965	.984	.980	.956	.839	.617	.996
C F1	.968	.967	.900	.986	.759	.598	.897	.372	.692	.033	.413	.673
C F2	.553	.979	.730	.995	.986	.384	.823	.520	.952	.619	.979	-.150
C F3	.327	.805	.604	.962	.571	.177	.965	.652	.220	.847	.733	.746

Table G9 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* hole

hole	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/hol/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.767	.996	.997	.998	.999	.958	.999	.690	.974	.984	.998	.979
V F2	.997	.982	.776	.992	.999	.780	1.000	.943	.985	.991	.988	.724
V F3	.995	.995	.991	.781	.999	.577	.994	.780	.980	.993	.994	.649
T F1	.998	.948	.776	.970	.997	.732	.999	.525	.997	.829	.987	.767
T F2	.996	.982	.987	.978	.993	.991	.999	.854	.986	.992	.997	.975
T F3	.997	.745	.976	.961	.785	.814	.995	.820	.994	.727	.993	.981
C F1	.944	.929	.567	.865	.733	.464	.907	.322	.896	.141	.846	.903
C F2	.841	.515	-.249	.761	.966	.425	.530	.699	.236	.789	.516	.749
C F3	.372	.766	.771	.958	.970	.891	.977	.928	.881	.874	.768	.952

Table G10 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* howl

howl	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/haʊl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.972	.982	.609	.986	.995	.984	.982	.960	.999	.949	.884	.999
V F2	.999	.711	.971	.471	.993	.996	.950	.806	.998	.977	.953	.999
V F3	.999	.987	.977	.972	.971	.839	.783	.610	.996	.994	.729	.746
T F1	.997	.984	.964	.937	.991	.583	.748	.910	1.000	.960	.809	.998
T F2	.990	.949	.778	.943	.988	.956	.996	.935	.999	.993	.983	.999
T F3	.995	.983	.957	.998	.989	.955	.994	.381	.996	.443	.974	.893
C F1	.831	.813	.950	.939	.783	.895	.893	.827	.780	.664	.876	.883
C F2	.577	.565	.918	.271	.603	.875	.821	.631	-.458	.595	.581	.619
C F3	.822	.673	.940	.772	.874	.984	.748	.245	.824	.655	.979	.314

Table G11 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* hull

hull	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/hʌl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.977	.983	.943	.996	.983	.995	.952	.933	.958	.976	.948	.994
V F2	.985	.971	.905	.998	.968	.997	.748	.997	.754	.939	.915	.585
V F3	.807	.988	.907	.999	.978	.998	.776	.969	.982	.960	.964	1.000
T F1	.772	1.000	.982	.987	.760	.996	1.000	.991	.984	.549	.997	.962
T F2	.991	.981	.958	.760	.994	.980	.999	.978	.975	.949	.977	.912
T F3	.929	.956	.980	.981	.699	.999	.765	.981	.853	.972	1.000	.994
C F1	.461	.963	.708	.698	.925	.984	.980	.756	.045	.460	.980	.059
C F2	.768	.627	.751	.427	.580	.808	.972	.218	.257	.623	.984	.787
C F3	.681	.971	.901	.841	.806	.780	.529	.782	.717	.563	.786	.862

Table G12 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* pal

pal	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pæl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.953	.987	.972	.707	.953	.996	.978	.933	.887	.956	.965	.809
V F2	.980	.999	.733	.994	.928	.999	.865	.991	.817	.767	.696	.999
V F3	.983	.986	.328	.937	.974	.975	.865	.996	.555	.969	.971	.763
T F1	.962	.997	.971	.979	.775	.719	.954	.962	.988	.530	.994	.687
T F2	.799	.999	.990	.787	.823	.790	.984	.914	.980	.994	.997	.996
T F3	.732	.984	.997	.995	.972	.984	.994	.748	.987	.982	.513	.530
C F1	.324	.895	.689	.988	.497	.964	.744	.471	.448	.663	.943	.412
C F2	.719	.994	.465	.971	.670	.738	.954	.666	.464	.459	.944	.688
C F3	.774	.910	.937	.993	.719	.814	.797	.844	.545	.889	.973	.990

Table G13 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* pale

pale	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pel/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.999	.980	.956	.971	.997	.780	.994	.658	.997	.990	.997	.993
V F2	.978	.992	.902	.651	.984	.963	.989	.883	.963	.965	.734	.990
V F3	.964	.889	.947	.903	.990	.787	.957	.286	.764	.918	.810	.997
T F1	.993	1.000	.991	.995	.798	.987	.995	.948	.733	.999	.918	.997
T F2	.981	.999	.995	.474	.991	.992	.974	.953	.580	.986	.981	.999
T F3	.936	.971	.748	.730	.958	.988	.969	.426	.544	.579	.911	.999
C F1	.457	.995	.842	.969	.914	.936	.791	.664	.542	.949	.586	.886
C F2	.866	.997	.138	.889	.864	.973	.953	.946	.861	.486	.066	.881
C F3	.674	.986	.851	.973	.981	.696	.973	.849	.888	.910	.959	.815

Table G14 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* par

par	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pɑr/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.943	.622	.895	.953	.937	.951	.761	.778	.311	.854	.976	.961
V F2	.760	.989	.923	.990	.995	.361	.917	.990	.853	.499	.963	.888
V F3	.789	.858	.736	.974	.813	.995	.948	.990	.937	.525	.705	.989
T F1	.995	.793	.970	.990	.971	.982	.859	.989	.768	.524	.600	.996
T F2	.912	.995	.982	.989	.979	.930	.972	.908	.966	.989	.960	.999
T F3	.994	.474	.963	.983	.963	.995	.596	.932	.993	.945	.871	1.000
C F1	.719	.997	.616	.788	.800	.991	.072	.959	.910	.931	.591	.274
C F2	.384	.991	.850	.961	.982	.985	.820	.956	.780	.913	.955	.900
C F3	.782	.975	.728	.858	.667	.322	.906	.829	.400	.587	.655	.646

Table G15 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* Paul

Paul	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pɔl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.760	.840	.706	.971	.954	.994	.676	.955	.607	.756	.991	.995
V F2	.924	.989	.682	.991	.990	.448	.946	.999	.949	.856	.961	.856
V F3	.963	.995	.988	.811	.992	.987	.957	.995	.881	.982	.991	.994
T F1	.996	.998	.960	.977	.981	.948	.760	.929	.954	.988	.995	1.000
T F2	.983	.999	.701	.983	.994	.952	.974	.986	.971	.972	.996	.999
T F3	.978	.994	.966	.570	.998	.822	.999	.688	.817	.972	.988	.998
C F1	.840	.977	.933	.780	.965	.985	.538	.816	.553	.700	.758	-.381
C F2	.896	.437	.928	.826	.828	.924	.969	.908	.112	.617	.360	.462
C F3	.964	.995	.914	.823	.813	.774	.979	.879	.293	.618	.609	.870

Table G16 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* pile

pile	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/paɪl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.910	.971	.984	.997	.998	.781	.965	.785	.989	.995	.980	.998
V F2	.981	.975	.994	.996	.963	.984	.498	.877	.984	.988	.954	.999
V F3	.675	.866	.976	.994	.960	.997	.427	.628	.990	.997	.937	.779
T F1	.994	.990	.971	.986	.999	.988	.768	.801	.988	.977	.911	.991
T F2	.971	.981	.901	.944	.995	.998	.993	.791	.808	.997	.998	.995
T F3	.978	.977	.979	.985	.995	.994	.981	.577	.965	.944	.943	.997
C F1	.949	.985	.725	.895	.964	.659	.922	.513	.805	.613	.911	.517
C F2	.956	.996	.879	.999	.898	.983	.898	.983	.646	.710	.746	.491
C F3	.993	.957	.850	.999	.981	.996	.911	.703	.826	.792	.735	.898

Table G17 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* Poll

Poll	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pɑl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.712	.912	.380	.979	.987	.863	—	—	—	—	—	—
V F2	.976	.985	.761	.989	.956	.966	—	—	—	—	—	—
V F3	.942	.823	.958	.998	.883	.995	—	—	—	—	—	—
T F1	.999	.997	.965	.999	.984	.962	—	—	—	—	—	—
T F2	.983	.992	.717	.799	.999	.796	—	—	—	—	—	—
T F3	.606	.983	.857	.999	.766	.791	—	—	—	—	—	—
C F1	.874	.928	.598	.994	.974	.858	—	—	—	—	—	—
C F2	.922	.191	.620	.601	.878	.502	—	—	—	—	—	—
C F3	.809	.910	.915	.990	.470	.483	—	—	—	—	—	—

Table G18 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* pool

pool	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pul/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.974	.999	.851	.974	.902	.939	.953	.697	.966	.486	.964	.478
V F2	.967	.818	.885	.930	.703	.928	.932	.965	.853	.944	.971	.996
V F3	.881	.970	.931	.982	.912	.706	.937	.948	.965	.896	.986	.999
T F1	.988	.996	.987	.995	.990	.949	.988	.966	.779	.984	.990	.999
T F2	.690	.993	.956	.990	.986	.976	.969	.999	.477	.992	.955	.974
T F3	.778	.662	.978	.974	.565	.991	.976	.997	.769	.984	.996	.961
C F1	.839	.992	.828	.812	.997	.717	.986	.198	.495	.610	.906	.961
C F2	.312	.921	.821	.764	.903	.831	.958	.821	.209	.511	.880	.806
C F3	-.511	.948	.630	.559	.096	.974	.734	.721	.936	.710	.951	.952

Table G19 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* poor

poor	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pʊr/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.980	.984	.952	.985	.681	.601	.992	.982	.990	-.161	.974	.631
V F2	.956	.859	.866	.599	.949	.658	.862	.963	.658	.689	.775	.887
V F3	.911	.983	.938	.999	.995	.946	.739	.975	.952	.529	.882	.683
T F1	.527	.991	.960	.991	.575	.975	.984	.936	.958	.968	.967	.772
T F2	.986	.995	.944	.791	.961	.996	.891	.992	.993	.990	.960	.990
T F3	.978	.999	.248	.825	.994	.697	.956	.950	.965	.992	.959	.996
C F1	.818	.962	.727	.894	.784	.949	.804	.895	.591	.451	.941	.552
C F2	.503	.759	.811	.967	.987	.650	.622	.879	.957	.730	.847	.334
C F3	.698	.839	.449	.946	-.160	.844	.737	.977	.939	.856	.948	.587

Table G20 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* pore

pore	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pɔr/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.835	.942	.652	.970	.950	.878	.920	.674	.957	-.333	.985	.868
V F2	.981	.424	.765	.753	.832	-.316	.980	.649	.963	.270	.943	.919
V F3	.966	.979	.961	.962	.892	.627	.983	.679	.981	.737	.920	.613
T F1	.996	.999	.836	.995	.981	.914	.970	.963	.975	.987	.400	.997
T F2	.889	.991	.733	.699	.984	.979	.909	.975	.983	.709	.960	.992
T F3	.914	.995	.298	.995	.678	.829	.969	.947	.817	.998	.987	.993
C F1	.965	.975	.476	.984	.895	.696	.893	.189	.781	.093	.912	.548
C F2	.839	.388	.923	.978	.948	.817	.704	.779	.889	.503	.743	.762
C F3	.575	.930	.874	.557	.829	.768	.632	.878	.432	.250	.776	.853

Table G21 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* power

power	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/paʊr/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.995	.997	.703	.997	.991	.862	.948	.976	.943	.997	.943	.998
V F2	.784	.997	.454	.985	.990	.987	.953	.961	.982	.998	.859	.999
V F3	.990	.998	.960	.992	.923	.967	.950	.971	.995	.994	.522	.992
T F1	.961	.999	.892	.996	.993	.848	.822	.898	.721	.993	.778	.999
T F2	.988	.989	.802	.997	.997	.919	.798	.774	.994	.650	.996	.782
T F3	.780	.997	.870	.998	.932	.917	.958	.989	.953	.992	.868	.824
C F1	.798	.810	.942	.778	.797	.506	.779	.793	.369	.864	.330	.670
C F2	.764	.763	.744	.945	.978	.768	.448	.972	.935	.084	.945	.935
C F3	.658	.796	.728	.736	.521	.508	.308	.867	.448	.871	.611	.086

Table G22 *Pearson correlation coefficients (r) for midpoint vs. mean measurements for* pull

pull	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6	
/pʊl/	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast
V F1	.778	.999	.801	.986	.712	.986	.967	.886	.629	.937	.730	.907
V F2	.907	.995	.502	.755	.991	.854	.980	.991	.941	.607	.990	.759
V F3	.679	.996	.968	.992	.951	.990	.869	.793	.916	.948	.942	.916
T F1	.803	.995	.506	.994	.997	.990	.998	.780	.962	.980	.991	.997
T F2	.993	.998	.928	.981	.995	.995	.990	.987	.982	.802	.955	.991
T F3	.987	.996	.992	.964	.755	.605	.980	.956	.270	.980	.980	.995
C F1	.856	.831	.948	.628	.779	.987	.966	.938	.731	.496	.786	.746
C F2	.790	.944	.698	.982	.994	.823	.914	.420	-.122	.608	.146	.628
C F3	.510	.985	.715	.751	.731	.332	.694	.916	.955	.330	.960	.440