Perceptual assimilation, discrimination, and acquisition of non-native and second-language vowels assimilated as uncategorised

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Statement of Authentication

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

……………[redacted]……………..

(Signature)

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"Delight in the LORD, and he will give you the desires of your heart."

(Psalm 37:4)

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Dedicated to Sohair Zarief

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ABSTRACT

Non-native and second-language (L2) phones are perceived in terms of their similarities and differences to the listener's native (L1) phonemes. A non-native phone that is reliably identified as similar to a single L1 phoneme is described as being *categorised* according to PAM/PAM-L2 (Best, 1995; Best & Tyler, 2007), and such categorised assimilations have been the focus of much of the research on non-native and L2 speech perception. It is also possible that non-native/L2 phones are perceived as being speech-like, but are not identified with any one particular L1 phoneme. In such instances, they are said to be assimilated as *uncategorised*. This thesis presents experiments designed to address how these uncategorised phones are perceived, discriminated, and acquired by adult L2 learners. The findings have theoretical implications for models of cross-language and L2 speech perception, and contribute to our understanding of the perception and acquisition of uncategorised phones.

The first question addressed in this thesis was whether there were any systematic differences in the way in which uncategorised non-native phones are assimilated within the L1 phonological system. In the first experiment, native Egyptian Arabic speakers residing in Egypt perceptually assimilated and rated all of the Australian English vowels in relation to their L1 vowels. Results revealed new assimilation types for uncategorised phones. They may be perceived as being moderately similar to just a single L1 phoneme (*focalised*), to two or more L1 phonemes (*clustered*), or unlike any of the L1 phonemes (*dispersed*). This suggests

that not all uncategorised phones are perceived in the same way, but rather, they vary in the extent to which they are perceptually identified with L1 phonemes.

The second set of experiments addressed the issue of how well pairs of non-native phones might be discriminated when one or both phones are assimilated as uncategorised (i.e., *Uncategorised-Uncategorised* and *Uncategorised-Categorised* assimilations, respectively). Native Australian English speakers discriminated Danish monophthongal and diphthongal vowel contrasts varying in assimilation type, including Uncategorised-Uncategorised and Uncategorised-Categorised. Discrimination accuracy was modulated by the presence of perceived phonological overlap in the categorisations to L1 phonemes, with partially overlapping contrasts discriminated less accurately than non-overlapping contrasts. By considering the different uncategorised assimilations and the presence of perceived phonological overlap to L1 categories, it was possible to fine-tune predictions for Uncategorised-Uncategorised and Uncategorised-Categorised assimilations much better than if overlap were not considered.

The final aim of this thesis was to examine the acquisition of uncategorised L2 phones in adults. It was predicted that new category formation would be more likely to occur for uncategorised, than for categorised, L2 phones. Egyptian Arabic speakers acquiring Australian English in an immersion setting were recruited for a 1-year longitudinal study. They were assessed on their perceptual assimilation of the English vowels, and also on their discrimination accuracy of English vowels that formed Uncategorised-Uncategorised and Uncategorised-Categorised assimilations, as it is these assimilations that should be easily acquired according to the PAM (Best, 1995) and SLM (Flege, 1995) theoretical models. The learners were not absolute beginners, but they differed on six factors related to L2 experience (i.e., length of residence, age of foreign language acquisition, age of immersion, proportion of L2 use, L2 vocabulary size, and duration of English as a foreign language training). There was no evidence of new category acquisition, perhaps because they had already reached a plateau in L2 learning at the start of the study, or possibly because a longer period of immersion may be needed to determine whether they show improvements over time. However, by considering variability among individual learners, the six factors were shown to predict discrimination accuracy to a certain extent, predominantly for Uncategorised-Uncategorised and Uncategorised-Categorised assimilations.

Overall, the experiments reported in this thesis provided a much-needed systematic and thorough investigation into the perceptual assimilation, discrimination, and acquisition of uncategorised non-native/L2 phones. The experiments demonstrated that uncategorised phones vary in their perceptual assimilation to the L1, and that discrimination accuracy is dependent upon the presence of perceived phonological overlap for contrasts involving uncategorised phones. This has important theoretical implications for both cross-language and L2 speech perception models. A number of interesting questions are also raised for L2 phonological category formation, answers to which have the potential to provide a step forward in our understanding of L2 acquisition.

CHAPTER 1

INTRODUCTION

CHAPTER 1: INTRODUCTION

1.1 Perceptual assimilation, discrimination, and acquisition of uncategorised phones

Spoken language is a central part of everyday life. It is used to convey a range of complex ideas, thoughts, and emotions. For listeners, the main aim is to extract meaning from the speech signal. To become competent language users, however, listeners must be able to identify and discriminate consonants and vowels (i.e., *phones*), which are often regarded as being the building blocks of speech, in particular of spoken words (Mitterer & Cutler, 2006). Adult language users are able to efficiently and effortlessly process the phones of their native-language (L1) and this is attributed to their extensive experience with the phones employed in their L1. However, this L1 attunement often, though not always, comes with a cost to non-native speech perception. Non-native phones are perceived in terms of their similarities and differences to L1 phonemes. A pair of non-native phones that are perceived as similar to two separate L1 phonemes will be more easily discernable than if they are perceived as instances of a single L1 phoneme. For example, for Arabic listeners, the vowels in the English words *hat* and *hut* are both often perceived as instances of a single L1 Arabic vowel, which is phonetically similar to the English vowel in the word *hut*. Consequently, these English vowels are likely to be difficult for Arabic speakers to distinguish.

Despite the importance of spoken language and speech processing, there are aspects of speech perception that are not yet well understood. The example provided earlier was of a non-native phone that is identified with an L1 phoneme. However, it is not always the case that a non-native phone is perceived as similar to just one L1 category -- it may instead be perceived as sharing similar phonetic features with more than one L1 phoneme. The Perceptual Assimilation Model (PAM: Best, 1995) describes such instances as *uncategorised* assimilations, where the uncategorised phones fall in between L1 categories in an untuned region within the native phonological space. Surprisingly, there has been remarkably little systematic examination of the perception of uncategorised phones. Perhaps a reason that this area has been largely neglected may be because, unlike categorised assimilations, uncategorised assimilations are unsystematic and unreliable, and it is therefore difficult to draw any meaningful conclusions about how uncategorised phones are perceived in relation to the L1. In this thesis, it is argued that uncategorised assimilations provide meaningful information about the organisation of the L1 phonological system and how the L1 influences the perception of foreign language phones. On that account, this thesis reports on experiments that investigated the perceptual assimilation, discrimination, and acquisition of uncategorised phones. The findings have important implications for theoretical models of cross-language and second-language (L2) speech perception.

Since uncategorised phones are assimilated within the L1 phonological space, it seems reasonable to speculate whether, and to what extent, they are perceived as similar to the surrounding L1 phonemes. For example, a given non-native phone may fall in between two or more L1 categories, while another may fall in a completely "untuned" region within the phonological space where the perceiver has not established any L1 categories. This prompted the first question addressed in this thesis: Are there any systematic differences in the way in which different uncategorised phones are assimilated to the L1 phonological system?

As described above, discrimination performance will vary for pairs of categorised phones depending on their perceived similarity to L1 phonemes and to one another. However, it is unclear how well pairs of non-native phones would be discriminated when one or both are uncategorised, and what factors might influence their discrimination performance. This led to the second question examined in this thesis: What are the discrimination accuracy levels for uncategorised phones, and what factors might modulate discrimination performance?

The first two issues focused on the perceptual assimilation and discrimination of *non-native* phones assimilated as uncategorised. This thesis also covers L2 acquisition in adults. Consider an Arabic speaker who attempts to acquire the English vowels in *hat* and *hut*. As they are assimilated to a single L1 phoneme, it may be difficult for the learner to acquire these English vowels. The perceptual assimilation of L2 phones to the L1 phonological system will influence the outcomes of L2 acquisition. For phones that are assimilated as uncategorised, how might they be acquired by adult L2 learners? When examining L2 acquisition, it is often important to also consider individual differences among learners that are likely to affect their ultimate attainment of the L2, such as age of L2 acquisition and their length of residence in the L2-speaking environment, just to name a few. Therefore, the following questions are also addressed: How well are uncategorised L2 phones acquired by adult L2 learners, and how might individual differences predict learning outcomes?

The following section provides a brief outline of the structure of the thesis chapters, and the topics discussed in each of the chapters.

1.2 Thesis overview

To assess the discrimination and acquisition of uncategorised phones, the experiments presented in this thesis will focus on vowels rather than consonants, as the research to date suggests vowels are more likely than consonants to be assimilated to the L1 as uncategorised. This thesis will begin by defining the unique characteristics of vowels and consonants in order to better understand how they differ from one another, and why vowels are ideal for addressing the research questions (Chapter 2). Chapter 3 will provide an overview of the relevant research in the areas of adult cross-language speech perception. First, to learn how the L1 shapes adults' perception of non-native speech, a brief description will be provided of how infants come to tune into the L1 phonology. This will then be followed by a review a cross-language speech perception model and how it accounts for non-native speech perception in adults. Chapter 4 will address adult L2 acquisition. Models of L2 speech learning will be described and evaluated. The latter half of that chapter will review several factors that have been shown to influence the outcome of L2 acquisition. Chapter 5 presents the research framework and the main research questions addressed in the subsequent experimental chapters. A description and justification of the stimuli, participant groups, and methodology used in the experimental series will also be discussed in that chapter.

Chapters 6 through 8 constitute the experimental chapters, which are presented in the form of stand-alone journal articles, except for Chapter 8, which is in the format of a traditional thesis chapter. The journal articles have been formatted so that they are consistent with the formatting of rest of the thesis (e.g., the experiments presented in Chapter 7 have been renumbered). The study presented in Chapter 6 examined the various ways in which non-native phones may be perceptually assimilated as uncategorised. The study was published in 2016 as an Express Letter in the Journal of the Acoustical Society of America. The experimental series presented in Chapter 7 addresses the question of how well uncategorised non-native phones are discriminated using both monophthongal and diphthongal vowels as stimuli. That paper is under revision in the Journal of Phonetics. Chapter 8 presents a longitudinal study aimed to track the acquisition of L2 uncategorised phones by adult learners who are in an immersion setting. The effects of factors related to L2 speech perception on L2 acquisition were also assessed. This thesis concludes with the General Discussion and Conclusions in Chapter 9. The current findings, implications for models of non-native/L2 speech perception, and directions for future research are discussed there.

The appendices contain copies of the background questionnaires used and the two parallel versions of the vocabulary size test presented in English and Arabic. Vowel measurements based on the Australian English vowel productions used for Experiments 1 and 5 are reported in the appendices. Tables displaying the perceptual assimilation results from Experiment 5, and raw data from that experiment are reported. Also included are conference abstracts and conference proceedings papers on my thesis project's findings from throughout my candidature.[1]

[1] A proportion of the data presented in Chapter 7 has been published as a conference proceeding for the 18th International Congress of Phonetic Sciences (ICPhS, 2015) Glasgow, UK. Also, a proportion of the data from Chapter 8 has been published as a conference proceeding for the 16th Australasian International Conference on Speech Science and Technology (SST, 2016) Sydney, Australia, and reported in an abstract for the Architectures & Mechanisms for Language Processing 2015 Valletta, Malta, and the 8th International Symposium on the Acquisition of Second-Language Speech (New Sounds, 2016) Aarhus, Denmark. Refer to Appendix I for the conference abstracts and proceedings.

CHAPTER 2

DIFFERENCES IN THE PRODUCTION AND PERCEPTION OF VOWELS AND CONSONANTS

CHAPTER 2: DIFFERENCES IN THE PRODUCTION AND PERCEPTION OF VOWELS AND CONSONANTS

The various languages of the world differ in the number and types of vowels and consonants that they employ. This thesis will examine how experience with categories of phones, or *phonemes*, in the L1 influences perception of foreign language and L2 phonemes, with a particular focus on the perception of non-native/L2 phones that are perceived as being unlike any one particular native phoneme. Before investigating these issues, it is first necessary to identify the different classes of phones, namely, consonants (Section 2.2.1) and vowels (Section 2.2.2), and their defining characteristics (Section 2.2), and to examine how their unique acoustic and articulatory features translate to differences in speech perception (Section 2.3). This chapter will begin with a brief description of the articulatory system and the articulators responsible for the production of the different phones. The descriptions provided in this chapter are primarily based on those from Catford (2001), Clark and Yallop (1995), Fromkin, Rodman, and Hyams (2009), and Ladefoged (2005).

2.1 Articulatory system

Humans are capable of producing a variety of phones, which are created using a sophisticated co-ordination of numerous articulators within the vocal tract as they assume complex shapes and varying positions (Finegan, 2008). The vocal tract consists of the lips, teeth, tongue, alveolar ridge, hard palate, velum, uvula, pharynx, larynx, trachea, and lungs (Ladefoged & Johnson, 2014; Sethi & Dhamija, 2002). The vocal tract is illustrated in Figure 2.1.

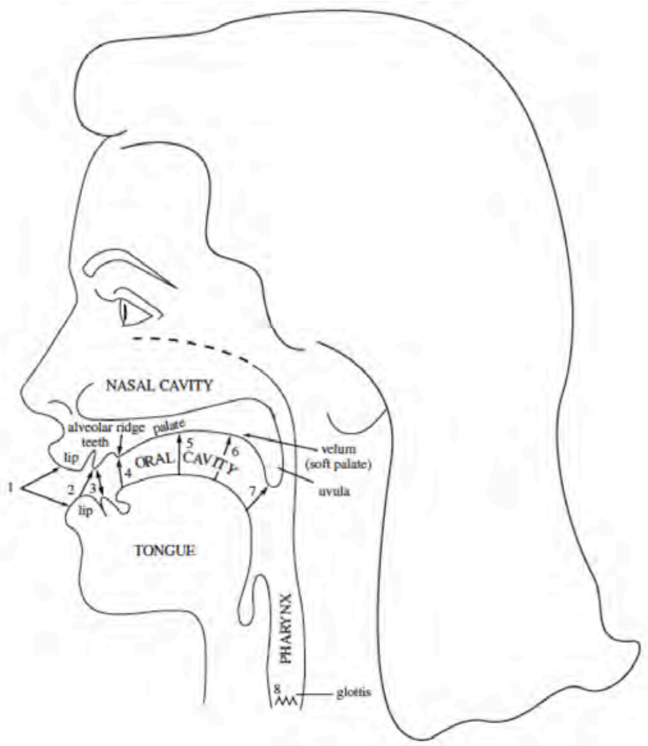

Figure 2.1: An illustration of the vocal tract (reproduced from Fromkin et al., 2009). The various places of articulation are indicated by the numbered arrows, and are referenced in Section 2.2.1.

Most phones are created with pulmonic air pressure, that is, air that is pushed out from the lungs through the vocal tract (Clark, Yallop, & Fletcher, 2007). There are also instances, however, where phones are not produced with pulmonic air pressure, and instead, air pressure is generated in the upper region of the vocal tract (Ball & Joan, 1999). Examples of this include click consonants and ejectives in Zulu (Kenstowicz, 2009). For phones involving pulmonic air pressure, the airflow first passes through the larynx. Within the larynx are the vocal folds, which are two small folds made out of muscle and connective tissue. These vocal folds narrow and tighten to varying extents. When airflow from the lungs builds up beneath the closed vocal folds, this pressure forces the vocal folds to open. After this pressure is released, the vocal folds close, only to be forced open again due to renewed pressure build-up beneath them. This process of vocal fold vibration is termed phonation, and is the source of voicing in voiced phones such as vowels and voiced consonants. The space between the vocal folds is called the glottis. The tract below the glottis is referred to as the subglottal vocal tract and the tract above the glottis is called the supraglottal tract. Above the larynx are three chambers, namely, the pharynx (throat), oral cavity, and nasal cavity.

Before these different regions of the vocal tract are described in further detail, it is necessary to first briefly explain the acoustics of phonemes. Vowels and various types of consonants consist of a fundamental frequency (F0) of the speaker's voice and a range of higher frequencies known as harmonics[2]. Each of the harmonics is a multiple of the fundamental frequency. For example, for a fundamental frequency of 300 Hz, there will be harmonics of 600 Hz, 900 Hz, 1200 Hz, and so on. The length and shape of the cavities of the vocal tract resonances, such that harmonics at certain frequency regions are emphasised while others are de-emphasised (Moore, 2014). Harmonic frequencies depend on the frequency of vocal fold vibration, while the resonance frequencies depend on size, length, and articulatory configurations within the vocal tract. It is these resonances, called formants, which give phonemes their distinctive acoustic quality.

As mentioned, one of the cavities above the larynx is the oral cavity. Within the oral cavity is the roof of the mouth, referred to as the palate, and it consists of hard and soft regions. Behind the teeth is the alveolar ridge, which forms part of the hard

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[2] There are some consonants that are aperiodic which do not contain a clear fundamental frequency or harmonics (e.g., /t, f/).

palate. The back end of the roof of the mouth is referred to as the soft palate, or velum. The velum is capable of lowering and raising as a way to control air flowing through the nasal cavity. When the velum lowers, airflow passes through the nasal cavity and the airflow is excited by the resonance frequencies of the nasal cavity. Nasalised phones are the result of this.

Also within the oral cavity is the tongue, a muscular speech organ that plays an important role in shaping the airflow and size of the oral cavity. The tongue is divided into several areas, namely, the tongue tip, tongue blade, and tongue body (front, centre, and back) and the tongue root in the pharynx. The different parts of the tongue are responsible for the production of specific phones. For example, /d, t/ are produced with the tongue tip touching the alveolar ridge, while the articulation of /g, k/ involves the back of the tongue body making contact with the velum. The lips are also capable of manipulating the airflow and extending the length of the oral cavity when they are protruded. This influences the formant frequencies, which are affected by the length and the shape of the vocal tract. As will be discussed in Section 2.2.2.3, the lips play an important role in changing the quality of vowel sounds.

Articulatory organs may be described as being either active or passive articulators (Sethi & Dhamija, 2002). Active articulators are articulatory organs that move from their resting position to assume another position. On the other hand, passive articulators are those that are not capable of moving (i.e., they are immobile), and the active articulators may approach or come into contact with them. Consider the production of /d, t/, which involve the tongue tip touching the alveolar ridge. In this example, the tongue is the active articulator, and the alveolar ridge is the passive articulator.

The process of generating speech by shaping the resonating cavities in the vocal tract, which in turn changes the resonance frequencies that are excited by the airflow, is termed articulation. Of the various sounds that the human vocal tract is capable of producing, phones may be classified as consonants or vowels. Now that a basic description of the articulatory system has been provided, the unique characteristics of consonants and vowels will be outlined in the following section. While the focus of this thesis is on speech perception, it is important to also consider differences in speech production as they have implications for speech perception (see Section 2.3). The following section will first outline the characteristics of consonants, followed by vowels, in order to understand the unique differences between the two classes of phones.

2.2 Types of phones

Vowels and consonants differ from one another both articulatorily and acoustically. Consonants involve an obstruction of the airflow to varying extents at some point along the vocal tract due to some sort of constriction or closure, while vowels are produced with a relatively unobstructed vocal tract. Additionally, vowels are longer in duration, have relatively higher amplitudes of resonances than consonants, are produced with slower and larger articulatory gestures, and involve larger muscles than those used to produce consonants.

2.2.1 Consonants

Consonants can be described in terms of their place and manner of articulation. Place of articulation refers to the regions of the vocal tract where the target gesture is produced. Most of these places of articulation are illustrated by the numbered arrows in Figure 2.1 (1. bilabial; 2. labiodental; 3. interdental; 4. alveolar; 5. palatal/alveopalatal; 6. velar; 7. uvular; 8. glottal). For instance, the bilabial consonants in Australian English such as /m/ and /b/ are produced when the upper and lower lips come together, while labiodental consonants are those when the upper teeth make contact with the lower lip such as the Australian English /f/ and /v/. For consonants known as coronals, each place can be further differentiated by the orientation of the tongue tip, that is, apical (tip contact), laminal (blade contact), or sublaminal (underside of tongue tip contact). The four basic places of articulation are: dental, alveolar, postalveolar, and alveopalatal/palatal.

Manner of articulation describes the relatively free flow or obstruction of the airflow. There are various manners of articulation: stops (plosives), nasals, trills, taps/flaps, fricatives (sibilants, lateral fricatives), affricates, approximants (glides, lateral approximants), ejectives, implosives, and clicks ("Handbook of the International Phonetic Association," 1999). For example, in Australian English, stop consonants such as /d/ and /p/ are produced when the air is momentarily blocked from escaping through the mouth or nose (i.e., full closure), and then released. In contrast, nasal consonants such as /m/ and /n/ involve a closure in the vocal tract as the velum lowers in order to allow the air to escape through the nasal cavity.

Consonants are also distinguished in terms of voicing. When producing certain consonants, the vocal folds may vibrate due to the air pressure from the lungs, with such sounds referred to as being voiced (e.g., /b, g, v/). Alternatively, the airflow may be allowed to pass freely through the vocal folds, as is the case for voiceless consonants (e.g., /p, k, f/).

An alternate approach to describing units of speech is from the articulatory phonology perspective, where speech production is regarded as a complex, dynamic, highly-organised process (Browman & Goldstein, 1989, 1992). Units of speech production may be defined as a coordinated set of articulatory events termed gestures. A particular gesture involves multiple articulators (e.g., lips, jaw, tongue) and the formation and release of constrictions. Consider the articulation of the consonant /b/, which is a bilabial stop consonant that involves the upper and lower lips being held tightly to momentarily block the air flow (closure). To describe this from the articulatory phonology approach, in order to block the air when producing /b/, closure is achieved by a lower lip (active articulatory) gesture that decreases the distance between the upper and lower lips until they meet and compress, and the lips would need to maintain the optimal amount of stiffness for this to occur.

2.2.2 Vowels

The perception of vowels will be the focus of this thesis, but prior to examining the literature on vowel perception, it is useful to first understand the unique characteristics of vowels and to outline the various features that distinguish vowels from one another. Vowels are normally voiced because as the air passes from the lungs it causes the vocal folds to vibrate. The air resonates within the cavities at each cavity's resonant frequency, giving rise to formants. The first three formants are normally used to distinguish vowels from one another.

Formants may be visually represented in a spectrogram, which is an acoustic analysis tool that provides a visual representation of the components of sounds such as frequency and intensity over time. Figure 2.2 displays the first (F1), second (F2), and third (F3) formants of the Australian English vowels /ɪ, ɐː, ʉː/ in the words *hid*, *hard*, and *who'd*, and the formants are indicated by the pointing arrows. Frequency (Hz) is displayed vertically with the spectrograms band-limited to the frequency range of 0-5000 Hz. Time (ms) is presented horizontally so that the longer the spectrogram, the longer the vowel duration. Darker bands indicate a greater concentration of energy than lighter bands. Individual vocal fold vibrations appear as dark vertical striations.

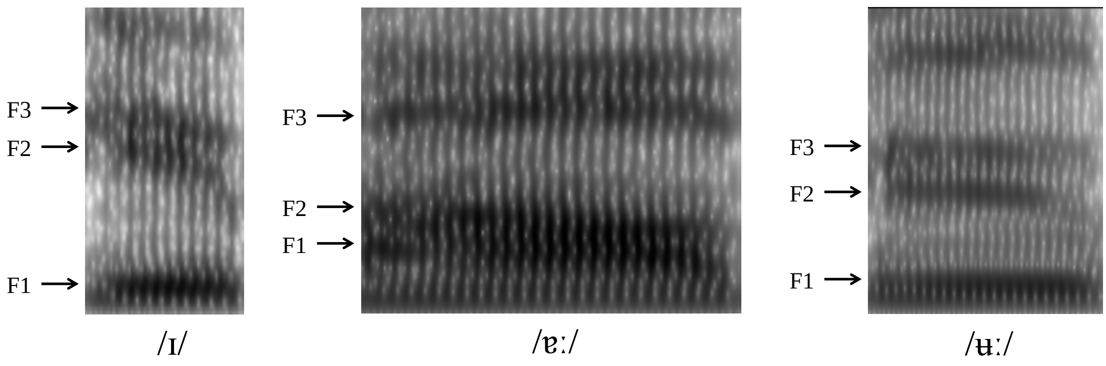

Figure 2.2: A spectrogram displaying the Australian English vowels in the words hid, hard, and who'd with F1, F2, and F3 indicated by the pointing arrows.

Vowels may be described and classified according to several variables, namely, tongue height (close-open), tongue position (front-back), lip rounding (rounded-unrounded), vowel duration, and vowel dynamics. These different variables differentiate one vowel from another. These characteristics will be described in more detail in the following sections.

2.2.2.1 Tongue height

Tongue height refers to the distance of the tongue body from the hard palate. Lowering or raising the tongue body towards the hard palate adjusts the tongue height, and this is further aided by lowering or raising the jaw. Vowels where the tongue is positioned lower in the oral cavity and the jaw is open are deemed open vowels, and also referred to as low vowels, while vowels where the tongue is raised towards the hard palate are referred to as close vowels, or high vowels. Mid vowels are those where the tongue is positioned in between those classified as open and close. For the vowel [ɪ] in *hid*, the tongue is close to the hard palate (close vowel), but the tongue assumes a much lower position for the vowel [ɐ] as in *hut* (open vowel).

In terms of the vowel formants, F1 is related to vowel height. There is an inverse relationship between tongue height and F1 frequency. Specifically, the higher the F1 frequency, the lower the vowel. Conversely, the lower the F1 frequency, the higher the vowel. As can be seen in Figure 2.2, F1 is higher for the open vowel [ɐ], than it is for the close vowel [ɪ].

2.2.2.2 Tongue position

The position of the tongue relative to the back of the oral cavity is also used to distinguish different vowels from one another, and it can also be described generally as tongue frontness-backness. Vowels produced where the tongue body is pushed toward the front of the mouth are classified to as front vowels, as is the case for the vowel [ɪ] in *hid*. Vowels where the tongue body is retracted toward the back of the oral cavity are deemed to be back vowels, such as the vowel [ɔ] in *hot* as pronounced in Australia. Note also that vowels classified as front vowels will differ in their degree of frontness. The degree of backness of a vowel correlates with F2. In this case, F2 frequency is higher for front vowels such as [ɪ], and lower for back vowels such as [ɔ]. Also, F2 may be affected by the length of the vocal track (e.g., lip protrusion, larynx lowering) and the corresponding relationship between F2 and F3.

Vowels may be visually displayed using a vowel quadrilateral, as is shown in Figure 2.3 (Ladefoged, 2005). It is used to represent the phonetic properties of vowels by considering the tongue height and position within the oral cavity. The frontness-backness of a vowel is represented from the left to the right of the diagram, respectively, and tongue height is denoted on the vertical axis so that close vowels are represented higher up on the diagram.

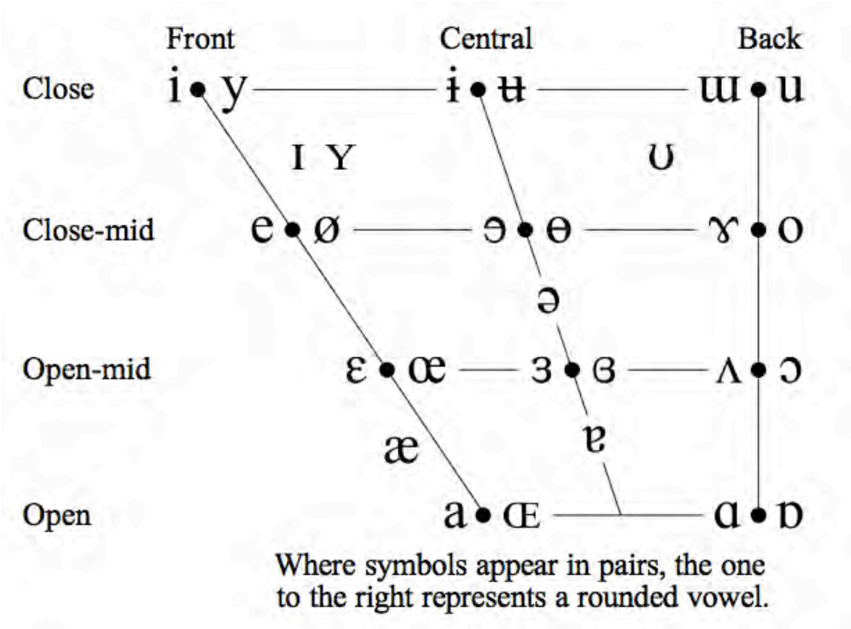

Figure 2.3: Vowel quadrilateral (reproduced from "Handbook of the International Phonetic Association," 1999).

2.2.2.3 Lip rounding

Vowels can also be distinguished from one another by the degree of lip rounding, a characteristic referring to the size of the aperture between the lips, which may also involve some degree of lip protrusion (Cox, 2012). For example, the vowel [ʊ] in *hood* is articulated with the lips rounded and protruded, while the articulation of the vowel [e] in *head* does not involve any lip rounding. The position of the lips may be spread, neutral, or rounded, as illustrated in Figure 2.4.

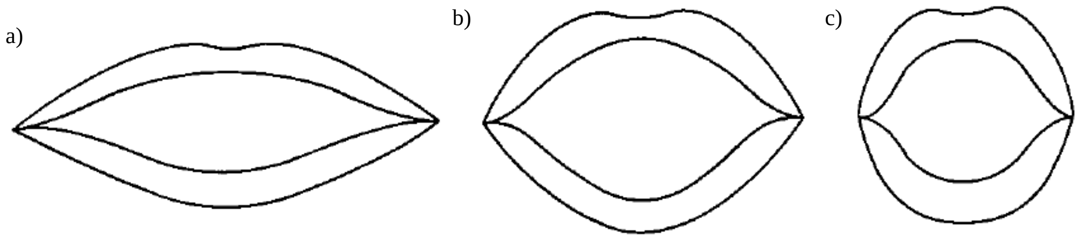

Figure 2.4: Different degrees of lip rounding, a) spread, b) neutral, and c) rounded (reproduced from Clark & Yallop, 1995).

Close vowels are associated with spread lip positions, while neutral lips tend to be associated with open vowels. This is because, unlike close vowels, open vowels are produced with the tongue lower in the mouth, also resulting in the lowering of the jaw, thus producing a greater degree of lip aperture. Therefore, lip rounding lowers the value of the F2 and F3. It is the F3 value that corresponds to lip rounding, although this information is not available in the vowel quadrilateral. Since vowels produced where the lip position is neutral or spread do not involve the lips being rounded, they are both classified as unrounded, while those that involve the lips being rounded are referred to as rounded vowels.

In many of the world's languages, it is common for the back vowels to be rounded while the front vowels are unrounded. In addition to back rounded and front unrounded vowels, some languages also employ front rounded and/or back unrounded vowels. For example, in Danish, the front rounded vowels /y, ø, œ/ contrast phonologically with the back rounded vowels /u, o, ɔ/ and front unrounded vowels /i, e, ɛ/ (Grønnum, 1998), while in Thai the back unrounded vowels /ɯ, ɤ/ contrast with the front unrounded vowels /i, e/ and back rounded vowels /u, o/ (Tingsabadh & Abramson, 1993). In front-back contrasts of rounded vowels, the back vowels are generally more rounded than the front vowels (Catford, 1977).

2.2.2.4 Vowel duration

Vowel length or duration may be affected by speaking rate and the consonantal context in which the vowel appears. Particular vowels also tend to be intrinsically longer or shorter in nature. For example, open vowels are generally longer than close vowels due to the greater articulatory movement required to produce such vowels (Lehiste, 1976; Lindblom, 1967). Vowel duration differences in these instances are not phonologically contrastive.

Vowel duration that results in differences in lexical meaning is regarded as a phonemic feature in many languages, and is referred to generally as vowel length (Catford, 1977). For instance, in Danish, the vowels /i, e, ɛ, a, u, o, ɔ, y, ø, œ/ differ in length from their long counterparts /iː, eː, ɛː, aː, uː, oː, ɔː, yː, øː, œː/. In phonetic transcriptions, the /ː/ symbol is used to represent a lengthened vowel. For some languages, pairs of intrinsically short and long vowels differ not only on vowel duration, but also on quality (i.e., formant frequencies). For example, the Australian English vowels /ʊ, ʉː/ differ in vowel duration, but /ʉː/ is also more fronted than /ʊ/ (Cox, 2012). In such instances, where duration is not the exclusive defining feature, the terms lax and tense are used instead of short and long, respectively. Laxness and tenseness refers to a tightening of the vocal tract muscles, such that tense vowels are generally produced with greater tension of the tongue muscles (and the lips, for rounded vowels). Australian English is unique in that it has tense/lax vowel pairs that differ only in vowel duration such as the vowel /ɐː/ and /ɐ/ for words like *heart* and *hut*, respectively (Cox & Palethorpe, 2007).

2.2.2.5 Vowel dynamics

Vowel dynamics refers to the presence of movement of the articulators during vowel production. When the tongue, lips, and jaw are in a relatively stable position over the course of production of a vowel such that there is no change in the vowel quality, a relatively steady state of articulation is achieved. Vowels produced in this manner are termed pure vowels, or monophthongs. In Australian English, the vowels /ɐ, e, ɪ, ɔ, ʊ, æ, ɐː, eː, iː, oː, ʉː, ɜː/ are classified as monophthongs (Cox, 2006; Cox & Palethorpe, 2007). While they are not 'true monophthongs' due to the slight changes in spectral properties across time, they are nonetheless classified as monophthongs since the spectral change is not substantial. For example, the /ɪ, iː/ contrast is not only differentiated by duration as /iː/ is produced with some degree of onglide which is not observed in /ɪ/ (Bernard, 1970).

While monophthongs are produced with the tongue and jaw in a relatively stable position throughout production, diphthongs are much more dynamic as they are produced with substantial movement of the tongue, jaw, or lips during articulation. The tongue, lips, and jaw assume a particular configuration at the start of production, and glide towards another position. Diphthongs contain two vowel targets, and are transcribed using two IPA vowel symbols, but are nonetheless perceived as a single vowel by native listeners (Cox, 2012). The diphthongs in Australian English are /ɑe, æɔ, æɪ, əʉ, ɪə, oɪ/ (Cox & Palethorpe, 2007), which are found in the Australian English words *hide, boat, bait, how, near*, and *hoist*, respectively. Note, while the vowel /ɪə/ is diphthongised in Australian English, this is not always the case in some dialects of English, such as in American English where it is often realised as a non-diphthongal vowel (Pike, 1947).

While monophthongs can be plotted and described in terms of their steady state formant value, diphthongs are better understood by charting the starting and ending F1 and F2 values, as depicted in Figure 2.5, which shows the transitional information of the Australian English diphthongs. Note, the vowel /eː/ is non-rhoticised in Australian English and is sometimes produced with some formant transitions, while in American English, for example, it is pronounced as a rhoticised vowel (Davenport & Hannahs, 2013).

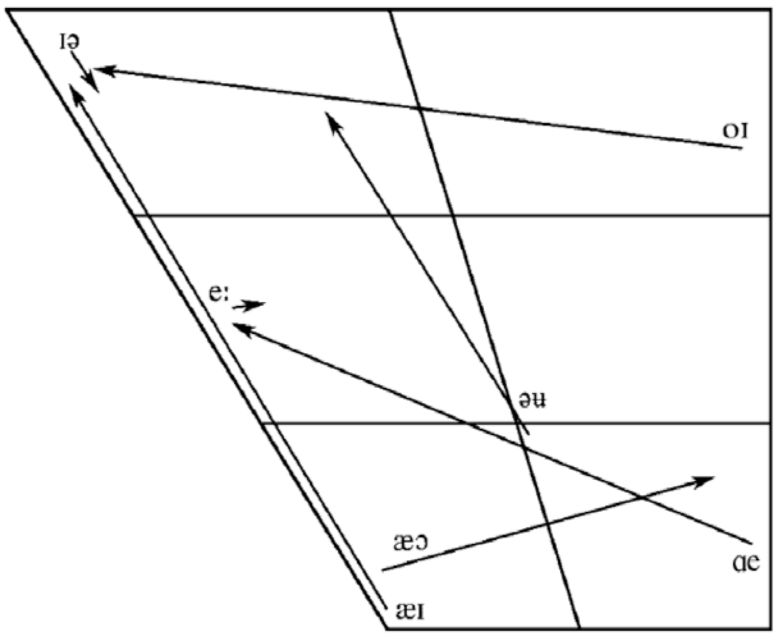

Figure 2.5: Trajectory of the Australian English diphthongs (reproduced from Cox & Palethorpe, 2007).

Section 2.2.1 outlined the characteristics of consonants and Section 2.2.2 provided a description of vowels. It is clear that the articulation of consonants and vowels differ from each other. Additionally, a distinction between monophthongal and diphthongal vowels was also made. As the focus of this thesis is on speech perception, it is important to now review how the differences between these various units of speech also translate to differences in perception. This will be discussed in the following section.

2.3 Perception of vowels and consonants

Differences in the perception of vowels and consonants can be observed as early as during infancy. Young infants are able to discriminate most pairs of contrasting phonemes (or contrasts) relatively well regardless of whether or not such contrasts are present in the language spoken in their surrounding environment (Best, 1994; Best, Goldstein, Nam, & Tyler, 2016; Werker, 1989). With increasing L1 experience, discrimination of non-native contrasts generally becomes difficult, reflecting the constraints of the L1. Infants tune into L1 vowels earlier than they do for native consonants. The influence of L1 attunement becomes apparent by 6-8 months of age for vowels (e.g., Polka & Werker, 1994) and by 10-12 months of age for consonants (e.g., Best, McRoberts, LaFleur, & Silver-Isenstadt, 1995; Werker, 1989; Werker & Tees, 2002).

Synthetic speech tokens varying in equal steps along an acoustic continuum are perceived as belonging to discrete categories, a phenomenon referred to as *categorical speech perception* (e.g., Pisoni & Lazarus, 1974). Vowels are perceived less categorically than consonants. In classic categorical speech perception studies, natural speech tokens (e.g., /b, d, g/) are used as the basis on which to create a continuum of synthesised speech tokens with acoustic cues systematically varied along each step of the continuum. The identification of consonants by adult listeners reveals a tendency to perceive the stimuli as belonging to a specific phonemic category, with a marked category boundary between contrasting consonants (Eimas & Corbit, 1973; Liberman, Harris, Hoffman, & Griffith, 1957). The perception of vowels, on the other hand, has been described as continuous, as the category boundary for vowels is less steep (Fry, Abramson, Eimas, & Liberman, 1962; K. N. Stevens, Liberman, Studdert-Kennedy, & Ohman, 1969). Additionally, listeners detect between-category distinctions more accurately for consonants than vowels, while within-category differences are detected more accurately for vowels than consonants (Fry et al., 1962; Pisoni, 1973). As vowels are less discretely perceived and articulated than consonants (Flege, Munro, & Fox, 1994; Strange et al., 1998), the vowels of a language are likely to form a single interconnected system (Bundgaard-Nielsen, Best, & Tyler, 2011b, 2011a).

Vowel identification has been shown to be aided by transitional cues (i.e., spectral/formant changes) available in the vowel. Specifically, the small changes in the spectral properties of some monophthongal vowels (as in Australian English), may aid vowel identification. In a study by Assmann, Nearey, and Hogan (1982), listeners were presented with full, isolated monophthongal vowels and gated monophthongal vowels, which were shortened vowels making any available diphthongisation non-perceptible. The full, isolated vowels were more accurately identified than the gated vowels. This suggests that spectral change across time benefits speech identification. This raises questions about the perception of diphthongs, which contain substantial spectral change across time in comparison to monophthongs. Since diphthongs contain rich dynamic information, it expected that there would be fewer errors identifying diphthongs than monophthongs. In any case, the perception of diphthongs is likely to differ from monophthongs given the differences between the two classes of vowels.

The focus of this thesis is on non-native phones that show uncategorised assimilations to the listeners’ L1. To examine the perception of uncategorised phones, vowels may be better suited to this purpose than consonants. In this chapter, the nature of vowels and the different vowel types was described, and the differences between vowels and consonants were outlined. It was described how vowels and consonants, as well as monophthong and diphthong vowels, differ in articulation, acoustics, and perception. Due to their unique features, vowel category boundaries are more fluid than those of consonants. Therefore, vowel perception is likely to be more variable than that observed with consonants, and non-native vowels are more likely than non-native consonants to be perceived as uncategorised. Examining the perception of vowels in particular provides an opportunity to examine the perception of different types of vowels, specifically, monophthongs and diphthongs. As already discussed, both vowel types vary greatly from one another in terms of articulatory and acoustic features, and an aim of this thesis will be to further explore how these differences translate to speech perception. The next chapter will examine how we come to tune into the vowels spoken in our immediate language environment, and how this L1 attunement shapes the perception of non-native vowels.

CHAPTER 3

PERCEPTION OF NON-NATIVE SPEECH

CHAPTER 3: PERCEPTION OF NON-NATIVE SPEECH

In this chapter, the role of experience with the native vowels and consonants in the perception of foreign language phones will be addressed. Adults often experience difficulty discriminating between a pair of foreign language/L2 vowels (e.g., /ɪ/ and /ɛ/) or consonants (e.g., /b/ and /p/) that are not phonologically distinctive in their L1. Young infants, on the other hand, are able to discriminate most vowel and consonant distinctions, including those that are not employed in the language in their immediate environment (e.g., Aslin & Pisoni, 1980; Werker, Gilbert, Humphrey, & Tees, 1981; Werker & Tees, 1984). Infants' near-universal speech perception sensitivity provides them with the ability to acquire any language spoken in their surrounding environment. This thesis is concerned with the perception of foreign language speech assimilated as uncategorised by *adult* listeners. In order to better understand the development of L1 attunement and the role that linguistic experience plays in the perception of foreign language speech in adults, it is necessary to briefly examine how infants come to tune into the phonemes of their L1 (Section 3.1) before turning our attention to non-native speech perception in adults (Section 3.2). The Perceptual Assimilation Model (PAM; Best, 1994, 1995) is a theoretical framework that was developed to account for cross-language speech perception by naïve listeners, and it will be reviewed in this chapter (Section 3.2.1). The chapter will conclude with the summary and aims of the part of this project that deals with the perception of non-native speech.

3.1 Infants' attunement to the native language

Developmental studies of cross-language speech perception have revealed that a shift from language-general to language-specific listening can be observed within the first year of life (e.g., Best et al., 1995; Werker & Tees, 1984). The emergence of language-specific listening in infants differs for non-native consonants and vowels. At 10-12 months of age, the influence of L1 attunement becomes apparent for consonants (Best et al., 1995). In a study comparing the perception of non-native consonant contrasts by infants of various ages, a decline in discrimination performance was found to occur toward the end of the first year (Werker & Tees, 1984). This is often referred to as perceptual reorganisation or perceptual narrowing (Werker & Tees, 1984, 2002). Infants are initially able to discriminate phonemes from native and non-native languages, but toward the end of the first year of life, their perceptual system is reorganised as they acquire the phonemes of their L1. The perception of the unfamiliar Nthlakampx velar (ejective) /k'/ versus uvular /q'/ glottalised consonants, and the Hindi retroflex /ʈ/ versus dental /t̪/ contrasts was examined in 6- to 8-month-olds, 8- to 10-month-olds, and 10- to 12-month-old infants in an English speaking environment, with a head-turn paradigm. The 6- to 8-month-olds were able to discriminate between both the Nthlakampx and Hindi contrasts, but discrimination accuracy was slightly worse for the 8- to 10-month-old infants. By 10- to 12-months, discrimination accuracy was poor for both contrasts, and the infants' performance at this age resembled that of English speaking adults. Infants in a Nthlakampx- or Hindi-speaking environment were still able to discriminate the Nthlakampx or Hindi contrasts, respectively, at 11- to 12-months of age due to continued L1 language experience with these contrasts.

The effect of L1 attunement on the perception of cross-language speech occurs earlier for vowels than consonants. English-learning infants at 4, 6-10, and 10-12 months of age differ in their discrimination of the German *lax* high front-rounded versus high back-rounded contrast /ʏ/-/ʊ/ and the *tense* high front-rounded versus high back-rounded contrast /y/-/u/ (Polka & Werker, 1994). Infants at 10-12 months of age displayed the poorest discrimination accuracy for both German vowel contrasts, while the 4-month-old infants were able to discriminate both contrasts well. Intermediate discrimination performance was observed for the 6-10 month olds, which suggests that L1 attunement for vowels begins to occur in the time period around 6-10 months. The early attunement to L1 vowels may perhaps be attributed to their acoustic salience in infant directed speech. The vowels in infant-directed speech are often longer in duration than those in normal speech (Banbrook, McLaughlin, & Mann, 1999), are hyper-articulated, that is, clearly produced with the vowel features exaggerated (Andruski, Kuhl, & Hayashi, 1999; Kuhl et al., 1997), and are often characterised by high pitch (Burnham, Kitamura, & Vollmer-Conna, 2002; Masapollo, Polka, & Ménard, 2015).

Various accounts have been proposed to explain the role of L1 experience on non-native speech perception. One such account proposes that discrimination of non-native contrasts declines during early language development due to a lack of *auditory exposure* to particular phonetic features that are not employed in the L1 (Aslin & Pisoni, 1980). Others have instead suggested that infant speech perception becomes reorganised due to their *linguistic experience* (Eimas, 1978). It has been proposed that initial speech perception abilities are based on acoustic cues, then shift to phonetic, then to the phonological properties of their L1. However, as will be discussed in Section 3.2, neither account is able to adequately explain findings whereby contrasts not previously encountered are discriminated well.

For infants to become competent language users, they must develop perceptual sensitivity to the phonetic and phonological distinctions used in their L1 (Best, Tyler, Gooding, Orlando, & Quann, 2009). To distinguish between the words *bat* and *bit,* infants must identify phonetic information that changes one word's meaning to another by tuning into the higher-order structures of speech in addition to recognising when a word's phonological identity remains intact in spite of irrelevant phonetic variation such as differences between speakers, gender, and regional dialects. These separate learning operations are known as *phonological distinctiveness* and *phonological constancy*, respectively (Best et al., 2009; see also Mulak & Best, 2013; Mulak, Best, Tyler, Kitamura, & Irwin, 2013). Having reviewed how experience with the L1 begins to affect perception in infancy, we now focus our attention on the effects of L1 attunement on cross-language speech perception in adults.

3.2 Adult cross-language speech perception

Language-specific attunement results in efficient, automatic, and rapid perception and processing of the L1. However, this some times comes at a cost to the perception of non-native speech. Adults have difficulty identifying and discriminating between most phones that are not phonologically contrastive in their L1. In a sense, they may be described as 'hearing with an accent' (Jenkins, Strange, & Polka, 1995), with the L1 phonological system being likened to a 'filter' or a 'sieve' through which non-native speech is perceived (Trubetzkoy, 1939). A well cited example of how L1 experience shapes adults' perception of foreign language speech is that of Japanese listeners' perceptual difficulties in identifying and discriminating between the English /r/ and /l/ contrast (see Aoyama, Flege, Guion, Akahane-Yamada, & Yamada, 2004;

Goto, 1971; Strange & Dittmann, 1984; Takagi & Mann, 1995). For example, MacKain, Best, and Strange (1981) examined the perception of the English minimally contrastive pair *rock-lock* by native Japanese listeners who have little to no English language experience, in addition to native Japanese speakers with extensive English language training, and native English controls. In an AXB discrimination task, participants were presented with three auditory tokens per trial (e.g., “rock-rock-lock”). The target phone in the second auditory token (“X”) belonged to the same phonological category as either the first (“A”) or last (“B”) auditory token. Participants needed to match the target phone in X with that in either A or B. Unlike the native English controls and the experienced Japanese speakers of English, the unexperienced Japanese listeners performed at chance level. This perceptual difficulty may be attributed to both the English /r/ and /l/ being perceived as the Japanese equivalent category /ɾ/.

Not all non-native contrasts are difficult to discriminate. In fact, adults demonstrate good discrimination performance on certain contrasts not previously encountered. For example, consider the click consonants of Zulu, which native English listeners perceive as non-speech sounds (e.g., finger clicks, coughs). American English speaking adults are able to discriminate Zulu click contrasts relatively well despite their lack of experience with such clicks (Best, McRoberts, & Sithole, 1988). It has been shown that experience with familiar phonetic features does not guarantee excellent discrimination performance. For instance, American English listeners have difficulty discriminating between non-native stop consonant voicing contrasts despite being exposed to these voice onset times as allophones in the L1 (Abramson & Lisker, 1970). Similarly, non-native listeners presented with contrasting pairs of non-native phones that differ in phonetic features similar to those employed in the L1 do not performance any better than non-native listeners without such phonetic familiarity (Polka, 1992). These results suggest that early exposure to non-native phonological contrasts, or lack of exposure, does not necessarily predict discrimination performance.

Several theoretical models have been proposed to explain the variability in non-native speech perception. This thesis investigates non-native phones that are not identified with any one particular L1 category. The Perceptual Assimilation Model (PAM; Best, 1994, 1995) is the only model that explicitly accounts for uncategorised assimilations. Therefore, it was employed as the guiding theoretical framework to investigate this issue for the current project. The Speech Learning Model (SLM: Flege, 1995, 2002) also accounts for phones that are perceived as being unlike any L1 category (i.e., dissimilated phones), but it does so in the context of the acquisition of L2 phones. Therefore, SLM will be discussed in Chapter 4, which focuses on L2 learning. The following section will provide a review of the PAM framework.

3.2.1 The Perceptual Assimilation Model

PAM (Best, 1994, 1995) is based on the direct realist perspective, which assumes that perceivers obtain information about the world directly via the perceptual system, as opposed to constructing representations or drawing inferences about the world (E. Gibson, 1969; J. Gibson, 1979). Speech perception is multi-modal because perceivers detect auditory, visual, and tactile information. With regard to the auditory modality, the primitives of speech perception are the distal articulatory gestures, that is, the various articulatory constrictions formed by the different articulators along the vocal tract. The acoustic energy is shaped by, and provides information about, the articulatory gestures. Perceptual learning, in the sense of Gibson and Gibson (1955), is regarded as an attunement to the phonetic-articulatory gestural patterns used in the L1.

PAM accounts for the effect of L1 attunement on the perception of non-native contrasts by naïve listeners. It predicts discrimination performance for pairs of contrasting non-native phones based upon the way in which individual phones are assimilated to the L1 phonological system. Therefore, the review of PAM will begin by examining perceptual assimilation of individual non-native phones followed by the discrimination of contrasting non-native phones.

3.2.1.1 Perceptual assimilation of individual non-native segments

Non-native segments are perceived in terms of their similarities and differences to L1 categories (Best, 1995). Individual non-native phones may be perceived and assimilated to the L1 phonological system in one of three ways:

1. *Categorised* as an L1 category if they are identified with an L1 phoneme and may be perceived as a good, an acceptable, or a deviant exemplar of the category
2. *Uncategorised* if they are perceived as speech-like but fail to resemble any single L1 category, and in such instances, the non-native segment falls in an untuned region within the native phonological space
3. *Non-assimilable* if the non-native phones are heard as non-speech (e.g., clicking, choking sound) and will be assimilated outside of the listener's native phonological space

The PAM assimilations are established using a perceptual assimilation task in which participants are required to identify non-native/L2 phones in relation to those in their L1. The distinction between categorised and uncategorised assimilations is based upon the use of a predetermined assimilation criterion, which provides an indication of the consistency with which participants assimilate a particular non-native phone to an L1 category label. Generally, studies testing PAM have employed a criterion of either 50% or 70%, but other categorisation thresholds have also been used. The use of a more stringent criterion (e.g., 90%) may result in a large number of uncategorised assimilations (see Harnsberger, 2001). When categorisation responses are averaged across individual participants, a non-native/L2 phone is deemed categorised if a particular L1 category label is selected above the preset threshold, but is deemed uncategorised if responses are below this threshold. It is important to consider the categorisation threshold to be used as it has implications for the assimilation type identified.

Non-native speech perception involves identifying phonetic features that signal higher-order phonological structures as well as fine-grained phonetic information. Non-native phones that are identified with an existing L1 category (i.e., categorised) suggest that the listener perceives phonological similarities between a non-native phone and an L1 category. Conversely, phones assimilated as uncategorised suggest that there is a weak phonological similarity between a non-native phone and any L1 phonemes. For uncategorised assimilations, the non-native phone may be perceived in terms of fine-grained phonetic features, which may be similar to those employed in the L1. Given the complexity of speech perception, it is worthwhile to investigate further how language users make use of both phonological and phonetic features when perceiving non-native phones.

The first research question to be investigated in this thesis is whether there are any systematic differences in the way in which uncategorised phones are assimilated to the listeners' L1 phonological system. Non-native phones that are categorised as an L1 phoneme may be perceived as a good, acceptable, or deviant exemplar of that L1 category. However, PAM does not make such a distinction for non-native phones assimilated as uncategorised. Since uncategorised phones are assimilated within the phonological system, they may have some degree of phonetic similarity to the surrounding L1 phonemes. In this thesis, it will be argued that phones assimilated as uncategorised provide meaningful and systematic information about the similarities (and differences) between native and non-native phones (Chapter 6). This will have important theoretical implications for PAM and its characterisation of uncategorised assimilations.

An examination of the perceptual assimilation patterns from previous research reveals different ways in which non-native phones may be assimilated as uncategorised. There are instances in which non-native phones are perceived as primarily similar to a single L1 phoneme, but are assimilated below the categorisation threshold. For example, Tyler, Best, Faber, and Levitt (2014), using a 70% assimilation criterion, found that American English listeners assimilated the Thai high back unrounded vowel in /bɤ/ at 55% to their L1 /ʌ/ vowel category, and this was also the modal response. Similarly, in Strange, Bohn, Trent, and Nishi (2004), the North German high back rounded vowel /ʊ/ was assimilated at 42% to American English listeners' /oʊ/ vowel category. These have been described as being 'weakly categorised' (Best, Shaw, Docherty, et al., 2015; Best, Shaw, Mulak, et al., 2015), or as 'borderline cases' (Harnsberger, 2001).

Another common perceptual pattern is of non-native phones that are perceived as phonologically similar to two or more L1 phonemes. For instance, in Escudero and Chládková (2010), the categorisation responses for the Southern British English vowel /ɪ/ were spread across the three Spanish vowels /u, e, i/ at 41%, 35%, and 21%, respectively. Similarly, the French /o/ was identified with the American English /u, o/ 43% and 41% of the time, respectively (Levy, 2009a). In Tyler et al. (2014), the French vowel in /bo/ was primarily assimilated two L1 categories, namely, /o, u/ at 44% and 38%, respectively. Such instances suggest that there is a weak phonological similarity between a non-native phone and several L1 categories.

While not directly evident in the literature, another possibility may be that a non-native phone is not perceived as being similar to any L1 category. Unlike the above assimilations, categorisation responses in this instance would appear highly variable, with no systematic selection of the L1 category labels. Such instances suggest that the phonetic (gradient) rather than the phonological features of the phone’s similarities to native phonemes are being detected.

Thus far, the discussion has focused on the perceptual assimilation of individual non-native phones. The issue that next arises concerns the discrimination performance for pairs of contrasting phones (i.e., *contrasts*), for which one or both non-native phones are assimilated as uncategorised.

3.2.1.2 Contrast assimilation types and predictions for discrimination

When non-native segments are considered in pairs, there are several contrast assimilations, and these result in differences in discrimination accuracy (Best, 1995):

1. *Two-Category* assimilation (TC): the two non-native phones are assimilated to two separate L1 phonological categories. Discrimination is predicted to be excellent.
2. *Category-Goodness* assimilation (CG): both non-native phones are assimilated to the same native category but one of the non-native phones is perceived as a

better exemplar of the native category than the other. Discrimination is expected to range from moderate to very good, depending on the degree of category goodness.

3. *Single-Category* assimilation (SC): both non-native phones are assimilated to the same L1 category, with both perceived as equally good (or poor) exemplars of that category. Discrimination is expected to be poor.
4. *Uncategorised-Categorised* assimilation (UC): one non-native phone is assimilated to a native category while the other phone is assimilated as uncategorised. Discrimination is expected to be very good.
5. *Uncategorised-Uncategorised* assimilation (UU): both non-native phones fall within the listener's native phonological space but fail to be categorised to a native category. Discrimination is predicted to range from poor to moderate/very good, depending on the phonetic distance between the two phones to one another and native categories.
6. *Non-Assimilable* (NA): both non-native phones fall outside the native phonological space and are both perceived as non-speech. Discrimination is predicted to range from good to very good, depending on the phonetic distance between the two phones.

The general PAM prediction is that TC will be the easiest to discriminate, followed by both CG and UC, with SC predicted to be the most difficult to discriminate. For both UU and NA assimilations, discrimination accuracy is likely to depend upon the similarity between the contrasting phones and to L1 phonemes, and it is therefore difficult to rank order them.

These predictions have been formulated to account for the discrimination performance of both consonant and vowel contrasts. Cross-language speech perception studies, however, have predominantly tested these predictions using non-native consonant contrasts that were assimilated as categorised. In Best et al. (2001), assimilation patterns have been shown to successfully predict discrimination performance of Zulu consonant contrasts by American English speakers. The discrimination performance of the Zulu plosive versus implosive voiced bilabial stops /b/-/ɓ/, the voiceless versus voiced lateral fricatives /ɬ/-/ɮ/, and the voiceless aspirated versus ejective (glottalised) velar stops /kʰ/-/k'/ contrasts was assessed. Following an AXB discrimination task, participants performed an assimilation task in which they were required to identify the non-native phone with an L1 category by transcribing the non-native phone that they heard using English orthography, and to provide any additional descriptions of the non-native phone (e.g. "it sounded like coughing"). Consistent with PAM predictions, the TC contrast /ɬ/-/ɮ/ was discriminated very well, followed by the CG contrast /kʰ/-/k'/, with the SC contrast /b/-/ɓ/ being the most difficult to discriminate.

In another study, English listeners' perception of Hindi retroflex and dental stop consonant place of articulation contrasts that differ in voicing was examined (Polka, 1991). The contrasting phones in the voiceless unaspirated (/t̪/-/ʈ/) and breathy voiced (/d̪ʰ/-/ɖʰ/) contrasts were each assimilated to a different L1 category (i.e., TC). However, the phones within the prevoiced (/d̪/-/ɖ/) and voiceless aspirated (/t̪ʰ/-/ʈʰ/) contrasts were both perceived as similar to a single L1 category (i.e., SC or CG). Based on these perceptual patterns, contrasts that were assimilated as TC (i.e., /t̪/-/ʈ/ and /d̪ʰ/-/ɖʰ/) were discriminated more accurately than contrasts assimilated as SC/CG (i.e., /d̪/-/ɖ/ and /t̪ʰ/-/ʈʰ/). These studies, among others (e.g., Best & Strange, 1992; Halle, Best, & Levitt, 1999), have provided support for the PAM predictions of discrimination using various consonant types and listener groups.

While the PAM predictions for discrimination have largely been tested using consonant contrasts, there is some support for PAM using non-native vowels. Although most of the studies that will be discussed did not directly test the PAM predictions, their findings will be interpreted within a PAM framework. For example, native Spanish speakers discriminated the English contrast /i/-/u/ at a 95% accuracy rate, but discriminated /ɑ/-/ʌ/ with 65% accuracy (Højen & Flege, 2006). Based on the perceptual assimilation results from Escudero and Chládková (2010), we conclude that /ɑ/-/ʌ/ was poorly discriminated because both phones within the contrast assimilated to the Spanish listeners' L1 /a/ vowel category (i.e., SC/CG), while the excellent discrimination of /i/-/u/ may be because the English /i/ and /u/ were categorised as their L1 /i/ and /u/, respectively (i.e., TC). Similarly, native American English listeners experienced difficulty differentiating between Parisian French front versus back rounded vowel contrasts (e.g., Gottfried, 1984; Levy & Strange, 2008; Strange, Levy, & Law II, 2009). Since front rounded vowels are non-phonemic in American English, they tended to be perceptually assimilated to back rounded vowels, despite being more phonetically similar to front unrounded vowels in terms of tongue height (Levy, 2009a). In a study by Levy (2009b) examining the discrimination of various French vowel contrasts, discrimination accuracy was poor for contrasts comprising a front versus back rounded vowel (e.g., /y/-/u/, /œ/-/u/, /œ/-/o/), presumably because both phones were categorised as a single L1 back rounded vowel category. However, discrimination was at ceiling or close to ceiling for contrasts consisting of a front rounded versus front unrounded vowel (e.g., /œ/-/i/, /œ/-/ɛ/, /y/-/ɛ/), as they were categorised as two separate L1 phonemes.

A recent cross-language vowel perception study that directly tested the PAM predictions was that conducted by Tyler et al. (2014), who assessed the perception of French (/bo/-/bõ/, /dø/-/dœ/, /sy/-/sø/), Norwegian (/ki/-/kʉ/, /ki/-/ky/), and Thai (/bɯ/-/bɤ/) vowel contrasts by native American English speakers. Unlike consonants, the perceptual assimilation patterns of the vowels revealed many instances of uncategorised assimilations. Furthermore, an examination of the individual assimilation patterns revealed a high degree of inter-individual differences. A given non-native phone may have a low categorisation percentage when assimilation scores were averaged across participants, despite being categorised highly by some individual participants. Therefore, individual discrimination scores were grouped together according to the PAM assimilation types, regardless of the contrast. For example, the discrimination accuracy scores for TC assimilations were grouped together, regardless of the contrast in which they occurred. In spite of the variability, the PAM predictions of discrimination were upheld such that TC and UC assimilations were discriminated more accurately than CG, followed by SC assimilations.

Cross-language vowel perception studies have primarily focused on monophthongal vowel perception. As discussed in Chapter 2, diphthongs differ from monophthongs in terms of their acoustic and articulatory properties, and have not been well studied in speech perception research. This highlights the need to examine both monophthong *and* diphthong vowel perception in an attempt to examine if, and how, they may differ in perceptual assimilation and discrimination.

As can be seen from the review of the empirical literature, the PAM predictions of discrimination have predominantly been assessed using non-native phones assimilated as categorised. Discrimination performance of uncategorised phones remains largely unexamined. The absence of empirical research into the discrimination of uncategorised phones has prompted the second research question. Recall that the current PAM prediction of discrimination for UU assimilations is broad (i.e., ranging poor to moderate/very good), making the formulation of testable hypotheses difficult. Indeed, in Tyler et al. (2014), contrasts assimilated as UU were excluded from analysis for this reason. Discrimination accuracy for UU assimilations is predicted to depend upon the degree of phonetic similarity of the two contrasting phones to one another and to L1 categories (Best, 1994). For a pair of uncategorised phones, if both phones are perceived as similar to the same set of L1 categories, suggesting that they are in close proximity to one another in the phonological space, then the listener should experience difficulty discriminating between them. Conversely, if these uncategorised phones are perceived as similar to a different set of L1 categories, suggesting that they are distant from one another in the L1 phonological space, then they should be easily discriminated.

The degree of overlap in the categorisations to L1 phonemes (i.e., *perceived phonological overlap*) may have important implications for discrimination accuracy. Although this idea has not been systematically examined from a PAM perspective, there is evidence to suggest that discrimination accuracy may be affected by the presence of overlap between the L1 phones that are perceived as similar to the contrasting non-native phones. For example, in Tyler et al. (2014), the vowels in the contrast /sy/-/sø/ were perceived as similar to a different set of L1 vowels, while /bɯ/-/bɤ/ were largely perceived as /ʌ/, with the former contrast discriminated more accurately than the latter. Similarly, Salento Italian speakers perceive the British English /ɑː/ and /ʌ/ as uncategorised, but both non-native vowels are perceived as similar to their native /a/ and /ɔ/ categories, and discrimination accuracy was at chance level (Sisinni & Grimaldi, 2009). Additionally, if it is indeed the case that phones may be uncategorised in different ways, different combinations of those assimilations may yield varying levels of discrimination accuracy. Taken together, this highlights the need for a thorough investigation into the discrimination performance of contrasts whereby one or both phones are assimilated as uncategorised (i.e., UU and UC). This issue will be investigated in more detail in Chapters 6 and 7.

3.3 Summary and aims: Perception of non-native speech

In summary, infants' speech perception abilities shift from being language-universal to language-specific, and this is attributed to their exposure to the ambient language environment. Examining non-native speech perception in adults allows us to better understand how the native phonological system is organised and how language experience shapes the perception of foreign speech. Of interest in this thesis is the perception of non-native phones that are assimilated as uncategorised. Since PAM accounts for non-native phones assimilated as uncategorised, it will be used as a guiding theoretical framework. Best (1995) states that uncategorised phones will be assimilated within the phonological system in between L1 categories. Based on findings from previous cross-language speech perception studies, there is indirect evidence to suggest that there might be various ways that segments might be uncategorised. In this thesis, a thorough investigation will be conducted in order to empirically test this notion. This issue is addressed in Chapter 6.

The focus of this thesis is not solely on the perception of individual, uncategorised, non-native phones, but also on the discrimination of contrasts whereby one or both phones within the contrast are assimilated as uncategorised. There may be variations in discrimination performance based on the degree of phonetic similarity between the contrasting phones to each other and to L1 categories, although this is not explicitly defined by PAM. If phones differ in the way they are assimilated as uncategorised, then it is possible that listeners will show variations in discrimination accuracy. This raises several important questions: How might we measure the ‘degree of perceived phonological similarity’? Does discrimination accuracy for UU or UC assimilations depend upon degree of phonological similarity? These questions will be addressed in the empirical studies presented in Chapter 7 using non-native monophthongs and diphthongs.

The focus of this chapter was on the perceptual assimilation and discrimination of uncategorised non-native phones. The next chapter will examine the acquisition of L2 phones that are assimilated as uncategorised and how models of L2 speech perception predict the learning outcome of such phones.

CHAPTER 4

SECOND-LANGUAGE ACQUISITION

CHAPTER 4: SECOND-LANGUAGE ACQUISITION

There is a wealth of research investigating the acquisition of L2 phones by adult learners. Learners are defined as those who are in the active process of acquiring a new language for the purpose of functioning in that language environment, instead of for purely educational requirements (Best & Tyler, 2007). To be able to recognise words in the L2, learners must either employ the existing L1 phonemes, or, when there is no equivalent for the L2 in the L1, they must establish new categories. For example, as described in Chapter 3, the English /r/ and /l/ contrast is difficult for native Japanese speakers to discriminate as both are perceived as instances of a single L1 phoneme. If no new category is acquired by Japanese learners of English, it is likely that minimally contrasting words such as *rock* and *lock* will be perceived as homophones. This illustrates a possible learning scenario where L2 phones assimilate to a single L1 category. What about new language phones that are not perceived as similar to any particular L1 phoneme? As will be discussed further in this chapter (Section 4.1), there are models of L2 speech learning that propose that new language categories are more likely to be acquired for uncategorised L2 phones than categorised phones. While Chapter 3 was concerned with how L1 attunement shapes the perception of uncategorised non-native vowels by naïve listeners, in this chapter, the focus shifts to the role uncategorised L2 phones might play in L2 acquisition.

Much of the research on L2 speech perception and acquisition has been conducted with L2 phones that are identified with an L1 phoneme (i.e., assimilated as categorised), and discrimination performance for L2 phones has been shown to differ between L2 learners from different L1 backgrounds. For example, native German and

Spanish learners of English differ in their discrimination of the English vowels /ɛ/ and /æ/ (Flege, Bohn, & Jang, 1997). These learners identified synthetic vowels across a *beat-bit* and *bat-bet* continuum. The Spanish speakers were able to easily distinguish between the English /ɛ/ and /æ/, possibly because these vowels were perceived as two contrasting L1 vowel categories (Spanish /e/ and /a/, respectively). Conversely, the German speakers were less successful in identifying a difference between these two English phones, suggesting that they may have perceived them as instances of a single L1 vowel category (German /ɛ/ or /ɛː/). A pair of L2 phones that are identified with a single L1 phoneme may be difficult to acquire (Bohn & Flege, 1990; Flege, 1987; Flege et al., 1994). This demonstrates that the L1 phonology and its similarities to the L2 influence the way in which L2 phones are perceived and acquired.

Differences in discrimination and identification for L2 phones may also be attributed to the specific phones under examination. For example, Japanese speakers show variable discrimination accuracy for certain pairs of L2 Australian English (AusE) vowels (Bundgaard-Nielsen, Best, & Tyler, 2011a). A *whole-system approach* was employed, which involved the listeners identifying all of the AusE monophthongs and diphthongs in terms of all of their monomoraic and bimoraic vowels, as well as all of the permissible combinations of the monomoraic vowels. In an AXB discrimination task, the AusE contrast /iː/-/ɪ/ (e.g., *beat* - *bit*) was discriminated very well, with the phones perceived as two separate L1 vowel categories, namely, /iː/ and /i/, respectively. On the other hand, Australian English /iː/-/ɪə/ (e.g., *bee* - *beer*) was discriminated poorly with both phones perceived as the single L1 phoneme /iː/. Similarly, native Serbian speakers' perception of the L2 English vowel contrasts /i/-/ɪ/ (e.g., *heed* - *hid*) and /æ/-/ɛ/ (e.g., *had* - *head*) revealed an influence of L1 experience. Unlike in English, the Serbian vowel phonological system does not distinguish between tense-lax vowel pairs or lax vowel contrasts that differ in tongue height. The late learners perceptually assimilated the English /i/ and /ɪ/ to their L1 /i/, although the English /ɪ/ was perceived as a better exemplar of their L1 /i/, than the English /i/. Discrimination accuracy was very good for this contrast. The vowels in the contrast /æ/-/ɛ/ were perceptually assimilated to the L1 /e/, and discrimination was poor.

Overall, while adult learners experience varying degrees of difficulty acquiring the phonological system of a new language, with increasing experience, they may show improvement for previously difficult-to-discriminate L2 contrasts (Best & Strange, 1992; Flege, Takagi, & Mann, 1995). However, they are unlikely to reach native-like levels of L2 proficiency even after several years of experience (Flege, Bohn, et al., 1997; Flege, MacKay, & Meador, 1999). Models of L2 speech learning make different predictions for acquisition depending on the perceived similarity between L1 and L2 phonemes. The Second Language Linguistic Perception model was developed to address language acquisition (Escudero, Benders, & Lipski, 2009; Escudero & Boersma, 2004). However, as it does not provide an account of L2 phones that are not identified with any existing L1 categories, it will not be considered further in this thesis. In the following section, a review of two of the most prominent theories of L2 acquisition will be provided, namely, the Speech Learning Model (SLM: Flege, 1995, 2002) and the Perceptual Assimilation Model extended to L2 learners (PAM-L2: Best & Tyler, 2007). Since both models account for uncategorised phones and make specific predictions for their acquisition, the investigation into new category acquisition will be based within the framework of these two models. This will be followed by comparing and contrasting each model in order to evaluate their predictions for the acquisition of uncategorised L2 phones.

4.1 Models of L2 Speech Perception

4.1.1 The Speech Learning Model

The Speech Learning Model (SLM; Flege, 1995, 2002) is based on the psychoacoustic approach, which assumes that the primitives of speech perception are acoustic features (e.g., formant frequencies, silent gaps, noise bursts). SLM accounts for the age-related changes in language learning across the life span and the eventual attainment of native-like production of L2 vowels. Studies in support of SLM have focused primarily on the production of new language vowels by bilinguals with extensive exposure, although SLM has been extended to account for L2 speech perception (Flege, 2002).

According to SLM, L1 and L2 categories share a common acoustic-phonetic space with both languages influencing one another in a bidirectional manner (Bohn & Flege, 1992). Specifically, L1 attunement influences L2 acquisition, and L2 acquisition causes perceptual changes to the pre-existing L1 categories (e.g., reorganisation of L1 categories due to category deflection). As a result of L1 experience, it is proposed that those acquiring an L2 later in life will not perceive or produce L2 phones in exactly the same way as native speakers of that language or as those who acquired the L2 earlier in life. This, however, does not imply that the perceptual system is static, but rather, L2 perception and production changes over time with experience (Logan, Lively, & Pisoni, 1991). While the same mechanism for language acquisition remains intact throughout the life span, the overall level of L2 proficiency differs between children and adults who are acquiring that language. Differences in L2 speech learning between those who acquire an L2 during early childhood (i.e., early learners) and those who acquire an L2 in adolescence or adulthood (i.e., late learners) are attributed to the degree of L1 attunement at the time of acquisition such that the earlier a new language is acquired, the more accurately it will be produced and perceived (e.g., Jia, Strange, Wu, Collado, & Guan, 2006).

SLM proposes that the likelihood of new categories being formed depends upon the degree of perceived similarity between the L1 and L2 phonemes. With respect to the L1, L2 phones may be classified as 'similar' or 'new' (Flege, 1986). 'Similar' phones are those that are perceived as being acoustically similar or equivalent to an existing L1 category (*equivalence classification*). They will be assimilated to that category. An equivalent phone will be produced in the same way as the L1 category that is it identified with (e.g., with a native accent) and new L2 category formation is thought to be blocked by equivalence classification. Due to equivalence classification, the L1 and L2 phonemes will be perceived and produced in the same way, and when they have been perceptually linked, they are referred to as *diaphones* (Flege, 1987; Peng, 1993). Diaphones are predicted to have a mixture of the properties of the L1 and L2 phones, and perception of diaphones to be intermediate between that of monolingual speakers of both languages. SLM suggests that, with experience, the learner may come to detect relevant phonetic differences between the L2 category and the closest L1 category, and may eventually develop a separate L2 category.

'New' L2 phones are those that are perceived as acoustically dissimilar from existing categories, and will therefore be distinguished from L1 categories (*dissimilation*). SLM predicts that dissimilated L2 phones will be easy for learners to acquire, and are also likely to be produced in a native-like manner (Bohn & Flege, 1992). When new phonetic categories are established, they cause L1 categories to shift from their usual position within the phonetic space, and lead to exaggerated L1 production. The L1 category may deflect away from a new L2 category in order to maintain sufficient contrast between the speech sounds. Consider the study by Bohn and Flege (1990) in which native German learners of English with differing levels of L2 experience identified stimuli on synthetic /bit/-/bɪt/ and /bɛt/-/bæt/ continua in English, for which /i, ɪ, ɛ/ have close counterparts in German, while /æ/ does not. Results revealed that L2 experience did not affect the perception of the continuum with similar German counterparts as endpoints (i.e., /i/-/ɪ/). However, an effect of experience was observed for the continuum containing the non-native vowel (i.e., /æ/), with more experienced L2 learners outperforming the inexperienced learners. This suggests that L2 speech perception improves over time for dissimilated L2 phones. When examining new language acquisition in adults, for dissimilation to occur, learners must first detect phonetic differences between the L1 and L2 phones during the initial exposure stage, before new categories are formed.

SLM proposes that new category formation is not only influenced by the similarities and differences between the L1 and L2 phones, but also by the age of exposure to the new language (Flege, 1995). Those who acquire the L2 early in life are more likely to develop new categories than those who acquire it later in life. Additionally, the number of vowels in the L1 inventory is also held to influence L2 category formation. It is suggested that the fewer L1 categories there are, the more likely L2 phones will be established as new categories (Flege, 1995).

4.1.2 The Perceptual Assimilation Model extended to L2 learners

The Perceptual Assimilation Model as extended to L2 learners (PAM-L2; Best & Tyler, 2007) was designed to predict the likelihood of establishing new L2 phonological categories based on their phonological and phonetic assimilation to L1 categories, which would in turn result in changes in discrimination performance for L2 contrasts over learning time. It primarily focuses on L2 speech perception, although it has been extended to account for speech production (e.g., Antoniou, Best, & Tyler, 2013; Antoniou, Tyler, & Best, 2012).

For PAM-L2, new language learning is possible throughout the lifespan, but is influenced by prior language experience. PAM-L2 assumes that there is a shared L1-L2 phonological system and posits that both phonetic *and* phonological levels interact during L2 acquisition. The outcomes vary depending on the L1-L2 phonetic and phonological similarities. If an L2 phone is perceived as phonologically and phonetically similar to an L1 phoneme, then it will be assimilated to the L1 phonological and phonetic category, and no perceptual learning is likely to occur.

Alternatively, when an L2 phone is perceived as phonologically equivalent to that L1 category, but is phonetically different, then it will share a phonological category with the L1, but with a distinct L2 phonetic category. The example provided by Best and Tyler (2007) helps illustrate this scenario. The French /r/ is pronounced as a voiceless uvular fricative [ʁ], while the English /r/ is produced as a liquid [ɹ]. Nonetheless, the French /r/ and English /r/ are treated as lexically equivalent. French speakers may even pronounce the /r/ in English words using their French /r/, and vice versa for English speakers producing the French /r/, despite the clear phonetic differences.

The two possibilities outlined thus far are of instances where an L2 phone is identified with, and assimilated to, an L1 phonological and/or phonetic category. When it is not perceived as similar to a single L1 phoneme (i.e., uncategorised), a new L2 phonological and phonetic category will be established. According to PAM-L2, it may not only depend upon the perceived similarity between an L2 phone and the L1 categories, but also the perceived similarity between pairs of contrasting L2 phones. A pair of uncategorised L2 phones that are similar to a different set of L1 phonemes will be easier to acquire than those that are perceived as similar to the same set of L1 phonemes. This is consistent with the notion of perceived phonological overlap discussed in Chapter 3 where overlapping contrasts are predicted to be more difficult to discriminate than non-overlapping contrasts, and so the same may hold true for L2 learning. Therefore, an examination of the perception of L2 vowels assimilated as UU and UC must account for the degree of L1-assimilation overlap as this may have implications for learning outcomes. However, as the PAM-L2 predictions for category acquisition have not yet been thoroughly tested, an initial investigation should examine whether it is possible for uncategorised L2 phones to be acquired as new categories, and further investigations should assess whether this is dependent upon the degree of overlap.

According to PAM-L2, the likelihood of new category formation depends on how L2 phonological contrasts are initially assimilated to the L1 phonological system. L2 contrasts that initially assimilate as:

1) SC: will form part of a common L1/L2 category. Discrimination should initially be poor, and is unlikely to improve over time.
2) CG: the deviant exemplar will eventually establish itself as a new L2 category, while the good exemplar will continue to form part of common L1/L2 category. Discrimination should improve over time.
3) TC: no further learning is required. Discrimination should initially be excellent and remain so.
4) UU and UC: the uncategorised phones will eventually be established as new L2 categories, while categorised phones will form a common L1/L2

phonological category. For both assimilation types, discrimination should improve over time, although category formation may depend upon the perceived relation of the L2 phones to the L1 phonological system.

Overall, PAM-L2 predicts that discrimination should improve for CG, UC, and UU, but not for SC and TC assimilations. These PAM-L2 predictions are based on adults who are immersed in the L2-speaking environment, with no prior exposure to that language, but are also applicable to other learning situations. Consider the study conducted by Bundgaard-Nielsen et al. (2011a) on L2 English language acquisition by native adult Japanese speakers. While the participants had extensive English language instruction prior to immersion, their instructors were non-native speakers. Consistent with the PAM-L2 predictions, discrimination accuracy for SC and TC assimilations did not change over immersion. This suggests that no new categories had been formed for the phones assimilated as SC and TC.

PAM-L2 argues that the majority of L2 perceptual learning occurs during the very early stages of acquisition. Perceptual learning has been shown to occur in adult learners in the first 6-12 months of L2 immersion, with a plateau effect in the amount of learning after this period (Aoyama et al., 2004; Munro & Derwing, 2008). During the initial stages of L2 acquisition, it is argued that linguistic pressure to discriminate between minimally contrasting L2 words force the learner to attune to phonetic differences that signal lexically distinctions. This linguistic pressure may force the learner to settle on a common L1/L2 assimilation, or cause the L2 phonetic category to split off from the L1 category and establish itself as a new L2 phonological category. It is hypothesised that a large L2 vocabulary size during these initial stages of L2 acquisition may cause the learner to fossilise, or settle on, a suboptimal common L1/L2 phonological category, thus curtailing further L2 phonological development (Best & Tyler, 2007).

4.1.3 Comparing and contrasting SLM and PAM-L2

PAM-L2 and SLM share common premises, but they also diverge in a number of areas. Both models posit that:

1) Adults retain the ability to acquire additional languages, but the outcomes of L2 learning are influenced by their L1 experience
2) There is a shared L1-L2 phonological/phonetic system
3) Phonetic and phonological learning occur early during L2 acquisition

Importantly, both models account for the acquisition of L2 phones that are not identified with a particular L1 category. For PAM-L2, these are referred to as uncategorised phones, which is consistent with the SLM notion of 'new' L2 phones. Both models posit that a new category is likely to be established for L2 phones in these instances. While SLM focuses on the perception of individual L2 phones, PAM-L2 makes its predictions based on L2 contrasts and how they are perceived in relation to each other and to L1 phonemes. PAM-L2 predicts that the formation of new phonological and phonetic categories is likely to depend upon the perceived similarity between pairs of contrasting L2 phones where non-overlapping phones are more likely to be acquired than those that overlap with the same set of L1 categories.

As both SLM and PAM-L2 account for uncategorised L2 phones and provide predictions for the acquisition, they will be used to guide the present investigation of how uncategorised L2 phones are acquired by adults. As previously mentioned, the PAM-L2 predictions are based on adults who are immersed in the L2-speaking environment, with no prior exposure to the L2. According to SLM, for dissimilation to occur, learners must first detect differences between the L1 and L2 phones during the initial exposure stage, before new L2 categories are formed. As bilingualism is common around the world, with over half of the world's population able to speak a second language (Grosjean, 1982), these ideal L2 learners would be difficult or impossible to recruit. There is a high possibility that the L2 learners recruited will vary to some extent in their degree of L2 experience. For this reason, it is important to consider the role of factors related to L2 experience on category formation. In fact, aside from the similarities and differences between the L2 and the L1, both models acknowledge that other factors may contribute to learning outcomes. For PAM-L2, Best and Tyler (2007) identify several environmental factors that play a role in L2 acquisition such as length of L2 residence, relative use of the L1 and L2, the quantity and quality of the L2 input, and the crucial role of an expanding L2 vocabulary on L2 category formation. The age of L2 acquisition is central for both PAM-L2 and SLM, where category formation is more likely to occur for early learners of the L2 than late learners. Therefore, an investigation of the acquisition of uncategorised L2 phones must also account for factors that affect learning outcomes. In the second half of this chapter, various factors that have been identified as influential to the success of L2 acquisition will be reviewed.

4.2 Factors related to L2 acquisition

A number of factors have been shown to influence the rate and proficiency of L2 acquisition in adult learners. One important factor is the context of language learning, which has implications for the quality and quantity of the L2 input (see Piske, 2007). In foreign language acquisition (FLA), the L2 is acquired in a classroom setting and it is not the dominant language spoken in the learner's environment. In second language acquisition (SLA), in contrast, the L2 is acquired in a naturalistic communicative context, where that language is widely used in the learner's surrounding environment (i.e., immersion setting), and it is this context for L2 learning that is the focus of PAM-L2. Best and Tyler (2007) argue that FLA may not be an ideal setting for L2 learning for a number of reasons. First, FLA is usually acquired in a formal setting and is very rarely used outside of the classroom. Second, language instruction is normally given by L1-accented speakers whose production of phonetic details of the L2 are often inaccurate, leading the learner to acquire a version of the L2 that is incorrect or different from that of native speakers of that language (Piske, Mackay, & Flege, 2001). Third, there is generally a greater focus on L2 lexical and grammatical instruction, rather than on conversational experience (Piske, 2007). Therefore, L2 acquisition that occurs in a naturalistic, immersion setting will be the focus of this thesis as it may be more ecologically valid than FLA.

In an immersion setting, adult L2 learners are likely to vary on a number of factors related to L2 acquisition, thus, it is important to consider the variability between individual learners. Studies on L2 speech perception have found that the following factors influence the success of L2 acquisition, and each factor will be discussed in detail in the sub-sections that follow:

- Age of foreign language instruction
- Age of immersion in the L2 speaking environment
- Length of residence in the L2 speaking environment
- Language use patterns
- L2 vocabulary size
- Duration of foreign language education

4.2.1 Age of foreign language instruction

When examining L2 acquisition in learners who have been exposed to that language prior to immersion, it is important to consider the age of acquisition if L2 instruction has occurred through formal instruction (i.e., FLA). Therefore, this thesis will consider the age of FLA, which it is defined as the chronological age that L2 acquisition commenced prior to immersion. For the majority of L2 speech perception studies, initial exposure may also be the chronological age of acquisition (AoA) in an immersion setting (i.e., SLA). This distinction is important as the age-related effects on language learning differ depending on the context in which L2 learning occurred. Empirical findings on the age-related effects from L2 learning in SLA and FLA contexts will be briefly reviewed.

Research on SLA demonstrates a younger learner advantage in L2 acquisition. Generally, learners who acquired the L2 during early childhood have less difficulty in acquiring an L2 and are more likely to attain native-like levels of perception and production, compared to those who acquired that language in adolescence or adulthood, and is the case for both L2 consonants (e.g., Flege, Munro, & MacKay, 1995; Mackay, Flege, Piske, & Schirru, 2001; Yamada, 1995) and vowels (e.g., Flege, Schirru, & MacKay, 2003; Krebs-Lazendic & Best, 2013; Munro, Flege, & MacKay, 1996; Piske, Flege, MacKay, & Meador, 2002). For example, in a longitudinal study, native Japanese children and adult learners of English who had been living in the L2-speaking country for an average of six months at the time of testing were assessed on their perception and production of the English /l/, /r/, and /w/ (Aoyama et al., 2004). The Japanese children, but not the adults, showed a significant improvement in their perceptual discrimination and production of /l/ and /r/ one year later, thus supporting the assumption that the earlier the L2 is acquired, the higher the degree of L2 proficiency.

In FLA, it is generally found that older learners have an advantage over younger learners (e.g., Bongaerts, van Summeren, Planken, & Schils, 1997; Fullana, 2006; García-Lecumberri & Gallardo, 2003). Consider the study by Jia et al. (2006) who examined the perception and production of various L2 English vowels by native Mandarin children, adolescents, and young adults who were living in China with no English immersion experience, who had 2 years or less of L2 immersion (recent arrivals), or had 3-5 years of L2 immersion (past arrivals). In an AXB L2 vowel discrimination task, the older participants residing in China who had no immersion experience were more accurate in discriminating between certain vowel contrasts than the younger learners with no immersion experience. For the past arrivals, discrimination accuracy was higher for the younger learners than for the older learners. A similar pattern of results was obtained for the L2 imitation task. It has been suggested that a younger-learner advantage in SLA may be because younger learners thrive from a richer L2 learning environment and from interactions with native speakers of that language (for a review, see Muñoz, 2008). Nonetheless, it is important to examine the age-related effects in L2 acquisition even among adults, as the learners recruited for the present project are likely to have already been exposed to the L2 in a formal classroom setting.

4.2.2 Age of immersion

The age of immersion (AoI) refers to the chronological age that an individual arrived in the L2 environment. In some cases, the AoI may also be the AoA, although AoI is normally the age that the learner receives their first substantial exposure to the L2 spoken by native speakers (MacWhinney, 2005; Muñoz, 2008). It is in an immersion setting that learners are forced to use the L2 for everyday communication (Flege & MacKay, 2011). This is also consistent with PAM-L2, where L2 acquisition is defined as the learning that occurs in an immersion setting, which is also how AoI is viewed in this thesis.

A number of studies have examined the role of AoI in the perception and production of L2 phones. These studies have shown that L2 phones are more likely to be perceived and produced in a native-like manner for those with a younger AoI, than those with an older AoI (e.g., Flege, Munro, et al., 1995). MacKay et al. (2001) examined the perception and production of the L2 English consonants /b, d, g/ by native Italian speakers who differed in their AoI and also in the amount of L1 use. Those with an older AoI (20 years of age) made more errors in identifying the English consonants than those with a younger AoI (8 years of age). Similarly, the younger the AoI of Japanese speakers to the US, the more accurate they were in correctly identifying English /r/ and /l/ tokens (Yamada, 1995).

Studies examining the effect of AoI on L2 vowel perception are comparatively limited, but existing findings mirror those obtained with consonants. In Flege et al. (1999), Italian speakers who moved to Canada were divided into three groups based on their AoI: early arrivals (AoI: 7 years of age), mid-arrivals (AoI: 14 years of age), and late arrivals (AoI: 19 years of age). In an oddity discrimination task, participants discriminated between pairs of English vowel contrasts (/i/-/ɪ/, /u/-/ʊ/, /æ/-/ʌ/, and /ɒ/-/ʌ/). The early arrivals performed as well as native English speakers on most L2 vowel contrasts, but discrimination accuracy deteriorated as the AoI increased.

AoI may be correlated with other variables, and this may in turn cloud the interpretation of the results. For instance, the findings on the effect of AoI on L2 perception were shown to be correlated with the quantity and quality of L2 input received by those with a younger AoI (Mackay et al., 2001). Child immigrants are normally enrolled in schools and, generally, interact more frequently with native L2 peers and adults. Additionally, AoI may also be correlated with language use such that younger arrivals use the L2 more often than the L1, while the opposite pattern of language use is normally observed with later arrivals (Jia & Aaronson, 2003). Therefore, it is important to take into account, or control for, factors related to AoI when examining L2 speech perception performance.

4.2.3 Length of residence

Length of residence (LoR) is defined as the duration of immersion in the L2-speaking country, and is often regarded as an indicator of L2 experience (Piske et al., 2001). Generally, a longer LoR is associated with more accurate L2 speech perception (e.g., Flege & Liu, 2001) and production (e.g., Flege, Takagi, et al., 1995) for a given AoI. In Flege et al. (1997), L2 learners of English from various L1 backgrounds (German, Spanish, Korean, and Mandarin) were grouped together according to LoR in the US (0.7 vs. 7.3 years). They identified synthesised vowels along a beat-bit (/i/-/ɪ/) and bat-bet (/æ/-/ɛ/) continua. For the bat-bet continuum, participants with a longer LoR made more use of spectral cues than those with a shorter LoR, and their performance more closely resembled that of native English speakers.

Some studies, however, have failed to find an effect of LoR on L2 vowel perception. For instance, in a study examining the identification of the L2 English vowels /i, ɪ, ɛ/, native Catalan speakers were assigned to one of two groups based on their LoR (Cebrian, 2006). The ‘experienced’ group consisted of Catalan-English speakers who had resided in the English-speaking country for 25 years on average, while the ‘less experienced’ group consisted of native Catalan speakers who were described as having very limited immersion experience. Both groups of Catalans identified the English /ɛ/ using spectral cues, which resembled native English speakers’ reliance on spectral cues, although both groups used duration to identify /i/ and /ɪ/. The authors concluded that LoR was not a significant predictor of L2 vowel identification (see also Flege et al., 1994).

The inconsistencies of the effect of LoR on L2 speech perception may be attributed to at least two factors (McAllister, Flege, & Piske, 2002; Munro & Derwing, 2008; Piske et al., 2001). One possible factor is the range of LoR examined, which may have been too narrow (Piske et al., 2001). For example, an effect of LoR may be found between a group with an average LoR of less than one year and another group with an average LoR of several years (Flege & Fletcher, 1992). Another possibility could be that L2 learning occurs mainly during the early stages of L2 immersion. For learners who have been immersed in an L2 speaking country for many years, additional immersion experience is unlikely to result in significant improvements in L2 speech perception because they have reached a plateau in perceptual learning (e.g., Aoyama et al., 2004; Best & Tyler, 2007; Munro & Derwing, 2008). This may explain why Cebrian (2006) found that ‘experienced’ learners, who had been residing in the L2 speaking environment for 25 years, did not perform significantly better than ‘inexperienced’ learners with less lengthy exposure.

The lack of effect of LoR on L2 speech perception may also be due to other related factors that were not accounted for, such as the amount of L2 input received during immersion. Consider an individual with a long LoR but very limited L2 speech input. In this instance, LoR would not be an accurate representation of L2 experience. Flege and Liu (2001) examined the perception of L2 English phones by L1 Chinese speakers. Participants were assigned to either the short-LoR group (0.5-3.8 years) or the long-LoR group (3.9-15.5 years), and each LoR group consisted of participants who were enrolled as students in L2 speaking universities, and non-students who had never been enrolled. Students with a longer LoR performed better than those with a shorter LoR. There was no difference in performance as a function of LoR for the non-students. Due to their occupations, most of the non-students received very little L2 input, particularly from native speakers. The authors concluded that LoR predicts L2 speech performance, but only if sufficient L2 input is received. Therefore, when examining LoR, it may be important to also consider the range or length of L2 immersion, and the quantity of the L2 input received. In the following section, the role of the quantity of L2 input in L2 acquisition will be discussed.

4.2.4 Language use

Language use describes the amount (percentage, ratio) that an individual communicates in the L1 or L2. This is normally a self-reported measure where participants are asked to estimate the amount of time that they communicate in one or both languages across various communicative environments (e.g., school, work, home), or to give a general estimate of L1 or L2 language use. The amount of L1 or L2 usage is sometimes regarded as a measure of the level of L2 experience such that more ‘experienced’ speakers use the L2 more often than the L1, and ‘inexperienced’ speakers use the L1 often, but seldom use the L2 (Flege, MacKay, et al., 1999).

Much of the research examining the amount of L1/L2 usage has been on speech production (Flege, 1995; Flege, Munro, et al., 1995; Flege, Yeni-Komshian, & Liu, 1999). It is commonly found that L2 speech production is more likely to be L1-accented if the L1 is used relatively more often than the L2 (e.g., Guion, Flege, &

Loftin, 2000). For example, native Italian speakers who were matched according to AoA (6 years old) but differed in L1 Italian language use (3% vs. 36%) had notable differences in their foreign accent in English, which was stronger for those who used the L1 more frequently than those who used it less frequently (Flege, Frieda, & Nozawa, 1997). This is even the case for L2 speakers who use the L1 more than the L2, despite having acquired the L2 at a young age (Flege & MacKay, 2004).

The influence of language use has also been shown to influence L2 speech perception. In Flege and MacKay (2004), native Italian speakers were assigned to one of four groups based on their age of L2 English acquisition (early vs. late learners) and percentage of L1 usage (low = 1-15% vs. high = 25-100%). Overall, the low-L1-use participants were more accurate in discriminating some of the English vowel contrasts than the high-L1-use participants. Differences in speech perception were also observed between the two groups of early bilinguals who differed in the amount of L1 use, where the early-low participants were able to better discriminate the L2 contrasts than the early-high participants (Flege, MacKay, et al., 1999; Højen & Flege, 2006). In summary, there is evidence to suggest that patterns of language use predict L2 speech perception performance even at the same AoA.

The studies discussed typically compute either the amount of L1 or L2 use, where it is generally assumed that a greater use of one language (e.g., L1) entails a lesser use of the other language (e.g., L2). To provide an accurate representation of language use, it may be more informative if learners are asked to report on both L1 and L2 use. This may be particularly useful, given that in some production studies, a null effect of language use on L2 proficiency may be due to the effect of the language not reported (e.g., Flege & Fletcher, 1992). For example, Thompson (1991) failed to find an effect of L2 use on L2 speech production but postulated the possibility that L1 use affected speech production. Therefore, taking into account both L1 and L2 use may provide a more accurate representation of a learner's language usage.

4.2.5 L2 vocabulary size

There are various aspects of vocabulary knowledge, including productive or receptive vocabulary knowledge, as well as the breadth and depth of the vocabulary knowledge (Read, 2000; Vermeer, 2001). One of the features of vocabulary knowledge that has received much research interest is vocabulary size, which refers to the number of words known (quantitative) rather than the nature of the words known (qualitative) (Karami, 2012). It is often regarded as a measure of language proficiency (Vermeer, 2001). L2 vocabulary size in adults may be assessed using one of a variety of tests such as the Vocabulary Levels Test (Beglar & Hunt, 1999; Nation, 1983), the Eurocentres Vocabulary Size Test (Meara & Jones, 1990), and the Vocabulary Size Test (Nation & Beglar, 2007).

A sufficient L2 vocabulary size is required to allow efficient communication in an L2 speaking environment. It has been estimated that 8000-9000 words is required to be able to read authentic texts (Nation, 2006). Additionally, an L2 vocabulary size may predict L2 speech perception performance and new language category formation in adults.

As discussed in Section 3.1.2, L2 vocabulary expansion plays a critical role in L2 perceptual learning in adults, according to PAM-L2 (Best & Tyler, 2007). The Vocab Model (Bundgaard-Nielsen, Best, & Tyler, 2011a, 2011b) extends this idea by predicting that an expanding L2 vocabulary may lead to L2 reattunement or L2 phonological category formation. Like PAM-L2, this is hypothesised to occur during the initial stages of L2 vocabulary acquisition for a learner who is in an immersion environment. Initial vocabulary acquisition forces the learner to attend to phonologically meaningful information not employed in the L1. The Vocab Model predicts that a large L2 vocabulary results in more consistent assimilation of L2 phones to L1 categories and better discrimination performance. Findings from Bundgaard-Nielsen et al. (2011a) suggest that L2 vocabulary expansion influences L2 category formation in learners who had already acquired a large L2 vocabulary by the time of immersion. Based on the results from the Nation and Beglar (2007) vocabulary size test, Japanese learners of English early in their first immersion in Australian English were assigned to either the ‘high vocabulary’ group (average of 7200 L2 words) or the ‘low vocabulary’ group (average of 5017 L2 words) using a median split. In a perceptual assimilation task, the high vocabulary group assimilated L2 phones more consistently to L1 categories than the learners in the low vocabulary group. It is important to note, however, that while the assimilations from L2 to L1 were more consistent for learners with a higher L2 vocabulary, from a PAM-L2 perspective, learners may not necessarily settle on an ideal or correct L1-L2 assimilation. Nonetheless, both approaches highlight the role that L2 vocabulary expansion plays on L2 perceptual reattunement.

With English often taught as a foreign language in many non-English dominant countries, it is likely that learners will have already acquired a large English vocabulary in L1-accented English prior to immersion in an English-speaking country. Nonetheless, as vocabulary size is a dynamic factor that may increase over time, it is possible to investigate how potential *changes* in L2 vocabulary size influence L2 perceptual learning.

4.2.6 Language training

This factor refers to the amount or duration of L2 training undertaken in the L2-speaking environment (i.e., SLA), or training that occurred prior to immersion in a formal, classroom setting (i.e., FLA). Like most of the factors already discussed, the duration or amount of L2 education is often perceived as a measure of L2 experience where the longer the duration of L2 education, the more accurately new language phones are perceived and produced. However, unlike the other factors, comparatively little research has examined the effect of language training on L2 acquisition, with most of the studies in this area on L2 production. Some studies have found that the amount of L2 instruction was not a significant predictor of the degree of L2 foreign accent (Flege, 1995; Thompson, 1991), or that it accounted for a small proportion of the variance in foreign accented ratings (Flege & Fletcher, 1992). In a study examining L2 segmental perception, native Catalan speakers who acquired English in the L2-speaking environment were compared with native Catalan speakers residing in the L1-speaking country on their identification of the same English vowels (/i, ɪ, e^{ɪ}, ɛ/). The two groups of Catalan speakers did not differ in their L2 vowel identification performance.

At first glance, these findings seem to suggest that duration of L2 training is poorly correlated with L2 proficiency. However, these results, among others, may have been confounded. When duration of L2 education is measured in an immersion setting, it is often correlated with other factors. For example, Flege, Yeni-Komshian, et al. (1999) found that the age of arrival in the L2-speaking country was correlated with the years of education participants had received during immersion such that the younger the age of arrival, the longer the duration of L2 education. Therefore, it is important to control for, or account for, factors correlated with language education.

Research in the area of L2 training is required given that it is relatively understudied, particularly in the domain of L2 segmental perception. Of particular interest is the number of years of L2 formal education undertaken *prior* to immersion. Given that English is taught as an L2 in many countries where it is not the dominant language, it is likely that it would have been acquired in a formal, classroom setting prior to immersion in an English-speaking country. Furthermore, examining L2 instruction in an immersion setting may be more appropriate when the population under investigation is children, rather than adults. Specifically, unlike adult immigrants, child immigrants are normally enrolled in schools, and thus, it may be useful to examine the duration of L2 learning in the L2 context. Therefore, if learners were exposed to the L2 prior to immersion, it is important to consider whether that exposure plays a role in L2 speech perception.

4.3 Summary and aims: L2 acquisition

Research in the area of adult L2 speech learning demonstrates that, while adults experience some degree of difficulty acquiring the L2, not all phones are difficult to acquire and learners show improvements over time. In this chapter, two models of L2 speech learning were reviewed, namely, SLM and PAM-L2. Both models predict that, when L2 phones are perceived as being unlike any particular L1 category, they should be relatively easy to acquire. For PAM-L2, category formation is also predicted to depend upon the degree of overlap to the L1 categories. In this thesis, PAM-L2 and SLM will be used to guide the investigation of the acquisition of uncategorised L2 vowels. Since PAM-L2 focuses on L2 contrasts, those that are assimilated as UU and UC by beginner learners will be tested. As L2 learning that occurs in an immersion setting provides learners with their first substantial exposure to the L2 as spoken by native speakers, acquisition will be assessed in learners who are in an immersion environment. To track changes in L2 discrimination performance, a longitudinal study will be conducted. This will be the first systematic study conducted to test for category acquisition of uncategorised L2 phones.

While SLM and PAM-L2 predict category formation for learners who are in the initial stages of acquisition, learners in this initial stage might be difficult to recruit. Instead of beginner learners, those recruited may vary on factors related to L2 experience. In this chapter, six factors that have been shown to influence the success of L2 learning were reviewed: age of FLA, age of immersion in the L2 speaking environment, length of residence in the L2 speaking environment, language use patterns, L2 vocabulary size, and duration of foreign language education. Given the interrelationship between these factors, it may be difficult to assess the effects of a single factor on L2 learning as this may cloud the interpretation of the results, particularly when participants are grouped together based on a particular variable (e.g., LoR), but differ widely on other variables (e.g., language use). Therefore, the role that these six factors may play in the acquisition of uncategorised L2 phones in adults who are in an immersion setting will be examined in a longitudinal study, which is presented in Chapter 8. The following chapter will describe the participant groups, stimuli, and experimental procedures of the experiments that comprise this thesis.

CHAPTER 5

RESEARCH PROJECT FRAMEWORK

CHAPTER 5: RESEARCH PROJECT FRAMEWORK

The general aim of this thesis is to provide a systematic examination of the perceptual assimilation, discrimination, and acquisition of uncategorised non-native vowel phones. As outlined in the earlier chapters of the thesis, there may be systematic differences in the way in which uncategorised phones are assimilated to the L1 phonological system (Chapter 3). This issue was addressed in Chapter 6 in a study examining the way in which Egyptian Arabic (EA) speakers perceptually assimilate Australian English (AusE) vowels to their L1 phonological system. The discussion in the earlier chapters also focused on how the discrimination accuracy levels of non-native uncategorised vowels have been largely overlooked. Therefore, in Chapter 7, this was assessed by having AusE speakers perceptually assimilate and discriminate between pairs of non-native Danish vowels. It was also argued that new L2 phonological categories are more likely to be acquired for uncategorised L2 phones, but that this requires further investigation (Chapter 4). This issue was assessed in the experiment reported in Chapter 8, which examined the acquisition of L2 AusE vowels by native EA speakers who vary on factors related to L2 acquisition.

In this chapter, the participant groups, stimuli, and experimental procedures that were used to address these aims will be described. The various participant groups will first be outlined (Section 5.1), followed by the stimuli (Section 5.2), and the experimental tasks (Section 5.3).

5.1 Participant groups

To assess the perceptual assimilation and discrimination of uncategorised non-native phones, listeners who are naïve to the stimulus language are ideal. Best and Tyler

(2007) defined functional monolinguals (i.e., non-native listeners) as those who are not actively acquiring or using an L2 and are naïve to the L2/non-native language. The L1 phonological inventories of the monolingual participant groups recruited are outlined in further detail in the subsections that follow.

5.1.1 Native Egyptian Arabic speakers (Chapter 6)

To address the question of whether there are any systematic differences in the way in which uncategorised non-native phones are assimilated to the L1 phonological system, listeners who are naïve to the stimulus language are most appropriate. Additionally, it has been suggested that listeners with a small L1 vowel inventory will be less likely to perceive phones from target language as similar to any L1 phones (Flege, 1995). With a large L1 vowel inventory, there is a greater number of possible L1 categories available to assimilate the non-native phones, and there is less unoccupied phonetic space. Therefore, to optimise the likelihood of observing the possible range of uncategorised assimilations, naïve listeners with a relatively small vowel inventory size, rather than those with a large vowel inventory, are required.

EA speakers are recruited for Experiment 1 (Chapter 6). EA is a Semitic language belonging to the Afro-Asiatic family (Maddieson, 1984) and is the language spoken in Cairo, which is in the lower regions of Egypt. The vowel inventory of EA consists of three short monophthongal vowels /a, i, u/, five long monophthongal vowels /aː, iː, uː, eː, oː/, and two diphthongs /ay, aw/[3], which are phonetically similar to /eː/ and /oː/, respectively (Woidich, 2005). The EA monophthongs are displayed in Figure 5.1.

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[3] Arabic diphthongs have been transcribed as either vowel-glide or vowel-vowel sequences (i.e., /aw/-/aj/ vs. /au/-/ai/). We employ the transcription approach of Thelwall and Sa'Adeddin (1990).

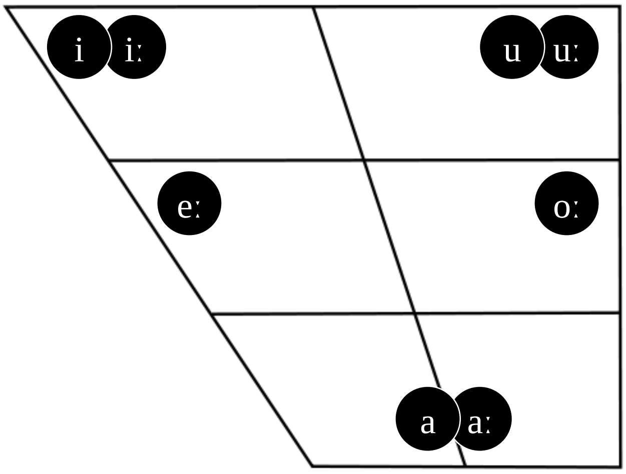

Figure 5.1: Monophthongal vowels of Egyptian Arabic.

This is clearly an unbalanced vowel system in that the long vowels /eː/ and /oː/ do not have short counterparts. Maddieson (1984) conducted an analysis of the phonological inventories of 317 languages and found that the long vowels /eː/ and /oː/ are more likely to appear in languages without short counterparts than any of the other long vowels. Given the relatively small vowel inventory, there is a high degree of allophonic variability (Woidich, 2005). For example, the short high vowels /i/ and /u/ are sometimes pronounced as ranging between [ɪ]-[e], and [ʊ]-[o], respectively. The long vowels /eː/ and /oː/ are often shortened to the allophones [e] and [o] in unstressed positions or before certain consonant clusters. Allophones include [æ, æː, ɑ, ɑː, ɛː, ɛ̽ː, e, o, ɪ, ɪː, ʊ, ʊː, ə] (Lehn & Slager, 1959; Selim & Anbar, 1987).

To ensure that the participants have had no extensive exposure to the stimulus language (AusE, see Section 5.2.1), cross-language speech perception data in Chapter 6 were collected from native speakers who were residing in their L1-speaking environment via an online study. This has the added benefit of being a cost-effective method for facilitating cross-language data collection.

5.1.2 Native Australian English speakers (Chapter 7)

The second research question concerning discrimination performance of non-native uncategorised vowels requires listeners who are naïve to the stimulus language. Furthermore, as the perceptual assimilation of non-native vowels to L1 vowels is highly variable among individual participants (e.g., Best, Shaw, Docherty, et al., 2015; Best, Shaw, Mulak, et al., 2015), it has been suggested that a larger sample size may be ideal if individual differences in assimilation are to be assessed (Tyler et al., 2014). Therefore, an easily accessible population of participants is preferred to ensure a sufficient sample size. Additionally, participants with diphthongs in their L2 vowel inventory provide an opportunity to examine how experience with L1 vowel dynamics affects the perception of non-native diphthongs. Native AusE speakers make an ideal group of listeners because, from a practical perspective, they are an easily accessible population. With this group it is possible to recruit a large number of participants (> 40) which is quite large compared to the relatively small sample sizes of previous cross-language vowel studies (e.g., Flege et al., 1997; Levy, 2009; Polka, 1995). Also, the AusE vowel inventory includes diphthongs, so it is possible to examine how experience with L1 diphthongs influences the perception of foreign language diphthongs. The AusE speakers were recruited from the Western Sydney University first year psychology undergraduate pool who are participating for course credits, and also from the Greater Western Sydney community.

AusE is a non-rhotic dialect of English, employing both vowel quality and duration to differentiate among vowels. In AusE, the vowels /ɐ, e, ɪ, ɔ, ʊ, æ, ɐː, eː, iː, oː, ʉː, ɜː/ are monophthongs, with /ɐ, e, ɪ, ɔ, ʊ, æ/ classified as short vowels and /ɐː, eː, iː, oː, ʉː, ɜː/ classified as long vowels, and the vowels /ɑe, æɔ, æɪ, əʉ, ɪə, oɪ/ are diphthongs (Cox & Palethorpe, 2007). Examples of AusE vowel contrasts that differ in length only include /ɐ, ɐː/ and /e, eː/. Certain AusE vowel pairs differ not only on duration, but also on quality (i.e., formant frequencies). For example, the AusE vowels /ʊ, ʉː/ differ in vowel duration, but /ʉː/ is also more fronted than /ʊ/ (Cox, 2012). The AusE monophthongs are plotted in Figure 5.2.

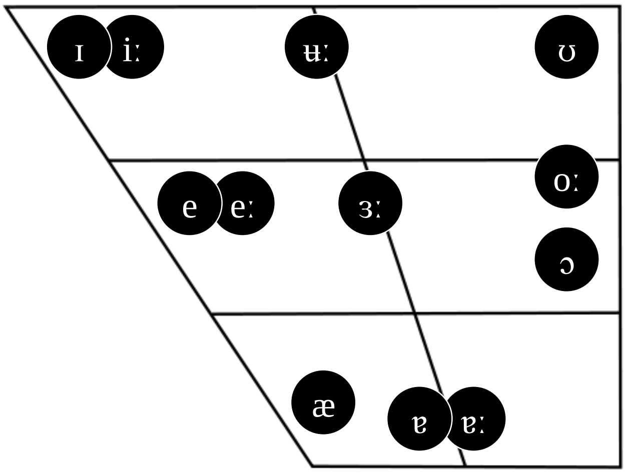

Figure 5.2: Monophthongal vowels of Australian English.

5.1.3 Egyptian Arabic L2-English learners (Chapter 8)

L2 learners were needed in order to examine the acquisition of uncategorised L2 vowels. Best and Tyler (2007) define L2 learners are those who are in the active process of acquiring an L2 for the purpose of functioning in the L2 language community, rather than for purely educational requirements. To assess category acquisition, PAM-L2 and SLM suggest that learners who are at the beginning stage of L2 acquisition are most appropriate. It was difficult to recruit absolute beginners, and so the learners recruited varied in several factors related to L2 acquisition. Nevertheless, the benefit of this is that there was an opportunity for assessing whether and how each of the six factors identified in Chapter 4 predicted L2 learning outcomes. However, to maximise the opportunity of observing the acquisition of L2 categories, learners with a relatively smaller L1 vowel inventory size than the L2 were recruited. According to SLM (Flege, 1995), for learners to develop new categories, they must discern phonetic differences between the L1 and L2 in order to develop new categories, and this is more likely to occur for learners with a smaller L1 vowel inventory size. For learners with a large vowel inventory size, it is likely that L2 vowels will be categorised or identified with an existing L1 vowel category. Furthermore, learners who are acquiring the L2 in an L2 immersion environment are needed as this provides an ecological assessment of L2 acquisition.

To investigate L2 learning, EA migrants who have moved to Australia as adults and were learning AusE in the L2 immersion environment were recruited. The EA vowel inventory is relatively small (10 phonemic vowel categories), in comparison to L2 AusE (18 phonemic vowel categories). There are a steadily increasing number of EA migrants in Australia. Based on reports by the 2006 Australian Bureau of Statistics, of the African-born population residing in Australia, 13.5% were born in Egypt (Australian Bureau of Statistics, 2006). Therefore, there was an opportunity to recruit a sufficient number of participants. Learners were recruited from adult English language learning programs (e.g., the Adult Migrant English program) and from the general migrant community in the Greater Western Sydney region, using flyers, online advertisements, and through word of mouth. They received monetary reimbursement for their participation.

5.2 Stimuli

The auditory vowel stimuli were produced by native female speakers of the stimulus language. Female speakers have been shown to make more use of clear speech strategies than males when producing vowels (Cox, 2006). Indicators of clear speech include an increase in vowel duration, longer targets for monophthongs and transitions for diphthongs, faster onglide and offglide, and a greater distinction between short and long vowels (Lindblom & Lindgren, 1985). This was expected to help participants identify meaningful phonetic features in the vowel stimuli.

The vowel stimuli were produced in /ˈhVbə/ nonsense words (see Bundgaard-Nielsen, Best, & Tyler, 2011a, 2011b; Strange et al., 1998). This syllable context was chosen for a number of reasons:

1) Producing the non-native/L2 vowels in real words, rather than nonsense words, may allow top-down lexical processing to influence non-native/L2 speech perception.
2) The syllable structure of the nonsense words (i.e., consonant-vowel-consonant-vowel) does not violate either the AusE or the EA listener's L1 phonotactic rules, ensuring that the processing of the non-native vowels is not affected by the L1 phonotactic structure (Strange, 2011).
3) Vowels presented in syllabic contexts are more accurately identified than vowels presented in isolation (e.g., Gottfried, 1984; Strange, Edman, & Jenkins, 1979; Strange, Verbrugge, Shankweiler, & Edman, 1976).
4) When the target vowels are presented in /ˈhVbə/ consonantal context, the extent of coarticulation is reduced as the production of /h/ involves relatively steady tongue, lips, and jaw positions, and /b/ involves very minimal to no movement of the tongue when produced (Strange et al., 2007). This is particularly important given that the consonantal context in which vowels appear has been shown to affect non-native/L2 vowel perception (e.g., Gottfried, 1984; Levy, 2009a; Levy & Strange, 2008).

The vowels from the stimulus languages are outlined in the following sections.

5.2.1 Australian English (Chapters 6 and 8)

The experiments presented in Chapters 6 and 8 employed AusE vowel stimuli. The characteristics of the AusE vowel inventory were described in Section 5.1.2. To assess the different ways uncategorised phones may be assimilated (Chapter 6), the entire AusE vowel system was employed. The results from this experiment were used to select a subset of the AusE vowel stimuli for the experiment presented in Chapter 8 for investigating L2 acquisition.

AusE, rather than another regional accent of English, serves as a suitable stimulus language for a number of reasons. The EA non-native listeners in Chapter 6 and the L2 learners in Chapter 8 must be naïve to the stimulus language. The participants in both experiments are naïve to the AusE dialect as most schools and universities/colleges in Egypt would offer exposure to American English or British English. Furthermore, an aim of this thesis is to investigate L2 learning in an *immersion* setting. As the setting is Australia, learners acquiring AusE as an L2 are required. If an L2 other than AusE was used, then tracking changes in L2 learning several times over the course of a year of L2 immersion would entail the experimenter travelling to and from the L2 speaking country.

The way in which the AusE vowel stimuli were recorded and prepared will be described in detail in Chapters 6 and 8. Briefly, two female speakers of AusE who grew up in the same Sydney region were recruited. At least 10 repetitions of each AusE vowel (i.e., the 12 monophthongs, six diphthongs, and schwa) were produced by each speaker to ensure that there was a sufficient number of final tokens. The auditory tokens were prepared using Praat (Boersma & Weenink, 2005). This process involved identifying, segmenting, and labeling the nonsense words and the target vowels. For the target vowel in each token, acoustic measurements were obtained, specifically, the target vowel duration, intensity, and the F1, F2, and F3 values at the 25%, 50%, and 75% of the vowel duration. The formant settings in Praat were adjusted manually for each individual token ensuring that the formant contours of the target vowel were tracked accurately. The intensity of each token was normalised. To achieve natural and clear sounding tokens, the onset and offset of each token was ramped, and any audible clicks were excised from the tokens. For the final set of stimuli, four acceptable tokens per vowel were selected from each speaker, based on similar intonation and target vowel duration.

5.2.2 Danish (Chapter 7)

Vowels from a language are required to test discrimination performance of uncategorised non-native vowel contrasts varying in degree of overlap with the other PAM assimilations. A language with a large vowel inventory size was ideal to maximise the possibility of obtaining a range of possible assimilation types. Also, a language with a large diphthong inventory was most appropriate in order to be able to assess the perception of diphthongs, which have not been systematically examined in previous research. Danish is an ideal stimulus language because of its large vowel inventory size and because it is a diphthong-rich language.

Danish is a Germanic language that is spoken in Denmark (Steinlen, 2005). It has 37 vowels in total, 20 of which are monophthongs and 17 are diphthongs (Grønnum, 1998). The vowels /i, e, ɛ, a, u, o, ɔ, y, ø, œ/ are considered to be short monophthong vowels, /iː, eː, ɛː, aː, uː, oː, ɔː, yː, øː, œː/ are long monophthong vowels, and /uj, iw, ew, ɛw, ɒw, yw, øw, œw, ɶw, iʌ̯, eʌ̯, æʌ̯, yʌ̯, øʌ̯, œʌ̯, uʌ̯, oʌ̯/ are classified as diphthongs. The long and short vowel pairs are distinguished purely in terms of duration, rather than vowel quality. However, the vowel pairs /o, oː/, /ɔ, ɔː/, and /a, aː/

are often reported as also differing in vowel quality. Danish vowels may also be distinguished in terms of the degree of lip rounding, with the vowels /y, yː, ø, øː, œː, œ, u, uː, o, oː, ɔ, ɔː/ classified as rounded, while the remaining monophthongs are unrounded. Danish has a crowded vowel space, particularly in the upper regions of the vowel quadrilateral, and it contains a large number of rounded front vowels. Figure 5.3 displays the Danish monophthong vowels.

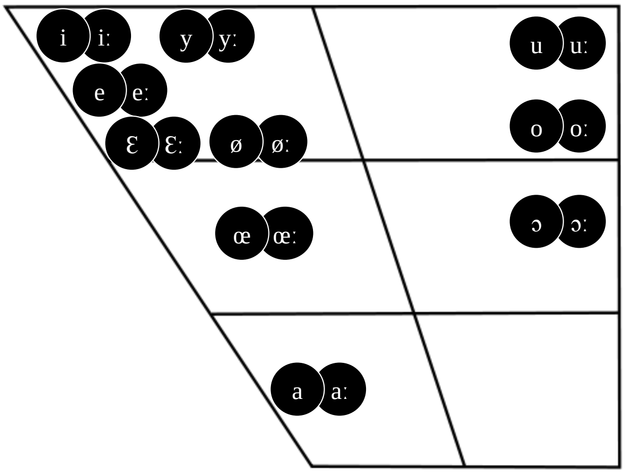

Figure 5.3: Monophthongal vowels of Danish.

A full description of the stimulus recording and preparation of the Danish vowel stimuli is reported in Chapter 7, and so only key aspects will be briefly outlined here. Three native Danish female speakers who were born in Copenhagen, Denmark were recruited. They produced all of the 37 Danish vowels in nonsense words, with at least seven repetitions per vowel each. As the quality of the first recordings was not of a high standard, the speakers were invited for a second recording session. To ensure that the selected tokens were produced as intended, the selection of the final set of stimuli was based on the results of a stimulus verification task. Five native Danish speakers identified the vowels with Danish keywords containing the Danish vowels, and they also rated the goodness of the tokens on a scale of 1 (very strange) to 7 (perfect). The Danish participants were recruited from Australia and Denmark via groups on social media websites. The final set of stimuli consisted of four repetitions per vowel, per speaker. Feedback from two native Danish speakers was also received on the accuracy of the Danish keywords as representing the intended vowels.

5.2.3 Questionnaires and vocabulary size test

To collect general language learning information and to identify participants who satisfied the participation criteria, a language background questionnaire was administered to the participants across all of the experiments reported in the thesis. For the L2 learners recruited for the experiment presented in Chapter 8, the language background questionnaire was used as a way of collecting information about five of the factors discussed in Chapter 4, and a vocabulary test was needed to measure L2 vocabulary size.

5.2.3.1 Language background questionnaire (Chapters 6, 7, 8)

A language background questionnaire was developed for non-native participants (Chapter 6 and 7), and another for L2 learners (Chapter 8). The questionnaire for the non-native participants appears in Appendix A. Participants were asked to provide general background information (e.g., age, sex, handedness), and to report hearing or vision impairments, as well as problems with language development (e.g., delayed language onset, difficulty learning new words, remembering names of objects), speaking (e.g., stuttering, lisping), or reading (e.g., confusing certain sounds or letters, dyslexia). Participants also provided information about their language learning history by indicating their native language and any additional languages they have been exposed to, and to rate their proficiency in each language in terms of speaking, understanding, reading, and writing abilities. Information about place of birth and places that the participant and their parents/guardians have resided in were also collected.

The language background questionnaire administered to the L2 learners contains the same questions as those outlined for the non-native listeners, but with the inclusion of additional questions specifically designed to assess L2 learning background and to assess the learners on 5 out of the 6 factors. These questions were adapted from those in the questionnaire presented in Li, Sepanski, and Zhao (2006). Participants were asked to indicate the date of arrival in Australia to allow length of residence to be calculated. They also reported their age of exposure to English and rated their proficiency in reading, writing, speaking, and understanding both English, and any additional languages that they had acquired. L1 and L2 usage was ascertained by asking participants to provide an estimate of the percentage of the time that they were exposed to, or spoke, their L1 or L2, respectively, in various social situations (e.g., at home, at work, while shopping, while visiting friends). Arabic and English versions of the questionnaire were prepared. They are presented in Appendix B.

5.2.3.2 Vocabulary size test (Chapter 8)

Vocabulary size refers to the number of words known as opposed to the nature of the words known (Karami, 2012). In this thesis, L2 vocabulary growth was measured over time to determine its role in L2 perceptual learning. A commonly used assessment of L2 vocabulary size is the L2-English Vocabulary Size Test (Nation & Beglar, 2007). The characteristics of this test, and how a bilingual version of the test was developed, are described below.

5.2.3.2.1 The Vocabulary Size Test

The Nation and Beglar (2007) Vocabulary Size Test is an assessment of decontextualised knowledge of written receptive vocabulary presented in a multiple-choice format. It is decontextualised because test items are presented in a single non-defining sentence. There are a number of useful features of this test that make it a suitable measure of vocabulary size (see Nation, 2012). First, because it samples test items from various word frequencies, it is useful for assessing a wide range of proficiency levels. This is particularly useful for tracking vocabulary growth as the learners become more proficient in the L2 over the course of a longitudinal study. Second, it has been shown that it is a valid and reliable measure of vocabulary size. Lastly, from a practical perspective, it is relatively easy to administer, score, and interpret, as well as being a readily available test.

The word frequencies are based on the British National Corpus. Test items are arranged roughly according to word frequency, with higher frequency words presented early during the test, and lower frequency words towards the end of the test. Four multiple-choice items are presented and participants are required to select the best definition or phrase for each test item. The response options are constructed in such a way that the frequency of the vocabulary used for the four alternatives is higher than that of the test item.

Vocabulary size was assessed three times during a year of L2 immersion. There are two vocabulary size tests available, both of which are suitable for measuring L2 vocabulary with non-native speakers, namely, a 14000 word family test and a 20000 word family test. The 14000 word family test contains 140 multiple-choice questions, with every 10 items selected from each 1000 word family level. For the 20000 word family test, every 5 items are sampled for each 1000 word family level and is also available in two parallel versions. Each version contains 100 multiple-choice items each and as stated in Nation (2012), these versions have been shown to be equivalent forms that are not significantly different (Version A: M = 81.37, SD = 16.662; Version B: M = 83.20, SD = 13.982). In order to avoid confounds associated with repeated administration of the same test, the two available parallel versions of the test were used to measure L2 vocabulary size and were alternated across the three testing sessions (e.g., T0 = Version A, T1 = Version B, T2 = Version A).

5.2.3.2.2 Bilingual versions of the vocabulary size test

The versions of those tests in their original form were not suitable for L2 learners as they require knowledge beyond that of L2 vocabulary. For example, consider the following test item:

19. thesis: She has completed her **thesis**.
a) talk given by a judge at the end of a trial
b) first year of employment after becoming a teacher
c) long written report of study carried out for a university degree
d) extended course of hospital treatment

As can be seen from this example, good reading abilities and grammatical knowledge is required (e.g., *talk given by a judge, at the end of a trial*), and the response options are also relatively long, thus, confounding the test. Bilingual versions of the L2 vocabulary size test were developed to overcome these issues. With previous bilingual versions of the test, the test items and the carrier sentences were presented in English while the multiple-choice options were translated to the test taker's L1 (e.g., Karami, 2012; Nguyen & Nation, 2011). Participants needed to select one out of four translated options that best match the test word. The bilingual versions of the tests that exist include Japanese, Korean, and Russian. However, to assess L2 English vocabulary knowledge of EA speakers, there is no Arabic-English bilingual version available. Therefore, as a part of this project, it was necessary to develop an Arabic-English bilingual version of the two parallel vocabulary size tests.

5.2.3.2.3 Developing an English vocabulary size test for Arabic-English bilinguals

The Arabic-English bilingual version of the tests were created in the same way as in Karami (2012) and Nguyen and Nation (2011). The multiple-choice response options were first translated from English to Arabic. If a phrase or description can be captured by a single Arabic word, then the single Arabic word was used, otherwise, the entire phrase or description was translated to Arabic. Arabic cognates and loan words were avoided. Below, is an example of an item from the English version of the test, where the words within brackets are the corresponding single words that replace the phrases:

11. soldier: He is a **soldier**.

a) person in a business **[businessman]**

b) person who studies **[student]**

c) person who uses metal **[metal worker]**

d) person in the army **[solider]**

The equivalent Arabic translated version of this item, using single Arabic words, would appear as:

11. soldier: He is a **soldier**.

ا/ رجُل أعمال

ب/ طَالِب

ت/ عَامِل المَعَادِن

ث/ جُندي

Several steps were then taken to ensure the correctness and readability of the translations. The translated versions were given to two native EA speakers who were also proficient in English. They were asked to check whether the translations were grammatically correct and whether the single word replacements were suitable word choices in EA. They were asked to make any amendments or suggestions for improvement. These suggestions were forwarded to a professional Arabic-English translator who made the necessary amendments. A focus group, which consisted of four EA-English bilingual speakers, was employed to test the readability of the tests. They were asked to pilot the tests and provide any comments about the translations. Again, comments and suggestions were collected from the focus group and sent to the same professional translator to make any amendments based on the suggestions from the focus group. The two parallel versions of the Arabic-English test are presented in Appendix C, along with the corresponding English versions.

5.2.3.2.4 Administration and scoring

The test was delivered in a paper and pen format. The test took approximately thirty minutes to complete. Participants may not be aided by the use of a dictionary, but the experimenter was allowed to help by pronouncing unfamiliar words. The test items are arranged according to frequency levels, with higher frequency items presented toward the beginning of the test. Participants were encouraged to complete all of the test items because there may be lower frequency words known by them due to their hobbies or profession (e.g., Nguyen & Nation, 2011). As mentioned, the vocabulary test was administered on all three testing sessions of the longitudinal study, with the two parallel versions of the test alternated across sessions for each participant. The order of presentation of the two versions were counterbalanced across participants.

The vocabulary size test is relatively simple to score. The test taker's vocabulary size is calculated by first determining the total number of correct responses and multiplying that score by 200. For example, with 40 correct responses out of a possible 100, the learner's L2 vocabulary size would be 8000 word families. The bilingual version of the test has been shown to result in scores that are approximately 10% higher than the non-translated version of the test (Elgort, 2011), possibly because the L1 translations avoid knowledge of L2 grammatical knowledge and reading ability.

5.3 Experimental tasks

The experiments reported in this thesis were designed to test various aspects of PAM and PAM-L2. As described in the studies reported in the earlier chapters of the thesis, tests of PAM/PAM-L2 involve a perceptual assimilation task with goodness-of-fit ratings to determine the PAM assimilation types preceded by a discrimination task. The tasks are conducted in this order to prevent listeners becoming overly sensitive to phonological similarities and differences between non-native and L1 phones. Therefore, both tasks were conducted in this thesis and they are described in detail in the sections that follow.

5.3.1 Perceptual assimilation task with goodness-of-fit ratings

To determine how non-native/L2 phones are assimilated to the L1 phonological system and to determine the PAM assimilation types across all of the experiments presented in the thesis, it was necessary to conduct a perceptual assimilation task, in which participants identified non-native/L2 phones in relation to L1 categories. Participants may identify non-native/L2 phones in relation to L1 phonemes by transcribing the non-native/L2 phones using L1 orthography (e.g., Best, McRoberts, & Goodell, 2001; Bohn, Best, Avesani, & Vayra, 2011), or by selecting from a set of forced-choice L1 response labels (e.g., Levy, 2009a; Tyler, Best, Faber, & Levitt, 2014). The latter method is the most commonly used and was the approach adopted for the thesis experiments. The L1 vowels were embedded within L1 keywords, rather than being presented in isolation because vowels presented in isolation are not easily transparent using orthographic symbols (Strange & Shafer, 2008).

A whole-system approach was used whereby listeners were presented with all possible L1 vowel categories to select from rather than a subset of L1 vowels. According to Bundgaard-Nielsen, Best, and Tyler (2011b), this approach is ideal for vowels because they are less categorically perceived than consonants (see Chapter 2), and so they are likely to form an interconnected system. Therefore, focusing on the entire L1 vowel inventory rather than a subset of it provides a more complete understanding of how the L1 vowel system shapes non-native speech perception.

A goodness-of-fit ratings task normally accompanies a perceptual assimilation task. In a goodness-of-fit ratings task, participants rate the similarity of the non-native/L2 phone in relation to the closest L1 phoneme on a Likert scale. In studies that test the PAM predictions, goodness ratings are used to distinguish between SC and CG assimilations. A significant difference in the goodness ratings between phones assimilated to the same L1 category indicate a CG assimilation, otherwise they are deemed SC assimilation, with the former predicted to be discriminated more accurately than the latter assimilation. Since the PAM predictions of discrimination were tested in the experiments reported in Chapter 7 and 8, it is important to distinguish between these two assimilation types. Therefore, in addition to the perceptual assimilation task, a goodness-of-fit ratings task was also employed.

A method for making inferences about L2 category formation is required in order to be able to assess category acquisition for uncategorised L2 phones. Consider the study by Bohn et al. (2011), in which Danish speakers identified English consonants twice, first using L1 consonants and then their choice of either L1 Danish or L2 English orthographic labels. Since the Danish participants were also proficient speakers of English, there were differences in their labeling across the L1 and L2 labeling tasks. For example, in Danish orthography, the English /w/ was often labeled as the Danish "V" or "B", but when English orthography was allowed, the English /w/ was identified as "W", which is not a Danish label. This demonstrated that when L2 speakers are given the opportunity to identify L2 phones with L2 category labels, they are able to demonstrate their ability to perceive phonological differences. Therefore, in Chapter 8, to be able to draw inferences about L2 category acquisition, participants completed an *L1 perceptual assimilation* task in which L2 phones were identified in relation to their L1 phonemes, in addition to an *L2 identification task* whereby they identified L2 vowels with L2 vowel category labels. It is possible that responses in this task may be highly variable, particularly for the least proficient L2 learners due to their lack of reading skills in the L2 (Strange & Shafer, 2008). In this case, categorisation responses in the L1 perceptual assimilation task may be more consistent than the L1 perceptual assimilation task. The way in which the results from this task were used to infer L2 category acquisition will be described further in the L2 learning study presented in Chapter 8.

5.3.2 Categorial discrimination task

A discrimination task allows a test of discrimination accuracy levels for UU and UC assimilations varying in overlap with the other PAM assimilation types (Chapter 7), and assessment of changes in discrimination accuracy for L2 vowel contrasts over time to determine whether these changes are associated with L2 category formation (Chapter 8). To address these research aims, it is useful to first identify and describe the characteristics of the different perceptual discrimination paradigms (see Strange & Shafer, 2008).

Generally, in auditory discrimination tasks, two or more stimuli are presented sequentially on a given trial, and listeners are required to make a judgment or comparison between the stimuli. One of the simplest forms of discrimination testing is an AX discrimination task whereby on a given trial, two tokens are presented sequentially. The primary token “X” may either be phonologically similar to the comparison token “A” (i.e., AA), or phonologically different from the comparison token (i.e., AB). Participants must determine whether the tokens are the ‘same’ or ‘different’. Other forms of discrimination testing involve the presentation of three tokens per trial as in an ABX, AXB, and an oddity discrimination task. In both the ABX and AXB tasks, “X” is from the same phonemic category as either the “A” or the “B” token. Listeners must match the “X” token with either token “A” or “B”. In an oddity discrimination task, there are two tokens belong to the same phonemic category, and the ‘odd’ token (i.e., token belonging to a different phonemic category than the other two tokens), may appear in any position (i.e., first, middle, last). While the ABX and AXB tasks involve making judgments based on similarity, an oddity discrimination task requires participants to indicate the position of the odd token.

The AXB discrimination paradigm was employed, as several features of this paradigm make it suitable for the experiments reported in this thesis. First, the AXB task entails lower memory load than the ABX and oddity discrimination tasks. Memory load refers to the ability to retain a memory trace for a previously presented stimulus while simultaneously making cognitive comparisons between the previous stimulus and a subsequent stimulus (Strange & Shafer, 2008). The oddity discrimination task is the most cognitively demanding of the tasks since the odd token does not have a constant position on a given trial. Unlike the ABX discrimination task, the AXB task is less cognitively demanding because token “X” (i.e., the comparison stimuli) is temporally equidistant from “A” and “B” tokens. While the AX task is the least cognitively demanding, the AXB task provides a more sensitive measure of finer stimulus differences than a simple same/different response (Macmillan & Creelman, 1991). Second, there is a smaller response bias in an AXB than AX discrimination task (Best et al., 2001). For these reasons, an AXB task was deemed the most suitable paradigm for testing discrimination accuracy in this thesis.

In the AXB discrimination task, physically different tokens were used for stimuli belonging to the same vowel category in order to encourage listeners to recognise the higher-order phonological structures regardless of irrelevant, within-category variation (Best et al., 1988; Polka, 1991, 1992). As participants must make phonological identity judgments, this task is often referred to as *categorial discrimination* (Best et al., 2001).

5.4 Summary

In this chapter, a description and justification for the participant groups, stimuli, and experimental procedures were provided. The characteristics of the various participant groups were outlined, and the vowel inventories of the various stimulus languages were described. An account of the L2 vocabulary size test and the steps that were taken to develop a bilingual version of the test were also provided, as well as the various questionnaires used. A perceptual assimilation task and a categorial AXB discrimination task were identified as suitable tasks for examining the perception and acquisition of uncategorised non-native and L2 phones.

Chapter 6-8 comprise the thesis experimental chapters. Chapter 6 presents Experiment 1 of this thesis. It was published in 2016 as an Express Letter in the Journal of the Acoustical Society of America. It evaluated the theoretical notion that phones may be uncategorised in different ways. In this study, native EA speakers perceptually assimilated and rated all of the AusE vowels in relation to their L1 vowel categories. Chapter 7 presents Experiments 2-4. This manuscript was submitted to the Journal of Phonetics and is currently under revision. The main aim of these experiments was to examine the discrimination performance of vowel contrasts assimilated as uncategorised, namely, UC and UU, and whether discrimination levels may be accounted for by considering degree of overlap. AusE speakers were assessed on their perception of Danish monophthongal and diphthongal vowel contrasts. Chapter 8 reports on Experiment 5, which examined the acquisition of uncategorised L2 AusE phones by EA speakers. It is in the form of a traditional thesis chapter. In a longitudinal study, L2 perceptual learning was tracked over one year of L2 immersion, and the influence of various factors related to L2 acquisition on category formation and L2 discrimination performance was examined.

CHAPTER 6

AN EXAMINATION OF THE DIFFERENT WAYS THAT NON-NATIVE PHONES MAY BE PERCEPTUALLY ASSIMILATED AS UNCATEGORISED

CHAPTER 6: AN EXAMINATION OF THE DIFFERENT WAYS THAT NON-NATIVE PHONES MAY BE PERCEPTUALLY ASSIMILATED AS UNCATEGORISED

Published in the Journal of the Acoustical Society of America as an Express Letter

6.1 Abstract

This study examined three ways that perception of non-native phones may be uncategorised relative to native (L1) categories: *focalised* (predominantly similar to a single L1 category), *clustered* (similar to ≥ 2 L1 categories), and *dispersed* (not similar to any L1 categories). In an online study, Egyptian Arabic speakers residing in Egypt categorised and rated all Australian English vowels. Evidence was found to support *focalised*, *clustered*, and *dispersed* uncategorised assimilations. Second-language (L2) category formation for uncategorised assimilations is predicted to depend upon the degree of perceptual overlap between the sets of L1 categories listeners use in assimilating each phone within an L2 contrast.

6.2 Introduction

There is ample evidence to suggest that native language (L1) attunement influences non-native speech perception in adults (Best et al., 2001; Tyler et al., 2014). One way to shed light on how experience with the L1 shapes speech perception is by testing listeners' perceptual assimilation of non-native phones (see Escudero & Williams, 2011; Gilichinskaya & Strange, 2010). Modeling the effects of L1 attunement on cross-language speech perception also has the applied benefit of accounting for the initial state of a second language (L2) learner and allowing predictions to be made about subsequent L2 development. According to the Perceptual Assimilation Model (PAM: Best, 1995), when a non-native phone is perceived as speech-like, but fails to resemble any particular L1 category, it is deemed *uncategorised*, and is likely to be acquired as a new category by L2 learners (PAM-L2: Best & Tyler, 2007). We postulate that uncategorised assimilations can be further differentiated, and present evidence here for three different ways in which non-native phones may be perceptually assimilated as uncategorised.

Non-native speech perception involves the detection of fine-grained phonetic information and identification of the abstract phonological-categorical functions of those phonetic details. According to PAM, listeners perceive non-native speech relative to the phonological and phonetic similarities and differences of the phonemes of their L1. A non-native phone may be *categorised* to an L1 category, and conceptually, with respect to its specific phonetic details, it may be perceived as an identical, an acceptable, or a deviant exemplar of that L1 category. Alternatively, a non-native phone may be perceived as speech-like, but without closely resembling any particular native category (i.e., *uncategorised*), and so falls in an untuned region of the listener's phonological system. The final possibility is that a non-native phone is heard as non-speech, thus falling outside the listener's native phonological space (i.e., *non-assimilable*). Studies conducted within a PAM framework have predominantly examined phones that were assimilated as categorised and non-assimilable, but uncategorised assimilations remain relatively understudied. Therefore, it is important to examine how uncategorised phones map onto the L1 phonological system in order to provide a comprehensive assessment of non-native speech perception, and the potential for L2 perceptual learning.

While PAM was developed to account for the perceptual assimilation of all speech segments (i.e., consonants and vowels), previous research has focused primarily on non-native consonants. In a recent study on the perceptual assimilation of non-native vowels, there was a high degree of within- and between-subject variability (Tyler et al., 2014). Unlike the perceptual assimilation of consonants, many of the vowels were uncategorised, possibly due to the less well-defined category boundaries for vowels than consonants. For this reason, vowels are ideal for examining the differing degrees to which non-native phones may be uncategorised.

In studies testing PAM predictions, uncategorised phones are operationally defined as those that are not consistently assigned to a single L1 category above a predefined threshold (e.g., 50%). However, observations of perceptual assimilation data patterns suggest three possible ways in which a phone might be uncategorised: (1) *focalised* responses: the non-native phone is perceived as primarily similar to a single L1 category but responses are below the categorisation threshold; (2) *clustered* responses: the uncategorised non-native phone is perceived as similar to a small set of L1 categories; and (3) *dispersed* responses: the listeners select a range of different L1 categories, which may reflect random responding when none of the available L1 categories are very similar to the stimulus phone.

This study evaluated the theoretical notion of uncategorised phones forming *focalised*, *clustered*, and *dispersed* responses. Listeners with a small L1 vowel inventory size are more likely to assimilate non-native vowels as uncategorised than those with a larger vowel inventory (Escudero & Williams, 2011). Therefore, Egyptian Arabic (EA) is ideal because it has 10 diphthongs and monophthongs (Lehn & Slager, 1959) as compared to the 19 of Australian English (AusE) (Cox & Palethorpe, 2007). To increase the possibility of observing uncategorised vowels, participants categorised and rated all AusE vowels in relation to their full EA vowel inventory. To ensure that listeners have had minimal exposure to the stimulus language, an innovative online method was used to collect cross-language speech perception data from participants residing in Egypt.

6.3 Method

6.3.1 Participants

Twelve native adult speakers of EA (10 females, M_{age} = 38.67 yrs, age range: 20-67 yrs) were recruited from universities in Egypt and through snowball sampling whereby each participant was asked to forward the link to the online experiment to some of their personal contacts. All were native-born speakers of EA, with no hearing, vision, or language impairments. They were not remunerated.

6.3.2 Stimuli and apparatus

The online experiment was programmed using Python and hosted using Google App Engine. The experiment was presented to participants using Firefox, Google Chrome, or Safari browsers. Participants were shown a grid containing /CVC/ or /CV/

keywords in Arabic orthography representing the entire Arabic short /a, i, u/ and long /aː, iː, uː, eː, oː/ vowels, and the diphthongs /aw, aj/ (transcribed as vowel-glide sequences: see Thelwall & Sa'Adeddin, 1990). To allow the EA listeners to be able to make choices reflecting fine-grained phonetic distinctions, we also included Arabic keywords containing allophonic variants of vowels [æ, æː, ɑ, ɑː, ɛː, ɛ̽ː, e, o, ɪ, ɪː, ʊ, ʊː, ə], and /ʔ/ (Lehn & Slager, 1959; Selim & Anbar, 1987). The vowels in each of the 24 keywords were highlighted in red, and a 7-point rating scale was also displayed. Two native AusE female speakers (34 and 44 yrs old) from the South-Western Sydney region were recorded in a sound-attenuated booth. The 12 AusE monophthongs /ɐ, e, ɪ, ɔ, ʊ, æ, ɐː, eː, iː, oː, ʉː, ɜː/, six diphthongs /ɑe, æɔ, æɪ, əʉ, ɪə, oɪ/, and /ə/ (Cox & Palethorpe, 2007) were produced in /ˈhVbə/ non-words. The stimuli were recorded using a Lenovo T520 laptop, running on Windows XP, at a 44.1 kHz sampling rate using a Shure SM10A headset microphone connected to an Edirol UA-25EX external USB sound card, with all equipment used in the present study provided by the MARCS Institute.

The recordings were high-pass filtered at 70 Hz to attenuate any low-frequency noise and correct for the direct current component. The onset and offset of each token were ramped by 10 and 20 ms, respectively. Any audible clicks were excised from the tokens. Four tokens of each nonsense word were selected from each speaker based on similar intonation and speaking rate, resulting in 152 tokens (19 vowels x 4 repetitions x 2 speakers). All tokens from a given speaker were amplified by a constant amount to normalise the vowel intensity across speakers while maintaining natural intensity differences across vowel categories.

6.3.3 Procedure

Written Arabic text instructed participants to sit in a quiet area and use headphones to listen to the auditory stimuli. Completion of the online experiment took 30-40 min. In an initial familiarisation phase, participants were guided through three step-by-step examples using the Arabic vowels /i, aː, aj/ in /ˈhVbə/ non-words, spoken by a native female Arabic speaker. Participants were instructed to attend to the first vowel in the non-words. In each example, participants clicked to play an auditory token. They were then asked to refer to the categorisation grid and find an Arabic keyword containing the most similar vowel to the one they heard. Participants were instructed that the same auditory token would then be presented a second time after which they needed to indicate how well the target vowel in the non-word matched the vowel in the chosen Arabic keyword on a scale from 1 (very strange) to 7 (perfect).

The trial structure for the category assimilation task with goodness-of-fit ratings was identical to the familiarisation phase, except that no feedback was provided and AusE tokens were used. The AusE vowels were pseudorandomised such that there were no more than three consecutive tokens from the same speaker, and that tokens from the same vowel category were not presented consecutively, regardless of the speaker. All participants completed the same pseudorandom order. There were 152 trials, with the last 10 trials additionally presented at the beginning to serve as warm-up trials; these were not included in the final analyses.

6.4 Results

There were no systematic differences in the way in which the AusE vowels were assimilated to the EA core phonemic versus allophonic categories, so the allophonic vowel categories were collapsed into the appropriate main phonemic category: [æ, ɑ, ɛː, ə] were collapsed into /a/, [ɪ] was collapsed into /i/, [ʊ] was collapsed into /u/, [e] was collapsed into /eː/, [o] was collapsed into /oː/, [æː, ɑː, ɛ̽ː] were collapsed into /aː/, [ɪː] was collapsed into /iː/, [ʊː] was collapsed into /uː/, and /ʔ/ was excluded from the analysis as it was rarely chosen. As in Bundgaard-Nielsen, Best, and Tyler (2011b), a non-native vowel was considered categorised if it was consistently assimilated to a particular L1 vowel category label more than 50% of the time, otherwise, it was deemed uncategorised. As can be seen in Table 6.1, only 3 of the 19 AusE vowels were consistently assimilated to an EA vowel category: AusE /ɐː/, /e/, and /ɔ/, were assimilated to EA /aː/ (87%), /i/ (60%), and /u/ (65%), respectively.

Table 6.1: *Mean percent categorisation and goodness ratings of Australian English vowels by Egyptian Arabic speakers, with Egyptian Arabic allophonic categories collapsed across appropriate main categories*

Assimilation type	AusE vowel	EA category label									
		a	i	u	aː	eː	iː	oː	uː	aw	aj
Categorised[b]	e	8	**60 (4.93)**[a]		3	12	12	1	1	1	2
	ɔ	2		**65 (5.06)**	1	1		16	10	2	3
	ɐː	7		2	**87 (5.41)**	2		1			
Focalised	ʊ	1		***45 (4.93)***[c]	1			22	27	3	
	iː	9	16	1	6	14	***49 (5.64)***	1		1	3
	ʉː	1	7	22	2	5	6	19	***35 (3.95)***		1
	ɪə	5	14		7	12	***36 (4.86)***			2	24
	ɑe	8			17	***36 (5.12)***	7	2	1	2	26
	æɔ	12	1	4	***43 (4.81)***	4		13	6	16	1
Clustered	ɐ	***45 (5.25)***	2	1	***40 (4.88)***	6	3			1	1
	æ	***30 (5.26)***	11	1	***46 (5.01)***	4	5		2	1	
	ɪ	5	***44 (5.24)***		5	8	***36 (4.66)***				1
	oː	1	1	***29 (4.82)***	1		1	***39 (5.49)***	***21 (4.83)***	7	
	æɪ	7	4		***22 (4.62)***	***25 (5.40)***	19		1	1	20
	əʉ	3	1	***34 (4.93)***	1	2	4	21	***27 (3.91)***	6	
	ə	18	***29 (5.29)***	***31 (4.22)***	1	3	6	2	8		1
Dispersed[d]	eː	11	23		20	17	23				6
	ɜː	7	12	23	7	11	16	6	9	6	2
	ɔɪ	8	3	13	5	9	14	7	14	11	16

[a] Numbers represent the percentage of each AusE vowel assimilated to an EA label, averaged across participants. The goodness-of-fit ratings are on a scale of 1 (sounds poor) to 7 (sounds perfect), also averaged across participants.

[b] Numbers in bold indicate the mean percent categorisation scores that have reached the 50% assimilation criterion, with the averaged goodness rating presented within parentheses.

[c] For Focalised and Clustered responses, the mean percent categorisation scores that are presented in bold italics represent the EA response label/s that was selected significantly more often than would be predicted by chance ($p < .05$).

[d] For Dispersed responses, none of the response choices were significantly greater than chance.

To differentiate among *focalised*, *clustered*, and *dispersed* uncategorised responses, t-tests were first conducted comparing the mean percent categorisation of an AusE vowel with each EA response option against a chance score of 10%, a value that takes into account the 10 possible EA phonological categories (see So & Best, 2014). For the average percent categorisation of a given AusE vowel to an EA response option, a significant p-value ($p < 0.05$) indicates that a specific EA label was selected significantly more often than chance. *Focalised* responses were defined as those where participants selected only one EA response label above chance for a given AusE vowel. *Clustered* responses were identified as those where more than one EA response label was selected above chance, and *dispersed* responses were those where no EA response label was selected more often than chance.

As can be seen in Table 6.1, the AusE vowels /ʊ, iː, ʉː, ɪə, ɑe, æɔ/ were assimilated as *focalised*, as EA /u, iː, uː, iː, eː, aː/, respectively. AusE /ɐ, æ, ɪ, oː, æɪ, əʉ, ə/ were *clustered* assimilations, with 2-3 EA response labels selected above chance per AusE vowel. Interestingly, responses for some *clustered* assimilations were split between short and long EA vowel (e.g., /ɪ/ as EA /i/ and /iː/). The AusE vowels /eː, ɜː, oɪ/ were *dispersed* assimilations, although EA label selection appears to be much more variable for /ɜː, oɪ/ than for /eː/.

6.5 Discussion

The predicted differentiation among *focalised*, *clustered*, and *dispersed* uncategorised assimilation types was clearly supported. These findings contribute to a better understanding of how listeners make use of both gradient phonetic details and abstract phonological categories in speech perception. *Focalised* and *clustered* assimilations suggest that, to a certain degree, listeners detect some phonetic information in non-native phones that is phonologically meaningful in the L1. However, with *dispersed* responses, listeners are sensitive only to the phonetic-gradient level of detail.

In the same way that PAM differentiates between the various ways that non-native segments may be categorised to an L1 phoneme, we have shown that uncategorised phones also differ in the way they map onto the L1 phonological system. Although this study has focused on perceptual assimilation of individual phones, it is possible to make different discrimination predictions for the three uncategorised assimilation types. According to PAM, discrimination accuracy for pairs of uncategorised phones (i.e., *Uncategorised-Uncategorised* assimilation type; UU) will range from poor to moderate/very good, depending on whether the two phones are perceived as similar to the same set of L1 categories and the similarity of the two phones to one another. By classifying uncategorised phones as *focalised*, *clustered*, or *dispersed*, more precise discrimination predictions may be made for UU contrasts. Assuming that a pair of uncategorised contrasting phones are each assimilated to a different L1 category or sets of L1 categories, phones assimilated as *focalised* (i.e., *focalised-focalised*) are predicted to be relatively easy to discriminate, followed by *focalised-clustered*, *clustered-clustered*, *focalised-dispersed*, *clustered-dispersed*, with *dispersed-dispersed* predicted to be the most difficult to discriminate.

Interestingly, certain pairs of AusE vowels were perceived as similar to the same set of EA vowel categories, such as the *clustered* AusE /ɐ/ and /æ/ vowels, where responses were both split between EA /a/ and /aː/. Recall that discrimination accuracy for contrasts assimilated as UU depends on the degree to which the contrasting phones are assimilated to the same set of L1 categories. Indeed, the degree of overlap between contrasting phones may affect discrimination performance (Tyler et al., 2014). As no single response is above chance in *dispersed* assimilations, it is only in *focalised* and *clustered* assimilation types that meaningful overlap could be encountered. UU *focalised*/*clustered* contrasts should be more accurately discriminated if both are assimilated to a different set of L1 categories (i.e., non-overlapping) such as AusE /iː/-/ʉː/ (*focalised* assimilation to EA /iː/ vs /uː/), than if they are assimilated to the same set of L1 categories (i.e., completely overlapping) such as AusE /iː/-/ɪə/ (*focalised* assimilation of both to EA /iː/). Those that overlap with some of the same L1 categories (i.e., partially overlapping) such as AusE /ɐ/-/æɪ/ (*clustered* assimilation to EA /a, **a̲**ː/ vs to /eː, **a̲**ː/, respectively), should be discriminated more accurately than contrasts that completely overlap, but less well than non-overlapping contrasts. Non-overlapping phones may be more discriminable because listeners are sensitive to the phonetic similarity of each non-native phone to different L1 phonological categories.

Our perceptual assimilation results also inform PAM-L2 predictions. Given that listeners fail to detect clear higher-order L1 phonological category invariants for *dispersed* assimilations, a new L2 phonological category is likely to be formed because there will be no systematic interference from previous L1 attunement. This is similar to the concept of a “new” L2 phone in the Speech Learning Model (Flege, 1995). For *focalised* and *clustered* assimilations, however, acquisition of a new L2 category is likely to depend on the degree of phonetic overlap with contrasting L2 phones. If the L2 *focalised* or *clustered* phone does not overlap with any other L2 category, then a new L2 category is likely to be acquired.

Differentiating between categorised and *focalised* phones depends upon the predefined categorisation threshold. Using a 50% assimilation criterion, AusE /iː/ was deemed uncategorised-*focalised* at 49%. The individual data reveals that 8 out of the 12 participants consistently categorised AusE /iː/ to EA /iː/. Due to the large individual differences, Tyler et al. (2014) split individuals' data by assimilation type rather than contrast type. However, it was not possible to employ this approach here due to an insufficient sample size.

Future studies are required to evaluate the hierarchy of discrimination predictions, and the effect of perceptual overlap on discrimination performance and L2 category formation in learners. Additionally, the development of alternate methods is required to replace the use of an arbitrary cut-off criterion, particularly for vowel perception.

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CHAPTER 7

DISCRIMINATION OF UNCATEGORISED NON-NATIVE VOWEL CONTRASTS IS RELATED TO PERCEIVED PHONOLOGICAL OVERLAP WITH NATIVE VOWEL CATEGORIES

CHAPTER 7: DISCRIMINATION OF UNCATEGORISED NON-NATIVE VOWEL CONTRASTS IS RELATED TO PERCEIVED PHONOLOGICAL OVERLAP WITH NATIVE VOWEL CATEGORIES

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7.1 Abstract

Non-native vowels perceived as speech-like but not identified with a particular native (L1) vowel are assimilated as uncategorised, and have received very little empirical attention. According to the Perceptual Assimilation Model (PAM: Best, C. T. [1995]. A Direct Realist View of Cross-Language Speech Perception. In W. Strange [Ed.], Speech Perception and Linguistic Experience: Issues in Cross-Language Research [pp. 171-204]. York Timonium, MD: York Press), contrasts where one or both phones are uncategorised are Uncategorised-Categorised and Uncategorised-Uncategorised, respectively. We reasoned that discrimination accuracy for these assimilations should be influenced by perceived phonological overlap (i.e., overlap in the categorisations to L1 vowels), and predicted excellent discrimination for non-overlapping contrasts, followed by partially overlapping, and completely overlapping contrasts. To test those predictions, Australian English speakers discriminated between Danish monophthongal and diphthongal vowel contrasts that formed Uncategorised-Categorised and Uncategorised-Uncategorised assimilations, varying in the presence

of overlap, in addition to Two-Category and Single-Category contrasts. The discrimination accuracy results supported our predictions. These findings have implications for PAM, and broader relevance to second-language learning models, as they allow for more precise discrimination predictions to be made based on assimilation type.

7.2 Introduction

Research on adult cross-language speech perception suggests overwhelmingly that attunement to the native language (L1) influences non-native vowel perception (Escudero & Williams, 2011; Strange et al., 1998; Tyler et al., 2014). Adults often experience difficulty in discriminating between certain pairs of non-native phonemes that are phonologically distinctive for native speakers of that language (i.e., they are contrasts), yet they are able to discriminate between other pairs of non-native contrasts reasonably well (see Best, McRoberts, & Goodell, 2001). For example, native Japanese speakers have difficulty perceptually distinguishing the English /r/ and /l/ consonants as they are not phonologically contrastive in the L1 and both are perceived as similar to the Japanese "tapped-r" which is usually realised as [ɾ] (see Aoyama, Flege, Guion, Akahane-Yamada, & Yamada, 2004; Goto, 1971; MacKain, Best, & Strange, 1981). In this example, both contrasting non-native consonants are perceived as similar to a single L1 category. In fact, the discrimination of contrasting non-native consonants that are each identified with a single L1 category has been the primary focus of cross-language speech perception research (e.g., Best et al., 2001; Polka, 1991; Strange & Dittmann, 1984). Relatively little is known, however, about how well pairs of vowels are discriminated when one or both of them is not perceived as similar to any single L1 vowel. The purpose of the present study was to provide a systematic examination of discrimination performance on contrasting non-native vowels that are not perceived as similar to any one particular L1 category.

One of the most prominent theories of cross-language speech perception that accounts for the variability in the discrimination of non-native phones is the Perceptual Assimilation Model (PAM: Best, 1994, 1995). PAM makes predictions of discrimination by naïve listeners based on how they perceptually assimilate non-native phones to their L1. Individual non-native phones may be assimilated to the L1 phonological system in one of three ways: a) categorised: a non-native phone may be assimilated to an L1 phoneme and be perceived as an excellent, moderate, or poor exemplar of that L1 category, b) uncategorised: a non-native phone may not be perceived as similar to any one particular L1 category, and so falls in an untuned region in between categories within the L1 phonological space, or c) non-assimilable: a non-native phone is not perceived as speech and so falls outside the listener's L1 phonological space. Phones are deemed categorised if assimilated to a single L1 phoneme above a particular categorisation threshold (e.g., 50%, 70%), otherwise they are deemed uncategorised (Antoniou et al., 2013; Bundgaard-Nielsen, Best, & Tyler, 2011b; Tyler et al., 2014).

With respect to contrasting pairs of non-native phones, PAM makes discrimination predictions based on the various ways they are assimilated. When the two contrasting phones are assimilated to separate L1 categories (*Two-Category assimilation, TC*), discrimination accuracy will be excellent. When one phone is categorised and the other is uncategorised (*Uncategorised-Categorised assimilation, UC*), discrimination will be very good to excellent. If both phones are assimilated to the same L1 category and are both perceived as either equally good or poor versions of the same L1 category (*Single-Category assimilation, SC*), discrimination accuracy will be poor. However, when one phone is perceived as a phonetically better version of the L1 category than the other (*Category-Goodness assimilation, CG*), discrimination accuracy will range from good to very good. TC assimilations are predicted to be the easiest to discriminate, followed by both UC and CG, with SC predicted to be the most difficult to discriminate. When both phones are uncategorised (*Uncategorised-Uncategorised; UU*), discrimination is predicted to range from poor to moderate/very good, depending on the phonetic similarity of the two phones to each other and to L1 phonemes.

Discrimination accuracy for contrasts involving categorised phones (i.e., TC, CG, SC, UC) has been examined in adults mostly using consonants and they have provided support for the PAM predictions of discrimination (e.g., Best et al., 2001; Best & Strange, 1992; Halle, Best, & Levitt, 1999; Polka, 1991), but there have been fewer studies using vowel stimuli (e.g., Bundgaard-Nielsen et al., 2011a, 2011b; Polka, 1995). In the study by Tyler et al. (2014), the perception of French (/bo/-/bõ/, /dø/-/dœ/, /sy/-/sø/), Norwegian (/ki/-/kʉ/, /ki/-/ky/), and Thai (/bɯ/-/bɤ/) vowel contrasts was assessed in native speakers of American English. Unlike the perceptual assimilation patterns of consonants, most of the vowels were assimilated as uncategorised when a 70% assimilation criterion was used. TC and UC assimilations combined were discriminated more accurately than CG, followed by SC assimilations. Despite the variability in vowel perception, Tyler et al. demonstrated that the PAM predictions hold true for monophthongal vowels. It is yet to be determined whether, and to what extent, the PAM predictions also apply for diphthongal vowels. Furthermore, Tyler et al. did not evaluate discrimination of UU vowel contrasts, which highlights the need for more focused investigations into the two uncategorised assimilation types, namely, UU versus UC.

While there has been no systematic examination of discrimination levels related to the two types of uncategorised assimilations, a recent study by Faris, Best, and Tyler (2016) demonstrated that there are at least three different ways in which non-native vowels may be assimilated as uncategorised. In a perceptual assimilation task, native Egyptian Arabic speakers identified all of the Australian English (AusE) monophthongs and diphthongs in terms of all possible L1 monophthongs, diphthongs, and allophonic variants of the monophthongs and diphthongs. The only AusE vowels that were categorised above the (lenient) 50% cut-off categorisation criterion were /ɐː/, /e/, and /ɔ/, which were categorised to the Egyptian Arabic /aː/, /i/, and /u/, respectively, while the remaining AusE vowels were uncategorised. For the uncategorised vowels, some were perceived as similar to a single L1 vowel category at above chance rates, but responses to that vowel were below the 50% threshold (a *focalised* assimilation). There were also instances whereby two or more L1 vowels were selected above chance (a *clustered* assimilation), and other cases where no one label was selected above chance (a *dispersed* assimilation). *Dispersed* assimilations suggest that the listener does not detect any phonological similarities between a non-native vowel and any of the L1 vowels. For both *focalised* and *clustered* responses, modest phonological similarities are detected between a non-native vowel and one or more L1 vowels, respectively. A revision of PAM's original definition of uncategorised assimilations will need to account for the different ways that uncategorised non-native vowels may occupy the space between L1 vowels, namely, *focalised*, *clustered*, and *dispersed*.

Given the various ways in which non-native vowels may be perceptually assimilated as uncategorised, when considered as contrasting pairs, a new set of predictions for discrimination are raised, which were not directly addressed in Faris et al. (2016). As mentioned, the three uncategorised types are identified using a perceptual assimilation task which assesses sensitivity to phonological information. Since phones assimilated as *focalised* and *clustered* are identified with one or more L1 phonological categories, respectively, there is the potential for *perceived phonological overlap* in the categorisations to L1 vowels and this may influence discrimination accuracy. Conversely, because vowels assimilated as *dispersed* are not perceived as similar to any of the L1 phonological categories, there will be very little to no systematic interference from the L1 phonology. Instead, *dispersed* phones may be perceived in terms of low-level phonetic features. Therefore, discrimination accuracy for contrasts involving two *dispersed* vowels should depend only on the degree of perceived phonetic similarity between the non-native vowels, and discrimination accuracy may range from moderate to excellent. Discrimination accuracy for contrasts involving at least one *dispersed* vowel (i.e., *dispersed-focalised*/*clustered*) may be very good because the listener perceives a phonological similarity to L1 categories for one phone and no phonological similarities for the other phone. The focus of the current investigation, however, was on perceived phonological overlap of *clustered* and *focalised* assimilations.

Faris et al. (2016) identified three likely instances of perceived phonological overlap for contrasts involving at least one uncategorised phone: 1) non-overlapping, 2) partially overlapping, and 3) completely overlapping (for similar ideas, see also, Antoniou et al., 2013; Bohn, Best, Avesani, & Vayra, 2011). Examples from Faris et al. will be used to illustrate how these overlap types are identified. A contrast is non-overlapping when the non-native phones are each identified with a completely different set L1 categories that are all selected above chance. An example of this are the vowels in the AusE contrast /iː/-/ʉː/, involving two *focalised* assimilations. For AusE /iː/, Egyptian Arabic /iː/ was the only label selected above chance (49% of the time), and Egyptian Arabic /uː/ was the only above-chance label selected for AusE /ʉː/ (35% of the time). Partially overlapping contrasts are those where there is at least one shared above-chance category. For the vowels in the AusE contrast /ɐ/-/æɪ/, the Egyptian Arabic vowels /a/ and /aː/ were selected above chance for the AusE /ɐ/, and the Egyptian Arabic vowels /aː/ and /eː/ were selected above chance for the AusE /æɪ/.

In this case, the shared L1 category was /aː/. Completely overlapping contrasts are identified as those where both non-native phones are assimilated to the same above-chance L1 vowel or set of L1 vowels. For instance, Egyptian Arabic /iː/ was the only above-chance label selected for both of the vowels in the AusE contrast /iː/-/ɪə/. Discrimination accuracy should be excellent for non-overlapping contrasts, because there are perceived L1 phonological differences between the non-native vowels, and poor to moderate for completely overlapping contrasts, but it may vary for partially overlapping contrasts according to the degree of overlap. On average, accuracy for partially overlapping contrasts should lie in between that for non-overlapping and completely overlapping contrasts. Thus, non-overlapping contrasts should be discriminated more accurately than partially overlapping contrasts, which should be discriminated more accurately than completely overlapping contrasts (non-overlapping > partially overlapping > completely overlapping).

It is important to note that there is limited set of ways that phones in UU and UC assimilations might overlap, depending on whether the uncategorised phones are *focalised* or *clustered*. For example, it is not possible for a *focalised* phone to partially overlap with another *focalised* phone or a categorised phone. On the other hand, a *clustered* phone cannot overlap completely with either a *focalised* phone or a categorised phone. The possible overlap types for UU and UC assimilations are presented in Table 7.1. Instances were a particular overlap type is not possible (e.g., a partially overlapping *focalised-focalised*/categorised contrast) are represented by a dash.

Table 7.1: *The range of possible perceived phonological overlap for responses deemed focalised or clustered for UU and UC assimilations of contrasting non-native vowels*

		Uncategorised phone 2		Categorised phone 2
		Focalised	*Clustered*	
Uncategorised phone 1	*Focalised*	No overlap – Complete overlap	No overlap Partial overlap –	No overlap – Complete overlap
	Clustered	No overlap Partial overlap –	No overlap Partial overlap Complete overlap	No overlap Partial overlap –

There is indirect evidence to suggest that the perceived phonological overlap may affect discrimination accuracy. For example, in Tyler et al. (2014), the vowels in the contrast /sy/-/sø/ were non-overlapping, while /bɯ/-/bɤ/ were partially overlapping. Discrimination accuracy was high for both, but the non-overlapping contrast was discriminated significantly more accurately than the overlapping contrast. In another study, for native Salento Italian speakers, the British English /ɑː/ and /ʌ/ are uncategorised with responses shared between their native /a/ and /ɔ/ categories (Sisinni & Grimaldi, 2009). These completely overlapping vowels were discriminated at chance level, while accuracy was much higher for the partially overlapping and especially the non-overlapping contrasts in Tyler et al. (2014). However, it is not yet clear why the absolute level of discrimination accuracy differed in the two studies. In Flege and MacKay (2004), native Italian listeners experienced difficulty discriminating the English contrasts /ɛ/-/æ/ and /ɒ/-/ʌ/, while /ʌ/-/æ/ was discriminated well. To explain the variability in discrimination accuracy, they developed a *classification overlap score*, which measures the extent to which pairs of contrasting vowels are categorised to the same L1 vowels. The general prediction was that the greater the amount of overlap, the poorer the discrimination accuracy. The example provided by Flege and MacKay (2004) helps demonstrate how an overlap score was computed. The English vowels /ɛ/ and /æ/ were identified as the Italian vowel /e/ 47% and 10% of the time, respectively, thus, these two English vowels overlapped with the Italian /e/ 10% of the time. The same two English vowels were also classified as the Italian /ɛ/ 53% and 75% of the time, respectively, with an overlap of 53%. The amount of overlap for each Italian vowel involved was then added, giving an overall overlap score of 63% for the /ɛ/-/æ/ contrast. An examination of the overlap scores revealed that the vowels in each of the contrasts /ɛ/-/æ/ and /ɒ/-/ʌ/, which were discriminated poorly, were also highly overlapping at 63% and 74%, respectively, while /ʌ/-/æ/ was discriminated very well and had a comparatively low overlap score of 15%. The authors concluded that the amount of overlap might have affected discrimination performance. Levy (2009a,b) used a similar overlap score (*cross-language assimilation overlap score*) to show that the higher the percentage of overlap between contrasting French vowels, the less accurately they were discriminated by American English listeners. Henceforth, both methods will be referred to as *overlap methods* and the degree of overlap calculated as *overlap scores*.

While the discussion thus far has provided indirect support for our prediction that non-overlapping assimilations will be discriminated more accurately than partially overlapping, followed by completely overlapping assimilations, previous studies have focused only on UU assimilations. In a study examining the perception of the English consonant contrasts /b/-/v/, /w/-/v/, and /ð/-/v/ by native Danish and Italian speakers, Bohn, Best, Avesani, and Vayra (2011) differentiated between two subgroups of UC assimilations, in an analysis of individual participants' assimilations. Non-overlapping contrasts were those where the participant chose a completely different set of L1 category labels for each phone within the contrast, while in overlapping contrasts, one or more of the same L1 category labels were selected for both non-native phones. Some of the participants showed evidence of overlap in their perceptual assimilation, but that did not account for the differences in discrimination.

Research investigating the role of language experience in vowel perception has centered primarily on monophthongal vowel perception, which is reflected in the studies reviewed here. As will be further discussed later in this paper, diphthongs, which differ markedly from monophthongs in terms of their acoustic and articulatory features, have not been considered or analysed in speech perception research. Therefore, there is reason to expect different patterns in cross-language perceptual assimilation and discrimination between the two classes of vowels. It was important in this study to examine whether, and how, monophthongs and diphthongs may differ in the ways they are assimilated and discriminated. Doing so will also provide a more complete account of non-native vowel perception.

The current paper examines, for the first time, the relationship between the presence of perceived phonological overlap and discrimination accuracy for non-native vowel contrasts assimilated as UU and UC. While previous findings suggest that overlap influences the discriminability of vowel contrasts, a systematic investigation is required that takes into account the PAM assimilations, particularly the three uncategorised assimilation types identified in Faris et al. (2016). It was predicted that the presence of perceived phonological overlap between contrasting non-native vowels will influence discrimination accuracy for both UU and UC assimilations, such that non-overlapping (N) > partial overlapping (P) > completely overlapping (C). Discrimination of non-overlapping contrasts should be excellent, because although L1 category membership may be ambiguous for one or both phones, perceivers detect an unambiguous L1 phonological contrast between the non-native phones. In this sense they are functionally akin to a TC contrasts (Antoniou et al., 2013), and so UC-N and UU-N should be discriminated as accurately as a TC assimilation. By similar reasoning, completely overlapping contrasts should be discriminated reasonably poorly because perceivers do not detect any L1 phonological contrast between the non-native phones, akin to an SC assimilation.[4] Discrimination accuracy for partially overlapping contrasts should lie in between the other two types, at a similar level to a CG assimilation. Therefore, we tentatively suggest that PAM assimilation types should be discriminated according to the following order, from most accurate to least accurate: {TC = UC-N = UU-N} > {CG = UC-P = UU-P} > {SC = UC-C = UU-C}.

To make precise discrimination predictions for UU and UC contrasts, an approach to determining overlap is required, but previous methods of measuring overlap may not be suitable for the purposes of this study. Bohn et al.'s (2011) overlap method was developed to account for the discrimination accuracy of uncategorised consonant contrasts, but it may not be applicable for uncategorised vowel contrasts. Compared to the perceptual assimilation of consonants, vowels are highly variable, that is, much less categorical (e.g., Best, Shaw, Docherty, et al., 2015; Best, Shaw, Mulak, et al., 2015; Fry, Abramson, Eimas, & Liberman, 1962; Liberman, Harris,

[4] It is possible that perceivers may be sensitive to phonetic goodness-of-fit in completely overlapping contrasts. In that case, discrimination accuracy should be at the level of a CG assimilation when perceivers detect a goodness-of-fit difference between the non-native phones, in terms of multiple native phonological categories. As the focus of this paper is on perceived phonological overlap, we leave the question of the influence of phonetic goodness-of-fit on discrimination of completely overlapping contrasts for a future investigation.

Hoffman, & Griffith, 1957; Tyler et al., 2014). If the method in Bohn et al. (2011) were employed with vowels, it is likely that there would be many more instances of overlapping contrasts, arrayed across complete and partial overlap. Also, this method does not consider cases where the average percent categorisation of a non-native vowel to an L1 vowel category is significantly above chance, as below chance responses may suggest that perceptual assimilation is highly inconsistent as if participants were responding randomly as in *dispersed* assimilations.

While the overlap method (Flege & MacKay, 2004; Levy, 2009b) provides a quantifiable measure of differences in amount of overlap, there are two reasons why it may not be a suitable method for the current study. First, our aim is to examine the effect of overlap on discrimination as a function of assimilation type, and to compare discrimination of UU and UC assimilations with the other PAM assimilations. Therefore, it is necessary to differentiate between categorised and uncategorised assimilations, and between the various PAM contrast assimilations, as these factors may affect discrimination accuracy. For instance, discrimination accuracy for /e^{I}/-/ε/ from Flege and MacKay (2004) was excellent (A’ score of .90) despite being highly overlapping at 87%. From a PAM perspective, /e^{I}/ and /ε/ form a TC assimilation as they were categorised, respectively, to the Italian /e/ 67% and /ε/ 53% of the time when a 50% criterion is used. As the perceivers detect an L1 phonological contrast for that TC assimilation, PAM predicts excellent discrimination, which could explain the high discrimination accuracy in spite of the high overlap score. Therefore, in addition to determining the presence of overlap, it is also important to consider assimilation type.

Second, the overlap score (Flege & MacKay, 2004; Levy, 2009b) considers any common label for the two vowels as constituting overlap, whereas Faris et al.

(2016) only consider those labels that are selected above chance. The degree of overlap may, therefore, be overestimated by the overlap score. For instance, in Faris et al. (2016), the two AusE contrasts /iː/-/ɪə/ and /ʊ/-/ʉː/ were both assimilated as UU and had similar overlap scores of 77% and 71%, respectively (Flege & MacKay, 2004; Levy, 2009b). The only above-chance category for both /iː/ and /ɪə/ was Egyptian Arabic /iː/ (UU-C), whereas for /ʊ/ the only above-chance category was Egyptian Arabic /u/ and for /ʉː/ it was only Egyptian Arabic /uː/ (UU-N). In spite of the similar overlap scores, our prediction would be that the contrast /ʊ/-/ʉː/ would be discriminated more accurately than /iː/-/ɪə/. Consider also /ɜː/-/oɪ/, a UU contrast in which both vowels are *dispersed* (no label is selected above chance). The overlap score would be 74%, whereas according to our framework, there should be no phonological overlap.

An alternative approach to identifying the presence of overlap of vowels forming UU and UC assimilations is required, which: a) differentiates between categorised and uncategorised assimilations, and therefore, differentiates among the PAM assimilations, b) accounts for the spread of responses for contrasting non-native vowels, and c) considers the mean percent assimilations for uncategorised vowels that are selected above chance level. Therefore, in this study, we propose an alternative approach for determining the presence of perceived phonological overlap.

We have devised a novel approach, taking advantage of classifying uncategorised responses as *focalised*, *clustered*, or *dispersed* (Faris et al., 2016). This allows precise discrimination predictions to be made for uncategorised vowels. While the overlap method (Flege & MacKay, 2004; Levy, 2009b) takes into account all of the categorisation responses for both contrasting phones, the new approach in this study involves identifying the mean percent categorisation responses of non-native vowels to L1 vowels that were selected *above chance*, as is the case for *clustered* and *focalised* assimilations. For uncategorised phones, identifying labels that are selected above chance suggests that there is some reliability in perceptual assimilation. The degree of overlap is determined by examining the extent to which the contrasting non-native vowels are identified with the same set of above-chance L1 vowel category labels. Recall, it was argued that non-native contrasts can be non-overlapping, partially overlapping, or completely overlapping (see Table 7.1). Therefore, the third aim will be to assess whether, and how well, our proposed approach accounts for the discrimination results of UU and UC assimilations. By way of comparison, the overlap scores (Flege & MacKay, 2004; Levy, 2009b) will also be calculated.

The aims of the current study were evaluated using monophthongal contrasts and diphthongal contrasts. Since monophthongs and diphthongs differ articulatorily and acoustically, there was an opportunity to investigate potential differences in speech perception. A whole-system approach was employed, where listeners identified all non-native monophthongs and diphthongs from the target language in relation to those in their entire L1 vowel inventory (Bundgaard-Nielsen, Best, & Tyler, 2011a, 2011b; Faris et al., 2016). To increase the probability of obtaining all possible assimilation types, a stimulus language with a large vowel inventory size and native listeners with a relatively smaller vowel inventory were required. The Danish vowel system, which comprises 37 vowels (20 monophthongs, 17 diphthongs) is an ideal stimulus language (Grønnum, 1998), while AusE speakers, with a vowel inventory size of 18 (12 monophthongs, 6 diphthongs), were recruited as the naïve listeners (Cox & Palethorpe, 2007). Previous cross-language vowel studies have typically involved 10-13 listeners (e.g., Flege, Bohn, & Jang, 1997; Levy, 2009b; Polka, 1995). Given the high degree of interindividual differences in the perceptual assimilation of vowels, we implemented the suggestion offered for future research in Tyler et al. (2014) and tested a larger participant sample (i.e., 48 participants per experiment) as in some other cross-language speech perception studies (40 participants, e.g., Escudero & Chládková, 2010; Escudero & Williams, 2011). The aim of Experiment 2 was to establish the perceptual assimilation patterns of the Danish vowels in relation to the AusE vowel system. The proposed predictions of overlap were tested with non-native monophthongs (Experiment 3) and diphthongs (Experiment 4).

7.3 Experiment 2: Perceptual assimilation

7.3.1 Participants

Forty-eight monolingual AusE speakers (38 females, M_{age} = 23 years, Age range: 18 years – 46 years) were recruited from the introductory psychology student pool at the Western Sydney University and from the Greater Western Sydney community. Students participated for course credit and members of the community received a small payment. All participants reported normal or corrected-to-normal vision and no hearing or language impairments. None of the participants indicated prior exposure to Danish.

7.3.2 Stimuli and apparatus

7.3.2.1 Stimulus recording

The stimuli were produced by three native Danish female speakers in a sound-attenuated booth at the MARCS Institute. All three speakers were 24 years of age and were born and raised in Copenhagen, Denmark. They produced the Danish short vowels /i, e, ɛ, ɑ, u, o, ɔ, y, ø, œ/, long vowels /iː, eː, ɛː, aː, uː, oː, ɔː, yː, øː, œː/, diphthongs /uj, iw, ew, ɛw, ɒw, yw, øw, œw, ɶw, iɐ̯, eɐ̯, æɐ̯, yɐ̯, øɐ̯, œɐ̯, uɐ̯, oɐ̯/, and

/ə/ (Grønnum, 1998) in /ˈhVbə/ nonsense words. A native AusE female speaker produced all the AusE lax vowels /ɐ, e, ɪ, ɔ, ʊ, æ/, tense vowels /ɐː, eː, iː, oː, ʉː, ɜː/, and diphthongs /ɑe, æɔ, æɪ, əʉ, ɪə, oɪ/ (Cox & Palethorpe, 2007) in /ˈhVbə/ context. One auditory token per AusE vowel (18 in total) was selected and these were used for a familiarisation task. The vowels were produced in a /ˈhVbə/ context to help reduce the effect of lingual consonant-vowel coarticulation on the production of the target vowel (Bundgaard-Nielsen, Best, & Tyler, 2011b; Strange et al., 1998).

The informants were instructed to speak in a natural, conversational manner, and to produce the tokens with a falling intonation. To prompt the speakers in correctly pronouncing each target vowel, real words containing the target vowels were presented alongside the nonsense words. Nonsense words were presented one at a time on a computer monitor situated in front of the speaker. Speech production was recorded using a Shure SM10A headset microphone connected to a computer via an Edirol UA-25EX external USB sound card, with a sampling rate of 44.1 kHz.

7.3.3 Stimulus preparation

Auditory recordings were high-pass filtered in Praat (Boersma & Weenink, 2005) at 70 Hz to attenuate any unwanted low-frequency rumble and to correct for the DC component. Vowel onset was defined as the onset of voicing as indicated by the onset of periodicity, and vowel offset was defined as the cessation of periodicity in the waveform. Each token was ramped so that there was a 10 ms fade-in and a 20 ms fade-out for the token onset and offset, respectively. Audible clicks were excised from the tokens using Praat, although tokens with clicks in the target vowel were excluded.

To ensure that all of the Danish vowels were produced as intended and to select the most suitable tokens for the final set of stimuli, five native Danish speakers verified all potential tokens in a computer-based self-paced identification task with goodness ratings. The participants were presented with a grid containing all of the 38 Danish vowels /i, e, ɛ, a, y, ø, œ, u, o, ɔ, iː, eː, ɛː, aː, yː, øː, œː, uː, oː, ɔː, iw, uj, ew, ɛw, yw, œw, øw, ɶw, ɒw, iɐ̯, uɐ̯, øɐ̯, eɐ̯, yɐ̯, oɐ̯, œɐ̯, æɐ̯, ə/ presented in the Danish keywords *hitte, det, let, mappe, hytte, bøtte, bønne, putte, mod, kop, kile, hele, hæle, hale, hyle, nøle, høne, hule, pose, måle, ivrig, huje, peber, evne, tyveri, søvnig, øvrig, røver, tov, birk, hurtig, kørsel, Per, styrke, sort, dørk, bær, snake*, respectively, with the target vowel sound highlighted in red. Participants heard the auditory token only once, and they were asked to identify the target vowel using one of the 38 Danish keywords. They then indicated how well the vowel in the auditory stimulus sounded in comparison to the vowel in the selected Danish keyword on a scale of 1 (very strange) to 7 (perfect). They were required to type in the chosen Danish keyword and goodness rating on each slide. The tokens for the vowels /eɐ̯, ew, øɐ̯, ɶw, øw, ə/ were inconsistently and/or incorrectly identified, and were therefore excluded from the present study.[5] Three tokens per speaker per vowel were selected, resulting in 288 tokens in total (32 vowels x 3 repetitions x 3 speakers).

As vowel intensity is likely to vary naturally depending on the vowel type, the final set of tokens was normalised across speakers such that the average intensity of the target vowels belonging to the same vowel category across all three speakers was calculated and the intensity of each individual token was scaled to the average intensity. Table 7.2 displays the acoustic measurements on the intensity of the target vowel, mean duration of the target vowel, and the mean F1, F2, and F3 formant values at 25%, 50%, and 75% of the target vowel duration. Pre-emphasis was applied from 50 Hz. To ensure the formant tracker accurately tracked the formant contours of the

[5] These Danish vowels were excluded because one or more of the speakers produced them incorrectly. This meant that there were not enough tokens per vowel category per speaker available.

target vowel, formant settings in Praat were tuned manually for each individual token. The analysis frequency ranged from 5000 – 6200 Hz, with 4 or 5 formants being tracked, and the window length was 25 ms.

Table 7.2: *Mean Danish target vowel intensity (dB), vowel duration (ms), and F1, F2, and F3 at 25%, 50%, and 75% of the vowel duration*

Danish vowel	Vowel intensity	Vowel duration	F1 (Hz)			F2 (Hz)			F3 (Hz)		
			25%	50%	75%	25%	50%	75%	25%	50%	75%
i	61	79	342	357	368	2384	2373	2310	3347	3277	2996
e	66	89	457	480	487	2341	2277	2143	3075	3039	2887
ɛ	65	87	512	537	540	2148	2074	1972	2930	2904	2760
a	68	107	915	910	854	1475	1452	1418	2754	2723	2700
y	60	93	362	377	382	2101	2079	1973	2609	2579	2422
ø	65	108	472	486	486	1852	1860	1784	2594	2568	2511
œ	65	113	508	529	523	1774	1754	1684	2605	2613	2566
u	62	96	418	425	424	923	899	839	2560	2555	2528
o	64	95	482	489	479	878	873	861	2681	2696	2690
ɔ	67	100	730	731	689	1208	1234	1229	2635	2629	2602
iː	59	169	330	325	338	2484	2498	2502	3536	3544	3473
eː	62	182	443	443	445	2465	2495	2505	3259	3308	3240
ɛː	65	176	476	482	503	2300	2289	2224	3039	3045	2950
aː	64	155	615	607	595	2214	2218	2171	2967	2975	2915
yː	59	171	348	339	345	2150	2150	2123	2534	2575	2548
øː	65	176	449	459	471	1890	1896	1866	2531	2537	2523
œː	65	178	484	490	498	1838	1840	1826	2607	2593	2591
uː	60	165	406	404	404	839	802	767	2490	2502	2511
oː	65	173	454	458	459	769	741	732	2740	2781	2802
ɔː	70	186	484	490	504	1088	1068	1048	2572	2603	2637
iw	61	157	377	427	428	2257	1751	1107	2825	2438	2508
uj	63	170	449	463	445	1036	1566	2040	2533	2489	2588
ɛw	65	166	511	545	514	2090	1632	1161	2759	2598	2597
yw	62	152	411	435	439	1919	1575	1112	2414	2370	2435
œw	65	162	535	534	500	1635	1352	1078	2496	2480	2539
ɒw	66	148	634	608	538	994	911	843	2692	2761	2822
iʌ̯	65	167	392	519	671	2345	2116	1723	3242	2965	2790
uʌ̯	67	176	466	530	691	770	1030	1221	2694	2653	2660
yʌ̯	65	176	390	502	615	2017	1797	1512	2541	2534	2611
oʌ̯	67	166	535	639	721	835	998	1151	2718	2738	2734
œʌ̯	68	164	689	751	773	1625	1505	1393	2602	2597	2606
æʌ̯	67	162	702	793	824	1985	1741	1543	2906	2765	2707

7.3.4 Procedure

Participants were tested in groups of up to three at Western Sydney University. They first completed a familiarisation task. The purpose of this task was to help make participants aware of the vowel sounds in the English keywords that would later be used in a perceptual assimilation task. On a given trial in the familiarisation task, participants heard an AusE vowel in /ˈhVbə/ context and needed to attend to the vowel in the first syllable. They were then presented with a 6 x 3 grid that contained the English keywords *up, bet, hid, hot, hood, had, hard, hair, heed, hoard, boot, her, hide, how, bay, boat, here,* and *hoist*, representing the AusE vowels /ɐ, e, ɪ, ɔ, ʊ, æ, ɐː, eː, iː, oː, ʉː, ɜː, ɑe, æɔ, æɪ, əʉ, ɪə, oɪ/, respectively, and the target vowel sound in each keyword was always presented in red. The participants selected an English keyword corresponding to the vowel in the token that they heard. If the incorrect label was selected, they were provided with feedback on the correct label. There were 100 trials, and participants who reached an arbitrary score of 60 correct were able to exit the task early. The 100 trials were presented in approximately five blocks with the trials randomised across blocks. Each participant was presented with a different randomised order of the trials.

Following the familiarisation task, participants performed a perceptual assimilation task with goodness ratings using the Danish vowels. The same grid containing the English keywords from the familiarisation task was used. On a given trial, the same auditory token was presented twice. After the initial presentation, participants used the computer mouse to select an English keyword that contained the vowel that was most similar to the vowel in the auditory token. The same token was presented a second time and the participants were required to indicate how native-like the vowel in the auditory token sounded in relation to the vowel in the selected English keyword on a scale of 1 (very strange) to 7 (perfect). No feedback was provided. Participants were given up to 6 s to select a category label and up to 3.5 s to rate the vowel, and if no response was registered for either part of the trial, that same trial was randomly repeated later so there would be no missing responses. There were 288 trials in total (32 vowels x 3 repetitions x 3 speakers), and each participant received a different randomised order of the trials. The intertrial interval (ITI) was 480 ms. To help reduce the effect of fatigue, there were three rest opportunities, and these were evenly distributed throughout the experiment based on the total number of trials (i.e., a break every 96 trials). The entire session duration was 50 minutes. Stimulus presentation and response collection was controlled using PsyScope X B57 (Bonatti, n.d.) on a MacBook laptop, Sennheiser HD 650 headphones, and an Edirol UA-25EX external USB sound card.

7.3.5 Results

In the familiarisation task, 41 out of the 48 participants were able to exit the familiarisation early after 60 correct responses. The remaining 7 participants obtained a mean of 43 correct responses (Range: 22 – 55 correct responses) after 100 trials. The AusE vowel labels that they had the most difficulty with were /ɐ, e, ɔ, eː, iː, æɪ, ɪə, ɑe, əʉ, oɪ/. Those who scored 60 correct labeled nearly all of the AusE vowels with high accuracy except for /əʉ/ (42% correct responses) as it was often confused with /ɔ/ (32% of responses). Although some previous studies have excluded participants who did not reliably identify native vowels (e.g., Polka, 1995), we elected to include the data from all participants in our three experiments because excluding those participants in the discrimination task may have resulted in a sample that is not representative of the general population (e.g., only those people with good metaphonological awareness).

The inclusion of those participants in our categorisation task may increase the level of statistical noise, but this should be offset by the large sample size (average overall accuracy: 70%).[6]

The mean percent categorisation results, and mean goodness ratings for the categorised and uncategorised (*focalised* and *clustered*) phones, both averaged across participants, are presented in Table 7.3 for the Danish short monophthongs, Table 7.4 for the long monophthongs, and Table 7.5 for the diphthongs. A non-native vowel was considered categorised if a particular L1 vowel category label was consistently selected more than 50% of the time, otherwise, it was deemed uncategorised (Bundgaard-Nielsen et al., 2011a, 2011b). The assimilation results for the Danish short monophthongs are presented first, followed by the long monophthongs, and then the diphthongs.

[6] Across all three experiments, there were only three cases where the assimilation types changed when only the participants who exited early were included, and only one of those cases involved a change in overlap. In Experiment 3, /oː/-/uː/ changed from UU-P to UC-P, and in Experiment 4, the UU-P contrast /yʌ̯/-/yw/ became UU-C, and the contrast /ɒw/-/ɛw/ changed from UU-N to UC-N.

Table 7.3: *Mean percent categorisation and goodness ratings out of 7 (in parentheses) of Danish short monophthong vowels, for Australian English speakers' most consistently selected vowel category*

Danish vowel stimulus	Australian English vowel response category																	
	æ	e	ɪ	ʊ	ɔ	ɐ	ɐː	eː	iː	ɜː	ʉː	oː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
œ				2	1		1	1	1	***86 (5.59)***	2	1		1	3		1	
i		2	***54 (5.26)***	1					*26 (5.02)*	1					*11 (5.16)*	3		
u				***61 (4.93)***	3	3					*25 (4.93)*	1		1			2	3
e	1	*11 (4.35)*	***55 (5.21)***					5	9	3			3		6	5	1	
y			1	*28 (4.39)*	2	*13 (3.62)*					***51 (4.94)***						2	3
ø		1		12	2	2			1	***58 (5.09)***	*17 (4.50)*			1	1		1	2
a	*21 (4.70)*					*18 (5.51)*	***55 (5.50)***	1				2					1	1
ɔ	2		1	4	***51 (5.38)***	9	*13 (4.34)*			2	2	7		3			3	3
ɛ		*36 (4.98)*	*11 (4.51)*				1	*21 (4.94)*	2	*14 (3.80)*		1	6		3	2	1	
o				*22 (4.76)*	*32 (4.21)*	2	1				7	*20 (4.60)*		*10 (3.63)*			4	2

Numbers represent the percentage of each Danish vowel stimulus assimilated to an AusE vowel category label, averaged across individual participants.

The goodness-of-fit ratings are presented within parentheses and are on a scale of 1 (very strange) to 7 (perfect), also averaged across individual participants, and are only displayed for the above-chance responses.

Numbers in boldface italics represent the mean percentage of each Danish vowel stimulus that was assimilated > 50% of the time to an AusE vowel response category (i.e., categorised).

Numbers in italics non-bolded indicate the mean percent categorisation scores for the uncategorised vowels that had been selected more often than chance level (5.56%).

Non-bolded non-italicised numbers represent the uncategorised responses that were not selected significantly more often than chance level.

Percentages have been rounded to the nearest whole number.

Table 7.4: *Mean percent categorisation and goodness ratings out of 7 (in parentheses) of Danish long monophthong vowels, for Australian English speakers' most consistently selected vowel category*

Danish vowel stimulus	Australian English vowel response category																	
	æ	e	ɪ	ʊ	ɔ	ɐ	ɐː	eː	iː	ɜː	ʉː	oː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
œː				5	1		1	1		***83 (5.61)***	5	1			1		1	1
iː		3	*16 (4.56)*	1					***56 (5.35)***	1		1			*18 (4.80)*	3		
uː			1	***54 (4.89)***	3	2					*30 (4.79)*	2		2			2	3
eː	2	3	*12 (4.68)*					3	***51 (5.07)***	2			8		*16 (5.08)*	1	1	
yː				*29 (4.35)*	2	8			1		***53 (5.14)***	1					1	4
øː			1	*16 (4.35)*	2	2		1		***51 (4.92)***	*20 (4.93)*	3		1	1		1	1
aː	4	*12 (5.13)*					2	*45 (5.29)*	2	6		1	*23 (5.36)*		3	1	1	
ɔː				*15 (4.14)*	*16 (3.93)*	1				9	4	*34 (4.62)*		*13 (4.28)*			2	5
ɛː	2	8	1				2	*49 (5.08)*	1	*13 (4.78)*			*12 (5.00)*		9		1	
oː				*20 (4.57)*	*11 (3.53)*	1	1				8	*41 (4.84)*		8			4	5

Numbers represent the percentage of each Danish vowel stimulus assimilated to an AusE vowel category label, averaged across individual participants.

The goodness-of-fit ratings are presented within parentheses and are on a scale of 1 (very strange) to 7 (perfect), also averaged across individual participants, and are only displayed for the above-chance responses.

Numbers in boldface italics represent the mean percentage of each Danish vowel stimulus that was assimilated > 50% of the time to an AusE vowel response category (i.e., categorised).

Numbers in italics non-bolded indicate the mean percent categorisation scores for the uncategorised vowels that had been selected more often than chance level (5.56%).

Non-bolded non-italicised numbers represent the uncategorised responses that were not selected significantly more often than chance level.

Percentages have been rounded to the nearest whole number.

Table 7.5: *Mean percent categorisation and goodness ratings out of 7 (in parentheses) of Danish diphthong vowels, for Australian English speakers' most consistently selected vowel category*

Danish vowel stimulus	Australian English vowel response category																	
	æ	e	ɪ	ʊ	ɔ	ɐ	ɐː	eː	iː	ɜː	ʉː	oː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
œʌ̯	1				1	1	*14 (4.55)*	4		***65 (5.21)***		5		1	2		1	3
uj	1		1	7	1	1			4		2	1	1			1	***74 (4.51)***	6
iʌ̯		1	7		1			3	6	6		1			***73 (5.89)***	2	1	
oʌ̯	2			1	6		3				1	***69 (5.08)***		3			9	4
œw		9	2	4	3	1	2	3	2	***52 (4.21)***	1	4	1	3	5	1	3	4
uʌ̯	2		1	*13 (4.41)*	2	1	1				6	***50 (4.57)***		8	1	1	*10 (3.39)*	4
æʌ̯							8	***52 (5.18)***		*10 (3.89)*					6			*13 (5.57)*
ɒw				4	*37 (4.62)*		1				1	*22 (3.86)*		*17 (4.55)*			4	*13 (3.89)*
ɛw		*15 (4.09)*	9	1		1	2	*16 (4.01)*	4	*26 (3.75)*	2	2	2	1	10	3	3	3
iw		2	*14 (3.82)*	5	1	*25 (3.55)*			10	3	*14 (3.55)*		1	2	8	2	9	3
yʌ̯			1	*16 (3.97)*	2	*14 (3.38)*		2	1	*17 (3.51)*	*17 (3.61)*	6		6	5	1	7	5
yw		1	7	*15 (4.13)*		*19 (3.06)*			3	1	*33 (3.73)*	2		2	2	2	7	5

Numbers represent the percentage of each Danish vowel stimulus assimilated to an AusE vowel category label, averaged across individual participants.

The goodness-of-fit ratings are presented within parentheses and are on a scale of 1 (very strange) to 7 (perfect), also averaged across individual participants, and are only displayed for the above-chance responses.

Numbers in boldface italics represent the mean percentage of each Danish vowel stimulus that was assimilated > 50% of the time to an AusE vowel response category (i.e., categorised).

Numbers in italics non-bolded indicate the mean percent categorisation scores for the uncategorised vowels that had been selected more often than chance level (5.56%).

Non-bolded non-italicised numbers represent the uncategorised responses that were not selected significantly more often than chance level.

Percentages have been rounded to the nearest whole number.

As can be seen in Table 7.3, only two of the Danish short monophthongs, namely, /ɛ, o/, were uncategorised. The Danish vowels /i, u, e, ɔ/ were each categorised as a lax AusE vowel, while the Danish /œ, y, ø, a/ were each categorised as an AusE tense vowel. In Table 7.4, the majority of the Danish long vowels were categorised as an AusE tense vowel, except for /uː/ which was categorised as an AusE lax vowel, while /aː, ɔː, ɛː, oː/ were all uncategorised. The results displayed in Table 7.5 show that the Danish diphthongs /uj, iʌ̯/ were categorised as the AusE diphthongs /ɪə, oɪ/, respectively, while the Danish diphthongs /œʌ̯, oʌ̯, œw, uʌ̯, æʌ̯/ were categorised as an AusE tense vowel. The Danish /uʌ̯/ was categorised to the AusE /oː/ at 50.23%. The remaining Danish diphthongs /ɒw, ɛw, iw, yʌ̯, yw/ were uncategorised. In total, 11 Danish vowels were uncategorised.

For the uncategorised vowels, to differentiate among *focalised*, *clustered*, and *dispersed* responses, we conducted individual *t*-tests to assess the mean percent categorisation of each Danish vowel for a given AusE category label against a chance score of 5.56% (see Faris et al., 2016). A significant *p*-value ($p < .05$) indicated that the AusE vowel category label was selected significantly more often than chance. Following Faris et al. (2016), *focalised* responses were identified as those where only one category label was selected significantly above chance, while for *clustered* responses, more than one category response label was selected more often than chance. For *dispersed* responses, no response label was selected at above chance levels. All 11 uncategorised Danish vowels were of the *clustered* type.

7.3.6 Discussion

The aim of Experiment 2 was to establish the perceptual assimilation patterns of the Danish vowels to the AusE vowel system in order to select Danish monophthongal and diphthongal vowel contrasts for Experiment 3 and 4, respectively. Given that vowels form an interconnected system amongst themselves, by taking a whole-system approach (following Bundgaard-Nielsen et al., 2011a; Faris et al., 2016), a comprehensive assessment of the perceptual assimilation of the Danish vowels to the AusE vowel system was possible, and by doing so, there was the potential for selecting contrasts that form a range of different PAM assimilation types. Unlike Faris et al. (2016), who found *focalised*, *clustered*, and *dispersed* assimilations of English vowels by Egyptian Arabic listeners, only *clustered* assimilations were obtained in this experiment. This suggests that the AusE listeners identified the uncategorised Danish vowels as being systematically related to more than one L1 vowel, rather than as being similar to only one, or not to any, L1 vowels. *Clustered* assimilations may have emerged because there are a greater number of possible L1 vowel categories available for AusE listeners to identify the non-native vowels with than the Egyptian Arabic listeners in Faris et al.

Studies that are conducted within a PAM framework have used an arbitrary categorisation criterion to differentiate between categorised and uncategorised assimilations. Here, mean percent categorisation responses above 50% were deemed categorised, while those below this threshold were regarded as being uncategorised (following Bundgaard-Nielsen et al., 2011a). For nearly all of the Danish vowels assimilated as categorised, there were instances where the same Danish vowel was perceived as similar to another AusE vowel category label more often than chance. For example, Danish /a/ was assimilated to AusE /ɐː/ 55% of the time, but the AusE category labels for /ɐ/ and /æ/ were also selected more often than chance for this same Danish vowel. This may be a reflection of the variability among individual participants' perceptual assimilations. The majority of the participants perceived the

Danish /a/ as being mostly similar to the AusE /ɐː/, while the remaining participants identified it as the AusE /ɐ/ or /æ/. This suggests that the use of an arbitrary assimilation criterion may not sufficiently reflect systematic responses that are below the categorisation threshold. This issue will be revisited in the subsequent discussion sections and in the General Discussion. With the perceptual assimilation patterns of the Danish vowels established, Experiment 3 examined the discrimination performance on UU and UC pairs of monophthongal vowels varying in perceived phonological overlap, and compared their performance with the other PAM assimilation types.

7.4 Experiment 3: Monophthong contrasts

One aim of Experiment 3 was to assess the effect perceived phonological overlap on the discrimination of UU and UC non-native monophthongal vowel contrasts. Another aim was to compare discrimination performance for these assimilation types with the other PAM assimilations. This was achieved by employing our proposed approach of identifying overlap (as described in the introduction), with the aim of assessing how well it was able to account for the discrimination data.

Where possible, contrasts selected were those where the target vowels differed on only one feature (i.e., either on vowel length, height, backness, or lip rounding). Also, to ensure consistency in the assimilation types obtained for the contrasts across Experiment 2 with those of Experiment 3 and 4, Danish vowels that were as highly categorised as possible (i.e., > 50%) were preferred. Based on the perceptual assimilation results from Experiment 2, there were no instances of completely overlapping contrasts, but only partially overlapping and non-overlapping UU and UC contrasts. Nevertheless, these cases do offer an opportunity to examine the effect of perceived phonological overlap on discrimination levels.

The contrast /œ/-/u/ formed a TC assimilation as /œ/ and /u/ were categorised as separate AusE vowels, namely /ɜː/ and /ʊ/, respectively. The phones in the contrast /ø/-/œ/ were both categorised as the AusE /ɜː/ and formed a CG assimilation, which was determined by using a *t*-test that revealed /œ/ was perceived as a better exemplar than /ø/ for the L1 /ɜː/, $t(90) = 2.257$, $p = .026$. The phones in the contrast /e/-/i/ were also categorised to a single AusE vowel, /ɪ/. Using a *t*-test, this contrast was deemed as an SC since both pairs of vowels were perceived as equally good (or poor) versions of the AusE /ɪ/, $t(92) = 0.166$, $p = .868$. For the two assimilations involving at least one uncategorised vowel, the contrast /ɛ/-/o/ was deemed UU-N and /o/-/œ/ was deemed UC-N. It is important to note that the vowels in the former assimilation differed on two features, namely, backness *and* lip rounding, but were selected as there were no other more suitable choices for this particular assimilation type. In both instances, there were no similarities in L1 response label selections for each contrasting phone, and so there are specific phonetic/phonological features between the two vowels that may be used to differentiate them. The contrast /oː/-/ɔː/ was assimilated as UU-P as each Danish vowel shared similarities with AusE /ʊ/, /ɔ/, and /oː/, while /oː/-/uː/ was deemed UC-P, with the only shared native category choice being AusE /ʊ/.

We predicted that performance would be excellent for the TC, UC-N, and UU-N contrasts, and good but less accurate for the CG, UC-P, and UU-P contrasts, and significantly poorer for the SC contrast. This may be summarised as: {TC (/œ/-/u/) = UC-N (/o/-/œ/) = UU-N (/ɛ/-/o/)} > {CG (/ø/-/œ/) = UC-P (/oː/-/uː/) = UU-P (/oː/-/ɔː/)} > SC (/e/-/i/).

7.4.1 Participants

Forty-eight monolingual Australian English speakers (41 females, M_{age} = 23.33 years, Age range: 17 years – 55 years) were recruited from the student pool at the Western Sydney University and from the Greater Western Sydney community. All participants were selected according to the same criteria used Experiment 2.

7.4.2 Materials and Procedure

The materials for Experiment 3 were a subset of those used in Experiment 2, the difference being that only the Danish vowels /œ/, /u/, /ø/, /e/, /i/, /uː/, /oː/, /o/, /ɔː/, and /ɛ/ were used. Participants first completed an AXB discrimination task, then a familiarisation task, followed by a perceptual assimilation task with goodness ratings.

An AXB discrimination task was completed for each of the 7 contrasts: /œ/-/u/, /o/-/œ/, /ɛ/-/o/, /ø/-/œ/, /oː/-/uː/, /oː/-/ɔː/, and /e/-/i/. Three consecutive auditory tokens were presented per trial, where the middle token (X) belonged to the same phonological vowel category as either the first (A) or the last (B) auditory token. The interstimulus interval was 1 s. All three tokens were physically different from one another and were produced by the three different speakers to ensure that responses were based on phonological judgments, rather than on acoustic differences. Participants were requested to attend to the vowel of the first syllable in each word, then to indicate whether the vowel of the middle (X) item matched the vowel category of the first (A) or last (B) item in the trial by selecting one of two keys (designated for first or last item in a trial) on a computer keyboard. If a response was not made within 2 s, that trial was randomly repeated later. The intertrial interval was 1 s. No feedback was provided. Prior to the experimental trials, participants were presented with four practice trials with feedback using the AusE vowel contrast /ɔ/-/æɪ/ produced by two AusE female speakers. This particular contrast was easy for them to discriminate because it formed a TC assimilation type, so it helped them understand the procedure of the AXB discrimination task.

There were 72 trials per contrast and all trials were randomised for each participant. The four possible AXB trial types, AAB, ABB, BBA, and BAA, were presented an equal number of times for each contrast. There were three tokens per vowel from each speaker. Using a latin-square design, each token was presented an equal number of times in each position (i.e., A, X, B). The AXB trials were blocked according to vowel contrast because non-native discrimination tasks are cognitively demanding, and presenting the trials in random order rather than by contrast would increase cognitive load, and to be consistent with other PAM studies (Antoniou et al., 2013; Bundgaard-Nielsen, Best, & Tyler, 2011a). The order of tested contrasts was pseudorandomised and counterbalanced across participants. The design and procedure for the familiarisation task and the perceptual assimilation task with goodness ratings for this experiment were the same as described in Experiment 2, except that the reduced stimulus set was used as opposed to all of the Danish vowels.

7.4.3 Results

7.4.3.1 Perceptual assimilation patterns

Examination of the results from the familiarisation task revealed that 38 out of the 48 participants exited early from the task by obtaining 60 correct responses before 100 trials had passed. The remaining 10 participants scored a mean of 47 correct responses (Range: 22 – 59 correct responses), and they had the most difficulty labeling the AusE vowels /ɐ, e, ɔ, iː, ʉː, æɪ, əʉ, æɔ/. Participants who exited early identified the majority of the AusE vowels with high accuracy except for /əʉ/ (35%

correct responses) as it was often confused with /ɔ/ (35% of responses). The average overall accuracy for the familiarisation task was 69%.

Similar to Experiment 2, a 50% assimilation criterion was used to establish the Danish vowels assimilated as categorised versus uncategorised. The Danish vowels /œ, i, u, e/ met the criterion for categorised, and were categorised as the AusE /ɜː/ (84%, average rating: 5.73), /ɪ/ (59%, average rating: 5.33), /ʊ/ (56%, average rating: 5.03), and /ɪ/ (56%, average rating: 5.28), respectively. The remaining Danish vowels were assimilated as uncategorised and were all *clustered*. There were no instances of *focalised* or *dispersed* responses. Table 7.6 displays the mean percent categorisations and the averaged goodness ratings.

Table 7.6: *Mean percent categorisation and goodness ratings out of 7 (in parentheses) of Danish short and long monophthong vowels for Australian English speakers' most consistently selected vowel category*

Danish vowel stimulus	Australian English vowel response category																	
	æ	e	ɪ	ʊ	ɔ	ɐ	ɐː	eː	iː	ɜː	ʉː	oː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
œ		1		3			1	2	1	***84 (5.73)***	3				2			
i	1	5	***59 (5.33)***			1			*19 (5.02)*						7	5		
u	1	2		***56 (5.03)***	5	3		1		1	*27 (5.16)*	2					1	1
e		*9 (4.89)*	***56 (5.28)***	1		1	1	5	8	4			1		8	5	1	
ø				*16 (4.61)*	3	2	1	3		*46 (5.41)*	*22 (5.04)*			1	2		1	1
ɛ	1	*39 (4.90)*	*13 (4.68)*	1			1	*19 (4.91)*	5	*13 (4.32)*		1	2		4	2		
o	1	1		*22 (4.85)*	*24 (4.47)*	1	2			1	7	*23 (4.69)*		*13 (4.41)*			3	1
oː	1			*20 (4.78)*	8	1					8	*43 (4.95)*		*13 (4.66)*			2	2
ɔː		1		*13 (4.64)*	*14 (4.50)*	1	1			8	5	*27 (4.31)*		*24 (5.02)*	1		4	2
uː		1		*49 (5.02)*	4	3	1	1			*34 (5.12)*	2		2			1	2

Numbers represent the percentage of each Danish vowel stimulus assimilated to an AusE vowel category label, averaged across individual participants.

The goodness-of-fit ratings are presented within parentheses and are on a scale of 1 (very strange) to 7 (perfect), also averaged across individual participants, and are only displayed for the above-chance responses.
Numbers in boldface italics represent the mean percentage of each Danish vowel stimulus that was assimilated > 50% of the time to an AusE vowel response category (i.e., categorised).
Numbers in italics non-bolded indicate the mean percent categorisation scores for the uncategorised vowels that had been selected more often than chance level (5.56%).
Non-bolded non-italicised numbers represent the uncategorised responses that were not selected significantly more often than chance level.
Percentages have been rounded to the nearest whole number.

7.4.3.2 Discrimination predictions based on perceptual assimilation patterns

The assimilation types of the majority of the contrasts in this experiment were consistent with those obtained in Experiment 2, with only the following two exceptions. In Experiment 2, /ø/-/œ/ had formed a CG assimilation, but it was an UC-P contrast in the current experiment. Additionally, the contrast /oː/-/uː/ which was a UC-P assimilation in Experiment 2 was instead a UU-P assimilation in Experiment 3. Based on the assimilations obtained in the current experiment, we predicted the following discrimination performance levels: {TC (/œ/-/u/) = UC-N (/o/-/œ/) = UU-N (/ɛ/-/o/)} > {UC-P (/ø/-/œ/) = UU-P (/oː/-/uː/; /oː/-/ɔː/)} > SC (/e/-/i/).

7.4.3.3 AXB discrimination

Mean percent discrimination accuracy varied across the seven contrasts.[7] The mean discrimination accuracy scores for each contrast are presented in Figure 7.1.

[7] An AXB task was used to assess discrimination performance because it circumvents responses biases (see also Best et al., 2001; MacKain et al., 1981; Strange & Shafer, 2008). Unlike AX discrimination tasks, for example, there are no false alarms and so it is not possible to calculate A’ or d’ for AXB tasks.

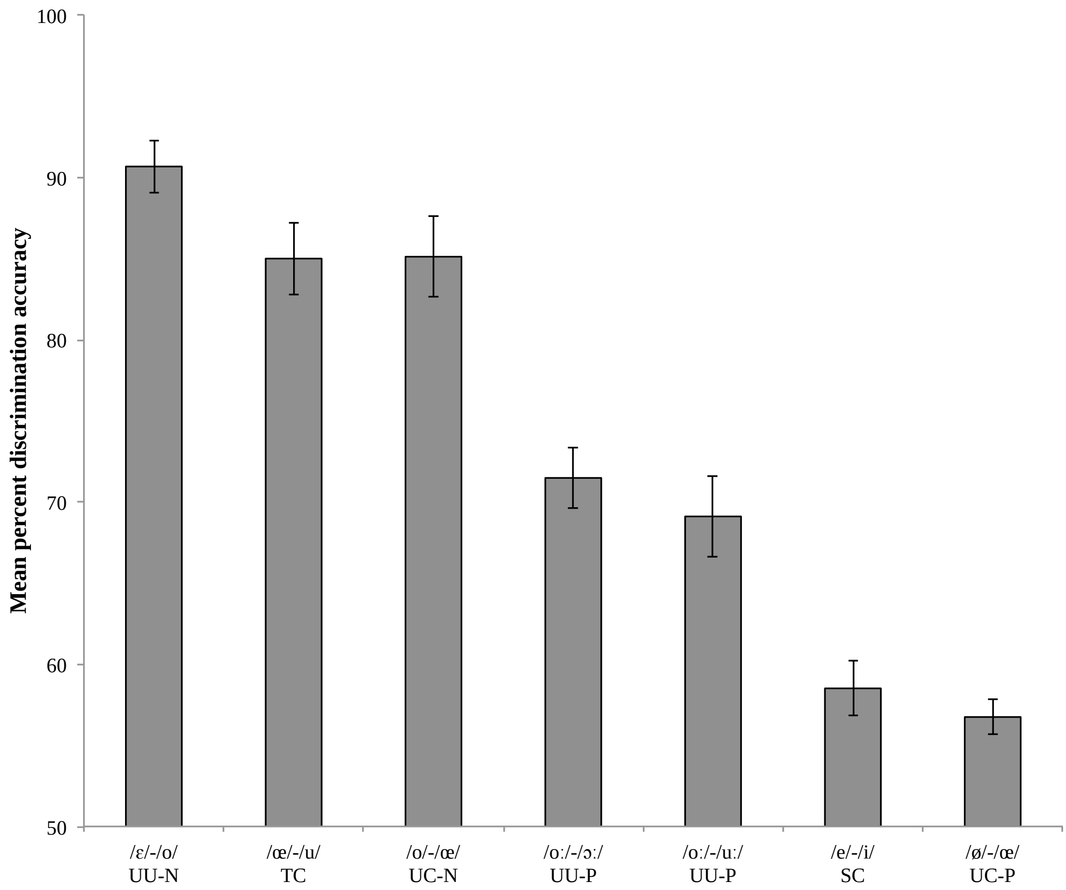

Figure 7.1: Mean percent correct discrimination scores for each of the seven Danish vowel contrasts varying in assimilation type, namely, TC, SC, UC-N, UC-P, UU-N, and UU-P assimilations. Error bars represent the standard error of the mean.

A one-way repeated measures Analysis of Variance (ANOVA) with Sidak post-hoc comparisons was conducted to determine whether discrimination accuracy varied between the vowel contrasts, with *contrast* as the within-subjects factor consisting of seven levels (i.e., the seven monophthongal vowel contrasts tested). The analysis suggested a significant difference in the mean percent correct discrimination scores among the contrasts, $F(6, 282) = 85.73$, $p < .001$, $\eta_p^2 = .65$. Sidak post-hoc comparisons revealed that there was no significant difference in discrimination performance between the UU-P contrasts /oː/-/ɔː/ (71%) and /oː/-/uː/ (69%), M_{diff} =

2.33%, $p = .998$, 95% confidence interval (CI): -4.22%−8.88%. UU-N /ɛ/-/o/ was discriminated more accurately than all of the other contrasts: TC /œ/-/u/, M_{diff} = 5.67%, $p = .005$, 95% CI: 1.07%−10.26%; UC-N /o/-/œ/, M_{diff} = 5.67%, $p = .04$, 95% CI: 0.14%−11.19%; SC /e/-/i/, M_{diff} = 32.17%, $p < .001$, 95% CI: 26.25%−38.08%; UC-P /ø/-/œ/, M_{diff} = 33.98%, $p < .001$, 95% CI: 28.80%−39.15%; UU-P /oː/-/uː/, M_{diff} = 21.58%, $p < .001$, 95% CI: 14.26%−28.91%, and; UU-P /oː/-/ɔː/, M_{diff} = 19.25%, $p < .001$, 95% CI: 13.74%−24.76%. Discrimination accuracy for TC /œ/-/u/ was not significantly different from UC-N /o/-/œ/, M_{diff} = 0.00, $p > .999$, 95% CI: -5.43%−5.43%, but more accurate than the UU-P /oː/-/uː/, M_{diff} = 15.92%, $p < .001$, 95% CI: 8.66%−23.17%, and UU-P /oː/-/ɔː/, M_{diff} = 13.58%, $p < .001$, 95% CI: -8.02%−19.14%. There was no significant difference in accuracy between SC /e/-/i/ and UC-P /ø/-/œ/, M_{diff} = 1.81%, $p > .999$, 95% CI: -3.83%−7.45%. To summarise: UU-N (/ɛ/-/o/) > {TC (/œ/-/u/) = UC-N (/o/-/œ/)} > UU-P (/oː/-/ɔː/; /oː/-/uː/) > {SC (/e/-/i/) = UC-P (/ø/-/œ/)}.

In order to compare our approach of determining perceived phonological overlap and that used in previous studies, an overlap score (Flege & MacKay, 2004; Levy, 2009b) was calculated for each contrast and compared against discrimination accuracy scores. As in Flege and MacKay (2004) and Levy (2009), for a given contrast, the overlap scores were computed by taking in account the assimilation percentages for *all* categories selected, rather than only the above-chance choices as is done for the overlap approach devised in this paper. The results are presented in Table 7.7. Inconsistencies were found between the discrimination accuracy scores and the overlap scores. For instance, on the basis of the overlap scores for the two contrasts assimilated as UU-P, it would seem reasonable to suggest that there should be differences in discrimination accuracy, although no significant differences in discrimination accuracy were found between these two contrasts. Similarly, with an overlap score of 57%, the UC-P contrast should have been discriminated more accurately than the SC contrast, which had an overlap score of 82%. However, discrimination accuracy was equally poor for both assimilations.

Table 7.7: *Overlap scores* (Flege & MacKay, 2004; Levy, 2009b) *and mean percent correct discrimination scores for each of the monophthongal vowel contrasts varying in PAM assimilation type*

PAM assimilation type	Contrast	Mean % correct discrimination	Overlap score
UU-N	/ɛ/-/o/	91	6
TC	/œ/-/u/	85	9
UC-N	/o/-/œ/	85	9
UU-P	/oː/-/ɔː/	71	71
UU-P	/oː/-/uː/	69	40
SC	/e/-/i/	59	82
UC-P	/ø/-/œ/	57	57

7.4.4 Discussion

The first aim of this experiment was to assess whether discrimination accuracy is influenced by perceived phonological overlap in pairs of monophthongal vowels forming UU and UC assimilations. We hypothesised that non-overlapping contrasts would be discriminated more accurately than partially overlapping contrasts. In general, discrimination accuracy was higher for non-overlapping contrasts than for partially overlapping contrasts. This supports our prediction and highlights the importance of perceived phonological overlap on discrimination accuracy.

The second aim was to compare discrimination accuracy for UU and UC contrasts varying in the presence of overlap with the other PAM assimilations. It was reasoned that discrimination may be excellent for TC and non-overlapping UC and UU assimilations, with good discrimination accuracy for the partially overlapping UC and UU assimilations, and with poor discrimination for SC. The AXB results revealed that UU-N assimilations were the most accurately discriminated. Unlike the other vowel contrasts used in this experiment, which differed on only one phonetic feature, these contrasting vowels (/ɛ/-/o/) differed on two features (i.e., tongue backness and lip rounding), and this may explain why it was the most accurately discriminated. TC and UC-N contrasts were discriminated equally well, and this may be attributed to the lack of overlap between the L1 vowel category labels selected for each vowel within the contrasts. Contrary to our predictions, UC-P assimilation was discriminated as poorly as SC. It is possible that any overlap, whether partial or complete, may result in comparatively poorer discrimination accuracy than non-overlapping contrasts, although completely overlapping contrasts are required to test this. Overall, our predictions were largely upheld. By accounting for the presence of overlap in UU and UC contrasts, it is possible to rank order their discrimination accuracy in relation to the other PAM assimilation types.

We argued that the overlap method (Flege & MacKay, 2004; Levy, 2009b) may not adequately account for discrimination accuracy. This argument was supported by results where the overlap score seemed to suggest that there should be differences in discrimination accuracy for pairs of contrasts for which there were no significant differences. Our approach of accounting for overlap seems to explain the discrimination results more effectively than the overlap method.

A comparison between Experiment 2 and 3 revealed inconsistencies in the perceptual assimilation patterns for the same stimuli. Consider the contrast /oː/-/uː/ which was assimilated as UC in Experiment 2 where /uː/ was categorised at 54%. However, in Experiment 3, this contrast was deemed UU since /uː/ was assimilated as uncategorised at 49%. This raises a question about the utility or suitableness of arbitrary assimilation thresholds. This issue will be revisited in the General Discussion.

The results from this experiment suggest that perceived phonological overlap influences discrimination accuracy. These results were obtained using contrasts comprised of monophthongs. In the next experiment, the effects of overlap on discrimination accuracy will be tested using pairs of contrasting non-native diphthongs.

7.5 Experiment 4: Diphthong contrasts

There are currently no systematic examinations of the discrimination of non-native diphthong contrasts. Therefore, this experiment assessed the effect of perceived phonological overlap on the discrimination of contrasts assimilated as UU and UC but using diphthongal vowels, and discrimination performance was compared with the other PAM assimilations. Again, our proposed approach of identifying overlap, or lack thereof, was employed in order to determine how well it accounts for discrimination performance.

There are clear acoustic and articulatory differences between monophthongs and diphthongs, despite both types being classified as vowels. Monophthongs are produced with the tongue and jaw, the active articulators, in a relatively stable position throughout production, while diphthongs involve marked movement of the active articulators during articulation (Catford, 2001). Diphthongs are often described as being a combination of two monophthongs, but native diphthongs are nevertheless perceived as a single vowel phoneme (Catford, 2001; Ladefoged, 2005). Due to their dynamic nature and the availability of rich information, diphthongs are generally more accurately identified than monophthongs (Assmann et al., 1982). Again, we tentatively predict the following rank order of discrimination accuracy: {TC = UC-N = UU-N} > {CG = UC-P = UU-P} > {SC = UC-C = UU-C}.

The discrimination of non-native/L2 diphthongs has been shown to support the PAM predictions. Bundgaard-Nielsen et al. (2011a) examined native Japanese speakers' perceptual assimilation and discrimination of all the Australian English monophthongs and diphthongs. The Australian English diphthongs /eɪ, ɑe, oɪ/ were categorised as the Japanese bimoraic vowel combinations /ei, ai, oi/, respectively, and /ɪə, æɔ/ were categorised to the bimoraic geminated vowels /iː, aː/, respectively, while /əʉ/ (the Australian realisation of the vowel in the GOAT lexical set) was the only uncategorised diphthong. As predicted by PAM, the UC /əʉ/-/oː/ contrast was discriminated more accurately than the SC /iː/-/ɪə/ contrast. While these results demonstrate that discrimination accuracy for vowel contrasts comprising a tense vowel and a diphthong are consistent with the PAM predictions, it is yet to be determined how well *pairs* of non-native diphthongs will be discriminated, or what the role is of perceived phonological overlap in discrimination performance.

The contrasts selected in Experiment 4 were based on the perceptual assimilation patterns obtained in Experiment 2. The contrasts /iʌ̯/-/oʌ̯/ and /iʌ̯/-/uj/ were assimilated as TC as the vowels within each contrast were categorised as separate AusE vowels, with the former contrast forming an L1 diphthong-tense vowel assimilation (AusE /ɪə, oː/) and the latter contrast forming an L1 diphthong-diphthong assimilation (AusE /ɪə, oɪ/). The vowels in the contrast /œw/-/œʌ̯/ were categorised as the AusE /ɜː/, but a significant difference in the averaged goodness ratings indicated that /œʌ̯/ was perceived as a better exemplar of the AusE /ɜː/ than Danish /œw/ ($t(90) = 3.778$, $p < .001$), thus forming a CG assimilation. The vowels in the contrast /uʌ̯/-/oʌ̯/ were categorised as the AusE /oː/, and formed a SC assimilation as both vowels were perceived as equally good (or poor) exemplars of the L1 category ($t(87) = 1.945$, $p = .055$). While there were no instances of completely overlapping contrasts to examine in this study, discrimination accuracy for partially overlapping and non-overlapping UC and UU contrasts were examined. The contrasts /iw/-/oʌ̯/ and /yʌ̯/-/uj/ were UC-N, and /ɒw/-/ɛw/ was UU-N. In both cases, the contrasting vowels were perceived as similar to a different set of native vowels. The contrast /ɛw/-/œʌ̯/ was deemed UC-P with the only shared native category being /ɜː/. The UU contrast /yʌ̯/-/yw/ was deemed partially overlapping, with AusE /ʊ/, /ɐ/, and /ʉː/ selected above chance for both of these Danish vowels.

7.5.1 Participants

Forty-eight participants (38 females, M_{age} = 20.94 years, Age range: 17-51 years) were recruited from the student pool from the Western Sydney University and from the Greater Western Sydney community. All participants were monolingual Australian English speakers, and the selection criteria were the same as that used to recruit participants for Experiment 2 and 3.

7.5.2 Materials and Procedure

The auditory tokens for the Danish vowels /ɒw/, /ɛw/, /iʌ̯/, /oʌ̯/, /uj/, /iw/, /œʌ̯/, /ɛw/, /œw/, /uʌ̯/, /yʌ̯/, and /yw/ from Experiment 2 were employed in this experiment. The experimental design and procedure for the AXB task were similar to that from Experiment 3. An AXB discrimination task was completed for each of the nine vowel contrasts: /iʌ̯/-/oʌ̯/, /iʌ̯/-/uj/, /iw/-/oʌ̯/, /ɛw/-/œʌ̯/, /yʌ̯/-/uj/, /ɒw/-/ɛw/, /œw/-/œʌ̯/, /uʌ̯/-/oʌ̯/, and /yʌ̯/-/yw/. Participants then completed a familiarisation task and a perceptual assimilation task with goodness ratings in which the design and procedure were the same as in Experiment 3. For the perceptual assimilation task, the participants were only presented with the subset of Danish diphthongs.

7.5.3 Results

7.5.3.1 Perceptual assimilation patterns

In the familiarisation task, 36 out of the 48 participants exited the task early after obtaining 60 correct responses. The remaining 12 participants obtained a mean of 50 correct responses (Range: 37 – 58 correct responses), and they had the most difficulty labeling the AusE vowels /ɐ, e, ɔ, ɐː, iː, ʉː, əʉ/. As in Experiment 2 and 3, the participants who exited early identified all AusE vowels with high accuracy, except for /əʉ/ (32% correct responses) as it was often confused with /ɔ/ (32% of responses). The average overall accuracy for the familiarisation task was 70%.

Using a 50% assimilation criterion, the Danish diphthongs /œʌ̯/, /uj/, /iʌ̯/, and /oʌ̯/ were deemed categorised, and were assimilated to the AusE /ɜː/ (71%, average rating: 5.81), /oɪ/ (59%, average rating: 5.20), /ɪə/ (59%, average rating: 6.14), and /oː/ (57%, average rating: 5.17), respectively. The remaining Danish diphthongs were assimilated as uncategorised and responses were *clustered*, with the exception of /ɛw/

which was assimilated as *focalised* to the AusE /ɪ/. There were no instances of Danish phones assimilated as *dispersed*. The mean percent categorisation results, and the mean category goodness ratings for the categorised phones, both averaged across participants, are presented in Table 7.8.

Table 7.8: *Mean percent categorisation and goodness ratings out of 7 (in parentheses) of Danish diphthong vowels for Australian English speakers' most consistently selected vowel category*

Danish vowel stimulus	Australian English vowel response category																	
	æ	e	ɪ	ʊ	ɔ	ɐ	ɐː	eː	iː	ɜː	ʉː	oː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
œʌ̯	1	3					9	5		***71 (5.81)***		3		1	3		1	1
uj	1	1	2	11	1	1			8	1	7			1	1	1	***59 (5.20)***	3
iʌ̯	1	2	*12 (4.75)*			2		4	8	6					***59 (6.14)***	2	1	1
oʌ̯	2	1		2	9	1	2	1		1	2	***57 (5.17)***		8			9	5
œw	1	4	*15 (4.25)*	9	8	2	1	1	3	*19 (5.00)*	9	1	1	8	3	5	4	6
uʌ̯	3	1		*17 (4.30)*	8	2	3	1		1	6	*37 (4.77)*	1	8	1		8	4
ɒw				5	*49 (4.64)*		1			1	2	8		*19 (4.67)*			3	*10 (4.15)*
ɛw	2	7	*27 (4.33)*	3	1	4	1	6	7	7	7		2	1	8	9	2	5
iw	2	2	11	*11 (3.88)*	1	*28 (3.54)*			4	2	*22 (4.15)*	1	1	1	4	2	3	3
yʌ̯	1	3	1	*11 (3.34)*	1	*18 (3.81)*	1	3	1	8	*19 (4.41)*	3	1	6	*11 (3.87)*	1	5	6
yw	1	2	6	*19 (3.91)*	1	*24 (3.74)*		1	2	2	*30 (4.84)*	1	1	1	4	2	2	2

Numbers represent the percentage of each Danish vowel stimulus assimilated to an AusE vowel category label, averaged across individual participants.

The goodness-of-fit ratings are presented within parentheses and are on a scale of 1 (very strange) to 7 (perfect), also averaged across individual participants, and are only displayed for the above-chance responses.

Numbers in boldface italics represent the mean percentage of each Danish vowel stimulus that was assimilated > 50% of the time to an AusE vowel response category (i.e., categorised).

Numbers in italics non-bolded indicate the mean percent categorisation scores for the uncategorised vowels that had been selected more often than chance level (5.56%).

Non-bolded non-italicised numbers represent the uncategorised responses that were not selected significantly more often than chance level.

Percentages have been rounded to the nearest whole number.

7.5.3.2 Discrimination predictions based on perceptual assimilation patterns

A comparison between the perceptual assimilation patterns in this experiment with those from Experiment 2 revealed that most of the assimilation patterns were confirmed in this experiment, but there were also instances where there were deviations from those obtained in Experiment 2. The contrast /ɛw/-/œʌ̯/ had formed a UC-P assimilation in Experiment 2, but in the current experiment it was UC-N. Additionally, /œw/-/œʌ̯/ was a CG assimilation type in Experiment 2, but in the current experiment it was UC-P. Lastly, /uʌ̯/-/oʌ̯/ was assimilated as SC in Experiment 2, but formed an UC-P assimilation in Experiment 4. Based on the assimilation patterns from this experiment, the following discrimination results were anticipated: {TC (/iʌ̯/-/oʌ̯/; /iʌ̯/-/uj/) = UC-N (/iw/-/oʌ̯/; /ɛw/-/œʌ̯/; /yʌ̯/-/uj/) = UU-N (/ɒw/-/ɛw/)} > {UC-P (/œw/-/œʌ̯/; /uʌ̯/-/oʌ̯/) = UU-P (/yʌ̯/-/yw/)}.

7.5.3.3 AXB discrimination

A one-way repeated measures ANOVA and Sidak post-hoc comparisons were conducted on the mean percent discrimination accuracy scores with *contrast* as the within-subjects factor consisting of nine levels (i.e., the nine contrasts under examination). The analysis suggested a significant difference in the mean percent correct discrimination scores among the contrasts, $F(8, 376) = 106.46$, $p < .001$, $\eta_p^2 = .69$. The mean percent correct discrimination for each contrast is presented in Figure 7.2. Results from the Sidak post-hoc comparisons showed that there was no significant difference in discrimination accuracy between the TC contrasts /iʌ̯/-/oʌ̯/ and /iʌ̯/-/uj/, $M_{diff} = 0.13\%$, $p > .999$, 95% CI: -3.59%−3.84%. There were also no significant differences between the UU-N contrast relative to TC /iʌ̯/-/oʌ̯/, $M_{diff} = 0.73\%$, $p > .999$, 95% CI: -2.25%−3.71%, or TC /iʌ̯/-/uj/, $M_{diff} = 0.60\%$, $p > .999$, 95% CI: -2.55%−3.75%. There were also no significant differences in discrimination accuracy between UU-P /yʌ̯/-/yw/ and UC-P /œw/-/œʌ̯/, $M_{diff} = 0.06\%$, $p > .999$, 95% CI: -5.62%−5.75%. For the UC-P contrasts, discrimination accuracy was significantly higher for /œw/-/œʌ̯/ than /uʌ̯/-/oʌ̯/, $M_{diff} = 14.06\%$, $p < .001$, 95% CI: 7.55%−20.57%. There were significant differences among the discrimination accuracy scores for the UC-N contrasts, where /iw/-/oʌ̯/ was discriminated more accurately than both /ɛw/-/œʌ̯/, $M_{diff} = 9.73\%$, $p < .001$, 95% CI: 4.49%−14.97%, and /yʌ̯/-/uj/, $M_{diff} = 4.77\%$, $p = .044$, 95% CI: 0.06%−9.48%, although there was no significant difference in discrimination accuracy between /ɛw/-/œʌ̯/ and /yʌ̯/-/uj/, $M_{diff} = 4.96\%$, $p = .220$, 95% CI: -0.99%−10.90%. The UC-N contrast /iw/-/oʌ̯/ was also discriminated more accurately than UC-P, /œw/-/œʌ̯/ $M_{diff} = 18.85\%$, $p < .001$, 95% CI: 13.05%−24.66%; UC-P /uʌ̯/-/oʌ̯/, $M_{diff} = 32.92\%$, $p < .001$, 95% CI: 27.39%−38.45%; and UU-P /yʌ̯/-/yw/, $M_{diff} = 18.79\%$, $p < .001$, 95% CI: 12.76%−24.82%. However, UC-N /iw/-/oʌ̯/ was not discriminated more accurately than TC /iʌ̯/-/oʌ̯/, $M_{diff} = 0.92\%$, $p > .999$, 95% CI: -2.59%−4.42%; TC /iʌ̯/-/uj/, $M_{diff} = 0.79\%$, $p > .999$, 95% CI: -2.57%−4.16%; or UU-N /ɒw/-/ɛw/, $M_{diff} = 0.19\%$, $p > .999$, 95% CI: -2.06%−2.43%. In this analysis, it appears that discrimination accuracy for individual contrasts varies in spite of similar assimilation type and the presence of overlap.

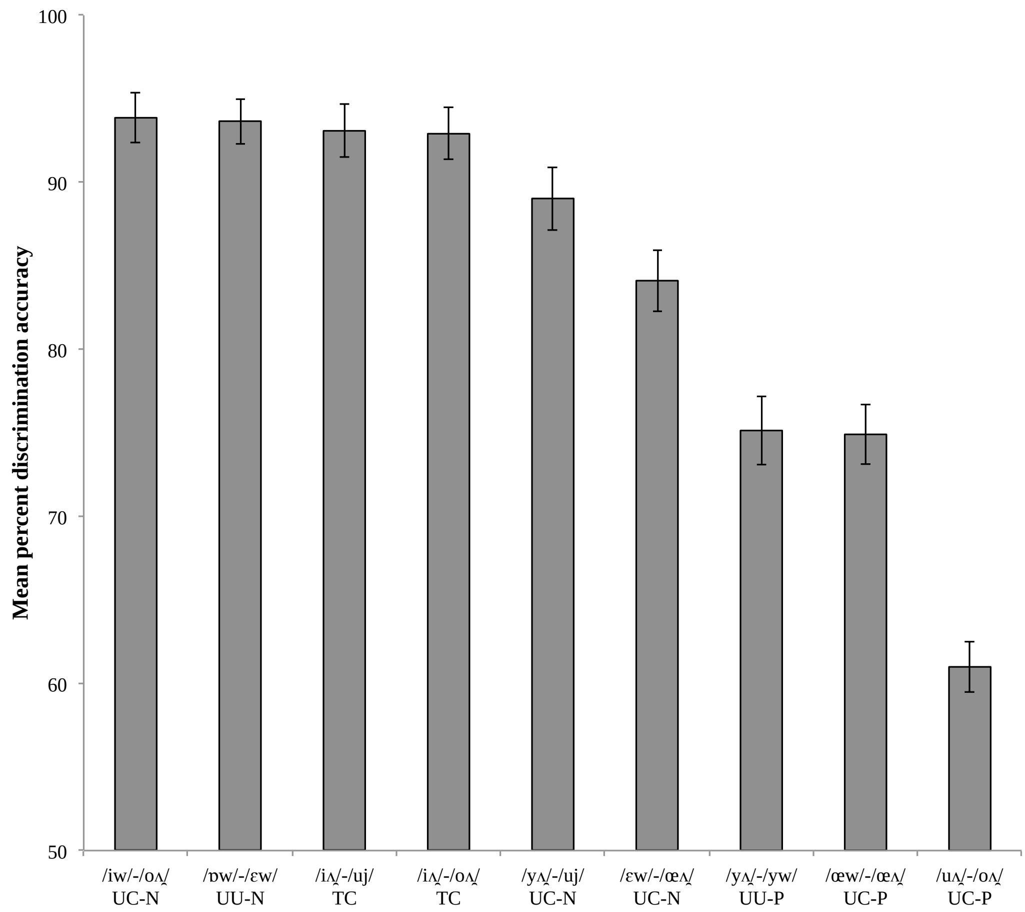

Figure 7.2: Mean percent correct discrimination scores for each of the nine Danish vowel contrasts varying in assimilation type, namely, TC, UC-N, UC-P, UU-N, and UU-P assimilations. Error bars represent the standard error of the mean.

To investigate the cause of the variability in discrimination accuracy for contrasts of the same assimilation type, overlap scores (Flege & MacKay, 2004; Levy, 2009b) were calculated for each contrast and compared against discrimination accuracy (see Table 7.9). Recall that differences in discrimination accuracy were found among contrasts assimilated as UC-N where /iw/-/oʌ̯/ was discriminated significantly more accurately than both /ɛw/-/œʌ̯/ and /yʌ̯/-/uj/. Indeed, /iw/-/oʌ̯/ has the lowest overlap score out of the three contrasts. The post-hoc analysis also revealed that for the UC-P contrasts, discrimination accuracy was significantly higher for /œw/-/œʌ̯/ than /uʌ̯/-/oʌ̯/. Based on the overlap scores, /œw/-/œʌ̯/ had an overlap score of 32%, which was lower than the overlap score of 77% for /uʌ̯/-/oʌ̯/. Nevertheless, while the overlap score may provide some insight into variable discrimination accuracy within an assimilation type, an examination of Table 7.9 shows that the overlap score on its own does not appear to be a good predictor of accuracy overall. For example, /yʌ̯/-/uj/ and /œw/-/œʌ̯/ have similar overlap scores but they differ substantially in discrimination accuracy.

Table 7.9: *Overlap scores* (Flege & MacKay, 2004; Levy, 2009b) *and mean percent correct discrimination scores for each of the diphthongal vowel contrasts varying in PAM assimilation type*

PAM assimilation type	Contrast	Mean % correct discrimination	Overlap score
UC-N	/iw/-/oʌ̯/	94	18
UU-N	/ɒw/-/ɛw/	94	16
TC	/iʌ̯/-/uj/	93	18
TC	/iʌ̯/-/oʌ̯/	93	7
UC-N	/yʌ̯/-/uj/	89	36
UC-N	/ɛw/-/œʌ̯/	84	23
UU-P	/yʌ̯/-/yw/	75	68
UC-P	/œw/-/œʌ̯/	75	32
UC-P	/uʌ̯/-/oʌ̯/	61	77

An alternate explanation for the variable discrimination accuracy scores could be that discrimination accuracy of contrasts within a given assimilation type varies around a population mean and that those distributions overlap. That is, a UC contrast at the upper end of the UC distribution may be discriminated more accurately than a TC contrast at the lower end of the TC distribution. This may not have been apparent in previous cross-language speech perception studies because they have generally tested PAM's predictions of discrimination using one contrast per assimilation type (e.g., Best et al., 2001; Bundgaard-Nielsen, Best, & Tyler, 2011a). However, an examination of the discrimination accuracy results across several studies reveals variability in discrimination performance for contrasts within a given assimilation type. For example, discrimination accuracy for SC contrasts may range from 50% (Bundgaard-Nielsen, Best, & Tyler, 2011a) to as high as 73% (Tyler et al., 2014). Discrimination of TC contrasts may also vary from 79% (Bundgaard-Nielsen, Best, & Tyler, 2011a) to 95% (Escudero & Chládková, 2010; Højen & Flege, 2006). Similarly, for UU-N contrasts, discrimination accuracy may range from A' of 0.52, which is near chance performance (Sisinni & Grimaldi, 2009) to 96% (Tyler et al., 2014) which is near ceiling. To compare discrimination accuracy scores of the various assimilation types, another one-way repeated measures ANOVA was conducted with the discrimination accuracy averaged across *assimilation type* and this was a within-subjects factor consisting of five levels (TC, UC-N, UC-P, UU-N, and UU-P).

The analysis revealed a significant difference in the mean percent correct discrimination scores among the assimilation types, $F(4, 188) = 146.92$, $p < .001$, $\eta_p^2 = .76$. The post-hoc comparisons revealed that there was no significant difference in discrimination performance between the UU-N (M = 94%, SE = 1.36%) and TC (M = 93%, SE = 1.47%) assimilations, M_{diff} = 0.60%, p = .995, 95% CI: -1.54%–2.75%, but that they were both more accurately discriminated than the other assimilations. The UC-N assimilations (*M* = 89%, *SE* = 1.51%) were discriminated more accurately than UU-P (*M* = 75%, *SE* = 2.05%), M_{diff} = 13.96%, *p* < .001, 95% CI: 9.11%−18.81%, and UC-P (*M* = 68%, *SE* = 1.36%), M_{diff} = 21.04%, *p* < .001, 95% CI: 17.95%−24.14%. The UC-P contrast was the most poorly discriminated, as discrimination accuracy was significantly poorer than TC, M_{diff} = 25.08%, *p* < .001, 95% CI: 21.38%−28.79%, UU-N, M_{diff} = 25.69%, *p* < .001, 95% CI: 22.01%−29.36%, UC-N, M_{diff} = 21.04%, *p* < .001, 95% CI: 17.95%−24.14%, and UU-P, M_{diff} = 7.08%, *p* = .003, 95% CI: 1.77%−12.04%. To summarise: {(UU-N = TC) > UC-N > UU-P > UC-P}.

7.5.4 Discussion

The main purpose of Experiment 4 was to assess the role of the presence of perceived phonological overlap on the discrimination performance of diphthongal contrasts assimilated as UU and UC. When mean percent correct discrimination scores were averaged across assimilation type, discrimination accuracy was higher for non-overlapping than for partially overlapping contrasts. While PAM predicts very good discrimination performance for UC assimilations, discrimination performance for UC assimilations was dependent upon the presence of overlap (as in Experiment 3). Specifically, UC-N assimilations were discriminated more accurately than UC-P assimilations. Overall, the PAM discrimination predictions were supported, and perceived phonological overlap accounted for differences in discrimination accuracy within PAM assimilation types for diphthongal contrasts.

The second aim was then to evaluate how the various UU and UC assimilations compared relative to the other PAM assimilations (i.e., TC, CG, and

SC). Of the other PAM assimilations, only TC assimilations were obtained. Nonetheless, the results revealed excellent discrimination for TC and UU-N assimilations. Contrary to our predictions, however, discrimination of UC-N contrasts, on average, was significantly less accurate than TC and UU-N. The variability observed in this experiment across contrasts of the same assimilation type suggests that a larger number of contrasts may need to be used to determine the precise rank ordering of assimilations with and without perceived phonological overlap.

When discrimination accuracy was evaluated at the level of individual contrasts, there was variability in the scores among contrasts of the same assimilation type and with the same degree of overlap. One possible explanation for this is that discrimination accuracy for contrasts belonging to the same assimilation type shows variability around a population mean, and that the distributions of discrimination accuracy for different assimilation types overlap to some extent. Alternatively, the overlap method may be able to explain some of the differences between discrimination accuracy when the analysis is at the level of individual contrasts. Another possibility is that the variations in discrimination may be due to the number of articulatory feature differences between the contrasting diphthongal vowels. Specifically, the greater the differences between the phonetic features of contrasting diphthongs, the more accurately they were discriminated. Both of these issues will be addressed in the General Discussion.

Overall, the results from Experiment 4 provide further support for the effect of perceived phonological overlap on discrimination accuracy using diphthongs. Assimilation types where there was no perceived phonological overlap were discriminated more accurately than those with perceived phonological overlap.

7.6 General discussion

The current series of experiments aimed to examine the effect of perceived phonological overlap on discrimination accuracy for the PAM assimilations types that involve an uncategorised phone, namely, UU and UC assimilations, and to compare their discrimination performance relative to TC, CG, and SC assimilations. It was hypothesised that discrimination would be excellent for non-overlapping contrasts, followed by partially overlapping, and completely overlapping contrasts. These predictions were tested by examining the perceptual assimilation and discrimination of Danish monophthongs and diphthongs by naïve AusE listeners. While only non-overlapping and partially overlapping contrasts were observed, the presence of overlap was related to discrimination accuracy such that non-overlapping contrasts were more accurately discriminated than partially overlapping contrasts. We argue that this difference is due to listeners' more effective detection of native phonological contrast when phones were non-overlapping than when they were partially overlapping. These predictions were supported for both monophthong (Experiment 3) and diphthong (Experiment 4) contrasts. This is the first study to provide a comprehensive assessment of the perceptual assimilation and discrimination of non-native diphthong contrasts.

Our results have shown that more precise discrimination predictions may be made for UU and UC contrasts when perceived phonological overlap is accounted for. This has important implications for PAM, which predicts very good discrimination for UC assimilations. However, it was not always the case that UC vowel contrasts were discriminated very well. In Experiment 3, the UC-P contrast was discriminated as poorly as the SC contrast. Similarly, while Best (1995) predicted poor to moderate/very good discrimination for UU assimilations, across Experiment 3 and 4, discrimination accuracy was excellent for UU-N assimilations, but poorer for UU-P assimilations. Therefore, discrimination accuracy for UC and UU assimilations appears to be modulated by perceived phonological overlap, and future studies testing PAM predictions should take into account perceived phonological overlap for UC and UU assimilations.

A second aim was to compare discrimination performance of UC and UU assimilations varying in the degree of overlap in relation to the other PAM assimilations. We tentatively predicted that discrimination accuracy would be excellent for TC, UC-N, and UU-N, poor for SC, UC-C, and UU-C assimilations, and moderate for CG, UC-P, and UU-P assimilations. Across Experiment 3 and 4, discrimination ranged from 85% to 94% for TC, UC-N, and UU-N, although UU-N was discriminated more accurately than TC in Experiment 3, and some of the UC-N contrasts were discriminated less accurately than the others in Experiment 4. For the partially overlapping contrasts, discrimination ranged from 57% to 75%, but the only SC contrast that was observed across the experiments fell within this range, at 59% correct. As there were no instances of completely overlapping assimilations, it is yet to be determined how discrimination accuracy would compare to SC assimilations, and to partially overlapping assimilations. Therefore, while the global predictions about the effects of perceived phonological overlap on discrimination were supported, the rank ordering of discrimination accuracy relative to other PAM assimilation types requires further investigation.

Variability in discrimination of contrasts of the same assimilation type was observed, and we provide a number of likely explanations. It is possible that this is due to variability around a population mean for a given assimilation type. For example, in Experiment 4, /iw/-/oʌ̯/ was discriminated more accurately than both /ɛw/-/œʌ̯/ and /yʌ̯/-/uj/, even though all three were assimilated as UC-N. It is possible that the accuracy of /iw/-/oʌ̯/ in this experiment was at the upper end of the range of possible accuracy scores for UC-N contrasts, at a point that overlaps with the distribution for TC contrasts. It may be case that, on average, TC contrasts are discriminated more accurately than UC-N contrasts.

Alternatively, the differences in discrimination accuracy may be due to inter-individual variability in the perceptual assimilation patterns, which was also observed in Tyler et al. (2014). In some instances, when averaged across participants, a given non-native phone may have a low overall categorisation percentage, despite being highly categorised by some individual participants. In Tyler et al., individual participants' discrimination scores were grouped together according to the PAM assimilation types, regardless of the contrast with which they occurred. For example, the discrimination accuracy scores for TC assimilations were grouped together, regardless of the contrast. This analysis was not possible here as we only included nine repetitions of each vowel in the categorisation task, as compared to 18 repetitions in Tyler et al. With nine repetitions (3 tokens x 3 speakers), there was insufficient statistical power to test categorisations against chance. Experiment 2 took 50 minutes and we did not wish to extend the testing session with additional presentations of each token. We chose to maintain the same number of repetitions in Experiment 3 and 4 to allow for direct comparison of categorisation patterns across experiments. Future research on cross-language vowel perception should anticipate some degree of inter-individual variability, and so an increased number of repetitions may be considered to allow individual differences to be examined.

It is interesting to consider which factors might contribute to contrasts being classified as overlapping versus non-overlapping. One possible factor could be the number of articulatory-phonetic features shared between non-native phones and L1 phonemes. In general, vowels in non-overlapping contrasts differed on a larger number of articulatory features than partially overlapping contrasts (i.e., tongue height, tongue backness, and lip rounding). This idea is consistent with the PAM principle that listeners perceive non-native phones in terms of their articulatory similarities to L1 phonemes, such that the greater the articulatory differences, the more phonetically distant they are (see Best, 1995; Best, Goldstein, Nam, & Tyler, 2016). Articulatory features might help explain the gradient differences in discrimination accuracy for contrasts within the same assimilation type. In Experiment 4, phonetic differences between pairs of diphthongs suggest that the number of feature contrasts for the vowel onset and offset may be related to discrimination accuracy, although it appears that phonetic-articulatory features for onset vowels were weighted more heavily than offset vowels. For example, in the UC-N contrast /iw/-/oʌ̯/, both the onset and offset of each vowel differed on tongue height, backness, and lip rounding. It was discriminated more accurately than the UC-P contrast /uʌ̯/-/oʌ̯/, for which the onset vowels differed only in tongue height and the offset vowels were identical. While it is difficult to make such direct comparisons in Experiment 3, the findings show that the UU-N contrast /ɛ/-/o/ was the most accurately discriminated contrast, possibly because the vowels differed on two features (i.e., tongue backness and lip rounding), while the next most accurately discriminated were the UC-N and TC assimilations which differed only on one phonetic feature. Thus, it appears that variability in discrimination accuracy for contrasts of the same assimilation type may be explained by the degree of articulatory-phonetic feature differences.

It is also necessary to explain why the perceptual assimilation patterns differed between Experiment 2 and Experiments 3 and 4. The different experimental conditions may provide one explanation. While Experiment 2 involved a perceptual assimilation task only, Experiments 3 and 4 involved a perceptual assimilation task preceded by a discrimination task. The tasks are not administered in the opposite order because labeling the stimuli first may bias responding in the discrimination task. In this case, however, participants' exposure to the stimuli in the discrimination tasks of Experiments 3 and 4 may have influenced perceptual assimilation relative to Experiment 2. Furthermore, participants in Experiment 2 categorised the entire Danish vowel system whereas those in Experiments 3 and 4 only categorised a subset of those vowels. The difference in context may also have affected the categorisation and ratings given. Despite the few inconsistencies in the perceptual assimilation patterns across experiments, we argue that it is worthwhile to first establish the perceptual assimilations prior to selecting the contrasts to be examined, as we did in Experiment 2, as these are likely to provide more accurate estimates of the perceptual assimilation patterns than selecting contrasts on the basis of articulatory-phonetic similarities and differences.

For most cases, when assimilation types changed from Experiment 2 to Experiments 3 and 4, a non-native vowel that was initially categorised above 50% dropped below the categorisation criterion in the later experiment. For example, in Experiment 2, Danish /uː/ was assimilated to the AusE /ʊ/ 56% of the time, but this dropped below the criterion to 49% in Experiment 3 even though the AusE category label for /ʊ/ was selected more often than chance. This has implications for contrast assimilations and raises the question of whether we should continue to use arbitrary categorisation thresholds to determine categorisation. There were also instances whereby a Danish vowel that was categorised above 50% to one AusE category also had above-chance responses to additional AusE categories. For example, in Experiment 2, the Danish /a/ was categorised to AusE /ɐː/ at 55%, but /ɐ/ and /æ/ were also selected more often than chance. Without a categorisation threshold, this vowel may have been considered as *clustered*. Removing arbitrary categorisation thresholds would have far-reaching consequences for PAM, and for related theories and models of L2 speech perception, but reconsideration of categorisation criteria seems to be a promising avenue for future theoretical development.

We introduced a novel approach for determining the degree of perceived phonological overlap, based on Faris et al. (2016). One of the criteria for this method was that it needed to differentiate between categorised and uncategorised assimilations in order to examine the effect of overlap on discrimination performance as a function of assimilation type. The results from both experiments were analysed and compared using our approach and the overlap method (Flege & MacKay, 2004; Levy, 2009b). There were some instances where the overlap scores (Flege & MacKay, 2004; Levy, 2009b) appeared to account for the variability in discrimination accuracy. In Experiment 4, /iw/-/oʌ̯/ was discriminated significantly more accurately than both /ɛw/-/œʌ̯/ and /yʌ̯/-/uj/ despite the fact that all three contrasts were assimilated as UC-N. The overlap scores showed that /iw/-/oʌ̯/ had the lowest overlap score out of the three contrasts. The overlap method results in a difference because it includes all responses, including those that are not selected significantly above chance. In contrast, our approach only considers responses that were selected above chance level. We observed cases where two contrasts had a similar overlap score but differed in discrimination accuracy (e.g., Experiment 4: /yʌ̯/-/uj/ and /œw/-/œʌ̯/), and cases where overlap scores differed markedly between a pair of contrasts without significant differences in discrimination accuracy (e.g., Experiment 3: /oː/-/ɔː/ and /oː/-/uː/). While the overlap method provided some insight into the cause of the differences in discrimination, it was able to account for only two sets of contrasts across both Experiment 3 and 4. It appears that our approach may account for the discrimination data more effectively than the overlap method when a more global, group level approach was taken, although further evaluation is required as we develop this approach further.

The notion that perceived phonological overlap influences discrimination accuracy may have implications for L2 learning. The Perceptual Assimilation Model extended to L2 learners (PAM-L2: Best & Tyler, 2007) predicts the likelihood of new L2 category formation, which would result in changes in discrimination accuracy over L2 learning time. For L2 phones forming UC or UU assimilations, PAM-L2 predicts that a new phonological category may be formed for the uncategorised phone/s within the contrast. Given the current findings, it is possible that new L2 category formation may depend upon the presence of perceived phonological overlap. Specifically, acquisition of new L2 categories may be more likely for non-overlapping phones, than for overlapping phones, and this would entail improvements in discrimination accuracy.

To conclude, by using a novel approach to identify the presence of perceived phonological overlap, we demonstrated that non-overlapping contrasts were discriminated more accurately than partially overlapping contrasts, and we evaluated PAM predictions for the first time using both monophthongal and diphthongal vowel contrasts. Our results have important implications for PAM as they allow for more precise predictions for discrimination accuracy to be made for UU and UC assimilations. We also observed that articulatory-phonetic differences may provide a quantifiable measure of phonetic distance when at least one non-native phone is uncategorised, and our results raise the question of whether arbitrary categorisation criteria are necessary to explain the effects of perceptual assimilation. We hope that the findings from this study will serve as the starting point for further research examining the effect of overlap on discrimination accuracy using a wider range of contrasts, assimilation types, and listener groups.

7.7 Acknowledgements

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CHAPTER 8

PHONOLOGICAL CATEGORY FORMATION AND DISCRIMINATION IN ADULT SECOND-LANGUAGE ACQUISITION: A LONGITUDINAL STUDY

CHAPTER 8: PHONOLOGICAL CATEGORY FORMATION AND DISCRIMINATION IN ADULT SECOND-LANGUAGE ACQUISITION: A LONGITUDINAL STUDY

8.1 Introduction

PAM-L2 and SLM postulate that L2 phones that are not identified with any particular L1 category are more likely to be acquired as new categories than those that are identified with L1 categories (Chapter 4). However, there has been no thorough investigation assessing the acquisition of uncategorised phones. Therefore, L2 vowels assimilated as uncategorised are ideal for investigating category acquisition. This chapter presents Experiment 5, which investigated the acquisition of L2 phonological vowel categories by adult learners in an immersion environment.

Both PAM-L2 and SLM hypothesise that category formation is likely to occur relatively early during acquisition. Given that over half of the world's population is bilingual (Grosjean, 1982), absolute beginner learners will always be difficult to recruit. This is particularly problematic when the L2 under investigation is English, as it is taught as a foreign language in many non-English speaking countries in a classroom-based setting, generally by non-native speakers ("English language statistics," 2013). Language acquisition in an immersion setting does, however, often mark learners' first substantial exposure to the L2 *as spoken by native speakers* (MacWhinney, 2005; Muñoz, 2008). Furthermore, it provides a more ecologically valid assessment of acquisition than foreign language learning in a classroom setting (Best & Tyler, 2007). L2 immersion is also the context for PAM-L2-based predictions. For these reasons, acquisition was assessed in learners who were in an immersion setting. With increasing L2 experience, PAM-L2 proposes that category formation should lead to improvements in discrimination accuracy. Therefore, a longitudinal study was conducted in order to examine the developmental changes that occurred in perceptual learning for adults with prior experience with that language and who were in an immersion environment.

As the participants recruited were not absolute beginner learners and were tested in an immersion context, they varied to some extent on factors related to L2 experience. Therefore, in addition to assimilation type, it was also necessary to account for other factors that were likely to influence learning. In Chapter 4, a number of factors were identified as influential to the success of new language learning, namely, 1) age of foreign language acquisition, 2) age of immersion in that language environment (AoI), 3) length of residence in the L2 speaking environment (LoR), 4) proportion of L2 use, 5) L2 vocabulary size, and 6) duration of foreign language education (FLA). In this study, the influence of these six factors on L2 speech perception were assessed.

The present study examined L2 speech perception and category acquisition of uncategorised phones by native Egyptian Arabic (EA) adults who had migrated to Australia and were learning Australian English (AusE). They had been exposed to English prior to immersion, although language instruction then was by non-native speakers. AusE vowel contrasts assimilated as UU and UC were selected because they are predicted to show improvements in discrimination accuracy over time (Best & Tyler, 2007). Although the learners in this study were not absolute beginners, the perceptual assimilation patterns from Experiment 1 (Chapter 6) provided an indication of how the AusE vowels would be assimilated by adult learners with no prior immersion experience. Based on the results of Experiment 1, two UC (/ʊ/-/ɔ/, /ɪ/-/e/) and seven UU (/ɪə/-/iː/, /æɪ/-/ɑe/, /əʉ/-/ʉː/, /oː/-/ʉː/, /oː/-/əʉ/, /æ/-/ɐ/, /eː/-/ɜː/) AusE vowel contrasts were selected for the current study. Perceptual learning was assessed during one year of L2 immersion in a longitudinal study involving three testing sessions (i.e., T0, T1, T2) separated by approximately 6-month intervals. The effect of the six factors related to L2 acquisition on new phonological category acquisition and discrimination accuracy were also examined.

The first question addressed in this study was whether there was evidence to suggest that new phonological categories had been formed and whether category acquisition could be predicted by any of the six variables outlined earlier. In previous research, evidence for new category formation was based on the ability of learners to produce L2 phones authentically (e.g., Bohn & Flege, 1992; Krebs-Lazendic & Best, 2013), or when identification responses mirrored those of native speakers (e.g., Bohn & Flege, 1990; McAllister et al., 2002). In this study, to make inferences about category formation, participants perceptually assimilated L2 vowels to both L1 *and* L2 vowel category labels. Consider the study by Bohn, Best, Avesani, and Vayra (2011), in which Danish listeners, who were also proficient speakers of English, identified English consonants twice, first using L1 orthographic labels, and then using their choice of either Danish or English orthographic labels. When given the opportunity to use L2 orthographic labels, it was then that they could demonstrate their ability to perceive phonological differences between the L1 and L2. For example, the English /w/ was often labeled as the Danish “V” or “B”, but when English orthography was allowed, it was labeled as the English “W”. Therefore, in the present experiment, by asking participants to categorise the AusE vowels to both L1 and L2 vowel category labels, they were able to demonstrate their sensitivity to phonological differences. Based on the perceptual assimilation results from both tasks, instances where an L2 phone was assimilated as uncategorised in the L1 but as categorised in the L2 were taken as indirect evidence suggesting that a new category had been acquired. Since the perceptual assimilation of vowels is highly variable (e.g., Best, Shaw, Docherty, et al., 2015; Best, Shaw, Mulak, et al., 2015; Tyler et al., 2014), and given the different levels of L2 experience of the participants, these perceptual assimilation patterns were determined for each individual learner, rather than for the learners as a group. Assuming that a plateau in perceptual learning had not yet been reached, it was predicted that there would be an increase in the number of new phonological vowel categories acquired over the course of this longitudinal study.

It was anticipated that new categories would be more likely to develop for learners with specific characteristics (e.g., a longer LoR, use the L2 more often than the L1). Therefore, it was necessary to also examine the role of the six factors in perceptual learning. Category formation was expected to be influenced to some degree by the six factors. Based on the empirical findings from previous research, it was hypothesised that a longer length of residence (e.g., Flege, Bohn, et al., 1997; Flege & Liu, 2001), an older age of foreign language acquisition (e.g., Jia et al., 2006), a younger age of immersion in that language environment (e.g., Flege, Munro, et al., 1995; Mackay et al., 2001), use of the L2 relatively more than the L1 (e.g., Flege & MacKay, 2004), a larger L2 vocabulary size (e.g., Bundgaard-Nielsen, Best, & Tyler, 2011a, 2011b), and a longer period of L2 training prior to immersion (e.g., Cebrian, 2006) were predicted to be associated with new category formation.

For PAM-L2, the likelihood of category acquisition depends not only on the perceived similarity of a single L2 phone and the closest L1 phonemes, but also on the relationship between pairs of contrasting L2 phones and their assimilation to the L1 phonological system. For contrasts assimilated as UU and UC, new categories are more likely to be formed for non-overlapping than overlapping contrasts (see Chapter 4). While this is an interesting issue to address, it was not investigated in the current study for two reasons. Firstly, from a theoretical perspective, both PAM-L2 and SLM predict that uncategorised phones, rather than categorised phones, are easier to acquire. Therefore, an initial investigation was necessary to first determine whether new categories would be formed for uncategorised L2 phones. Based on the outcomes of the present study, future investigations will then be able to determine whether this is dependent upon presence or absence of overlap. As overlap was not assessed in this initial examination, assessments of phonological category formation were based on individual L2 vowels as in studies of SLM, rather than on contrasts as in PAM-L2.

Secondly, from a practical perspective, investigating the role of overlap on category acquisition in this study would further increase the duration of the testing sessions, which were already two hours long each. In order to maximise the opportunity of observing perceptual learning over time, a large number of L2 contrasts were employed (i.e., nine AusE vowel contrasts), but to limit the length of the testing session, only nine repetitions of each vowel category were included in the perceptual assimilation task. If UU and UC assimilations were to be differentiated based on overlap, or lack thereof, a large number of token repetitions would be required to conduct tests against chance. Additional repetitions of the auditory vowel tokens would greatly extend the duration of the testing sessions, and this would also likely to increase the attrition rate.

The second research aim was to investigate changes in L2 discrimination accuracy over this period of immersion. According to PAM-L2, new category formation should lead to improvements in discrimination accuracy over time for UU and UC assimilations, but should remain excellent for TC and poor for SC assimilations. This highlighted the importance of assessing changes in discrimination levels as a function of assimilation type. This was first investigated using the mean percent discrimination accuracy scores based on the overall group perceptual assimilation patterns in order to determine whether discrimination accuracy changed for each contrast over time. This issue was then evaluated as a function of individual participants' perceptual assimilations. Specifically, as the learners varied in L2 experience, and because perceptual assimilation of vowels was variable across individuals, the same approach as in Tyler et al. (2014) was adopted whereby discrimination accuracy scores were grouped according to individual participants' assimilations, rather than vowel contrast. To assess changes in discrimination over time as a function of assimilation type, the discrimination accuracy scores were grouped as in Tyler et al. (2014) for T0 only, and the discrimination accuracy scores for these baseline assimilations were compared against those from the same participants at T1 and T2. If the scores were regrouped according to assimilation type across all three sessions, no changes in discrimination would be expected because assimilation type is kept constant throughout. Again, if a plateau had not been reached, it was predicted that new category formation should result in improvements in discrimination accuracy over time for UU and UC assimilations, but not for TC and SC assimilations.

In the absence of improvements in discrimination accuracy over time, it was nevertheless expected that discrimination accuracy for the contrasts would vary as a function of assimilation type. Thus, the third aim of this study was to assess the PAM predictions for relative performance on discrimination according to assimilation type. Discrimination was predicted to be excellent for TC assimilations, very good for CG, and poor for SC assimilations (Best, 1994, 1995). Discrimination accuracy for UC was predicted to be on par with CG assimilations, but would range from poor to moderate/very good for UU assimilations.[8]

The fourth aim was to examine whether any of the six factors predicted vowel discrimination accuracy as a function of the PAM assimilation types. The factors were hypothesised to influence discrimination levels for UU and UC assimilations, which PAM-L2 predicts would show changes in perceptual learning with increasing L2 experience. However, the factors were not expected to influence discrimination accuracy for TC and SC assimilations because discrimination for these is determined by L1 phonological attunement. For example, because contrasting phones forming a TC assimilation are assimilated to separate L1 categories, discrimination is predicted to be excellent, regardless of the variations among learners on any of the factors. Listeners are simply able to employ native categories to distinguish between them.

8.2 Method

8.2.1 Participants

The native adult EA speakers were recruited from the Greater Western Sydney community and through snowball sampling whereby each participant was asked to forward a letter of invitation to the study to some of their personal contacts (Singh, 2007). At T0, there were 38 native adult EA speakers (20 females, M_{age} = 41 years;

[8] Since the presence or absence of perceived phonological overlap was not determined for L2 contrasts in this study, the predictions for UU and UC assimilations were based on the original predictions from Best (1994, 1995).

age range: 17 – 73 years). As can be expected with longitudinal studies, there was attrition at later testing sessions. At T1, the sample consisted of 35 participants (20 females, M_{age} = 41 years, Age range: 17 – 73 years), and there were 31 participants remaining at T2 (19 females, M_{age} = 42 years, Age range: 17 – 73 years). Overall, the retention rate from T0 to T2 was 82%, which is relatively high in longitudinal studies (Capaldi & Patterson, 1987). Only the data from the 31 participants who completed all three sessions will be included in the analyses presented in this experiment. This will allow comparisons across time to be made for the same group of participants. They received monetary reimbursement for their participation. The 31 participants varied to some extent on each of the six factors across time (see Table 8.1). None of the participants reported hearing or language impairments, and all had normal or corrected-to-normal vision. None of the participants had any extended stay in an English-speaking country prior to immersion in Australia. Participants who had received English language instruction prior to immersion indicated that they had been exposed to British or American English but that this language instruction had been from non-native English speakers. Three of the participants were born in Libya but had moved to Egypt and resided there from about the age of 17 years – 20 years. Two other participants were born in Egypt but had lived in Libya for some years during adulthood for their work, before finally moving to Australia. These five participants completed all three sessions of the study.

Table 8.1: *Mean, standard deviation (SD), and range for each of the six factors at T0, T1, and T2*

	T0				T1				T2			
Variable	Mean	SD	Range Min.	Range Max.	Mean	SD	Range Min.	Range Max.	Mean	SD	Range Min.	Range Max.
Age at FLA onset	13	11	2	52	Unchanged from T0				Unchanged from T0			
Age of immersion	41	13	16	71	Unchanged from T0				Unchanged from T0			
English FLA instruction	9.19	5.69	0	23	Unchanged from T0				Unchanged from T0			
Length of residence	1.37	0.85	0.03	3.19	1.89	0.80	0.61	3.72	2.43	0.79	1.15	4.30
Proportion of L2 use	0.36	0.14	0.06	0.57	0.41	0.12	0.14	0.66	0.40	0.16	0.05	0.65
L2 vocabulary size	9232	2608	4600	14200	9000	2645	4200	14400	8819	3062	4000	13000

Age at FLA and age of immersion: chronological age in years; English FLA instruction: duration of English language training prior to L2 immersion in years; Length of residence: length of immersion in Australia in years; L2 vocabulary size = number of L2 word families acquired. The factor ‘proportion of L2 use’ was calculated by taking into account the average percentage of both L1 and L2 use.

8.2.2 Stimuli and apparatus

The auditory stimuli used in this experiment were taken from the /ˈhVbə/ nonsense words used in Experiment 1 (Chapter 6: Faris, Best, & Tyler, 2016). The vowels used in this experiment were a subset of those used in Experiment 1. Based on the vowel contrasts under examination (i.e., /ʊ/-/ɔ/, /ɪ/-/e/, /ɪə/-/iː/, /æɪ/-/ɑe/, /əʉ/-/ʉː/, /oː/-/ʉː/, /oː/-/əʉ/, /æ/-/ɐ/, and /eː/-/ɜː/), tokens for the following vowels: /æ, ɐ, ɪ, e, ʊ, ɔ, eː, ɜː, iː, oː, ʉː, æɪ, ɑe, ɪə, əʉ/ were employed in this study. Four tokens per vowel category were selected from both speakers resulting in a total of 120 tokens (15 vowels x 4 repetitions x 2 speakers). The mean acoustic measurements of these vowels are displayed in Table 8.2, and the vowel measurements on the full AusE vowels used in Experiment 1 are presented in Appendix D. The pre-emphasis was applied from 50 Hz. To ensure accurate tracking of the formant contours of the target vowel, formant settings in Praat were tuned for each individual token. The analysis frequency ranged from 5000-6200 Hz, with 4 or 5 formants being tracked, and the window length was 25 ms. Stimulus presentation and response collection for the AXB and perceptual assimilation tasks were controlled using PsyScope X B57 on a MacBook laptop, Sennheiser HD 650 headphones, and an Edirol UA-25EX external USB sound card.

Table 8.2: *Mean vowel durations and the mean F1, F2, and F3 formant values at the 25%, 50%, and 75% points of the target vowel duration for the stimuli*

AusE vowel	Vowel duration (ms)	F1 (Hz)			F2 (Hz)			F3 (Hz)		
		25%	50%	75%	25%	50%	75%	25%	50%	75%
ɐ	63	944	902	788	1477	1388	1306	2888	2880	2895
e	68	672	661	630	2199	2125	1886	2983	2937	2873
ɪ	55	401	436	439	2600	2505	2228	3113	3006	2863
ɔ	68	733	713	655	1091	1088	1048	2985	3000	2995
ʊ	64	432	437	416	919	888	865	2804	2815	2765
æ	74	978	958	880	1739	1703	1622	2838	2834	2848
eː	148	592	616	645	2404	2358	2165	3051	3066	2992
iː	126	418	404	390	2703	2773	2755	3363	3305	3188
oː	149	512	528	536	898	849	861	2934	2965	2986
ʉː	121	415	410	397	1925	1889	1806	2623	2597	2597
ɜː	149	613	626	626	1876	1835	1781	2846	2888	2868
ɑe	156	976	976	837	1450	1681	1935	2924	2836	2838
ɪə	162	387	467	603	2710	2529	1992	3269	3097	2975
æɪ	143	755	605	479	2223	2465	2552	3001	3073	3136
əʉ	142	661	591	491	1568	1666	1709	2720	2732	2728

8.2.3 Procedure

Participants were tested three times during the course of a year of L2 immersion, separated by approximately 6-7 months (T0-T1: *M* = 202 days, Range: 177 – 264, *SD* = 25; T1-T2: *M* = 235 days, Range: 189 – 322, *SD* = 30). Each session consisted of nine categorial AXB discrimination tasks, two perceptual assimilation tasks, a questionnaire, and an L2 vocabulary size test. Each session took approximately 2 hours to complete. Participants first completed a discrimination task for each of the nine AusE vowel contrasts. On each trial, they were presented with three auditory tokens. Participants matched the vowel in the middle token “X” with either the first

“A” or last “B” token. Vowels from the same phonemic category were physically different tokens produced by a different speaker to ensure that judgments were based on the phonological characteristics of the vowel. That is, “A” and “B” were produced by the one speaker, and “X” by the other speaker. The interstimulus interval was 1 s. Participants were instructed to attend to the first vowel in the nonsense word. Responses were made by selecting one of two labeled keys on a computer keyboard that corresponded to the position of the phonologically matched token. If a response was not recorded within 2 s, the trial ended and it was reinserted into the pool of remaining trials. No feedback was provided. Participants were first familiarised with this task using three practice trials using the AusE vowel contrast /ɐː/-/ɔ/ and they received feedback. This contrast constituted a TC assimilation type, and because it was easy for them to discriminate, it helped them understand the procedure of the AXB discrimination task. This particular contrast was not included in the test blocks. The practice tokens were from a different female AusE speaker than those in the experimental trials. Each AXB task consisted of 64 trials, which were randomised for each participant. All four trial types (i.e., AAB, ABB, BAA, BBA) were presented an equal number of times per contrast. With three tokens per speaker, a Latin-square design was used to ensure that each token was presented an equal number of times in each position (i.e., A, X, B). The order of presentation of each contrast was pseudorandomised across the three sessions for every participant.

Participants then completed two perceptual assimilation tasks with goodness-of-fit ratings. In the L1 perceptual assimilation task, participants were presented with a /ˈhVbə/ nonsense syllable over headphones and were again instructed to attend to the target vowel in the first syllable. This was followed by the presentation of a grid of Arabic CVC or CV keywords, in Arabic script, containing all L1 core phonemic

(/a, i, u, aː, iː, uː, eː, oː, aw, aj/) and allophonic ([æ, æː, ɑ, ɑː, ɛː, ɛ̽ː, e, o, ɪ, ɪː, ʊ, ʊː, ə]) vowel categories, and /ʔ/, with the vowels highlighted in red in each keyword. The Arabic categorisation grid and rating scale are displayed in Figure 8.1. Participants used a computer mouse to select the L1 keyword containing the vowel closest to the auditorily presented AusE vowel. The token was presented a second time, after which participants rated its goodness-of-fit to their chosen EA vowel using a scale from 1 (very strange) to 7 (perfect).[9] No feedback was provided.

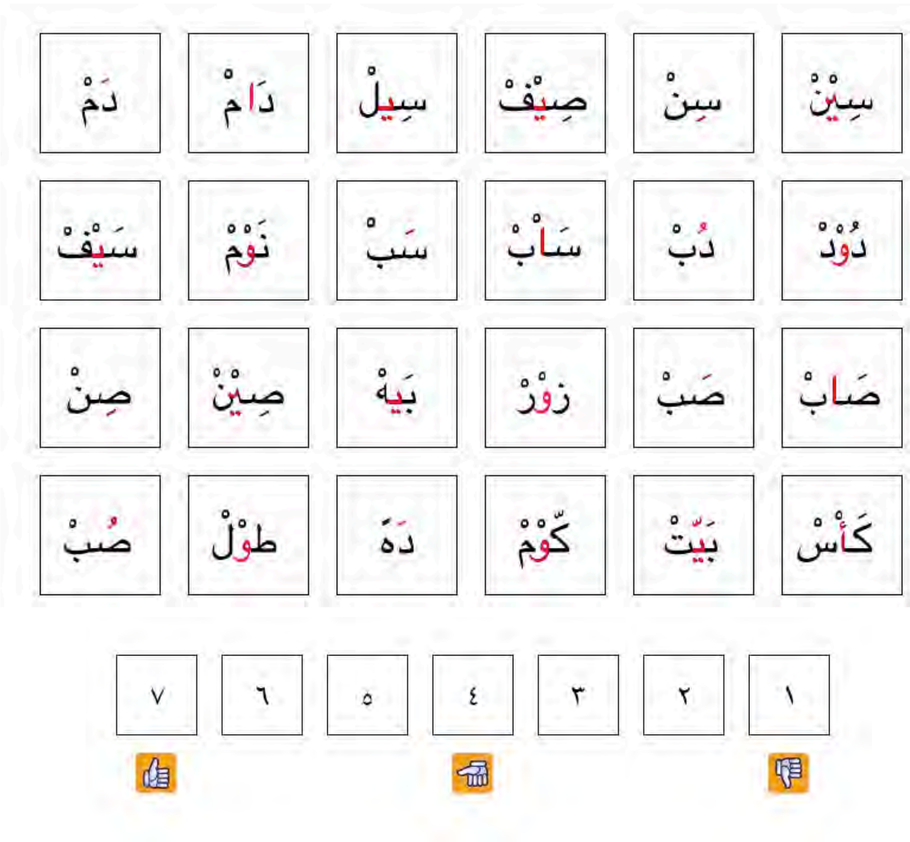

Figure 8.1: The categorisation grid and rating scale for the L1 perceptual assimilation task.

[9] Note that in Figures 8.1 and 8.2, the hand symbols indicating very strange vs. perfect goodness-of-fit in the 7-point rating scale are presented in the opposite direction. In Arabic, text is read from right to left, and in English text is read left to right, and so this why the hand symbols are presented in this way for the different language tasks. The hand symbols correspond to the same numbers on the scales (i.e., “thumbs down” = very strange; “thumbs up” = perfect).

A keyword selection and rating response were required to be made within 6 s and 3.5 s, respectively, otherwise the entire trial was reinserted into the random sequence. This task consisted of 120 trials (15 vowels x 4 repetitions x 2 speakers), the intertrial interval was 500 ms, and the presentation order of the trials was randomised for each participant. The order of administration of the AXB contrasts was counterbalanced across participants, and across sessions for individual participants.

To allow inferences to be made about new L2 phonological category formation, participants also completed an L2 identification task. The procedure was similar to that of the L1 task except that participants identified the L2 AusE vowels /æ, ɐ, ɪ, e, ʊ, ɔ, eː, ɜː, iː, oː, ʉː, ɑe, æɪ, ɪə, əʉ/ as one of the L2 AusE vowel category labels *had, up, hid, bet, hood, hot, hair, her, heed, hoard, boot, hide, bay, here,* and *boat,* respectively. All of the AusE monophthongs and diphthongs were highlighted in red. The order of presentation of the two perceptual assimilation tasks was counterbalanced across participants. With the help of the experimenter, participants were given the opportunity to familiarise themselves with the Arabic and English keywords used. The English categorisation grid and rating scale are displayed in Figure 8.2.

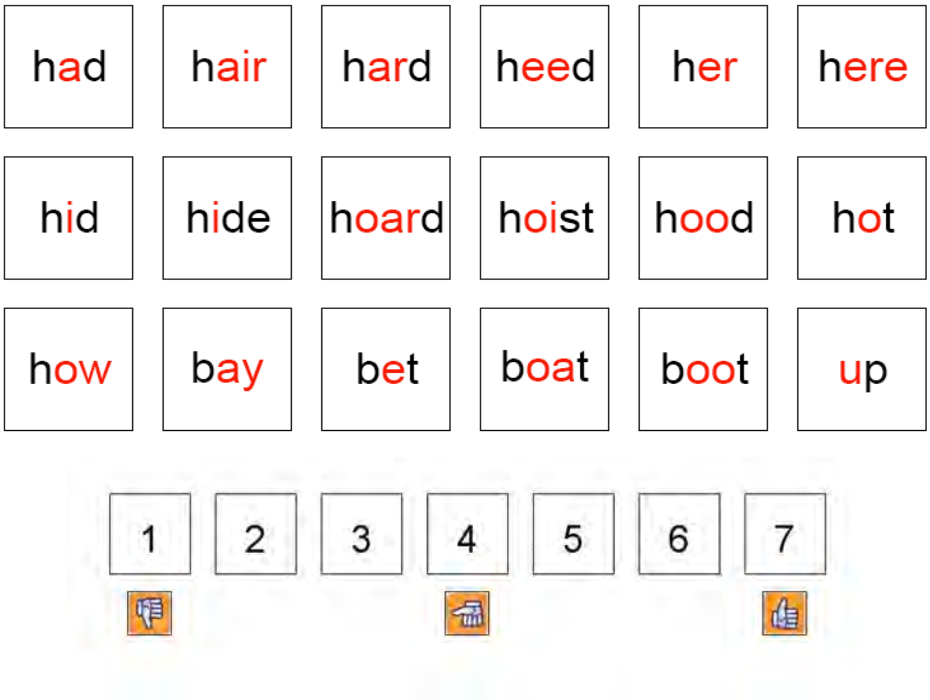

Figure 8.2: The categorisation grid and rating scale for the L2 identification task.

In order to collect information on the participants' age of FLA, AoI, LoR, length of EFL, and proportion of L2 use, a language background information questionnaire was administered at T0 (see Appendix B). The same questionnaire was given at T1 and T2, except that the participants only completed the sections that asked about their L2 usage.

L2 vocabulary size was assessed using a bilingual Arabic-English version of the Nation and Beglar (2007) Vocabulary Size Test that was developed for use in this project (see Chapter 5, section 5.4.2). Given that participants needed to complete the vocabulary size test three times in total, the two available parallel versions of the test were used and were alternated across testing sessions to minimise confounds associated with repeated administration of the same test.

8.3 Results

As the main aim of this study was to examine L2 phonological category acquisition, this section first reports on analyses conducted for determining whether any new L2 categories had been formed during this longitudinal study. Since the learners varied on length of residence in this language environment, age of FLA, age of immersion, proportion of L2 use, L2 vocabulary size, and duration of English as a foreign language training, it was also important to consider whether and how the six variables predicted category acquisition. Changes in discrimination of newly-acquired vowel categories were also investigated as PAM-L2 predicts that new category formation should be accompanied by improvements in discrimination accuracy. Analyses are also reported for determining whether the PAM predictions of discrimination were supported with L2 AusE vowel contrasts and adult EA learners, and for determining whether the six variables predicted discrimination.

8.3.1 New L2 phonological category formation and the role of the six factors in predicting category acquisition

8.3.1.1 Group results for the L1 and L2 perceptual assimilation tasks

Inferences about new L2 phonological category formation were made, in the first instance, based on the overall group perceptual assimilation patterns from both L1 and L2 perceptual assimilation tasks. When an L2 phone was uncategorised in the L1, but categorised in the L2, this was taken as indirect evidence to suggest that a new phonological category had been acquired. L2 vowels were deemed categorised if an L1 category label (in the L1 perceptual assimilation task) or L2 category label (in the L2 identification task) was selected more than 50% of the time, on average, for that given L2 vowel, otherwise it was deemed uncategorised.

The results of the L1 perceptual assimilation task at T0, T1, and T2 revealed that there were no systematic patterns in the perceptual assimilation of AusE vowels to core L1 phonemic versus allophonic vowel categories, so the allophonic vowel categories were collapsed into the appropriate main phonemic categories (see also Chapter 6: Faris et al., 2016). As the majority of the L2 vowels were assimilated as uncategorised in both the L1 and the L2, the mean percent categorisation responses and mean goodness-of-fit ratings for both the L1 and L2 perceptual assimilation tasks for T0, T1, and T2 are presented in Appendix E.

Across all three sessions, none of the AusE vowels were assimilated to an L2 vowel category label above the 50% assimilation threshold, but there were a few cases whereby L2 vowels were categorised to L1 vowels. At T0, when the mean percent categorisations were averaged across participants, AusE /ɐ/ was categorised to EA /aː/ 51% of the time (average goodness ratings: 4.59). At T1, the AusE vowels /æ/ (average goodness ratings: 4.32) and /ɐ/ (average goodness ratings: 4.28) were assimilated as categorised to EA /aː/ at 52% and 51% of the time, respectively. At T2, AusE /æ/ was categorised to EA /aː/ 56% of the time (average goodness ratings: 4.38), while /ɐ/ was now uncategorised at 49%. Taken together, there was no evidence to suggest new L2 phonological categories had been acquired when the perceptual assimilation patterns were analysed at the group level.

8.3.1.2 Individual L1 and L2 perceptual assimilation results

An examination of individual participants' perceptual assimilations revealed that there was a high degree of inter-individual variability in whether a given L2 vowel was assimilated as categorised or uncategorised in the L1 and L2. With such variability, examination of individual participants' perceptual assimilations may instead provide a more accurate test of category formation. Therefore, for each individual participant, instances whereby an L2 vowel was uncategorised in the L1 but categorised in the L2 were identified (see Appendix F). At T0, 14% (64 out of 465 observations) were of instances of an L2 vowel uncategorised in the L1 but categorised in the L2, 12% (56 out of 465 observations) at the T1, and 13% (61 out of 465 observations) at T2. Based on individual participants' assimilations, there was again no evidence for an increase in the number of L2 categories acquired over time.

8.3.1.3 Influence of the six factors on individual L2 category formation across time

While there was no increase in the number of vowels acquired over time, it is possible to examine the influence of the six factors in predicting which participants have acquired new vowel categories at each time point. To examine whether any of the six variables predicted new phonological category formation, separate binomial logistic regression analyses were run on individual participants' discrimination accuracy scores at each time point. This particular analysis was suitable for addressing this research question because the aim was to predict the probability of category acquisition (i.e., new category formed vs. no new category formed) for each of the 15 AusE vowels based on a number of continuous predictor variables (i.e., length of residence, age of FLA, age of immersion, proportion of L2 use, L2 vocabulary size, and duration of English as a foreign language training).

An exploratory binomial logistic regression was run at T0 as there were no theoretical reasons to enter specific variables or groups of variables into the model in a particular order. With all six factors entered simultaneously into the model at T0, the model was significant, $\chi^2(6) = 25.59$, $p < .001$, and the factors explained 9.7% of the variance (Nagelkerke R^2). L2 vocabulary size was the only factor to predict L2 category acquisition (p = .008), with an increase in L2 vocabulary size associated with an increased likelihood of acquiring a new L2 category. These results provided an indication of whether new categories had already been acquired prior to this longitudinal study.

Three out of the six variables remain constant over time (i.e., age of FLA, AoI, length of EFL), and the other three variables changed over the three sessions (i.e., LoR, L2 vocabulary size, L2 use; see Table 8.1). Since one of the aims of this study was to examine the influence of the six variables on discrimination accuracy *over time*, for T1 and T2, the factors were entered into the model in steps. In the first step of the model, the *varying predictors*, which were the three factors that change over L2 learning time, were entered (i.e., LoR, L2 vocabulary size, L2 use), and at Step 2, the *constant factors* that remain the same over time were entered (i.e., age of FLA, AoI, length of EFL). This provided an opportunity to assess the unique contribution of the varying factors on category acquisition.

At T1, the model was statistically significant when the varying predictors were entered first, $\chi^2(3) = 16.52$, $p = .001$, and accounted for 6.7% of the variance (Nagelkerke R^2). L2 vocabulary size predicted L2 category acquisition ($p < .001$), such that an increase in L2 vocabulary size was associated with an increased likelihood of acquiring a new L2 category. The model with only the constant factors was also significant, $\chi^2(3) = 9.18$, $p = .027$. An examination of the model with all six predictors was significant, $\chi^2(6) = 25.70$, $p < .001$, and explained 10.3% of the variance (Nagelkerke R^2), with a larger L2 vocabulary size and a younger age of immersion predicting L2 category formation.

At T2, when the varying predictors were entered at Step 1, the model was statistically significant, $\chi^2(3) = 28.65$, $p < .001$, and accounted for 11.1% of the variance (Nagelkerke R^2). A larger L2 vocabulary size and a greater proportion of L2 use predicted category formation. The model containing only the constant factors was not significant, $\chi^2(3) = 1.99$, $p = .575$, but the model with all six predictors was significant, $\chi^2(6) = 30.63$, $p < .001$, and accounted for 11.8% of the variance observed, with L2 vocabulary size and proportion of L2 use as significant predictors of category formation, although no additional factors emerged as significant predictors.

8.3.1.4 Summary of L2 phonological category formation results

According to the overall group perceptual assimilation patterns from both L1 and L2 perceptual assimilation tasks, there was no evidence to suggest new L2 phonological categories had been acquired. Inferences about new L2 phonological category formation were then evaluated based on individuals' perceptual assimilation patterns, although there was no increase in the number of vowels acquired over time. By examining the role of six factors in predicting category formation, the results revealed that a larger L2 vocabulary size predicted new category acquisition at each time point. A younger age of L2 immersion (T1) and a high proportion of L2 use (T2) also emerged as significant predictors of L2 category formation.

8.3.2 Examining changes in discrimination accuracy over time and assessing PAM's predictions for discrimination

Changes in discrimination accuracy across time are predicted to depend upon assimilation type. Discrimination accuracy should improve for UU and UC assimilations, but should remain consistent for TC and SC assimilations (Best & Tyler, 2007). Therefore, in order to examine potential changes in discrimination performance over time, it was necessary to first establish the PAM assimilation types for each of the nine AusE vowel contrasts. The PAM assimilation types for each contrast were determined in the same way as in previous studies (e.g., Best et al., 2001; Bundgaard-Nielsen, Best, & Tyler, 2011a; Tyler et al., 2014). Specifically, a contrast was deemed TC if members of that contrast were assimilated to two separate L1 categories more than 50% of the time. When one phone within a contrast was categorised, but another was uncategorised (< 50%), then this was deemed an UC assimilation, but was an UU if both contrasting phones were uncategorised. If both members of that contrast were assimilated to the same native category, a significant difference between the average goodness ratings in a *t*-test indicated that this was a CG assimilation type, otherwise it was a SC assimilation.

8.3.2.1 Group results for changes in discrimination accuracy over time as a function of vowel contrast

Changes in L2 discrimination accuracy and assessments of the PAM predictions were first investigated as a function of the overall group perceptual assimilation patterns. For the EA L1 perceptual assimilation task, the eight of the nine AusE vowel contrasts, /ʊ/-/ɔ/, /ɪ/-/e/, /ɪə/-/iː/, /æɪ/-/ɑe/, /əʉ/-/ʉː/, /oː/-/ʉː/, /oː/-/əʉ/, and /eː/-/ɜː/, were assimilated as UU across all three testing sessions. For the remaining contrast, /æ/-/ɐ/, at T0, it formed an UC assimilation since the AusE /ɐ/ was categorised to the EA /aː/ at 51% (average rating: 4.59), but AusE /æ/ was not categorised over 50%. It was assimilated as a SC assimilation at T1, $t(57) = -0.17$, $p = .866$, as both were labeled as EA /aː/, and there were no significant differences in the goodness ratings between /æ/ (average rating: 4.32) and /ɐ/ (average rating: 4.28). At T2, this contrast was UC since the AusE /æ/ was categorised to the EA /aː/ at 55% and /ɐ/ was assimilated as uncategorised at 49%. For the AusE L2 identification task, all of the AusE vowel contrasts were assimilated as UU at T0, T1, and T2. The mean percent discrimination accuracy scores for each of the nine AusE vowel contrasts at each testing session are displayed in Figure 8.3.

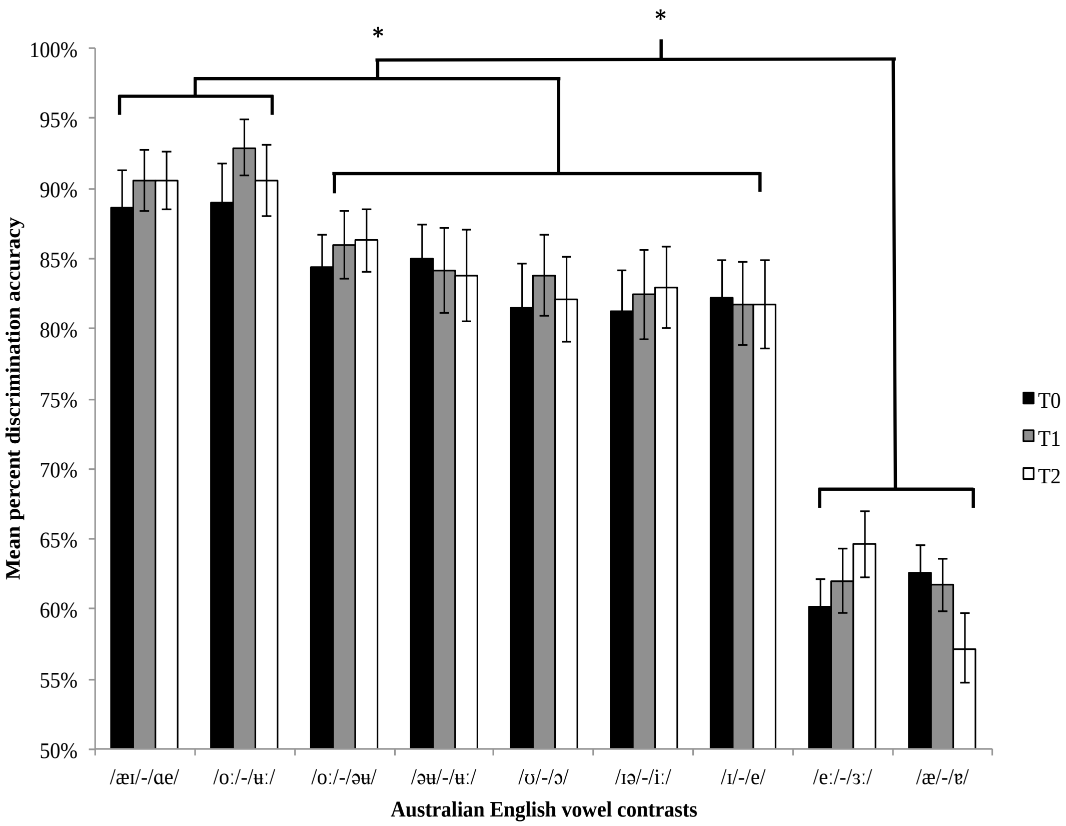

Figure 8.3: Mean percent discrimination accuracy for the nine AusE vowel contrasts at T0, T1, and T2. Error bars represent the standard error of the mean. Asterisks indicate statistically significant differences in discrimination accuracy between the AusE vowel contrasts.

An analysis of variance (ANOVA) was conducted on the mean percent discrimination accuracy scores to determine whether there were any changes in discrimination accuracy over L2 learning time and to also test the PAM predictions for discrimination. There were two within-subjects factors, namely, *Contrast* which was composed of nine levels (i.e., the nine AusE vowel contrasts), and *Time* with three levels (i.e., T0, T1, T2). Using a Huynh-Feldt adjustment for the degrees of freedom for main effects and interactions that involved *Contrast* and *Time*, the main effect of *Time* was not significant, $F(1.73, 50.08) = 0.35$, $p = .673$, indicating that there were no changes in discrimination accuracy over time. There was a significant main effect of *Contrast*, $F(4.56, 132.36) = 71.76$, $p < .001$, which suggest that discrimination accuracy scores varied among the different contrasts. The interaction between *Time* and *Contrast* was not significant, $F(11.59, 336.14) = 0.93$, $p = .519$. Sidak post-hoc tests revealed that /æɪ/-/ɑe/, /əʉ/-/ʉː/, and /oː/-/əʉ/ were the most accurately discriminated of the contrasts, while /eː/-/ɜː/ and /æ/-/ɐ/ were the most poorly discriminated. There was no significant differences in discrimination among the contrasts /ʊ/-/ɔ/, /ɪ/-/e/, /ɪə/-/iː/, and /oː/-/ʉː/. To assess whether these differences might be better explained by L2 vocabulary size, the participants were assigned to one of two groups, namely, a High-Vocabulary group an a Low-Vocabulary group based on a median split of their L2 vocabulary size at T0. The data and analyses are presented in Appendix G. Briefly, the High-Vocabulary group performed better overall in L2 discrimination than the Low-Vocabulary group, but there were no improvements over time for either group.

8.3.2.2 Individual results for changes in discrimination accuracy and assessing PAM's predictions for discrimination as a function of individual assimilations

Recall from the analysis of category acquisition (Section 8.2.1) that there was inter-individual variability in the perceptual assimilation patterns. When the L2 vowels were considered as contrasts, there was also variability in the PAM assimilation types across participants for a given contrast. For example, in the EA L1 perceptual assimilation task, /oː/-/əʉ/ was assimilated as UU at the group level across all three testing sessions. However, for the majority of individual participants, this same contrast was assimilated as UU or UC across all three sessions. Due to the high degree of inter-individual variability within the group, the group-level data are unlikely to provide a clear assessment of changes in discrimination levels over time as a function of assimilation type. Therefore the individual assimilation approach to data analysis as in Tyler et al. (2014) was followed. This involved identifying each individual participant's assimilation type for each of the nine vowel contrasts. This was conducted for the L1 and L2 perceptual assimilation tasks, and for all three testing sessions. As there were only nine repetitions of each vowel in the categorisation tasks, it was not possible to further differentiate between the various uncategorised assimilations and the presence or absence of overlap. Contrasts were simply grouped together as UU or UC.

When the assimilation patterns across the L1 and L2 were compared, there were instances whereby a contrast was assimilated as a SC in the L1 but as a TC in the L2.[10] In this scenario, when participants were restricted to using L1 vowel category labels, their responses suggest that they perceived the contrasting L2 vowels as perceptually similar to a single L1 phoneme. However, when given the opportunity to categorise L2 vowels to L2 vowel category labels, they could demonstrate their ability to perceive phonological differences (see Bohn et al., 2011). Therefore, by taking into account both L1 and L2 assimilation types, either the L1 or L2

[10] For reference, each individual participant's assimilation type in the L1 and the L2, along with the mean percent discrimination accuracy scores for each of the nine AusE vowel contrasts across the three testing sessions are provided in Appendix H.

assimilation was selected (i.e., *preferred L1/L2 assimilation*) based on the following criteria:

1) If an L1 or L2 contrast was assimilated as UU but the assimilation type in the other language involved a categorised L2 phone, then the assimilation type with the categorised phone was preferred. For example, if a contrast was assimilated as UU in the L1, but as a TC in the L2, then the L2 assimilation type was preferred, because according to PAM-L2, learners must employ existing categories or develop new categories in order to be functional in the new language. Word recognition would not be possible if both phones are uncategorised.
2) If one or both L2 phones were assimilated as categorised in the L1 and L2 (i.e., TC, UC, CG, SC), then the L1 or L2 assimilation type that is predicted by PAM to result in the more accurate discrimination was preferred as this suggests that the learner can distinguish between the phones within the contrast.

Table 8.3 displays the percentage of occurrence, as well as the number of observations (279 observations in total), of each preferred L1/L2 assimilation across the three sessions. There were more instances of UU and UC assimilations than any of the other PAM assimilation types, and the percentage of occurrence for each preferred L1/L2 assimilation type remained relatively stable across time.

Table 8.3: *Percentage of occurrence of each preferred L1/L2 assimilation type at T0, T1, and T2. The number of observations for each assimilation type are provided in parentheses*

Preferred L1/L2 assimilation type	Time		
	T0	T1	T2
SC	6% (16)	6% (16)	7% (20)
CG	1% (3)	0% (1)	1% (4)
TC	9% (24)	9% (26)	10% (29)
UC	40% (111)	41% (114)	39% (109)
UU	45% (125)	44% (122)	42% (117)

To assess whether discrimination accuracy varied over time as a function of assimilation type, the mean discrimination accuracy scores for the preferred L1/L2 assimilations at T0 were grouped according to individual participants' assimilation type, rather than contrast. For example, the mean discrimination accuracy scores for TC assimilations were grouped together regardless of the contrast (see, Tyler et al., 2014). The preferred L1/L2 assimilation types at T0 were used as a baseline and compared with discrimination accuracy at T1 and T2 for the same contrast regrouping used at T0. Due to the small number of preferred L1/L2 CG assimilations, they were excluded from the following analyses. The discrimination accuracy results according to preferred L1/L2 assimilation type across the three sessions are presented in Figure 8.4.

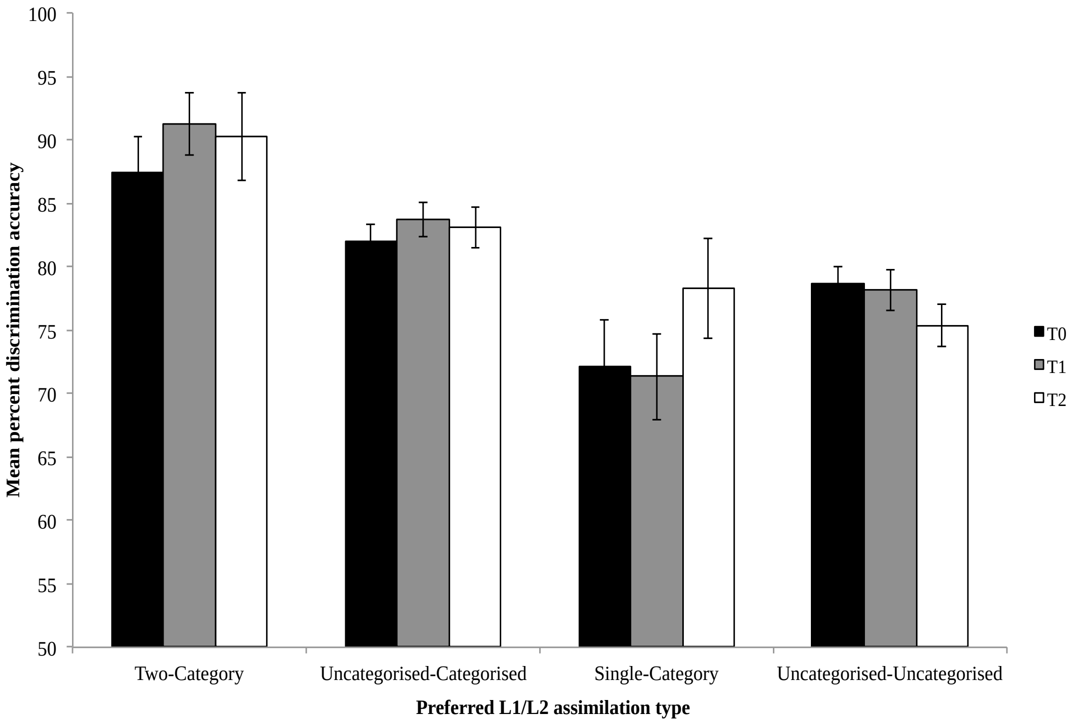

Figure 8.4: Mean percent discrimination accuracy for preferred L1/L2 assimilation type at T0, T1, and T2. Error bars represent standard error of the mean.

A 4 x (3) mixed ANOVA was conducted on the regrouped discrimination accuracy data. Each regrouped contrast was treated as an independent observation. *Assimilation Type at T0* was a between-subjects factor, and consisted of four levels (i.e., TC, UC, SC, UU), and *Time* was a within-subjects variable which consisted of three levels (i.e., T0, T1, T2). Using a Huynh-Feldt adjustment for the degrees of freedom for main effects and interactions that involved *Time*, the main effect of *Time* was not significant, $F(1.71, 464.53) = 0.07$, $p = .903$. There was a significant main effect of *Assimilation Type at T0*, $F(3, 272) = 5.49$, $p = .001$, suggesting that there was a meaningful difference in the discrimination accuracy scores among the preferred L1/L2 assimilation types when collapsed across time. The interaction between *Time* and *Assimilation Type at T0* was not significant, $F(5.12, 464.53) = 0.61$, $p = .695$. Tukey HSD post-hoc comparisons indicated that SC assimilations were discriminated less accurately than TC assimilations, M_{diff} = -18.06%, *p* = .001, *SE* = 4.67%, 95% confidence interval (CI) = -30.14 to -5.98%, UC assimilations, M_{diff} = -12.47%, *p* = .008, *SE* = 3.87%, 95% CI = -22.48 to -2.46%, and UU assimilations, M_{diff} = -10.14%, *p* = .044, *SE* = 3.85%, 95% CI = -20.08 to -0.20%. There were no significant differences among the discrimination accuracy scores for TC, UC, and UU assimilations. This may be summarised as: {TC/UC/UU} > SC.

8.3.3 Effect of the six factors on discrimination accuracy

A separate standard multiple regression analysis was conducted at T0, T1, and T2 in order to examine the relationship between the six predictors on the discrimination accuracy of the preferred L1/L2 assimilation types. It was not possible to run a single multiple regression analysis with the T0 assimilations as a baseline and with *Time* as a factor as in the analysis reported above. As already discussed in Section 8.2.1, three out of the six variables remain constant over time (i.e., age of FLA, AoI, length of EFL) and the values for the other three predictors varied (i.e., LoR, L2 vocabulary size, L2 use). If a single multiple regression analysis were run, in addition to the values of the six variables at T0, the values for the three varying factors at both T1 and T2 would need to be added to the regression model, resulting in 12 factors in total in a single model. This would require a sample size of least 116 (Tabachnick & Fidell, 2007) or 180 (Stevens, 2009). Therefore, there was insufficient statistical power given that the sample size was already relatively small (*N* = 31) for a multiple regression analysis. It was necessary to interpret the regression analyses with caution.

Table 8.4 shows the bivariate Pearson correlation coefficients between the mean percent discrimination accuracy scores for each preferred L1/L2 assimilation type with each of the six factors at T0, T1, and T2. Discrimination accuracy for TC and SC assimilations was not significantly correlated with any of the variables, except at T0 where a shorter LoR was correlated with more accurate discrimination for TC assimilations, and T2, whereby a younger AoI was associated with more accurate discrimination for SC contrasts. Both UC and UU assimilations yielded a larger number of significant correlations, particularly at T0.

Table 8.4: *Bivariate Pearson correlations between the mean percent discrimination accuracy scores for each preferred L1/L2 assimilation type with each of the six predictor variables for T0, T1, and T2*

Variables	T0				T1				T2			
	SC	TC	UC	UU	SC	TC	UC	UU	SC	TC	UC	UU
% Disc. Acc.	69	88	80	79	69	91	83	78	78	90	83	75
Age of FLA onset	0.00	-0.16	-0.48**	-0.33**	-0.02	-0.01	-0.15	-0.09	0.20	-0.28	-0.05	-0.19*
Age of immersion	-0.32	-0.05	-0.22*	-0.15	0.11	-0.05	0.04	-0.02	-0.45*	-0.02	0.08	0.04
English FLA instruction	-0.06	0.14	0.44**	0.31**	-0.08	0.18	0.20*	0.15	0.11	0.07	0.25**	0.09
Length of residence	-0.32	-0.42*	-0.43**	-0.26**	-0.37	0.01	-0.19*	-0.18*	-0.22	0.07	-0.20*	-0.06
Proportion of L2 use	-0.22	0.00	0.28**	0.11	-0.20	0.01	-0.12	-0.02	0.30	0.29	0.06	0.29**
L2 vocabulary size	-0.14	0.33	0.43**	0.11	0.34	0.12	0.29**	0.12	0.20	-0.09	0.45**	0.29**

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

To examine whether variability in discrimination accuracy for a given assimilation type can be accounted for by any of the six factors, separate multiple regression analyses were run for each preferred L1/L2 assimilation type. Similar to the binomial logistic regression (see Section 8.2.1), an exploratory standard multiple regression was conducted at T0 with all of the six factors entered simultaneously into the model. At T1 and T2, a hierarchical multiple regression was performed in which the factors were entered into the model in steps, with the three varying factors (i.e., LoR, L2 vocabulary size, L2 use) entered at Step 1 and the constant factors (i.e., age of FLA, AoI, length of EFL) entered at Step 2.

At T0, discrimination accuracy for UC assimilations was predicted by the variables, $F(6, 104) = 8.46$, $p < .001$, and accounted for approximately 32.8% of the variance (R = 57.3%, adjusted R^2 = 29.9%). The model revealed that the younger the age of FLA, the more accurately the UC contrasts were discriminated. Discrimination accuracy for UU assimilations was also significantly predicted by the variables, $F(6, 118) = 3.48$, $p = .003$, and accounted for approximately 15% of the variance (R = 38.8%, adjusted R^2 = 10.7%). The younger the age of FLA, the higher the discrimination accuracy.

At T1, the variables predicted discrimination accuracy only for UC assimilations. In the first step of the hierarchical multiple regression with the varying predictors entered first, the model was statistically significant, $F(3, 110) = 4.02$, $p = .009$, and accounted for 9.9% of the variance (R = 31%, adjusted R^2 = 7.4%) in discrimination accuracy. Only L2 vocabulary size made a significant unique contribution to the model, with a larger L2 vocabulary size associated with higher discrimination accuracy ($\beta = .31$, $p = .019$). Entering the constant factors at Step 2, the total variance explained by the full model was 11.4% (R = 33.8%, adjusted R^2 =

6.4%), $F(6, 107) = 2.30$, $p = .04$. The introduction of the constant variables explained an additional 1.5% of the variance in discrimination accuracy after controlling for the varying factors, although this was not a significant contribution, $F(3, 107) = 0.61$, $p = .61$. That is, none of the constant factors explained any additional variance in discrimination accuracy.

At T2, the variables predicted discrimination accuracy for SC, UC, and UU assimilations. For SC assimilations, when the varying factors were entered first, the model was not significant, $F(3, 16) = 1.29$, $p = .311$. At Step 2, the model was significant, $F(6, 13) = 4.25$, $p = .014$, and accounted for 66.2% of the variance (R = 81.4%, adjusted R^2 = 50.6%) in discrimination accuracy of the entire model. A younger AoI predicted high discrimination accuracy scores ($\beta = -.823$, $p = .003$), while a longer LoR ($\beta = -.46$, $p = .025$) and an older age of FLA ($\beta = .70$, $p = .007$) predicted poorer discrimination accuracy.

For UC assimilations, the model was statistically significant when the varying predictors were entered first, $F(3, 105) = 9.15$, $p < .001$, and those variables accounted for 20.7% of the variance (R = 45.5%, adjusted R^2 = 18.5%) in discrimination accuracy. A large L2 vocabulary size predicted high discrimination accuracy scores ($\beta = .48$, $p < .001$). At Step 2, with the constant factors now entered into the model, an additional 4.7% of the variance was accounted for, but this was not significant, $F(3, 102) = 2.14$, $p = .099$.

For UU assimilations, the model was statistically significant when the varying predictors were entered first, $F(3, 113) = 6.11$, $p = .001$, and the varying factors accounted for 14% of the variance (R = 37.4%, adjusted R^2 = 11.7%) in discrimination accuracy. Both high L2 use ($\beta = .23$, $p = .014$) and L2 vocabulary size ($\beta = .27$, $p = .008$) predicted high discrimination accuracy scores. With the addition of the constant factors at Step 2, the overall variance explained was 30.4% (*R* = 55.1%, adjusted R^2 = 26.6%), $F(6, 110) = 8.00$, $p < .001$. The additional variance explained at Step 2 was 16.7%, $F(3, 110) = 8.64$, $p < .001$. All of the variables predicted discrimination accuracy, except for LoR. Again, the greater the L2 use (β = .36, $p < .001$) and L2 vocabulary size (β = .53, $p < .001$), the higher the discrimination accuracy. Also, a younger age of FLA (β = -.29, $p = .032$), an older AoI (β = .44, $p < .001$), and a smaller duration of EFL training (β = -.35, $p = .012$), were associated with higher accuracy for UU contrasts were discriminated.

A summary of the results of the multiple regression analyses for T0, T1, and T2 is presented in Table 8.5. The presence of the pointing arrows in the cells indicate that discrimination accuracy is predicted by a particular preferred L1/L2 assimilation type. The direction of the arrows reflects the direction of the prediction. More specifically, arrows pointing up indicate that a *higher* value predicts accurate discrimination, while arrows pointing down indicate that a *lower* value predicts accurate discrimination.

Table 8.5: *Summary of the multiple regression analyses of the factors that predicted discrimination accuracy scores for each preferred L1/L2 assimilation type T0, T1, and T2*

Variable	T0		T1	T2		
	UC	UU	UC	SC	UC	UU
Age at FLA onset	↓	↓		↑		↓
Age of immersion				↓		↑
English FLA instruction						↓
Length of residence				↓		
Proportion of L2 use						↑
L2 vocabulary size			↑		↑	↑

At each time point, discrimination accuracy for the preferred L1/L2 assimilations types that were found to be predicted by the factors are displayed.
↑ = a *higher* value predicted *accurate* discrimination (e.g., ↑ L2 vocabulary size predicted accurate discrimination for UC assimilations at T1 and T2).
↓ = a *lower* value predicted *accurate* discrimination (e.g., ↓ age of FLA onset predicted accurate discrimination for UC and UU assimilations at T0).

8.4 Discussion

This experiment examined L2 phonological category acquisition and discrimination over one year of immersion in adult learners, and the role of factors related to L2 acquisition on speech perception. Native EA speakers were tested on their perception of AusE vowel contrasts assimilated as UU and UC.

8.4.1 Summary and evaluation of the research aims

8.4.1.1 New L2 phonological category formation and the role of the six factors in predicting category acquisition

The first aim was to assess L2 phonological category formation and the role of the six variables in predicting category formation. It was predicted that there would be an increase in the number of L2 phonological vowel categories acquired over the course of this longitudinal study if a plateau in L2 learning had not yet been reached. In this study, category formation was operationally defined as instances whereby an L2 vowel was assimilated as uncategorised in the L1, but categorised in the L2. When this was examined on the group perceptual assimilation patterns, there was no L2 perceptual learning. Similarly, in examining individual participants' perceptual assimilations, the percentage of category formation was found to be relatively stable across time (i.e., T0 = 14%; T1 = 12%; T2 = 13%). The hypothesis was not supported. The consistency in the number of new vowel categories acquired over the course of this longitudinal study suggests that the learners may have already reached a plateau in L2 perceptual learning prior to immersion.

Since the participants differed on a number of factors related to L2 experience, six factors were taken into account to determine whether they predicted new category formation. It was predicted that category formation would be influenced to some extent by the six factors. For PAM-L2, L2 vocabulary expansion is predicted play an important role in category formation. The findings from Bundgaard-Nielsen et al. (2011a) suggested that L2 vocabulary expansion is associated with new category acquisition, despite the learners having already acquired a large L2 vocabulary at the time of L2 immersion. In the present study, a larger L2 vocabulary size was associated with category acquisition at T0, T1, and T2. The vocabulary size for an average native English adult is approximately 20000 words (Nation & Waring, 1997). The learners in this study had a relatively high L2 vocabulary size at T0, averaging at approximately 9000 words per million over across the three sessions, so there remains room for vocabulary expansion and possibly category formation.

8.4.1.2 Examining changes in discrimination accuracy over time

The second research aim was to determine whether there were any changes in discrimination accuracy over time, as category acquisition should result in improvements in discrimination accuracy for UU and UC assimilations, but should remain stable for TC and SC assimilations (Best & Tyler, 2007). Again, it was predicted that if the learners had not yet reached a plateau in L2 acquisition, improvements in discrimination accuracy across the three testing sessions should be observed. This was first evaluated on the overall group perceptual assimilation patterns. Despite eight vowel contrasts assimilated as UU in the L1 and L2 across all three sessions, there were no improvements in L2 discrimination accuracy over time. This is not consistent with the PAM-L2 prediction.

When discrimination scores were grouped according to individual participants' assimilations as in Tyler et al. (2014), there was still no significant main effect of time, indicating that there were no changes in discrimination accuracy for the preferred L1/L2 assimilations types over time. As with the group analyses, the PAM-L2 predictions for L2 learning were not supported given that discrimination accuracy for UU and UC assimilations did not change over time. According to PAM-L2 and SLM, L2 perceptual learning is predicted to occur rather rapidly during the early stages of acquisition. It is possible that the stability in the percentage of phonological category acquisition and discrimination accuracy scores may be because the learners had already reached a plateau in L2 perceptual learning as they were not absolute beginners at the time of initial testing.

An alternative explanation may be that the learners had not yet reached a plateau in their L2 learning and have yet to develop new categories. Across all three sessions, there were a larger proportion of instances of UU and UC assimilations, compared to relatively few TC and SC assimilations. Similarly, with only 12-14% of instances in which an L2 phone was uncategorised in the L1 but categorised in the L2, it is possible that with increasing immersion experience, uncategorised phones will either be assimilated as categorised to an L1 phoneme, or develop as new categories. While the majority of L2 learning is predicted to occur during the early stages of acquisition, there is no consensus on this cut-off period. Improvements in L2 perceptual learning have been shown to occur over a long period of immersion experience. For example, Japanese learners' discrimination of the English /ɹ/ and /l/ has been shown to improve with increasing L2 experience. Best and Strange (1992) found that Japanese speakers with an average of 18-48 months of L2 immersion experience performed more like native English speakers in their identification and discrimination of the English contrasts /ɹ/-/l/ and /ɹ/-/w/, than those with less than seven months of immersion experience. Similarly, Japanese speakers with an average of 21 years of L2 immersion experience were more accurate in identifying the English

/ɹ/ and /l/ consonants than those with an average of just two years of immersion (Flege, Takagi, & Mann, 1995). While this study contributes to the relatively limited longitudinal studies available on L2 vowel acquisition, it remains to be determined whether the learners in the current investigation would show improvements in L2 perceptual learning beyond one year of immersion. When the varying factors (i.e., LoR, L2 use, L2 vocabulary size) were entered first into the regression models to test whether they made a unique contribution to predicting category formation, at least one or more varying factors significantly predicted category acquisition at T1 and T2. Therefore, with increasing L2 experience, it is possible that L2 categories would be formed. Future studies should consider conducting longitudinal studies that span a considerable period of L2 immersion.

It is interesting to note that the learners had a large L2 vocabulary size at T0, suggesting that they either employed existing L1 categories, or have developed new categories, either of which is required in order to be able to recognise words in the L2 and for distinguishing between minimal pair words. It was surprising then that there was a large proportion of uncategorised assimilations, and that this did not appear to change over time. It is possible that the learners had already acquired new categories, but the L2 categorisation task may have been too difficult for them to be able to indicate their perception of the L2 in relation to the L2 vowel category labels. To overcome this issue, future research may incorporate additional tasks aimed at assessing the learners' ability in distinguishing between minimally contrasting words containing the target L2 phones. Performance on word recognition tasks might suggest that either new categories had been acquired or the L2 had been assimilated to an L1 phoneme.

8.4.1.3 Assessing PAM's predictions of discrimination

While there were no changes in L2 perceptual learning over time, variations in discrimination accuracy as a function of assimilation type were assessed. Based on the PAM predictions for discrimination, discrimination was predicted to be excellent for TC assimilations, very good for CG and UC assimilations, and poor for SC assimilations. Discrimination accuracy was predicted to range from poor to moderate/very good for UU assimilations.

Based on the overall group perceptual assimilation patterns, discrimination accuracy varied among the contrasts, despite there being no differences in assimilation type. For example, the contrasts /æɪ/-/ɑe/, /əʉ/-/ʉː/, and /oː/-/əʉ/ were discriminated more accurately than /ʊ/-/ɔ/, /ɪ/-/e/, /ɪə/-/iː/, and /oː/-/ʉː/, despite all of these contrasts assimilated as UU in both the L1 and the L2. An explanation for the variable discrimination accuracy scores could be that discrimination accuracy of individual contrasts within a given assimilation type varied around a population mean. This is similar to the findings of Experiment 4 (Chapter 7). Alternatively, these differences may be attributed to the high degree of inter-individual differences in perceptual assimilation and discrimination accuracy. As a result, the assessment of discrimination accuracy based on the vowel contrasts was clouded by the variability in individual participants' responses.

Since assimilation types varied across individual participants for a given contrast, individual participants' discrimination scores were grouped together according to the PAM assimilation types, regardless of the contrast as in Tyler et al. (2014). Participants were given the opportunity to perceptually assimilate the L2 vowels to L1 and L2 vowel category labels. Similar to Bohn, Best, Avesani, and Vayra (2011), when the assimilation patterns across the L1 and L2 were compared, there were instances whereby the L2 assimilation patterns indicated that the participants could perceive phonological differences. Therefore, the PAM predictions for discrimination were tested using the preferred L1/L2 assimilations, which take into account both the L1 and L2 perceptual assimilation patterns of each vowel contrast. TC, UC, and UU assimilations were discriminated equally well, and were more accurately discriminated than SC contrasts. Inconsistent with the PAM predictions were that discrimination levels were equally good between TC and UC assimilations. As already mentioned, it is possible that discrimination accuracy for contrast assimilations vary around a population mean, and the distributions of discrimination accuracy for different assimilation types may intersect to some extent. Therefore, the PAM predictions for discrimination are partially supported when discrimination data are analysed according to individual participants' perceptual assimilations.

8.4.1.4 Effect of the six factors on discrimination accuracy

The fourth aim of this study was to assess whether any of the six variables predicted vowel discrimination. It was predicted that a longer LoR, an older age of FLA, a younger AoI, higher use of the L2, a large L2 vocabulary size, and a long period of EFL would influence discrimination levels for UU and UC assimilations, but not for TC and SC assimilations. Note, the relatively small sample size require that the results be interpreted tentatively. Future research should aim for a larger participant sample.

Across all testing sessions, none of the factors reliably predicted discrimination accuracy for TC assimilations. This suggests that it is attunement to the L1 that aids perceivers in discriminating TC contrasts, which is consistent with the PAM/PAM-L2 framework. As hypothesised, the factors played a role in predicting discrimination accuracy for UU and UC assimilations. A large L2 vocabulary size predicted discrimination accuracy for UC assimilations only at T1 and for both UC and UU assimilations at T2. This is consistent with PAM-L2 and with the results from Bundgaard-Nielsen et al. (2011b). It is interesting to note that L2 vocabulary size also emerged as a significant predictor for category acquisition at T0, T1, and T2. Overall, this suggests that a large L2 vocabulary size predicts new category acquisition.

The results also revealed that a younger age of FLA predicted high discrimination accuracy scores for UC and UU assimilations at T0, and for UU assimilations at T2. This stands in contrast with studies examining the age effects of FLA, in which it is generally found that L2 speech perception is more accurate the older the age of FLA (e.g., Fullana, 2006; García-Lecumberri & Gallardo, 2003; Jia et al., 2006). Instead, this finding appears to be consistent with research on SLA that show a younger learner advantage in L2 acquisition. Language learning context aside, this younger learner advantage may be attributed to the state of development of the L1 phonological system at the time of L2 acquisition. If acquisition occurs in the early stages of language development, before the L1 phonological system is fully formed, L1 interference should be minimal, as is the case of early, rather than late, L2 learners (e.g., Sebastián-Gallés, Echeverría, & Bosch, 2005). Generally, the more developed the L1 phonological system, the greater its influence on L2 acquisition. This explanation is consistent with models of L2 acquisition such as PAM-L2 and SLM.

For SC contrasts, a younger age of immersion predicted accurate discrimination, but discrimination became worse for participants who had a longer length of residence, which is inconsistent with findings from some of previous research (e.g., Flege, Bohn, et al., 1997; Flege & Liu, 2001), but, is consistent with PAM-L2 and SLM. Additional exposure will only serve to consolidate the perceived similarity of the L2 phones to the L1 category, and so other instances of minimally contrasting words containing those L2 phones will fail to be distinguished. This is likely to cause word recognition difficulties in that language (e.g., Broersma & Cutler, 2008; Pallier, Colomé, & Sebastián-Gallés, 2001). The relevant phonetic differences that were initially perceived poorly become more difficult to perceive with increasing experience. Therefore, over L2 experience, further L2 phonological development is curtailed as the learner settles on a suboptimal common L1/L2 phonological category. This does not imply that perceptual retuning will not be possible. Rather, it will be difficult for the learner to 'unlearn' the perception of the L2. Therefore, factors related to L2 acquisition help predict discrimination accuracy as a function of the PAM assimilations types.

Many of the remaining results on the influence of the six factors in discrimination performance at T2 were unexpected and not easily interpretable. For example, the older the age of L2 immersion and the shorter the duration of English FLA, the more accurately UU assimilations were discriminated. Perhaps a larger participant sample is required in order to be able to draw reliable conclusions.

While this study examined a number of factors that have been shown to influence L2 speech perception, it is possible that other factors that were not accounted for might have also played a role in predicting L2 discrimination and perceptual assimilation. Some studies have found a relationship between musical training and L2 speech perception (e.g., Arellano & Draper, 1972). For example, in Gottfried (2007), American English speakers with musical training were better than those without musical training in identifying whether a sine-wave tone changed in pitch, and also in identifying the four Mandarin lexical tones. Furthermore, in a same-different discrimination task using different combinations of the four Mandarin tones, discrimination accuracy was significantly higher for those with musical experience than those without musical training. These findings seem to suggest that those with musical experience become more sensitive to phonetic differences in non-native speech. Another factor that may influence L2 speech perception is the quality of L2 exposure received during immersion. L2 learners with a similar LoR have been shown to differ based the amount of L2 input received, particularly from native speakers of the L2 (Flege & Liu, 2001). Furthermore, early-learners typically outperform late-learners in their perception of the L2, presumably because child immigrants are enrolled in schools and receive quality L2 input from native speakers (Jia et al., 2006). Quality of L2 input was not included as a factor as it is difficult to quantify.

8.4.2 Limitations and directions for future research

This study provided an initial investigation into the acquisition of phonological categories for uncategorised phones. For PAM-L2, the presence of perceived phonological overlap is also predicted to influence L2 category formation. In the current study, with an insufficient number of repetitions per vowel category, it was not possible to determine the different uncategorised assimilations or the presence of perceived phonological overlap for individual participants. PAM-L2 predicts that new categories are more likely to be acquired for non-overlapping L2 contrasts, than for those that overlap with the same L1 categories. The effects of overlap on L2 learning outcomes it yet to be determined. Due to individual variability in perceptual assimilations, future research should increase the number of stimulus tokens in order to be able to assess the role of overlap on L2 learning.

The analyses conducted were based on individual participants’ data. This was due to the high degree of inter-individual variability in the perceptual assimilation of the L2 vowels. In fact, even native speakers of English have been shown to be inconsistent in their perceptual assimilation of vowels from other regional accents of English (e.g., Best, Shaw, Docherty, et al., 2015; Best, Shaw, Mulak, et al., 2015). This may be attributed to the unique nature of vowels, whereby their category boundaries are more fluid than those of consonants, and are perceived less categorically than consonants (e.g., Fry, Abramson, Eimas, & Liberman, 1962; Stevens, Liberman, Studdert-Kennedy, & Ohman, 1969). This variability may also be due to the differences in L2 experience among the learners. In their current state, PAM and PAM-L2 do not consider individual variability in perceptual assimilation, although the results from this study suggest that it may be important to account for it.

Another common finding in the results was that the learners had a large vocabulary in the L2, yet there were many uncategorised assimilations in both the L1 and L2 assimilation tasks. One possibility may be that the categorisation tasks were too difficult. More specifically, there were a large number of vowel category response labels for participants to select from in the L1 EA perceptual assimilation task (24 labels) and in the L2 AusE identification task (18 labels). Furthermore, Strange and Shafer (2008) argue that the L2 task may be particularly difficult for L2 learners with poor L2 reading proficiency. This task was administered as part of a whole-system approach and because it allowed for inferences to be made about new category acquisition. It is possible that the learners had already acquired new categories, but they responded randomly in the L2 identification task because they did not have the phonological awareness to be able to indicate their phonological knowledge. Unlike in the experiments reported in Chapter 7, a familiarisation task was not included in this study. The familiarisation task in those experiments helped make the participants aware of the vowels sounds in the keywords that would later be used in the perceptual assimilation task. The reason it was not included in this study was because the duration of the experiment was already relatively long and a familiarisation task for both the Arabic and English keywords would further extend the duration of the testing sessions. Instead, with the guidance of the experimenter, the participants were given the opportunity to familiarise themselves with both sets of keywords. It is possible that the lack of a familiarisation task may have contributed to the high degree of variability in the perceptual assimilation to the L1 and the L2 vowel category labels. Perhaps an intensive familiarisation phase may be included in future studies to ensure that the learners are familiar with the target vowels in the keywords. Alternatively, L2 acquisition may instead be examined in learners who are acquiring an L2 with vowels that are more transparent in the orthography than they are in English, or as already suggested, alternative tasks may be used to assess the time course for word recognition of words containing the target L2 phones.

There may be systematic errors made by the L2 learners in the discrimination of the AusE vowel contrasts. Using a simpler task, such as an AX discrimination task, may have helped provide insight into the types of errors that the L2 learners are making. While studies in support of PAM have used an AXB discrimination task as a bias-free measure and to maximise the opportunity for perceivers to detect differences between contrasting non-native phones, in an L2 acquisition context, there may be a benefit in teasing apart whether learners have equal difficulty detecting phonological difference (different trials in an AX paradigm) as they do hearing through irrelevant variation (same trials in an AX paradigm). This is a possible avenue of investigation for future research into L2 speech perception.

8.4.3 Summary

In summary, the consistency in the number of new vowel categories acquired and discrimination accuracy suggest that no new L2 vowel categories had been acquired over the course of this longitudinal study. Possible explanations were that the learners had already previously reached a plateau in L2 perceptual learning, or that a longer period of L2 immersion may be required to determine whether the learners would develop new categories. Despite the high degree of inter-individual variability in L2 vowel perceptual assimilations, the PAM-L2 predictions for discrimination were supported. Results revealed that discrimination accuracy was influenced by the six factors, but this was dependent upon assimilation type. For instance, none of the factors reliably predicted discrimination accuracy for TC assimilations. However, the factors predicted discrimination accuracy predominantly for UU and UC assimilations. L2 vocabulary size consistently predicted both category acquisition and discrimination accuracy over time. This study has provided an initial investigation into the acquisition of phonological vowel categories. The findings from this study may be extended by future research. Further studies on L2 acquisition are recommended that test the PAM-L2 and SLM predictions. One possible area of investigation that was suggested was to determine the role of the presence of overlap in category formation.

CHAPTER 9

GENERAL DISCUSSION AND CONCLUSIONS

CHAPTER 9: GENERAL DISCUSSION AND CONCLUSIONS

This thesis presented a systematic examination of the perceptual assimilation, discrimination, and acquisition of uncategorised non-native/L2 vowels. The empirical findings have provided much-needed data on the perception of uncategorised phones, and they also have implications for models of cross-language and L2 speech perception. This thesis presented five experiments, incorporating two new stimulus sets, which consisted of the whole AusE and Danish vowel systems produced by multiple speakers. The aim of Experiment 1 (Chapter 6) was to test whether uncategorised non-native vowels vary in the way that they are assimilated to the L1 phonological system. Experiments 2-4 (Chapter 7) investigated discrimination accuracy for non-native monophthong and diphthong vowel contrasts involving at least one uncategorised phone, and the influence of perceived phonological overlap in predicting discrimination accuracy. Experiment 5 (Chapter 8) was a longitudinal study that examined both the acquisition of uncategorised vowels by adults in an immersion environment, and the role of individual differences in predicting learning outcomes. In this final chapter, a summary of the empirical findings of each experiment will be provided, followed by an evaluation of the theoretical implications. Broader issues and patterns in the results across all of the experiments, methodological advancements, limitations of the current studies, and directions for future research, will also be discussed.

9.1 Evaluation of the findings

The first aim of this thesis was to investigate whether there are different ways in which non-native phones may be assimilated as uncategorised. This issue was evaluated in Experiment 1 (Chapter 6). Based on the perceptual assimilation patterns observed from previous cross-language speech perception studies, it was predicted that uncategorised non-native vowels may be perceived as predominantly similar to a single L1 phonological vowel category (*focalised*), perceived as similar to two or more L1 vowel categories (*clustered*), or unlike any of the L1 phonemic categories (*dispersed*). Native Egyptian Arabic (EA) speakers categorised and rated all of the Australian English (AusE) vowels in relation to all of their L1 vowel categories. In support of the hypothesis, the perceptual assimilation results supported the three uncategorised assimilation types. This finding suggests that there are systematic differences in the ways in which uncategorised phones are assimilated to the L1 phonological system and in the extent to which they are identified with L1 vowels.

Having demonstrated that *individual* phones vary in how they are assimilated as uncategorised, the second aim was to determine how well *pairs* of non-native phones may be discriminated when one or both are uncategorised, and what factors might influence discrimination accuracy. PAM predicts that discrimination accuracy will be very good for UC assimilations, but may range from poor to moderate/very good for UU assimilations, depending on the phonetic distance between the two phones to one another and to native categories (Best, 1995). Indirect evidence from previous cross-language speech perception research suggests that discrimination accuracy may be influenced by the presence of overlap in the categorisations to L1 vowels (e.g., Bohn et al., 2011; Flege & MacKay, 2004; Levy, 2009b; Sisinni & Grimaldi, 2009; Tyler et al., 2014). For both UC and UU assimilations, it was hypothesised that the presence of overlap between the L1 categorisations would result in contrasts being less accurately discriminated, than if there were no overlap. This issue was addressed in Experiments 2-4 (Chapter 6). The purpose of Experiment 2 was to establish how AusE speakers perceptually assimilate the Danish vowels to their L1 vowel categories. The results were used to select monophthongal and diphthongal vowel contrasts varying in overlap for Experiments 3 and 4, respectively. Discrimination accuracy for partially overlapping and non-overlapping UC and UU assimilations was compared with accuracy for TC and SC assimilations. Excellent discrimination was observed for TC contrasts and for non-overlapping UC and UU assimilations, while discrimination for partially overlapping contrasts was relatively less accurate, and sometimes as poor as for SC assimilations. Therefore, the results supported the hypothesis and revealed that the presence or absence of overlap affects discrimination accuracy. By taking into account the different uncategorised assimilations and their overlap to L1 categories, more accurate predictions for discrimination may be made for UC and UU assimilations, than if overlap were not considered.

The third aim of the present thesis was to examine the acquisition of uncategorised phones by L2 learners. According to PAM-L2 and SLM, new L2 category formation is more likely to occur for L2 phones that are perceived as being unlike any particular L1 category, than those that are identified with an existing L1 phoneme. In Experiment 5 (Chapter 8), adult L2 learners in an immersion environment were recruited for a 1-year longitudinal study. The EA speakers were tested on their perception of AusE UU and UC vowel contrasts (as established in Experiment 1). It was hypothesised that, if a plateau in L2 perceptual learning had not yet occurred, new categories may be acquired and that this should result in improvements in discrimination accuracy over time. This hypothesis was not supported, as there was no evidence to suggest that L2 phonological categories had been acquired over the course of this immersion period. Discrimination accuracy scores were also consistent across time. It is possible that the learners had reached a plateau in their L2 learning, or that a longer period of immersion may be required to determine whether the learners would continue to make progress.

As the learners were not absolute beginners, it was possible to investigate the influence of six factors related to L2 acquisition on variability in learning outcomes across the sample (i.e., length of residence, age of FLA, age of immersion, proportion of L2 use, L2 vocabulary size, and duration of English as a foreign language training). The six factors were all expected to predict category formation and discrimination accuracy to some extent, particularly for assimilation types involving at least one uncategorised vowel. In line with this hypothesis, the factors predicted discrimination accuracy predominantly for UU and UC assimilations.

9.2 Theoretical implications of the findings

9.2.1 Implications for PAM

The findings have implications for PAM in terms of its conceptualisation of uncategorised assimilations. Best (1995) identified uncategorised assimilations as instances in which non-native phones are assimilated to the L1 phonological space but in between L1 categories. The results from Experiment 1 demonstrated that uncategorised vowels may be perceived as predominantly similar to a single L1 phonological category (*focalised*), to two or more L1 phonological categories (*clustered*), or as unlike any of the L1 phonemes (*dispersed*). In the same way that PAM differentiates between phones assimilated as categorised (i.e., good, acceptable, or deviant exemplar of the L1 category), Experiment 1 revealed that uncategorised phones also vary in how they are perceived in relation to L1 categories. Therefore, the PAM definition for uncategorised assimilations needs to be revised in order to take into account the three uncategorised assimilations. Based on the current findings, Best's (1994, 1995) conceptualisation of an uncategorised assimilation may be redefined as a non-native segment that is perceived as speech, but its gestural properties may modestly resemble a single L1 phoneme, multiple L1 phonemes, or may be discrepant from any L1 phonemes.

According to PAM, perceivers employ both fine-grained phonetic information and higher-order phonological information when listening to non-native/L2 speech (Best, 1995). When non-native/L2 phones are identified with L1 phonological categories (i.e., assimilated as categorised to an L1 phoneme), it can be inferred that listeners detect phonological similarities between the non-native and native phones. It is difficult to draw inferences about the type of information that is detected by listeners for uncategorised assimilations because they are simply described as phones that are assimilated to the L1 phonological space but in between L1 categories. By identifying the specific uncategorised assimilation types introduced in the present thesis, it is now possible to infer how listeners make use of phonological and phonetic information. As non-native phones assimilated as *focalised* and *clustered* are perceived as similar to one versus to more native phonological categories, respectively, it can be inferred that listeners detect phonological information in those contrasts. Conversely, given that phones that are assimilated as *dispersed* are perceived as being unlike any of the L1 phonological categories, listeners must detect fine-grained phonetic features rather than phonological information. Thus, the findings of this thesis support the idea that listeners make use of both phonological and phonetic information when perceiving uncategorised phones, but that this is dependent upon the specific uncategorised assimilation, with phonological information detected for *focalised* and *clustered* assimilations, but phonetic when they are *dispersed*.

The results of the current experiments are also consistent with the PAM proposal that non-native phones are perceived in terms of their articulatory similarities and differences to L1 phonemes, such that the greater the articulatory differences, the more phonetically distant they are from native phonemes (Best, 1995; Best et al., 2016). Vowels that were assimilated as *focalised* and *clustered* shared phonetic-articulatory features (i.e., tongue height, tongue backness, lip rounding) with the closest L1 vowel phoneme/s. For example, in Experiment 1, the AusE /ʊ/ was assimilated as *focalised* to the EA /u/, and both are rounded, high, back vowels. Similarly, the *clustered* AusE vowels /æ/ and /ɐ/ were both perceived as similar to the EA vowels /a/ and /aː/, which share similar tongue height, and are also unrounded. On the other hand, as *dispersed* phones are perceived as being unlike any of the L1 phonemes, they are phonetically distinct from L1 vowels. For instance, in Experiment 1, the *dispersed* AusE /oɪ/ and /ɜː/ do not have phonetically similar counterparts in the L1 EA.

The PAM predictions for discrimination were supported in Experiments 3-5. These findings are also consistent with previous studies that tested the PAM predictions using consonants (e.g., Best et al., 2001; Best & Strange, 1992; Halle et al., 1999; Polka, 1991). With relatively fewer studies using vowels than consonants, a recent study by Tyler, Best, Faber, and Levitt (2014) established that the PAM predictions also apply for vowel contrasts. There was a high degree of inter-individual variability in perceptual assimilation, possibly due to the small sample size. As a result, the PAM predictions were assessed by grouping discrimination accuracy scores according to individual participants' assimilations, instead of by contrast. With a larger sample size, Experiments 3 and 4 tested the PAM predictions according to the group perceptual assimilation patterns. These results provide further support for PAM based on group perceptual assimilation patterns using both monophthongal and diphthongal vowel contrasts.

The current findings also have implications for the PAM discrimination predictions for non-native vowel contrasts assimilated as UU and UC (Best, 1995). Discrimination accuracy for UU assimilations is predicted to range from poor to moderate/very good depending on the similarity of the two phones to one another and to native categories. It is therefore difficult to make specific predictions for UU assimilations, or to rank order their discrimination accuracy with the other PAM assimilations. While PAM predicts very good discrimination for contrasts assimilated as UC, because they also involve an uncategorised phone, based on the various uncategorised assimilations, it was argued that it might also be possible to further fine-tune this discrimination prediction. By taking into account the presence of perceived phonological overlap in the L1 categorisations, more precise predictions for discrimination were made for UU and UC assimilations. Discrimination was hypothesised to be excellent for non-overlapping contrasts, followed by partially overlapping, and completely overlapping contrasts. Contrary to the prediction made by Best (1995), discrimination accuracy was found to be poor for UC assimilations when the contrasts are partially overlapping. In fact, this type of contrast was discriminated as poorly as the SC contrast in Experiment 3. Similarly, excellent discrimination was observed for both UU-N and TC assimilations, but discrimination was relatively poorer for UU-P assimilations (Experiment 3 and 4). Therefore, by accounting for the presence or absence of perceived phonological overlap, it is possible to formulate specific and testable predictions for complete, partial, and non-overlapping UU and UC assimilations. It also becomes possible to compare their discrimination levels relative to the other PAM assimilations. As there were no instances of completely overlapping contrasts in Experiments 3 and 4, it is yet to be empirically determined how discrimination performance will compare with non-overlapping and partially overlapping contrasts. Future research should confirm these new discrimination predictions on contrasts that are completely overlapping, partially overlapping, and non-overlapping.

The question that then arises is what might contribute to contrasts being classified as overlapping, partially overlapping, or non-overlapping. The number of articulatory-phonetic features shared between non-native phones and L1 phonemes may be a possible factor. Non-overlapping vowel contrasts differed on a larger number of articulatory-phonetic features than the partially overlapping vowel contrasts (Experiment 3 and 4). For instance, in Experiment 3, the UU-N Danish contrast /ɛ/-/o/ was the most accurately discriminated of the contrasts, possibly because these vowels differed on two articulatory-phonetic features (i.e., tongue backness and lip rounding) in comparison to the other contrasts, which differed on only one such feature. Similarly, in Experiment 4, the number of articulatory-phonetic differences between contrasting Danish diphthongs were related to discrimination accuracy performance. For example, the contrast /oʌ/-/iw/ was assimilated as UC-N, and both the onset and offset of each vowel differed on tongue height, backness, and lip rounding. On the other hand, for the vowels in the UC-P contrast /uʌ/-/oʌ/, the onset vowels differed only in tongue height and the offset vowels were identical. Articulatory features might help explain the differences in discrimination accuracy for contrasts varying in the presence of overlap. The non-overlapping contrasts were discriminated more accurately than the partially overlapping contrasts. It is interesting and of potential importance to theories of L2 speech learning that the extent of the phonetic-articulatory distance between contrasting vowels provides some indication about the absence versus presence of perceived *phonological* overlap.

The focus of this thesis was on perceived phonological overlap of *focalised* and *clustered* uncategorised assimilations. It was argued that listeners detect only phonetic information for non-native phones assimilated as *dispersed*. For contrasts involving at least one *dispersed* vowel (i.e., *dispersed-dispersed* or *dispersed-focalised*/*clustered*), there may be perceived *phonetic* overlap. Unlike perceived phonological overlap, the articulatory-phonetic features detected for contrasts involving *dispersed* phones may be fine-grained articulatory features that are not lexically meaningful in the L1. Discrimination based on perceived phonetic overlap is predicted to range from moderate to excellent, depending on the phonetic similarity of the non-native vowels. The greater the presence of phonetic overlap, the less accurately such contrasts will be discriminated. Further tests are necessary to establish discrimination accuracy levels for contrasts composed of phones assimilated as *dispersed*.

To differentiate between uncategorised and categorised assimilations, an arbitrary 50% assimilation criterion was employed in all of the experiments reported in this thesis (Bundgaard-Nielsen, Best, & Tyler, 2011a, 2011b). Non-native/L2 vowels that were identified as an L1 or L2 vowel response category label more than 50% of the time were deemed categorised, while responses below this threshold were regarded as being uncategorised. However, the use of an arbitrary assimilation criterion may be problematic when categorisation responses are just below the predefined threshold. Borderline cases would be encountered when assigning a continuous measure (mean percent categorisation responses) to a set of discrete labels (categorised vs. uncategorised). In Experiment 1, the AusE /iː/ was deemed to be uncategorised *focalised* because it was assimilated to the EA /iː/ 49% of the time. Similarly, in Experiment 4, the Danish /ɒw/ was assimilated to the AusE /ɔ/ at 49%, and again, was deemed uncategorised, despite being selected more often than chance. These cases call into question the suitability of a predefined arbitrary categorisation criterion because a non-native/L2 phone that is assimilated at 51% is unlikely to be perceived differently in any substantial or substantive way than if it were assimilated at 49%.

Alternative methods for determining categorisation might better account for perceptual assimilation data. One possible solution might be for tests against chance to be employed for determining whether phones are assimilated as categorised versus uncategorised. Categorised assimilations may be identified as instances in which a given category response label is selected significantly above chance, and that this label is chosen significantly more often than any other label. If both criteria are not met, then the non-native/L2 phone would be deemed uncategorised. *Focalised* assimilations may be those where only one category label is selected above chance, but that label was not selected significantly more often than any other label. *Clustered* assimilations would be identified as those where several response categories are selected above chance, and do not significantly differ from each other, but differ from the remaining below-chance responses. *Dispersed* assimilations would be regarded as those in which no label is selected above chance. This approach might help resolve some other issues related with the use of an arbitrary assimilation threshold. For example, in Experiment 2, there were instances whereby a Danish vowel was categorised above the 50% criterion, but another response category was selected above chance for this same Danish vowel. Further research should assess whether other methods might better account for perceptual assimilation responses.

9.2.2 Implications for PAM-L2 and SLM

PAM-L2 and SLM predict that new categories are more likely to be acquired for uncategorised than categorised L2 phones, particularly during the early stages of learning. To date, there had been no systematic or thorough investigation on the acquisition of uncategorised phones. Contrary to the models' predictions, no evidence was found to suggest new categories had been formed over a one-year immersion period. This may be because the learners were not beginners and so they had already reached a plateau in perceptual learning in relation to achieving a critical level of L2 vocabulary, as proposed by Best and Tyler (2007). An English vocabulary size of 6000-7000 words is needed to be able to comprehend spoken conversational English (Nation, 2006). The learners in the study by Bundgaard-Nielsen, Best, Kroos, and Tyler (2011) were split into low- versus high-vocabulary based on this 6000-word threshold. The average L2 vocabulary size of the learners in Experiment 5 was 9000 words, which is much higher than this cut-off. Unlike in Bundgaard-Nielsen and colleagues, L2 vocabulary size was assessed using a translated bilingual version of the Nation and Beglar (2007) vocabulary size test. The bilingual versions have been shown to result in higher estimates than non-translated versions as they avoid difficult grammar of the L2 definitions and L2 reading skills (Elgort, 2011). This may explain the comparatively higher average L2 vocabulary size of the learners in Experiment 5 than those in the study by Bundgaard-Nielsen and colleagues. However, even if a non-translated version of the test were employed, the average L2 vocabulary size is still likely to surpass the 6000-word threshold.[11] Categories are required to recognise words in the L2, and for distinguishing between minimally contrasting lexical items. With an already large L2 vocabulary size at T0, the learners in Experiment 5 would have been expected to have already developed new L2 categories or to categorise L2 vowels to existing L1 vowel categories. However, this was not the case as there was a large proportion of uncategorised assimilations at T0 and the number of uncategorised phones remained relatively unchanged over time. The question then raised is why there are many L2 phones assimilated as uncategorised when the learners have a large L2 vocabulary size.

Recent findings by Shaw et al. (submitted, 3/2017) may also help shed light as to why the vowels remained uncategorised, despite participants having a large L2 vocabulary size. In line with the PAM framework, Shaw et al. argued that, despite phonetic variation within natural speech, listeners are generally able to assimilate phones to L1 categories. In Experiment 5, listeners were presented with nonsense words containing the target vowels. In the absence of lexical information, listeners may instead rely on other information when parsing speech. Consequently, listeners may fail to commit to a given L1 vowel (i.e., assimilate it as categorised) because they are attempting to resolve the lexical identity of the stimulus, and have redirected their attention from detecting the phonological identity of the stimulus, to detecting speech variation instead. Based on this viewpoint, the uncategorised assimilations (i.e., non-committed assimilations) may be the result of learners focusing their perception on fine-grained phonetic details, rather than on linguistically meaningful information.

[11] Bilingual versions of the tests result in scores that are approximately 10% higher than those using non-bilingual versions. With an average L2 vocabulary size of 9000 words, the average L2 vocabulary size for the learners in Experiment 5 are estimated to be 8100 words if using the non-bilingual test. This is well above the 6000 word threshold required to understand conversational English spoken language (Nation, 2006).

The large number of uncategorised assimilations may also indicate that the learners have not yet acquired new phonological categories. Previous research has suggested that perceptual learning may occur over a longer period of immersion (Best & Strange, 1992; Flege, Bohn, et al., 1997; Flege, Takagi, et al., 1995). It is possible that one year was insufficient to observe any developmental changes. A longitudinal study that spans a considerable period of immersion is needed in order to help confirm whether perceptual learning occurs rapidly during the early stages of learning as suggested by PAM-L2 and SLM, or whether learners would show improvements in L2 perceptual learning with increasing L2 experience.

As already discussed in Chapter 8, it is also likely that the learners had already acquired new categories, but due to the difficulty of the L2 categorisation task, they may not have had the phonological awareness to be able to indicate their perception of the L2 vowels in relation to the L2 vowel category labels, hence the large number of uncategorised assimilations. Future research on L2 acquisition could include additional tasks aimed at assessing the learners' ability to distinguish between minimally contrasting words containing the target L2 phones. For example, using a visual world eyetracking paradigm, the timecourse of word recognition for lexical items containing phones assimilated as uncategorised may be examined. If the vowel in the target auditory word is uncategorised, it may be reasonable to expect that accuracy would be poor as the listeners are responding randomly, and reaction time may be long as they consider the competitors and fillers during the decision phase. On the other hand, high accuracy scores and a fast response time for spoken L2 words containing target vowels would suggest that either new categories had been acquired or the L2 had been assimilated to an L1 phoneme.

While Experiments 1-4 focused on cross-language speech perception by naïve listeners, their results have implications for L2 acquisition. According to PAM-L2, category formation is more likely to occur for L2 contrasts if they are perceived as similar to a different set of L1 categories, than those that overlap with the same set of L1 categories (Best & Tyler, 2007). The role of perceived phonological overlap on L2 acquisition presents a potential area of investigation for future research, given that our initial investigation, Experiment 5, assessed the acquisition of uncategorised L2 vowels regardless of overlap. Based on the results of Experiment 1, the UU AusE contrast /iː/-/ʉː/ was non-overlapping, as the vowels within this contrast were perceived as different EA vowels, namely, *focalised* assimilation to EA /iː/ vs /uː/, respectively. It is predicted that separate phonological and/or phonetic categories may be formed for these L2 vowels. Conversely, the phones within the UU AusE contrast /iː/-/ɪə/ were perceived as similar to the same L1 vowel, namely, EA /iː/. No new phonological categories are likely to be acquired for these completely overlapping vowels. L2 learning outcomes may also depend upon the presence of perceived phonetic overlap for L2 contrasts composed of at least one *dispersed* vowel (i.e., *dispersed-dispersed* or *dispersed-focalised*/*clustered*).

Aside from the similarities and differences between L1 and L2 phones, PAM-L2 and SLM acknowledge that other factors may also influence L2 acquisition and discrimination. For PAM-L2, factors that may influence L2 learning outcomes include length of L2 residence, relative use of the L1 and L2, and the quantity and quality of the L2 input, and in particular, L2 vocabulary expansion. For both PAM-L2 and SLM, the age of L2 acquisition is predicted to play a central role in new category formation, with younger learners more likely to acquire new categories than older learners. The results of Experiment 5 have implications for both models, as it was demonstrated that six factors related to L2 experience accounted for variability in speech perception and acquisition to some extent:

1) In support of the PAM-L2 principles, a consistent predictor of L2 speech perception was L2 vocabulary size. A large L2 vocabulary size predicted more accurate discrimination for L2 contrasts assimilated as UU and UC, and was associated with new category acquisition across all three time points.
2) A younger age of immersion (category acquisition at T1; discrimination accuracy at T2) and greater use of the L2 (category acquisition at T2) also emerged as significant predictors of category formation and discrimination at T0. These factors are predicted by PAM-L2 to influence perceptual learning.
3) A younger age of FLA onset was associated with more accurate L2 discrimination accuracy for UU and UC assimilations. This is inconsistent with research demonstrating that L2 speech perception is more accurate the older the age of FLA (e.g., Fullana, 2006; García-Lecumberri & Gallardo, 2003; Jia et al., 2006). Rather, the results are in line with those from SLA, which show a younger-learner advantage in speech perception (e.g., Flege et al., 2003; Krebs-Lazendic & Best, 2013; Piske et al., 2002). Language learning context aside, this is consistent with both PAM-L2 and SLM which suggest that the later in life that L2 learning begins, the more established the L1 categories would have become, and thus, L1 attunement will exert an increasing influence on the perception of L2 phones. Previous research demonstrates that L2 speech perception improves with increasing L2 immersion (e.g., Flege, Bohn, et al., 1997; Flege & Liu, 2001).
4) Results in Experiment 5 revealed that, with an increasing length of residence, discrimination became worse for SC contrasts. This finding is in line with both PAM-L2 and SLM. Additional exposure to the L2 may reinforce the perceived

similarity of the L2 phones to the L1 category as other instances of minimal pair words containing those L2 phones will be difficult to discriminate. Phonetic differences that are required to distinguish such pairs of phones will become more difficult to perceive with increasing experience.

5) A longer period of EFL predicted poor discrimination performance for UU assimilations at T2. Based on extrapolations from PAM-L2/SLM, the longer the period of English FLA, the greater the exposure to L1-accented L2 input. This results in the acquisition of an L2 category that is incorrect or different from that of native speakers of that language (Piske et al., 2001).

Therefore, by taking into account individual differences among the learners, it was possible to identify how factors related to L2 acquisition influence category formation and discrimination. Investigations of L2 acquisition must also account for factors that affect learning outcomes.

9.3 Methodological advances, limitations, and future directions

The experiments reported in the present thesis have helped shed light on the perception and acquisition of non-native/L2 vowels assimilated as uncategorised. This section will discuss a number of methodological advances, various limitations of the thesis experiments, and identify ways in which these limitations may be addressed by future research. Other possible avenues for further investigation will also be outlined.

9.3.1 Methodological advances

All of the experiments presented in this thesis employed a whole-vowel-system approach. As in Bundgaard-Nielsen, Best, and Tyler (2011a, 2011b), this involved participants identifying all non-native/L2 monophthong and diphthong vowels from the stimulus language in relation to all of the vowels in their L1 inventory. An added benefit of this is that two new high-quality stimulus sets have been developed consisting of recordings of the whole AusE and Danish vowel system produced by two and three native speakers, respectively. I plan to make these available for use by the scientific community. Focusing on the entire L1 vowel inventory rather than on a subset of it allowed for a more comprehensive assessment of the perceptual assimilation patterns of the non-native/L2 vowels to the L1 vowel system. This approach may be particularly useful with vowels because they are less categorically perceived than consonants and are likely to form an interconnected system. In the L1 perceptual assimilation task in Experiment 5, participants identified L2 vowels with L1 core phonemic *and* allophonic vowel category response labels. While there were no systematic differences in their selection between the two, the allophonic vowels were included to allow the listeners to make more fine-grained selections, and allowed us to discover that they do not consistently make such fine-grained distinctions in this task. Also, the contrasts employed in Experiment 5 were based on the perceptual assimilation patterns of Experiment 1, and the results of Experiment 2 allowed for contrasts to be chosen for Experiment 3 and 4. By using a whole-system approach, there was an opportunity to select a range of contrasts assimilations, which would not have been possible if only a subset of the L1 and non-native/L2 vowels had been used.

To ensure that the Danish vowel stimuli in Chapter 7 were produced as intended, a stimulus verification task was conducted to select the most suitable tokens. This involved obtaining identification and goodness ratings from native Danish speakers on the vowel stimuli. As a result, the tokens for the Danish vowels

/eʌ, ew, øʌ, œw, øw, ə/ were excluded because they were incorrectly produced by one or more by the native speakers. Despite presenting the Danish vowels in keywords to aid the speakers in their pronunciation, it is possible that these vowels have a low functional load in Danish and hence, the speakers found it particularly difficult to produce them in the /ˈhVbə/ nonsense words. This highlights the importance of verifying vowel stimuli from native speakers as it helps ensure that meaningful and valid interpretations of the data are made when non-native/L2 stimuli are used. It is recommended that future cross-language and L2 speech perception research routinely verify stimuli with native speakers, particularly when the vowels from the stimulus language are foreign to the experimenter/s, as was the case in Experiments 2-4.

As reviewed in Chapter 7, methods for measuring overlap had been developed in previous research to help explain variability in discrimination accuracy among non-native contrasts. For example, an overlap score was developed by Flege and MacKay (2004) and Levy (2009) to help account for discrimination accuracy levels of non-native vowel contrasts. Similarly, the overlap method developed by Bohn, Best, Avesani, and Vayra (2011) accounted for overlapping and non-overlapping consonant contrasts assimilated as UC based on individual participants' assimilations. In Experiment 3 and 4 (Chapter 7), a novel approach was developed for determining the presence of perceived phonological overlap in the L1 categorisations. Unlike the overlap method (Flege & MacKay, 2004; Levy, 2009b), assimilation type was also taken into consideration. This was a similar approach to that developed by Bohn et al. (2011).[12] In this thesis, it was argued that focusing on overlap alone might not be sufficient for explaining discrimination accuracy, but that it is also important to

[12] The current approach for determining overlap diverged from the method in Bohn et al. (2011) in that it only considered average percent categorisations to L1 category labels that were selected significantly above chance.

account for assimilation type. The results of Experiments 3 and 4 clearly demonstrate the importance of considering assimilation type, in addition to overlap. The discrimination accuracy results were analysed using the method developed in this thesis and compared against the overlap method (Flege & MacKay, 2004; Levy, 2009b). In Experiment 3, the overlap scores for /oː/-/ɔː/ and /oː/-/uː/ would suggest that they should have differed in discrimination accuracy. However, there was no significant difference in discrimination between these two contrasts. The lack of discrimination difference may instead be due to the fact that both were assimilated as UU-P. It is recommended that future research adopt the approach employed in this thesis in order to provide a more accurate understanding of how perceived phonological overlap predicts discrimination accuracy for non-native/L2 uncategorised phones.

Part of this thesis involved developing an Arabic-English version of the Nation and Beglar (2007) Vocabulary Size Test for use in Experiment 5. The two parallel versions of the test were translated from English to Arabic. A bilingual test was needed because the tests in their original form require knowledge beyond that of L2 vocabulary (i.e., good L2 reading abilities and grammatical knowledge). Although other bilingual versions of the test are available (e.g., Japanese, Korean, and Russian), it was necessary to create an Arabic-English bilingual version. The major challenge in creating an Arabic-English version of the tests was ensuring that the translations were valid. To address this issue, feedback on the translations was obtained from native EA speakers and a focus group consisting of four EA-English bilingual speakers, and the comments were relayed to a professional Arabic-English translator. Paul Nation (one of the developers of the test) was also consulted on multiple occasions regarding the translation process. Therefore, an Arabic-English bilingual version of the two vocabulary size tests is now available for use for future studies, providing a useful tool for measuring L2 English vocabulary size in Arabic speakers.

An interesting finding to emerge from the experiments in Chapter 7 was that the perceptual assimilation patterns differed between Experiment 2 and Experiments 3 and 4. As already mentioned, the results from Experiment 2 were used to select vowel contrasts for Experiments 3 and 4, but the perceptual assimilations were not always the same when the categorisation task was repeated. One possible reason for this is the different experimental contexts. Experiment 2 involved a perceptual assimilation task only, while Experiments 3 and 4 involved a perceptual assimilation task, preceded by a discrimination task. It was decided not to administer the perceptual assimilation task first because labeling the stimuli could bias responding in the discrimination task. Another possible explanation for the experiment difference is that participants were presented with all of the Danish vowels in Experiment 2, but only with a subset of those vowels in Experiments 3 and 4.

Similarly, the perceptual assimilation patterns in Experiment 1 were used to select the contrasts for Experiment 5. The results across the two experiments varied, with many more uncategorised assimilations in Experiment 5, although this was not surprising given the large differences in the experimental conditions (e.g., Experiment 1 was an online study while Experiment 5 was conducted face-to-face). Furthermore, Experiment 5 involved L2 learners who are in an immersion environment, while those in Experiment 1 were naïve listeners residing in Egypt. Despite the few inconsistencies in perceptual assimilation patterns observed, it is recommended that future studies first establish the perceptual assimilations in this way prior to selecting the contrasts to be tested. This helps provide a more accurate estimate of the perceptual assimilation patterns, rather than selecting contrasts based on phonetic similarities and differences alone, which is generally the approach employed in previous studies. This is particularly important when vowels are used as stimuli because of the variability in their perceptual assimilation patterns. Also, some of the stimuli selected were those that were close to the 50% categorisation threshold. For example, in Experiment 2, the Danish vowels /uː/ and /uʌ̯/ were assimilated as categorised at 54% and 50.23%, respectively, but were then uncategorised in Experiments 3 and 4, respectively. If the selected stimuli had been highly categorised, perhaps they would have remained categorised when tested again in Experiments 3 and 4. Therefore, it is also recommended that future studies select stimuli that are categorised well above whichever thresholding procedure is applied.

One novel aspect of this thesis was that an innovative online study was developed in order to collect cross-language speech perception data from participants residing in Egypt (Experiment 1). In addition to being a cost-effective method, it helped ensure that the listeners had minimal exposure to the stimulus language. There were several challenges encountered in the development of this online study. First, it was important that participants would be able to correctly complete the experiment since they did not have the opportunity to ask questions or seek clarification as they would in a laboratory study. To help overcome this issue, simple step-by-step instructions were provided, along with examples using auditory vowel stimuli. Second, because the link to the online study was widely distributed, it was necessary that the final data set was from participants who met the inclusion criteria. Participants completed a background information questionnaire after the completion of the experimental task, and their IP address was also collected to be sure that they were residing in Egypt. Third, it was important that the design of the perceptual assimilation task in the online study mirrored that of Experiments 2-5 as much as possible for consistency and to allow comparisons to be made of the results. There were a number of design features of the online study that made this possible. For instance, to ensure that the participants did not return to previously answered trials, each trial was programmed to disappear right after a response had been made, and it was not possible for them to change their response after it had been made. Fourth, in an attempt to prevent low response rates, the online study was programmed to be compatible with multiple browsers (i.e., Firefox, Google Chrome, or Safari). One unavoidable issue that affected data collection was that, in certain parts of Egypt, the internet bandwidth was very low. While the study was programmed so that responses were automatically saved as they were made, when the internet connection was lost during the experiment, it was not possible to obtain a full data set due to missing responses. Future investigations should consider the target population and their access to the internet as this can affect the final sample size.

9.3.2 Limitations

A limitation of the present project pertains to the recruitment of participants for Experiment 5. The first issue concerns the particular sample of learners recruited. PAM-L2 and SLM predict that category acquisition would be more likely to occur in beginner learners. An ideal sample for Experiment 5 would be EA speakers who have recently migrated to Australia, with no prior exposure to the L2. Some of the methods of recruitment included advertising the study in adult English language learning programs, posting the study on several websites and social media groups, and through snowball sampling. Despite the intention and effort to recruit absolute beginner learners, recruitment of that population was difficult. Instead, the learners varied to some extent on a number of factors related to L2 experience. To test the PAM-L2 and

SLM hypotheses about category acquisition in beginners, perhaps learners acquiring an L2 other than English could be more easily recruited at beginner stages.

The second issue is related to the size of the sample. The regression analyses conducted in Experiment 5 involved predicting L2 category acquisition and discrimination accuracy based on six factors. With six factors, a sample size of at least 90 (Stevens, 2009) or 110 (Tabachnick & Fidell, 2007) would be required to ensure that there was sufficient statistical power for these analyses. Given the available timeframe for this project and the difficulty in recruiting beginner learners, the final sample size was 31. Consequently, the results need to be interpreted with caution.

Another methodological issue concerns the number of stimulus tokens involved in the experiments. Analyses based on individual participants' perceptual assimilation patterns may require a large number of tokens per vowel category, in addition to a large sample size. Following the suggestion in Tyler, Best, Faber, and Levitt (2014), a larger sample size was used in the experiments of this thesis to overcome individual differences in perceptual assimilation for vowels. Forty-eight non-native listeners were recruited for both Experiments 3 and 4, and 31-35 L2 learners in Experiment 5, compared to the 10-13 listeners in previous cross-language vowel studies (e.g., Flege, Bohn, et al., 1997; Levy, 2009b; Polka, 1995; Tyler et al., 2014). While a large number of participants were recruited, it was not possible to further differentiate among UU and UC assimilations based on presence of overlap in Experiment 5. This experiment involved only eight repetitions of each vowel in the categorisation task, compared to the 18 repetitions in Tyler et al., and so there was an insufficient number of observations to perform tests against chance. Therefore, it is recommended that future research on non-native/L2 vowel perception increase the number of repetitions of the stimuli, as well as the participant sample, to allow individual differences to be examined.

9.3.3 Future directions

A number of potential areas for future investigation were suggested throughout this chapter. Briefly, more research is required testing the PAM predictions for discrimination using vowel contrasts, as they are comparatively limited in number compared to studies using consonant contrasts. As there were no instances of completely overlapping contrasts in this project, research assessing discrimination accuracy on all three types of overlap (i.e., completely overlapping, partially overlapping, and non-overlapping) is needed, with regard to both phonological *and* phonetic overlap. L2 studies examining the role of overlap in category formation are required, as the results are likely to have implications for PAM and for related theories of L2 learning. Longitudinal studies that track L2 perceptual learning over a considerable period of immersion are encouraged in order to determine when exactly during immersion new categories begin to develop. Such studies may also include tasks that aim to assess L2 word recognition for minimally contrasting words containing the target L2 phones.

The findings from this project also raise a number of other important questions to be addressed in future research. The focus of this thesis was on vowel perception. Given the articulatory and acoustic differences between vowels and consonants, it is possible that the effects observed here for uncategorised vowels may not apply to uncategorised consonants. As consonants are more categorically perceived than vowels are, is it possible for non-native/L2 consonants to be assimilated as uncategorised *focalised*, *clustered*, or *dispersed*? Would discrimination accuracy for pairs of non-native/L2 consonants assimilated as UC or UU also be dependent upon overlap, similar to vowels? Future tests of the PAM-L2/SLM predictions for phonological category acquisition should also examine uncategorised consonants. It is hypothesised that new categories will be acquired earlier during in L2 learning for consonants than for vowels. Consonants and vowels not only differ in their articulatory and acoustic properties, but they also play a different role in relation to the lexicon. More specifically, in the L1, consonants have been shown to have a more functional role in word recognition than vowels (e.g., Bonatti, Pena, Nespor, & Mehler, 2005; Nespor, Peña, & Mehler, 2003). If more weight is given to consonants than vowels in L1 word recognition, the same may be true in the L2. In line with PAM-L2, linguistic pressure to recognise words in the L2 may force the learner to establish new categories for consonants earlier than for vowels. Longitudinal studies using consonants are required to test between this prediction.

9.4 Conclusions

With a wealth of research on non-native/L2 phones assimilated as categorised, the purpose of this thesis was to provide an examination of the perceptual assimilation, discrimination, and acquisition of uncategorised vowels. It was demonstrated that there are three ways in which non-native phones might assimilate as uncategorised, namely, *focalised*, *clustered*, and *dispersed*. Discrimination accuracy for non-native contrasts assimilated as UU and UC was shown to be poorer for partially overlapping than for non-overlapping contrasts. Although there was no evidence to suggest that new categories had been acquired for uncategorised L2 phones, variability in discrimination accuracy was accounted for by six factors related to L2 experience (i.e., length of residence, age of FLA, age of immersion, proportion of L2 use, L2 vocabulary size, and duration of English as a foreign language training). However, different factors played a different role in predicting L2 speech perception, and were dependent upon assimilation type. In sum, the results of the experiments presented in this thesis provide a large step forward in our understanding of perceptual assimilation and discrimination of non-native phones, and raise interesting questions for future research on L2 phonological acquisition.

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APPENDICES

APPENDIX A

The language background questionnaire that was administered to the naïve Australian English listeners in Experiments 2-4 (Chapter 7).

Date: _______________ Participant Number: _______________

Background Information

1. Age: ______

2. Which hand do you write with? *(please circle)*: **Left** **Right** **Ambidextrous**

3. Gender: **Male** **Female**

4. Do you currently have any hearing problems? **YES** **NO**

- *If **YES**, please describe the nature of the problem.*

5. Do you have any vision problems that are ***not*** corrected by glasses or contact lenses? **YES** **NO**

- *If **YES**, please describe.*

6. Did/do you or any of your immediate family *(parents, siblings)* have any special problems with language development *(e.g. delayed language onset, serious difficulties in learning new words, or remembering the names of objects)*?

YES **NO**

- *If **YES**, who has/had the problem? What is/was the nature of the problem? At what age did it occur? Did/does it require a speech therapist?*

7. Did/do you or any of your immediate family *(parents, siblings)* have any special problem with speaking *(e.g. stuttering, lisping, etc.)*?

YES **NO**

- *If **YES**, who has/had the problem? What is/was the nature of the problem? At what age did it occur? Did/does it require a speech therapist?*

8. Did/do you or your immediate family *(parents, siblings)* have any special problems with learning to read *(e.g. confusing certain sounds or letters, dyslexia)*?

YES **NO**

- *If **YES**, who has/had the problem? What is/was the nature of the problem? At what age did it occur? Did/does it require a speech therapist?*

9. How old were you when you were first exposed to the English language *(e.g. from birth, 2yrs, 5yrs)*?

____

10. Were any languages other than English spoken in your home when you were growing up? **YES** **NO**

- *If **YES**, please list each language, how well you are able to speak, understand, read, and write each of the languages, indicate whether you consider yourself to be a native speaker of that language, and list the members of your family who were speaking that language (e.g., mother, father, grandmother, brothers and sisters).*

Language	**Indicate your level of ability by circling a number** ***1**= very little **5**= very well*				Are you a native speaker?	Family members who speak it
	Speak	Understand	Read	Write		
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	

11. Please list any other languages that you have learned outside the family *(e.g., studied at school, extended stay in another country)*, how old you were when you when you began to learn each one, and how well you speak, understand, read, and write them.

Language	Age at which you began to learn each language *(and how many years studied if at school)*	**Indicate your level of ability by circling a number** ***1**= very little **5**= very well*			
		Speak	Understand	Read	Write
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

12. Please list the place you were born, and all of the places you have lived, and what ages you were when you lived in each one.

City, State/Region, & Country	**What age period did you live there?**
______________________________	Birth until: ______________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________

13. Where did your mother and father grow up? Please fill in as detailed information as you can

Mother	**Father**
City, State/Region, & Country	*City, State/Region, & Country*
______________________	______________________

Thank you very much!

APPENDIX B

The language background questionnaire that was administered to the Egyptian Arabic L2 learners of Australian English in Experiment 5 (Chapter 8). The questionnaire was presented to the participants in Arabic, but an English translated version of that questionnaire is also presented here for convenience. The full questionnaire was completed at T0 in order to obtain information from participants on the following six factors: length of residence, age of FLA, age of immersion, proportion of L2 use, L2 vocabulary size, and duration of English as a foreign language training). At T1 and T2, in order to collect information about the proportion of L2 usage, participants only completed questions 15−17.

التاريخ: __________ نمرة المُشارك : _______________

معلومات عن الخلفيه

١/ العُمر:

٢/ بأي يد تكتُب بها؟ الشمال اليمين كلاهما

يُرجى وضع دائره

٣/ النوع: ذكر أنثى

٤/ هل لديك أي مشكله في السمع؟

نعم لا

إذا كانت الإجابه بنعم يُرجى توضيح نوع المشكله.

٥/ هل لديك أي مشاكل في الرؤيه التي لم يتم تصحيحها عن طريق النظارات أو العدسات اللاصقه؟ نعم لا

إذا كانت الإجابه بنعم يُرجى التوضيح.

٦/ لمَ / لا أنت أو أي من أفراد أسرتك المُباشره (الأباء و الأشقاء) لديهم أي مشاكل خاصه مع تطور اللغه (على سبيل المثال تأخُر ظهور اللغه صعوبات خطيره في تعلُم كلمات جديده أو تذكُر أسماء الأشياء)؟

نعم لا

إذا كان الجواب بنعم الذي عنده المُشكله أو التي كانت عنده المُشكله؟ ماهي كانت طبيعة المُشكله أو كيف كانت طبيعة المُشكله؟ في أي سن أنها حدثت؟ لمَ / لا أنها لاتتطلب المُعالج للغه؟

٧/ لمَ / لا أنت أو من أفراد أسرتك على الفور (الأباء و الأشقاء) لديهم أي مشاكل خاصه مع الحديث (مثل الـتأتأة و اللثغ إلخ)؟

نعم لا

إذا كان الجواب بنعم الذي عنده المُشكله أو التي كانت عنده المُشكله؟ ماهي كانت طبيعة المُشكله أو كيف كانت طبيعة المُشكله؟ في أي سن أنها حدثت؟ لمَ / لا أنها لاتتطلب المُعالج للغه؟

٨/ لمَ / لا أنت أو من أفراد أسرتك على الفور (الوالدين , الأشقاء) لديهم أي مشاكل خاصه مع تعلُم القراءه (مثل بعض الأصوات المُربكه أو الرسائل, إضطراب في القراءه)؟

نعم لا

إذا كان الجواب بنعم الذي عنده المُشكله أو التي كانت عنده المُشكله؟ ماهي كانت طبيعة المُشكله أو كيف كانت طبيعة المُشكله؟ في أي سن أنها حدثت؟ لمَ / لا أنها لاتتطلب المُعالج للغه؟

٩/ ماهو التاريخ الذي وصلت فيه إلى إستراليا ؟

____

١٠/ كم كان عمرك المره الأولى حينما تواجهت مع اللغه الإنجليزيه (على سبيل المثال عمرك سنتين أو ستة عشر سنه أو ثلاثونَ سنه) ؟

____

١١/ وأية لغات أخرى غير العربيه التي تحَدثوا بها في منزلك عندما كنت تنضُج ؟

نعم لا

إذا كان الجواب بنعم و يُرجى ذكر كل لغه و إذا كنت قادرا على الكلام والفهم والقراءه وكتابة كل لغه من اللغات و حدد إذا كنت تعتبر نفسك أن تكون لغتك الأصليه هي تلك اللغه وقائمه أيضا عائلتك الذين يتحدثون تلك اللغه (على سبيل المثال الأم و الأب و الجده و الأخوه و الأخوات) .

لغه	حدد مستواك في القدره بوضع دائره حول العدد ١ = القليل جدا ٥ = بشكل جيد للغايه				هل أنت تتكلم لغتك الأصليه ؟	أفراد الأسره التي يتحدثون بها
	التكلّم	الفهم	القراءه	الكتابه		
	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	نعم لا	
	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	نعم لا	
	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	نعم لا	
	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	نعم لا	

١٢/ يُرجى ذِكر أي لُغه تعلمتهاخارج أفراد الأُسره (على سبيل المِثال دُرسَت في المدرسه / الجامعه, ممتده في بلد آخر, في العمل, من الإنترنت) كم كان عُمرك عندما بدأت لمعرفة كُل لُغه. وإلى أي مَدى تتكلم وتفهم وتقرأ وتَكتُب .

لغه	كم كان عمرك عندما بدأت لمعرفة كل واحد (وكم عدد السنوات التي درستها في المدرسه)	حدد مستواك في القدره بوضع دائره حول العدد ١ = القليل جدا ٥ = بشكل جيد للغايه			
		التكلُم	الفهم	القراءه	الكتابه
		١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥
		١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥
		١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥
		١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥	١ ٢ ٣ ٤ ٥

١٣/ يُرجى ذكر مكان ولادتك , وجميع الأماكن التي عاشوا فيها , وماالأعمار عندما كنت تعيش في كل مكان.

كم كان عمرك عندما عشت هناك؟	المدينه , الدوله / المنطقه و البلد
من الولاده إلى أن : ____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________

١٤/ أين نضج أبيك وأمك؟ أملأ المعلومات مفصله عن ماتستطيع .

أم

المدينه , الدوله / المنطقه و البلد

____

أب

المدينه , الدوله / المنطقه و البلد

____

***

١٥/ هل سبق لك أو حضور فصل باللغه الإنجليزيه حاليا أو مدرسه ناطقه باللغه الإنجليزيه أو مكان العمل ؟

نعم

لا

إذا كان الجواب بنعم ماهي التواريخ التي بدأتها والتواريخالتي قُمت بإيقافها ؟ كم عدد الأيام والساعات لمّ لا تحضر في الأسبوع؟ إذا كنت تحضر دروس اللغه الإنجليزيه حيث لم تدرُس وماذا كان إسم الدوره؟

١٦/ في المتوسط في الأسبوع و يُرجى تقدير إلى أقرب ١٠% عدد المرات التي تتكلم أو يتعرضون للغه العربيه في كل هذه الأماكن أو في الحالات. يُرجى وضع "X" في المربع المناسب.

	٪٠	٪١٠	٪٢٠	٪٣٠	٪٤٠	٪٥٠	٪٦٠	٪٧٠	٪٨٠	٪٩٠	٪١٠٠
في المنزل											
في العمل											
زيارة الأسره											
زيارة الأصدقاء											
أثناء التسوق											
في الفصل / المدرسه											
في الحفلات / التجمعات											
الكنيسه / الجامع , إلخ											
البرامج التلفزيونيه الإنجليزيه أفلام											

١٧/ في المتوسط في الأسبوع , يُرجى تقدير إلى أقرب ١٠% عدد المرات التي تتكلم أو يتعرضون للغه الإنجليزيه في كل هذ الأماكن أو المواقف. يُرجى وضع "X" في المربع المناسب .

	٠٪	١٠٪	٢٠٪	٣٠٪	٤٠٪	٥٠٪	٦٠٪	٧٠٪	٨٠٪	٩٠٪	١٠٠٪
في المنزل											
في العمل											
زيارة الأسره											
زيارة الأصدقاء											
أثناء التسوق											
في الفصل / المدرسه											
في الحفلات / التجمعات											
الكنيسه / الجامع , إلخ											
البرامج التلفزيونيه الإنجليزيه أفلام											

شكرا جزيلا لك !

Date: _______________ Participant Number: _______________

Background Information

1. Age: ______

2. Which hand do you write with? *(please circle)*: **Left Right Ambidextrous**

3. Gender: **Male Female**

4. Do you currently have any hearing problems? **YES NO**

- *If **YES**, please describe the nature of the problem.*

5. Do you have any vision problems that are ***not*** corrected by glasses or contact lenses? **YES NO**

- *If **YES**, please describe.*

6. Did/do you or any of your immediate family *(parents, siblings)* have any special problems with language development *(e.g. delayed language onset, serious difficulties in learning new words, or remembering the names of objects)*?

YES NO

- *If **YES**, who has/had the problem? What is/was the nature of the problem? At what age did it occur? Did/does it require a speech therapist?*

7. Did/do you or any of your immediate family *(parents, siblings)* have any special problem with speaking *(e.g. stuttering, lisping, etc.)*?

YES **NO**

- *If **YES**, who has/had the problem? What is/was the nature of the problem? At what age did it occur? Did/does it require a speech therapist?*

8. Did/do you or your immediate family *(parents, siblings)* have any special problems with learning to read *(e.g. confusing certain sounds or letters, dyslexia)*?

YES **NO**

- *If **YES**, who has/had the problem? What is/was the nature of the problem? At what age did it occur? Did/does it require a speech therapist?*

9. How old were you when you were first exposed to the English language *(e.g. from birth, 2yrs, 5yrs)*?

____

10. Were any languages other than English spoken in your home when you were growing up? **YES** **NO**

- *If **YES**, please list each language, how well you are able to speak, understand, read, and write each of the languages, indicate whether you consider yourself to be a native speaker of that language, and list the members of your family who were speaking that language (e.g., mother, father, grandmother, brothers and sisters).*

Language	**Indicate your level of ability by circling a number** ***1****= very little* ***5****= very well*				Are you a native speaker?	Family members who speak it
	Speak	Understand	Read	Write		
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	YES NO	

11. Please list any other languages that you have learned outside the family *(e.g., studied at school, extended stay in another country)*, how old you were when you when you began to learn each one, and how well you speak, understand, read, and write them.

Language	Age at which you began to learn each language *(and how many years studied if at school)*	**Indicate your level of ability by circling a number** ***1****= very little* ***5****= very well*			
		Speak	Understand	Read	Write
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

12. Please list the place you were born, and all of the places you have lived, and what ages you were when you lived in each one.

City, State/Region, & Country	**What age period did you live there?**
______________________________	Birth until: ____________________
______________________________	__________________________
______________________________	__________________________
______________________________	__________________________
______________________________	__________________________
______________________________	__________________________

13. Where did your mother and father grow up? Please fill in as detailed information as you can

Mother	**Father**
City, State/Region, & Country	*City, State/Region, & Country*
________________________	________________________

***

15. Have you previously or are you currently attending English language classes, an English-speaking school, or workplace?

- *If* ***YES****, what were the dates that you started and the dates that you stopped? How many days and hours did/do you attend per week? If you attended English classes, where did you study and what was the name of the English course?*

16. In an average week, please estimate to the nearest 10% how often you speak or are exposed to **Arabic** in each of these places or situations. Please place an '**X**' in the appropriate box.

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
At home											
At work											
Visiting family											
Visiting friends											
While shopping											
At class/school											
At parties/gatherings											
At church/mosque, etc.											
TV shows/movies											

17. In an average week, please estimate to the nearest 10% how often you speak or are exposed to **English** in each of these places or situations. Please place an '**X**' in the appropriate box.

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
At home											
At work											
Visiting family											
Visiting friends											
While shopping											
At class/school											
At parties/gatherings											
At church/mosque, etc.											
TV shows/movies											

Thank you very much!

APPENDIX C

The two parallel versions of the Nation and Beglar (2007) L2 Vocabulary Size Tests were translated from English to Arabic for Experiment 5 (Chapter 8). They were used to determine L2 English vocabulary size in Egyptian Arabic speakers. The translated Arabic versions of the tests, in addition to the English versions, are presented here. In the English versions, there are often single words or short phrases (displayed in bold and in brackets) presented alongside some of the multiple-choice options. These indicate instances in which a single word/phrase was used to replace an entire sentence for the Arabic versions (refer to Chapter 5 for details about how the translated tests were developed).

Vocabulary Size Test: Version A

1. see: They **saw it**.

ا / أُغلِقَتْ بإحكامْ

ب/ إنتَظَروها

ت/ نَظَروا إليهاْ

ث/ بداؤوا الأَمْر

2. time: They have a lot of **time**.

ا / نُقوْدْ

ب/ طَعَامْ

ت/ وقت

ث/ أصْدَقاءْ

3. period: It was a difficult **period**.

ا / سُؤالْ

ب/ وَقْتْ

ت/ مايَنبَغى القيامْ بِه

ث/ كِتابْ

4. figure: Is this the right **figure**?

ا / جَوابْ

ب/ مَكْانْ

ت/ وَقْتْ

ث/ رَقَمْ

5. poor: We **are poor**.

ا / فُقَراءْ

ب/ نَشعُرْ بِسَعادَةّ

ت/ نَحْنُ مُهتَميينْ جدِاً

ث/ كَسوْلينْ

6. microphone: Please use the **microphone**.

ا / مَاكينهَ لِصُنعْ الطَعامْ ساخِنْ

ب/ مُكَبِرْ الصوتْ

ت/ مِجهَرْ

ث/ مُتَنَقِلْ

7. nil: His mark for that question was **nil**.

ا / سَئ جِداً

ب/ لا شَئ

ت/ جَيدْ جِدَاً

ث/ مٌتَوَسِطْ

8. pub: They went to the **pub**.

ا / حانَة

ب/ مَكانْ لِحِفظْ الفِلوسْ

ت/ مَركَز تَسَوقْ

ث/ حَمام سِباحَه

9. circle: Make a **circle**.

ا / رَسَم تَقريبي

ب/ مِساحَه فارغِه

ت/ دآئِرةَ

ث/ حُفرةَ كَبيرَه

10. dig: Our dog often **digs**.

ا / يَحِلْ المَشاكِل مَعْ الأشياء

ب/ يَحفُر

ت/ يُريد أن يَنامْ

ث/ يَدخُل المَاءْ

11. soldier: He is a **soldier**.

ا / رجُل أعمال
ب/ طَالِب
ت/ عَامِل المَعَادِن
ث/ جُندي

12. restore: It has been **restored**.

ا / إتكرَر
ب/ وزعِت رُمِّمَت
ت/ خَفَضَتْ سِعرَه
ث/

13. pro: He's **a pro**.

ا / جَاسْوسْ
ب/ غَبي
ت/ مُراسِل صَحَفي
ث/ رُمِّمَ

14. compound: They made a new **compound**.

ا / إتِفاقيهَ
ب/ مُرَكَب
ت/ شَرِكه
ث/ تَنَبؤ

15. deficit: The company **had a large deficit**.

ا / عَجزْ في الميزانيةَ
ب/ تَخفيضْ القيمَه
ت/ خِطَة الإنفاق
ث/ أكثَر الودائِع المَصرَفيهَ

16. strap: He broke the **strap**.

ا / وَعدْ

ب/ غِطَاء

ت/ طَبَقْ مُسَطَحْ

ث/ حِزامْ

17. weep: He **wept**.

ا / أنهى المُقَررْ التَعليمىْ

ب/ بَكىْ

ت/ ماتْ

ث/ قَلَق

18. haunt: The house is **haunted**.

ا / مَليانَ زَخرفَه

ب/ أجرّ المَنزِل

ت/ فارِغُ

ث/ مليىء بِالأشْباح

19. cube: I need one more **cube**.

ا / دَبوسْ

ب/ مُكَعَبْ

ت/ كوب طَويل لَيسَ لَه طَبَق

ث/ بِطاقَه

20. butler: They have a **butler**.

ا / كَبير الخَدَمْ

ب/ مُنشارْ

ت/ مُعَلِم خاصْ

ث/ غُرفَهَ مٌظْلِمهَ تَحتْ المَنزِلْ

21. nun: We saw a **nun**.

ا / دودةَ

ب/ حادِثْ رَهيبْ

ت/ راهِبَه

ث/ نْورْ ساطِعْ في السَماء غيرْ مَعْروفْ

22. olive: We bought **olives**.

ا / زَيتونْ

ب/ ورودْ قُرُنفِلْ

ت/ مَلابِس سِباحَه للرِجالْ

ث/ مَعَاوِلْ للحَفْرْ

23. shudder: The boy **shuddered**.

ا / هَمسْ

ب/ تقريبا سقط

ت/ إرتَجَفْ

ث/ صَرَخْ

24. threshold: They raised the **threshold**.

ا / علّم

ب/ مُستوى

ت/ سَقفْ

ث/ فَوائِدْ

25. demography: This book is about **demography**.

ا / عِلم طبَقاتْ الأرضْ

ب/ عِلم الهَندَسةَ

ت/ عِلم حَرَكَة الماءْ

ث/ عِلم السُكانْ

26. malign: His **malign** influence is still felt.

ا / جَيدْ

ب/ شِريرْ

ت/ مُهِمْ جِداً

ث/ سِر

27. strangle: He **strangled her**.

ا / خَنَقَها

ب/ يَتَدَلَلْ لَها

ت/ خَطَفَها

ث/ أعجَبَها كثَيراً جِداً

28. dinosaur: The children were pretending to be **dinosaurs**.

ا / القَرَاصِنهَ

ب/ الجِنياتْ

ت/ التِنينْ

ث/ حَيواناتْ عاشَتْ مُنذُ فَترهَ طَويلهَ مَضَتْ

29. jug: He was holding **a jug**.

ا / إبْريقْ

ب/ دردَ شه

ت/ القُبَعهَ

ث/ قُنبِلهَ

30. crab: Do you like **crabs**?

ا / رَقائقْ

ب/ أطواقْ ناشِفهَ ومَحكومهَ

ت/ كابوريا

ث/ الصَراصيرْ

31. quilt: They made a **quilt**.

ا / عَقد الوَرَثه
ب/ عَقدْ
ت/ لِحَاف
ث/ قَلَم ريشَه

32. tummy: Look at my **tummy**.

ا / وِشاحْ لِتَغطيةُ الرأسْ
ب/ البَطنْ
ت/ سَنجابْ
ث/ إبهَام اليَد

33. eclipse: **There was an eclipse**.

ا / عاصِفهَ
ب/ أنا سَمِعتَ شَئ خَبَطَ الماءْ
ت/ مَجزَرهَ
ث/ كُسوفْ

34. excrete: This was **excreted** recently.

ا / أُفرِزَ
ب/ وَضَح
ت/ حقيقْ
ث/ وضِعَت عَلى قائمَه مِن الأُمورْ غَيرْ القانونيهَ

35. ubiquitous: Many unwanted plants **are ubiquitous**.

ا / صَعبهَ التَخَلُصْ مِنها
ب/ عِندَها جُذورْ طَويلهَ وقَويهَ
ت/ مُنتَشِرَة في كُلْ مَكانْ
ث/ بيموتوا في الشِتاءْ

36. marrow: This is **the marrow**.

ا / تَعْويذةَ لِجَلبْ الحَظْ السَعيدْ

ب/ النُخاعْ

ت/ عَصا التَحَكُّمْ

ث/ زيادَه في المُرَتَبْ

37. cabaret: We saw the **cabaret**.

ا / اللَوحةَ غَطَتْ الحائِطْ كُلَهُ

ب/ المَلهيَ

ت/ صَرصورْ

ث/ حوريةُ البَحرْ

38. cavalier: He treated her **in a cavalier manner**.

ا / بِعجْرَفة

ب/ بِشَهامةَ

ت/ إرتِباكْ

ث/ بَنَوي

39. veer: The car **veered**.

ا / إرتَجَفْ

ب/ انحَرَفت

ت/ عَمَلْ صوتْ عاليْ جِداً

ث/ إنزَلَقِتْ

40. yoghurt: This **yoghurt** is disgusting.

ا / طَميْ

ب/ جَرْحْ

ت/ زَبادي

ث/ فَواكِهه كَبيرَه وبَنَفسَجيةَ مَعْ لَحَمْ لَينْ

41. octopus: They saw **an octopus**.

ا / بومة

ب/ غَواصَه

ت/ طائِره مَروَحيه

ث/ أخطَبوطْ

42. monologue: Now he has a **monologue**.

ا / نَظاره لِعينْ واحِدهَ

ب/ حوارْ ذاتيْ

ت/ مَوقِفْ مَعَ القوهَ

ث/ جَعَلْ الصورهَ مَنْ خِلالْ الانِضِمامْ مَعاً بِطُرُقْ الَرسائِل المُثيرهَ لِلإهتِمامْ

43. candid: Please **be candid**.

ا / كُنْ حَذِر

ب/ كُنْ مُتَعَاطِف

ت/ كُنْ عَادِل

ث/ كُنْ صَريحاً

44. nozzle: Aim the **nozzle** toward it.

ا / عَدساتْ الكاميرا

ب/ رُقَعَه مِن الجِلدْ الجافْ

ت/ فوَهَةْ الأنبوبْ

ث/ جُزءْ حْادْ مِن الشوكَه

45. psychosis: He has **a psychosis**.

ا / عَدَم القُدرهَ عَلى الإنتِقالْ

ب/ رُقعهَ ملَوَنهَ بِشَكل غَريبْ في الجِلدْ

ت/ جِهازْ الجِسمْ الذي يُعالِج السُكَر

ث/ ذُهان

46. ruck: He got hurt in the **ruck**.

ا / حوضْ

ب/ شِجارْ

ت/ حَشودْ مِنْ لاعبينْ الكُرَةَ

ث/ سِباق عَبرْ حَقلْ مِن الثَلجْ

47. rouble: He had a lot of **roubles**.

ا / ياقوتْ

ب/ أقَارِبْ

ت/ العُملةَ الروسيةَ

ث/ الأخلاقياتْ أو غيرَها مِن الصُعوباتْ في العَقلْ

48. canonical: These are **canonical examples**.

ا / الأمثِلةَ التي كَسَرَتْ القَواعِدْ المُعتادَه

ب/ أمثَلهَ مأخوذَه مِن كِتابْ دينيْ

ت/ أمثِلة نَموذَجية

ث/ أمثِلهَ أُكتِشِفَت قَريباً جِداً

49. puree: This **puree** is bright green.

ا / هَريسْ

ب/ الثيابْ التي تَرتَديها النِساءْ في الهِندْ

ت/ جِلدْ الفاكِهةَ

ث/ مادَة فَساتينْ السَهرَة رقَيقةَ جِداً

50. vial: Put it in a **vial**.

ا / الجِهازْ الَذي يُخَزِن الطاقهَ الكَهرَبائيهَ

ب/ بَلَد الإَقامهَ

ت/ مَشَهَد دِراميْ

ث/ قارورةَ

51. counterclaim: They made **a counterclaim**.

ا / دَعوىَ مُضادةَ

ب/ إعادَة المالْ

ت/ إتِفاقْ بين شَرِكتينْ لتبادُلْ العَمَلْ

ث/ لِحَاف

52. refectory: We met in the **refectory**.

ا / غُرفَة الطَعَام

ب/ مَكتَب العَدل

ت/ المَضجَع

ث/ مُستَنبَتْ زُجاجيْ

53. trill: He practised the **trill**.

ا / زَغرُده

ب/ كَمانْ

ت/ رَمية

ث/ دَوَران رَقصَة الباليه

54. talon: Just look at those **talons**!

ا / قِمَمْ الجِبالْ

ب/ مَخَالِب

ت/ دِرع

ث/ الحُمَقي

55. plankton: We saw a lot of **plankton** here.

ا / النَباتاتْ السامَه الَتي تَنتَشِر بِسُرعهَ جِداً

ب/ نَباتاتْ أو حَيَواناتُ صَغيره جِداً في الماءْ

ت/ الأشَجارْ المُنتَجه خشَبها صَلبْ

ث/ إنهيارْ التُربهَ

56. soliloquy: That was an excellent **soliloquy**!

ا / أُغنيهَ لِستِه أشخاصْ
ب/ حَكمهَ
ت/ الأضواء والموسيقىَ تُستَعمل للتَرفيه
ث/ مُناجاة النَفسْ

57. puma: They saw a **puma**.

ا / مَنزِل صَغيرْ مَصنوعٌ مِن الطوبْ والطينْ
ب/ شَجَره مِن البُلدان الحَاره والجَافه
ت/ قِطْ بَريْ وضَخْمْ
ث/ إعْصارْ

58. augur: It **augured well**.

ا / وَعَدَتْ بِأشياء جَيدة في المُستَقبَلْ
ب/ إتَفقَ مَع ماكانَ متَوقِعاً
ت/ كانَ اللَون الَذي يَبدو جَيداً مَع شئ آخر
ث/ رَنَ بِصَوت واضِح وجَميلْ

59. emir: We saw the **emir**.

ا / طيرْ لَهُ ذَيل بِه ريشَتانْ طَويلَتانْ ومَثنيتانْ
ب/ مُرَبيهْ
ت/ زَعيمْ الشَرقْ الأوسَط لَديهِ سُلطانْ عَلى أرضِهِ
ث/ مَنزِل مَصنوع مِن كتُل الجَليدْ

60. didactic: The story **is very didactic**.

ا / تَعَليمى
ب/ مِنْ الصَعَبْ جِداً أن نُصَدِق
ت/ يَتنَاول إجراءاتْ مُثيرةَ
ث/ هو مَكتوبْ مَعَ مَعنَى غَير واضِحْ

61. cranny: Look what we found in the **cranny**!

ا / بيع الأشياءْ غير المَرغوبْ فيها

ب/ شَقْ

ت/ عُلّيَة

ث/ صَندوقْ خَشبَي كَبيرْ

62. lectern: He stood at the **lectern**.

ا / مِنضَدة القِراءة

ب/ مَذبَح

ت/ حَانَه

ث/ آخِر الحافةَ

63. azalea: This **azalea** is very pretty.

ا / شُجيرة صَغيرة كَثيفَة الزّهوْرْ

ب/ نَسيجْ طبَيعي خَفيفْ

ت/ قِطعةَ طَويلةَ مِنْ مادَه تُلبَس في الهِند

ث/ صَدّفه

64. marsupial: It is **a marsupial**.

ا / حَيَوان مَعَ قَدَمينْ صَلبَهَ

ب/ النَبات الَذي يأخُذعِدة سَنَوات ليَنمو

ت/ عَبَاد الشَمسْ

ث/ حيوان ذو جِراب

65. bawdy: It was very **bawdy**.

ا / لا يُمكِن التَنَبؤ بِه

ب/ بَرئ

ت/ هرَعَ

ث/ غَير لائِقْ

66. crowbar: He used a **crowbar**.

ا / عَتَلَة
ب/ إسمْ مُستَعارْ
ت/ مَخَرَز
ث/ عَصا المَشي خَفيفهَ ومِن الحَديدْ

67. spangled: Her dress was **spangled**.

ا / تَمَزَقَ إلى شرائح رَقيقهَ
ب/ مُغطاه بديكورات صَغيره ولامِعه
ت/ الطَيات
ث/ دُمِرَ مِن خِلال لَمس شئ حار جِداً

68. aver: She **averred** that it was the truth.

ا / رَفَضِت الإتِفاقْ
ب/ أكَّدَتْ
ت/ إعتَقّدَت
ث/ حَذَرَت

69. retro: It had **a retro look**.

ا / نَظرهَ عَصريهَ للغايهَ
ب/ مَظهَر قِطعهَ مِن الفَنْ الحَديثْ
ت/ شَكلْ يوحيْ بِعصْرْ سابِقْ
ث/ مَظهَر مِن شَئ في وَقتْ سابِقْ

70. rascal: She is such **a rascal** sometimes.

ا / كافِرهَ
ب/ طالِبهَ متُخصِصهَ
ت/ عامِلِهَ تبذُلْ مَجهودْ
ث/ شَقية

71. tweezers: They used **tweezers**.

ا / الدَبابيسْ الوَرَقيهَ

ب/ قِطَع صَغيرهَ مِن الخُيوطْ لِقَفل الجُروحْ

ت/ مَلاقِطْ

ث/ آداه قَويهَ لِقَطع النبَاتاتْ

72. bidet: They have a **bidet**.

ا / حوضْ منُخَفِض لغِسلْ الجِسمْ بَعد إستِعمالْ المِرحاضْ

ب/ كَلبْ بنُي كبَيْر وشَرِس

ت/ حَمام خَاص للسِباحه وصَغير

ث/ خادِمْ

73. sloop: Whose **sloop** is that?

ا / قُبَعَه صَغيرهَ

ب/ قارِبْ إبحارْ صَغيرْ

ت/ باقي أكْلْ

ث/ عَمَل غيَر مُنظَمْ

74. swingeing: They got **swingeing fines**.

ا / غرَامات باهظة

ب/ غَراماتْ صَغيرهَ جِداً

ت/ غراماتْ صَغيرهَ مَدفوعهَ على أوقاتْ

ث/ الغرَاماتْ التي تَختلَف على الدَخلْ

75. cenotaph: We met at the **cenotaph**.

ا / كنَيسهَ مُهمه وكَبيره

ب/ مَكانْ عامْ في وسَط المَدينهَ

ت/ ضَريحْ تِذكاريْ

ث/ مَحطة قِطارْ تَحَت الأرضْ

76. denouement: I was disappointed with the **denouement**

ا / حَل العُقدةَ في الرِوايه

ب/ دفع مبلغ من المال للحصول على جزء من العمل

ت/ شَقَّهَ

ث/ التَقريْر الرَسمي لِنتائِج لِقاء سياسيْ

77. bittern: She saw a **bittern**.

ا / زٌجاجةَ كَبيرةَ لتِخزين السَائِل

ب/ ثُعبانْ صَغيرٌ في الحَشائِش الخَضراءْ

ت/ طائِرْ شَبيهْ بِمالكْ الحَزينْ

ث/ طُيور مائيه مَع سيقانْ طَويلةَ وتُنادي بِصوتْ عاليْ

78. reconnoitre: They have gone to **reconnoitre**.

ا / يُفِكِروا مَره أخرى

ب/ لإستِكشافْ مَكانْ جَديدْ

ت/ يأخُذوا وقَتْ طَيب للإحتِفال بِحدَث سَعيد

ث/ يَشكون رَسمياِ

79. magnanimity: We will never forget her **magnanimity**.

ا / مُهمةَ جِداً وأخلاقْ غَيرْ سَليمةَ

ب/ الشَجاعةَ

ت/ شَهامتها

ث/ كلَماتْ صَادِقةَ

80. effete: He has become **effete**.

ا / ضَعيفٌ

ب/ مُدمِن عَلي الكُحولْ

ت/ غَير قادِر على مُغادَرة سَريرهُ

ث/ سَريعْ الغَضَبْ

81. rollick: They were **rollicking**.

ا / يَقودْونَ السَيارةَ بِسُرعةَ جِداً

ب/ البَقاءْ بَعيداً عَنْ المَدرَسةَ دونَ أنْ يُسمَحونَ لهم

ت/ يَلهونَ بِطَريقةَ حَماسيهَ وصاخبةِ

ث/ التَزَحلُقْ عَلي الجَليدْ

82. gobbet: The cat left a **gobbet** behind.

ا / جُزء مِنْ المَوادْ المُمَزقَةَ

ب/ عَلامَة القَدمْ

ت/ بُرازْ

ث/ كومْ مِن الأكلْ راجِعةَ مِنْ المِعدةَ

83. rigmarole: I hate the **rigmarole**.

ا / رَقَصةَ سَريعَه جِداً وصَعبةَ مَع ثَمانيةَ أشْخاصْ

ب/ شَخصيةَ مُمَثِل مُضحِكةَ في المَسرَح

ت/ إستِمارة الضَرائِبْ

ث/ طَويلةَ ومُعَقدةَ ولا فائِده مِنها لمَجموعة الإجراءاتْ

84. alimony: The article was about **alimony**.

ا / مَشاعِرْ المَرارةَ والإنزِعاجْ بِشَكل حادْ

ب/ المْال لِرِعاية الأطْفالْ تُدفَع بإنتِظامْ بَعد الطَلاقْ

ت/ إعْطاء الثَناءْ عَلى الأفكارْ المُمتازةَ

ث/ حَديدْ يُكسَر بِسُهولةَ وأبيَضْ مِزرِقْ

85. roughshod: He **rode roughshod**.

ا / سافَرْ بِدونْ تَحضيرْ جَيدْ

ب/ جَعَلَ أخطاءْ كَثيرةَ

ت/ لايُراعيْ مَشاعِرْ الآخَرينْ

ث/ لم يهتَمْ بِراحَة نَفسِه

86. copra: They supply **copra**.

ا / مُبيداتْ حَشَريهَ

ب/ لِب جوزْ الهِندْ المُجَفَفْ

ت/ مُخَدِرْ

ث/ حَبلْ قَوي يُستَخدَمْ في السُفُنْ الشُراعيهَ

87. bier: She lay on the **bier**.

ا / كُرسي الحَديقهَ مَثني

ب/ حَشيشْ قُربْ النَهرْ

ت/ دُخولْ السُفُنْ إلي الرَصيفْ

ث/ النَعشْ

88. torpid: He was **in a torpid state**.

ا / متُرَدِدْ

ب/ مَليئهَ بِمَشاعِرْ قَويهَ جِداً

ت/ الخَلطْ والقَلَقْ

ث/ خامِلْ

89. dachshund: She loves her **dachshund**.

ا / قبُعَه مِنْ الفَروْ الدافئ

ب/ بُساطْ سَميكْ مَع أنماط خاصه

ت/ كلب صغير مع أرجُلْ قَصيرهَ وظَهر طَويلْ

ث/ آلاتْ موسيقيهْ قَديمهَ مَع إثني عَشرْ وتَرْ

90. cadenza: What did you think of the **cadenza**?

ا / أُضيفَتْ عَلى الكيْكهَ كِريمهَ وفواكِههْ

ب/ صنَدوقْ كَبيرْ يتَدلى مِن سِلكْ الَذي يَحمِل الناسْ فَوقْ الجَبَلْ

ت/ الرَقصْ البطَئ والرسَمي مِن إيطاليا

ث/ عَزفْ مٌنَفرِدْ يُظهِرْ مَهارة الموسيقيَ

91. obtrude: These thoughts **obtruded themselves**.

ا / ضَيَعوا أنفُسَهمْ أو فَقَدوها

ب/ لا يَتفِقْ مَعْ بَعضٌهمْ البَعضْ

ت/ إختَلَطْ بَعضَهُم البَعضْ

ث/ تَطَفُلْ

92. panzer: They saw the **panzers** getting nearer.

ا / لاعِبينْ في فِرقَة الموسيقىَ

ب/ طائِراتْ مُقاتِله

ت/ دَبّابات

ث/ شُرطيهَ

93. cyborg: She read about **a cyborg**.

ا / إنسانْ نِصفْ آليْ

ب/ آله موسيقيهَ مْعَ أربعَينْ وتَرْ

ت/ صَغيرْ وأختِرِعَ مُنذَ عَهدْ قَريبْ

ث/ الرياحْ الدافِئهَ في الشِتاءْ

94. zygote: It is **a zygote**.

ا / لاقِحَة

ب/ الكثيرْ مِنْ العَناءْ عَلى لا شَئ

ت/ وَجَدوا حَيواناتْ صَغيرهَ في جَنوبْ أفريقيا

ث/ بنُدُقيه تُستَخَدَمْ في دَفعْ الصَواريخْ

95. sylvan: The painting had a **sylvan** theme.

ا / الحُبْ المَفقودْ

ب/ إعتِقادْ

ت/ غابهَ

ث/ عَشيرهَ غَير رسَميهَ

96. sagacious: She had many ideas that were **sagacious**.

ا / ذكَيهَ

ب/ مُثيرْ للسُخريهَ والوحشيهَ

ت/ حَولَ إيذاءْ الناسْ وأذيتَيْ

ث/ مُتمَرِده وثائرِهَ

97. spatiotemporal: My theory is **spatiotemporal**.

ا / أرَكِز عَلى التفَاصيلْ الصَغيرهَ

ب/ مُزعِجْ للناسْ

ت/ صارِمْ غيَرْ مَقبولْ

ث/ زَمانيْ ومَكانيْ

98. casuist: Don’t **play the casuist** with me!

ا / تَركزُه فَقَطْ عَلى اللَذهَ النَفسيهَ

ب/ يَعتَقِد في نَفسِه مِثلْ رَجُل قَوي

ت/ يُصدُر أحكامْ عَلى سِلوكي في آداءْ الواجِبْ

ث/ مِن الغبَاءْ

99. cyberpunk: I like **cyberpunk**.

ا / الأدويه الطَبيعيهَ

ب/ نوعْ واحِدْ مِنْ قِصَه خَياليهْ

ت/ الفَنْ والعِلمْ في الأكلْ

ث/ مُجتَمَع مَحكومْ بِخبُراءْ التَقنيهَ

100. pussyfoot: Let’s not **pussyfoot around**.

ا / إنتِقادْ بِشكلْ غيرْ مَعقولْ

ب/ نَحتاطْ ونَحتَرِزْ لِتَجَنُبْ المواجَهة

ت/ مواجَهة غَيرْ مبُاشِرهَ

ث/ بَدأ فَجأة

Vocabulary Size Test: Version B

1. drive: He **drives** fast.

ا / يَسبَحْ

ب/ يتَعَلَمْ

ت/ يَرمي الكَورةَ

ث/ يَسوقْ

2. jump: She tried to **jump**.

ا / تَطفوْ

ب/ تَقْفُزْ

ت/ مَوقِفْ سَيارةَ

ث/ تَرَكَضَ

3. shoe: Where is **your shoe**?

ا / الآباءْ

ب/ مَحَفظةَ

ت/ قَلَمْ

ث/ حِذاءْ

4. standard: **Her standards** are very high.

ا / كُعُوبْ

ب/ مُستَواها

ت/ دَرَجهْ

ث/ تَكاليفَها

5. basis: This was used as the **basis**.

ا / إجابةَ

ب/ مَكانْ لأخذْ قِسطاً مِنْ الراحةَ

ت/ الخَطوةَ التاليةَ

ث/ الجُزءْ الأساسيْ

6. maintain: Can they **maintain i**t?

ا / الحِفَاظ عَلى
ب/ تَكَبيرْ
ت/ تَحَسُن
ث/ أحرَزّوا

7. stone: He sat on a **stone**.

ا / حَجَرْ
ب/ بَرَاز
ت/ سِجَادةَ
ث/ فَرعْ

8. upset: I am **upset**.

ا / مُتعِبْ
ب/ مَشهورْ
ت/ غنَي
ث/ مغتمّ

9. drawer: The **drawer** was empty.

ا / دُرجْ
ب/ المَكانْ الَذي يَتِم الإحتِفاظْ بالسَيارات
ت/ ثَلاجهْ
ث/ قَفَصْ

10. joke: We did not understand his **joke**.

ا / نُكتَه
ب/ كِذبْ
ت/ طَريقَة الكَلامْ
ث/ طَريقة التَفكيرْ

11. pave: It was **paved**.

ا / مَسدودْ

ب/ مُنقَسِم

ت/ أعْطى حَوافْ الذَهَبْ

ث/ مَرصوفْ مُعَبَدْ

12. rove: He couldn't stop **roving**.

ا / ثَملْ

ب/ التَنَقُلْ

ت/ أزيزْ

ث/ عَمَلْ جادْ

13. lonesome: He felt **lonesome**.

ا / جاحِدْ

ب/ تَعبانْ

ت/ وَحِيدْ

ث/ نَشيطْ

14. allege: They **alleged it**.

ا / زعموا

ب/ مَسروقْ

ت/ ثَبُتَوا

ث/ مُعَارِضْ

15. remedy: We found a good **remedy**.

ا / مَطعَمْ

ب/ عِلاَجْ

ت/ وَصْفَةٌ أكلْ

ث/ المُعَادَلاتْ

16. dash: They **dashed** over it.

ا / إندَفَعوا

ب/ يتحركون بِبُطءْ

ت/ قاتلَوا

ث/ نَظرهَ سَريعهَ

17. peel: Shall I **peel it**?

ا / أنقع

ب/ أقشر

ت/ أُبيض

ث/ أقَطِعْ شَرائِحْ

18. bacterium: They didn't find a single **bacterium**.

ا / جَرثومْ

ب/ نبَاتْ مَعَ ورودْ حَمراء أو بُرتقُاليه

ت/ جَمَلْ

ث/ الشَئ الَذي قَدْ سُرِقَ وبيعَ إلي مَتجَرْ

19. thesis: She has completed her **thesis**.

ا / حُكمْ

ب/ فَترَة التَجرِبهَ

ت/ أطروحَه

ث/ تمَديدْ مَسارْ العِلاجْ في المُستَشفى

20. authentic: It is **authentic**.

ا / أصْليّ

ب/ صاخبِهَ جِداً

ت/ قَديمْ

ث/ قَاحِلْ

21. miniature: It is **a miniature**.

ا / مِجهَرْ

ب/ مُصَغَرَه

ت/ جَرَاثِيمْ

ث/ خَطْ صَغيرْ يَربُط الرَسائِل في الكِتابَة

22. fracture: They found a **fracture**.

ا / كَسَر

ب/ قِطَع صَغيره

ت/ مِعطَفْ قَصيرْ

ث/ شَهادة الخَصمْ

23. patience: He **has no patience**.

ا / مَشغولْ

ب/ لايوجَدْ لَديهَ إيمانْ

ت/ لا يَصبُرْ

ث/ ظالِمْ

24. scrub: He is **scrubbing it**.

ا / الخَدْش

ب/ إصْلاحهِ

ت/ غَسَلَها وفَرَكها

ث/ رَسْمْ تَقريبي

25. vocabulary: You will need more **vocabulary**.

ا / كَلَماتْ

ب/ مَهارة

ت/ نقُودُ

ث/ البنَادِقْ

26. accessory: They gave us **some accessories**.

ا / تأشيْرةَ

ب/ أوامِرْ رَسميةَ

ت/ الخياراتْ

ث/ قِطَعْ إضْافيةَ

27. compost: We need some **compost**.

ا / دَعَمْ قوَي

ب/ تَساعِد عَلى الشُعورْ بِالتَحَسُن

ت/ أسمَنتْ

ث/ سَمادْ

28. fen: The story is set in **the fens**.

ا / مُستنقَعْ

ب/ الجِبَالْ

ت/ الأحياءْ الفَقيرةَ

ث/ مُنذُ وَقْتْ طَويلْ

29. puritan: He is a **puritan**.

ا / الشَخصْ الَذي يَجِبْ أن يَلفِتْ الأنظارْ

ب/ مُتَزَمِّتْ

ت/ البَدو المُتنَقَلِينْ

ث/ بَخيلْ

30. awe: They looked at the mountain **in awe**

ا / قَلقْ

ب/ إهتِمامْ

ت/ بِمَهابةَ

ث/ برهبة

31. bristle: The **bristles** are too hard.

ا / سَلهَ لِحَملْ الأسماكْ
ب/ شَعرْ قَصيرْ خِشِنْ
ت/ سَرائِرْ قابِلهَ للطي
ث/ نَعلْ الأحذيَهْ

32. erratic: He was **erratic**.

ا / تَقيْ
ب/ سَئ للغْايهَ
ت/ غايهَ في الإحتِرامْ
ث/ غَيرْ مُنتَظِمْ

33. null: His influence **was null**.

ا / كانَتْ نتَائِجْ جَيدهَ
ب/ مَعْدوماً
ت/ باطِلهَ
ث/ إستَمَرَت وقتاً طَويلاً

34. perturb: I was **perturbed**.

ا / مُقتَنِعْ
ب/ قَلِقْ ومُحتارْ
ت/ الفَسادْ الجِنسي
ث/ مَنقوعْ

35. peasantry: He did a lot for the **peasantry**.

ا / الفَلاحينْ
ب/ مَعَبدْ
ت/ نادي رِجالْ الأعمالْ
ث/ طَبَقَة الناسْ العامِلهَ

36. palette: He lost his **palette**.

ا / سَلةُ الأسْماكْ

ب/ شَهيةَ

ت/ إنثىَ رفَيقةُ الشَبابْ

ث/ لَوحَة الألوانْ

37. devious: Your plans are **devious**.

ا / خَدّاعةَ

ب/ مَدروسةَ

ت/ غيَرْ مَدروسةَ

ث/ غاليْ

38. stealth: They did it by **stealth**.

ا / إنفْاقْ مبَلَغْ كبير مِنْ المْالْ

ب/ إكْراهْ

ت/ خِلسَةَ

ث/ عَدَمْ إتِخاذْ أي إشْعارْ مِنْ المَشاكِلْ التي قابَلتَهَمْ

39. hallmark: Does it have a **hallmark**?

ا / خِتِمْ لِتاريخْ إنتِهاء الصَلاحيهَ

ب/ ختِمْ لإظهارْ جَودتَهِ

ت/ الخِتم المَلَكي

ث/ عَلامهَ أو صَبغهَ لمَنعْ النَسخْ

40. haze: We looked through the **haze**.

ا / شُباكْ صَغيرْ ومُستَديرْ في السَفينهَ

ب/ ضَبَابْ

ت/ سَتائر النافِذه مَصنوعهَ مَصنوعهَ مِن الخَشَبْ أو البِلاستيكْ

ث/ قائِمَةُ الأسْماءْ

41. gimmick: That's a good **gimmick**.

ا / شَي عاليْ تَقَفي عَليهِ لأجْلْ أنْ تَشتَغِلْ فَوقْ سَطحْ الأرضْ

ب/ مَحَفَظةَ

ت/ حَرَكةَ أو صورةَ للحُصولْ عَلى الإنتِباهْ

ث/ وَسيلَةَ للتَحايُلْ

42. yoga: She has started **yoga**.

ا / حياكَةَ

ب/ شَكلْ مِنْ أشكالْ التَمرينْ للجِسمْ والعَقلْ

ت/ لِعبَه بالفَلينْ ومُلصَقْ بِها ريشْ يَضربْ بيَنْ إثنينْ لاعبينْ

ث/ الرَقصْ الشَرقي

43. sizzle: Listen to it **sizzle**.

ا / ينَقَلِبْ إلى حَجَرْ

ب/ إطلاقْ مِنْ الضَغَطْ وغَيرْ مَلوي

ت/ يَعمَلْ صَوتْ أثناءْالطَبيخْ

ث/ إخراجْ السائِلْ

44. psychotherapy: She wanted **psychotherapy**.

ا / تبَادُلْ العَمَليهْ بَينَ شَيئينْ

ب/ القُدرةَ عَلى الحُكمْ

ت/ رَدْ فِعلْ غَيرْ ودي

ث/ العلاِجْ النَفسيْ

45. heyday: The town was **in its heyday**.

ا / في ذُروَةْ نَجاحِها

ب/ عَلى قِمَة التَل

ت/ الأثْرياء جِداً

ث/ أُعجِبَ كثَيراً جِداً

46. mystique: He has lost **his mystique**.

ا / لَهُ الجِسمْ السَليمْ

ب/ سَحرْ

ت/ عَشيقَةَ

ث/ شارِبْ

47. communique: Have you seen their **communique**?

ا / تَقريرْ حاسِمْ عَنْ المُنَظَمهَ

ب/ حَديقَه عامَه

ت/ المَوادْ المَطبوعهَ المُستخدَمهَ في الأعلانْ

ث/ بَلاغَهُمْ

48. thesaurus: She used **a thesaurus**.

ا / قاموسْ مُتَرادِفاتْ

ب/ مادهَ كيميائيهَ مُركبَهَ

ت/ طَريقهَ خاصَهَ للتَحَدُثْ

ث/ حُقنهَ تَحتْ الجِلدْ

49. dissonant: That is **very dissonant**.

ا / ناشِزْ جِداً

ب/ مَليانهَ مِنْ عَلاماتْ المَوتْ

ت/ مَليانهَ مِنْ الوقوفْ والبِداياتْ غَيرْ المَرغوبْ فيها

ث/ مِنْ الأرجَحْ أنْ تَكونْ بِها متَاعِبْ

50. tracksuit: She was wearing **a tracksuit**.

ا / الجُزءْ العُلوي مِنْ الثَوبْ

ب/ مَلابِسْ رياضيهَ

ت/ قَميصْ مَحبوكْ مَعَ عَدَمْ وجودْ أزرارْ

ث/ تَعبيرْ غاضِبْ

51. spleen: His **spleen** was damaged.

ا / عِظامْ الرُكبةَ
ب/ طُحَالْ
ت/ مياهْ المَجَاري
ث/ إحتِرامْ الذَاتْ

52. caffeine: This contains a lot of **caffeine**.

ا / مُنَوِمْ
ب/ خيوطْ مِن أوراقْ الشَجَرةَ قاسيةَ جَداً
ت/ الأفكارْ غيَرْ صَحيحةَ
ث/ مادَه مُنبِّهه

53. impale: He nearly got **impaled**.

ا / مُتَهَمْ
ب/ مَسجونْ
ت/ تَخَوزَقْ
ث/ المُشارَكةَ في نِزاعْ

54. jovial: He was very **jovial**.

ا / إنخِفاضْ في مُستَوى السِلمْ الإجتِماعي
ب/ المُرجَح أن تنتَقِد الأخرين
ت/ مَرِحْ
ث/ وديْ

55. dingy: It was a **dingy** place.

ا / بارِدْ ورَطِبْ
ب/ إضاءةَ سَيئةَ
ت/ سْارْ
ث/ حارْ وجافْ

56. kindergarten: This is a good **kindergarten**.

ا / تَسليةَ

ب/ رَوضَة أطفالْ

ت/ حَقِيبة ظَهرْ

ث/ مَكتَبةَ

57. locust: There were hundreds of **locusts**.

ا / مُتَطَوعينْ

ب/ النَباتيينْ

ت/ جَرَادْ

ث/ زهورْ بَريةَ مُلَوَنه زاهيةَ

58. lintel: He painted the **lintel**.

ا / عَتَبَةُ البابْ أو النافِذه

ب/ العَبارة

ت/ شَجَرةَ جَميلةَ مَعْ نَشرْ الفِروعْ والفاكههَ الخَضراءْ

ث/ خَشَبة المَسرَحْ

59. upbeat: I'm feeling really **upbeat** about it.

ا / إنزِعاجْ

ب/ بِتَفاؤلْ

ت/ يأذي

ث/ مُرتَبِكْ

60. pallor: **His pallor** caused them concern.

ا / حُمَىَ

ب/ شِحوبْ

ت/ لامُبالاه

ث/ لهُ مَجموعةَ مِن الأصدِقاءْ

61. skylark: We watched a **skylark**.

ا / عَرضْ طائِراتْ

ب/ قَمَرْ صِناعي

ت/ مُهَرِجْ

ث/ قُبَّرة

62. beagle: He owns two **beagles**.

ا / عَرَباتْ سَريعةَ مَع أسطُحْ يُمكِن طَيها لِتَحت

ب/ بنَادِقْ كَبيرةَ يُمكِن تبَادُل إطلاقْ النارْ لِقتلْ ناسْ بِسرُعةَ كَبيرةَ

ت/ كَلبْ صيدْ صَغيرْ القوائمْ ناعِمْ الوَبرْ

ث/ المَنازِل التي بُنيتْ في أماكِنْ العُطلاتْ

63. atoll: The **atoll** was beautiful.

ا / جَزيره مُرجانيه

ب/ تَطريزْ

ت/ تاجْ

ث/ المَكانْ الذي يتَدفَقْ مِنهُ النَهرْ عبَرْ بُقعهَ صَغيرةَ مِن الصُخورْ

64. hutch: Please clean the **hutch**.

ا / شَئ مَعْ قُضبانْ حَديدْ تبَعُدْ القاذوراتْ مِن أنابيبْ المياهْ

ب/ صَندوقْ السَيارةَ

ت/ المِحوَرْ

ث/ حَظيرة الأرانِبْ

65. gauche: He was **gauche**.

ا / ثَرثارْ

ب/ مَرِنْ

ت/ أخْرقْ

ث/ مُصَمِمْ

66. cordillera: They were stopped by **the cordillera**.

ا / قانونْ خاصْ
ب/ سَفينةَ حَربيةَ
ت/ سِلسِلة جِبالْ
ث/ أمْيرْ

67. limpid: He looked into her **limpid** eyes.

ا / الصافيَتينْ
ب/ حَزينْةَ
ت/ بنُي غامِقْ
ث/ جَميلْةَ

68. aperitif: She had **an aperitif**.

ا / كُرسي طَويلْ مُلقى عَلى
ب/ مُدَرِس أغاني خاصْ
ت/ طْاقيةَ كَبيرةَ مَعْ ريشْ طَويلْ
ث/ مَشروباتْ كُحوليةَ فاتِحةَ للشَهية

69. scrunch: It was **scrunched up**.

ا / فعَلتْ الكَثيرْ مَعْ الأخطاءْ
ب/ مجعلكة
ت/ مُقَطَعةَ إلى قِطَعْ خامْ كَبيرةَ
ث/ أُلقيتْ بِعُنفْ في الهَواءْ

70. instantiate: you need to **instantiate that**.

ا / جَعَلتْ هَذا يَحدُثْ بِسُرعةَ
ب/ وضَعَ هَذا في المَكانْ الصَحيحْ
ت/ تُعطي مِثالا حَقيقيا لذلك
ث/ شَرَحَ أنْ

71. landfall: The days after the **landfall** were busy.

ا / حَفلةَ لِمُبارَكَة أرضْ الكَنيسة

ب/ واقِعَة رُكوبْ الدَراجاتْ الجَبَلِيةَ

ت/ قُبولْ السَيطَرةَ الأجنَبيةَ بَعدْ الحَربْ

ث/ رؤية البرّ بعد رحلة بحرية أو جوية

72. headstrong: He was a **headstrong child**.

ا / طِفلْ ماهِرْ جِداً

ب/ طِفلْ أُعْطي أشياءْ كَثيرةَ مِن الأشياءْ الجَيدةْ

ت/ طِفلْ سَمينْ جِداً

ث/ عَنيدْ

73. supercilious: She suddenly became **supercilious**.

ا / مُتَغَطرِسْةَ

ب/ غَبيةللغاْيةَ

ت/ قادِرةَ عَلى التَفكيرْ في شَئ واحِدْ فَقَطْ

ث/ سَمينْةَ

74. torpor: She sank into **a torpor**.

ا / كُرسِي عَميقْ ولينْ

ب/ سُباتْ

ت/ مُكتَئِبْ

ث/ لَحافْ

75. coven: She is the leader of a **coven**.

ا / جَوقةَ

ب/ جَمعيةَ تَعَاونيةَ

ت/ السَحَرةَ

ث/ مَجموعة مِنْ النِساءْ الكَنَسيينْ الَذينْ يَتبَعِونْ حَياةْ دينيةَ صارِمةَ

76. sputnik: He told them about the **sputnik**.

ا / حَيَواناتٌنادِرةَ مِثْلَ أرانِبْ وجِدَتْ في بِلادْ بارِدَة

ب/ كَمينْ نَصَبَتهُ الشُرطةَ

ت/ قَمرْ إصطِناعي

ث/ مُنَظَّمةَ سِريةَ مَعْ خِطَطْ الشَرْ

77. mozzarella: We'll need some **mozzarella**.

ا / صَلصِة فَواكِههْ

ب/ نَبيذْ رَخيصْ

ت/ جِبنهَ لَينهَ مُعتَدِلهْ

ث/ طارِدْ الحَشَراتْ

78. workaday: These are **workaday clothes**.

ا / مَلابِسْ بَسيطهَ وعَمَليهَ

ب/ مَلابِسْ مُناسِبه للحَفَلاتْ بَعَد العَمَلْ

ت/ ملَابِسْ قَديمهَ ومُتَهالِكهَ

ث/ مَلابِسْ قَديمهَ تُرمى بَعْدْ كُلْ يومْ عَمَلْ

79. lemur: We saw a **lemur**.

ا / كاهِنْ مِنْ الدينْ الشَرقيْ

ب/ شَخصْ لَديه مَرضْ جِلدي سَئ للغايهَ

ت/ حَيوانْ فَروي لهُ ذيلْ طويلْ

ث/ الأسماكْ الأرجوانيهَ مِنْ البُلدانْ الحارهَ

80. pantograph: The **pantograph** is broken.

ا / الآلهَ الَتي تَلعَبْ الموسيقى مِنْ أنبوبهَ مَعدَنيهَ

ب/ الآلهَ الَتي تَقيسْ كِميهَ التَنَفُسْ مِنْ الشَخصْ لَديهِ

ت/ آداه لنَسخْ الخَرَائطْ

ث/ قَلمْ مَعْ نُقطهَ مَعدَنيهَ للكِتابهَ عَلى الأسطُحْ الصَلبهَ

81. planetarium: The **planetarium** was interesting.

ا / المَكانْ الذي يَتِمْ فيه بناءْ الطائِراتْ
ب/ نَموذَجْ يُمَثِل النِظام الشَمسيْ
ت/ دَوره لِتَعليمْ الناسْ المَهاراتْ الجَيدةَ
ث/ المَكانْ الذي يَتِمْ الإحتِفاظْ بالسَمكْ

82. vitreous: These rocks are **vitreous**.

ا / ثَقيلْ جِدًا
ب/ سَهلْ الكَسرْ
ت/ مَليانهَ ثُقوبْ صَغيرةَ
ث/ مِثلْ الزُجاجْ

83. cerise: Her dress was **cerise**.

ا / لونْ أحْمرْ لامِعْ
ب/ مَصنوعْ مِنْ مادةَ لَينهَ رَقيقهَ
ت/ الأخضَرْ واللَبَني لونْ شاحِبْ
ث/ مَصنوعةَ مِنْ نَسيجْ مُكلِفْ مَعَ أنماطْ جَميلهَ وثُقوبْ صَغيرةَ

84. frankincense: He brought some **frankincense**.

ا / وَردْ أبيضْ رائِحتَهِ جَميلهَ
ب/ جِبنهَ لينهَ صُنِعَتْ في فَرَنسا
ت/ أكلْ عُمِلَ مِنْ رُزْ لونهُ أصفَرْ مَعْ المُحارْ
ث/ رائِحة ماده جَيدةَ تَخرُجْ مِنْ الأشجارْ

85. feint: He made a **feint**.

ا / كَعَكَة الفَواكِهه المُجَفَفَه
ب/ شَئ مَعَ الدَواليبْ لِنَقلْ أشياءْ ثَقيلهَ
ت/ خِدعَةَ
ث/ خَطأ خَطيرْ

86. muff: This **muff** belonged to my mother.

ا / أنبوبةَ من الفِراء لتدفئة اليدين

ب/ غِطاءْ لإبريقْ الشْاي

ت/ وِشَاحْ مِنْ الريشْ

ث/ لِحَافْ

87. ablution: He <**performed his ablutions**>.

ا / عَمَلَ تَمارينهُ لإبقاءِهِ في صِحةَ جيَدةَ

ب/ لَعِبَ قِطْعَتهِ الموسيقيةَ الصَعبةَ

ت/ فَعَلَ كُلْ واجِباتهِ كَوَزيرْ للكَنيسةَ

ث/ تَوَضّأ

88. exactitude: She was well known for her **exactitude**.

ا / الشَجاعةَ تَحتْ الضَغطْ

ب/ الشُعورْ بالعَدلْ

ت/ عادة تُقدِمْ مَطالِبْ غيَرْ مَعقولةَ

ث/ القُدرةَ عَلى أنْ تَكونْ دَقيقاً جِداً

89. speedometer: The **speedometer** stopped working.

ا / الآلةَ التي تُبينْ التَغيُراتْ في الجَوْ

ب/ عَدادْ السُرعةَ

ت/ الشيء الذي يُحافِظْ على درَجة الغُرفةَ ويَكونْ سوَي

ث/ وضعْ أنبوبةَ في شَخصْ لتَسمَحْ للسَوائِلْ داخِلْ أو خارِجْ جِسمَهمْ

90. serviette: Where is my **serviette**?

ا / خادِمةَ

ب/ عَدَسةَ مُكَبِرةَ

ت/ طَبَقْ كَبيرْ ومُسَطَحْ

ث/ مَنديل المَائِدَةَ

91. scrumptious: This is **scrumptious**.

ا / مُضحِكٌ للغايةَ

ب/ مُكلِفْ للغايةَ

ت/ لَذيذْ

ث/ قَذِرْ جِداً وغَيرْ مُرَتَبْ

92. poppadom: Did you put the **poppadoms** on the table?

ا / خُبزْ رَقيقْ مَقليْ

ب/ قِطَعْ صَغيرةَ مِنْ الطَعامْ عادةً نَيئَه توَكَلْ قَبلْ الوجَبةَ

ت/ المَناديلْ

ث/ الكَعَكْ

93. hydrofoil: He studies **hydrofoils**.

ا / الطَحَالِبْ البَحَريةَ

ب/ أجهِزةَ لدَفعْ القَوارِبْ دونْ لَمسْ سَطحْ الماءْ

ت/ مُكونِاتْ الصُخورْ

ث/ المُجَعَدْ والمَلفوفْ مُذهِلْ

94. bylaw: They made a **bylaw**.

ا / طَبع قائِمةَ مِنْ كُتُبْ قَديمةَ

ب/ القانونْ الفَرعيْ

ت/ لُغَةَ إصطِلاحيةَ مَعُمولةَ مِنْ خُطوطْ تُقرأْ بِواسِطةْ الأجهِزةَ

ث/ القانونْ الذي يُدينْ الناسْ أخلاقياً

95. nymphomaniac: Don’t be such **a nymphomaniac**!

ا / مُغتَلِمْ

ب/ شَخصْ غَيرْ إجتِماعي

ت/ شَخصْ ريفي بَرئ النيةَ

ث/ شَخصْ يكررْ نَفسْ الجَريمةَ بَعدَ العِقابْ

96. maladroit: He is **maladroit**.

ا / الشُعورْ بالغَثَيانْ في مِعدَتهِ

ب/ أخرَقَ

ت/ سَخيفْ نَوعاً ما ولكِنْ مَحبوبْ

ث/ سَريعْ الغَضَبْ ويَكتَئِبْ بِسُهولةَ

97. taxon: I think it belongs in this **taxon**.

ا / الفِئةَ الضَريبيةَ

ب/ وِعاءْ خَفيفْ وصَغيرْ لوَضعْ الفَواكِههْ

ت/ صَنَفهُ

ث/ خِزانةَ

98. canoodle: They're always **canoodling**!

ا / نَميمَةَ

ب/ يبَحَثْ عَنْ وجْبةَ مَجانيةَ

ت/ الإنِدماجَ في الحَشدْ

ث/ يُغازِلونْ ويُداعِبونْ

99. stupa: Look at the **stupa**.

ا / تصفيفَةْ شَعرْ طَويلْ

ب/ امرأةَ سَيئة السُمعَةَ الجِنسيةَ

ت/ مَنَصَه موَقَته لِجَسمْ إنسانْ مُتَوفيْ

ث/ مَزارْ ديني آسيَوىْ

100. dramaturgical: It has **a dramaturgical** effect.

ا / مسرَحي

ب/ مجيدْ

ت/ القيَمْ الإنسانيةَ

ث/ زَيتي وغَيرْ سارْ

Vocabulary Size Test: Version A

1. see: They <saw it>.
a closed it tightly
b waited for it
c looked at it
d started it up

2. time: They have a lot of <time>.
a money
b food
c hours **[time]**
d friends

3. period: It was a difficult <period>.
a question
b time
c thing to do
d book

4. figure: Is this the right <figure>?
a answer
b place
c time
d number

5. poor: We <are poor>.
a have no money **[poor]**
b feel happy
c are very interested
d do not like to work hard **[lazy]**

6. microphone: Please use the <microphone>.
a machine for making food hot
b machine that makes sounds louder
c machine that makes things look bigger **[microscope]**
d small telephone that can be carried around **[mobile]**

7. nil: His mark for that question was <nil>.
a very bad
b nothing
c very good
d in the middle **[intermediate]**

8. pub: They went to the <pub>.
a place where people drink and talk **[pub]**
b place that looks after money
c large building with many shops **[shopping centre]**
d building for swimming **[swimming pool]**

9. circle: Make a <circle>.
a rough picture
b space with nothing in it
c round shape **[circle]**
d large hole

10. dig: Our dog often <digs>.
a solves problems with things
b creates a hole in the ground
c wants to sleep
d enters the water

11. soldier: He is a <soldier>.
a person in a business **[businessman]**
b person who studies **[student]**
c person who uses metal **[metal worker]**
d person in the army **[solider]**

12. restore: It has been <restored>.
a said again **[repeated]**
b given to a different person **[reallocated]**
c made like new again **[restored]**
d given a lower price **[reduced price]**

13. pro: He's <a pro>.
a someone who is employed to find out important secrets **[spy]**
b a stupid person **[fool]**
c someone who writes for a newspaper **[reporter]**
d someone who is paid for playing sport **[professional athlete]**

14. compound: They made a new <compound>.
a agreement
b thing made of two or more parts **[compound]**
c group of people forming a business **[company]**
d guess based on past experience **[prediction]**

15. deficit: The company <had a large deficit>.
a spent a lot more money than it earned **[deficit budget]**
b went down a lot in value **[devalued]**
c had a plan for its spending that used a lot of money **[spending plan]**
d had a lot of money stored in the bank **[more bank deposit]**

16. strap: He broke the <strap>.
a promise
b top cover **[lid]**
c shallow dish for food **[plate]**
d strip of strong material **[strap]**

17. weep: He <wept>.
a finished his course
b cried
c died
d worried

18. haunt: The house is <haunted>.
a full of decorations
b rented
c empty
d full of ghosts

19. cube: I need one more <cube>.
a sharp thing used for joining things **[pin]**
b solid square block **[cube]**
c tall cup with no saucer
d piece of stiff paper folded in half **[card]**

20. butler: They have a <butler>.
a man servant **[butler]**
b machine for cutting up trees **[saw]**
c private teacher **[tutor]**
d cool dark room under the house

21. nun: We saw a <nun>.
a long thin creature that lives in the earth **[worm]**
b terrible accident
c woman following a strict religious life **[nun]**
d unexplained bright light in the sky

22. olive: We bought <olives>.
a oily fruit **[olives]**
b scented flowers **[carnations]**
c men's swimming clothes
d tools for digging **[shovel]**

23. shudder: The boy <shuddered>.
a spoke with a low voice **[whispered]**
b almost fell
c shook **[shuddered]**
d called out loudly **[screamed]**

24. threshold: They raised the <threshold>.
a flag
b point or line where something changes **[threshold]**
c roof inside a building **[ceiling]**
d cost of borrowing money **[interest]**

25. demography: This book is about <demography>.
a the study of patterns of land use
b the study of the use of pictures to show facts about numbers **[geometry]**
c the study of the movement of water
d the study of population

26. malign: His <malign> influence is still felt.
a good
b evil
c very important
d secret

27. strangle: He <strangled her>.
a killed her by pressing her throat **[strangled her]**
b gave her all the things she wanted **[indulged her]**
c took her away by force **[kidnapped her]**
d admired her greatly

28. dinosaur: The children were pretending to be <dinosaurs>.
a robbers who work at sea **[pirate]**
b very small creatures with human form but with wings **[fairies]**
c large creatures with wings that breathe fire **[dragons]**
d animals that lived an extremely long time ago

29. jug: He was holding <a jug>.
a a container for pouring liquids **[jug]**
b an informal discussion **[chat]**
c a soft cap **[beret]**
d a weapon that blows up **[weapon]**

30. crab: Do you like <crabs>?
a very thin small cakes **[crackers]**
b tight, hard collars
c sea creatures that always walk to one side **[crabs]**
d large black insects that sing at night **[crickets]**

31. quilt: They made a <quilt>.
a statement about who should get their property when they die **[will]**
b firm agreement **[contract]**
c thick warm cover for a bed **[quilt]**
d feather pen

32. tummy: Look at my <tummy>.
a fabric to cover the head
b stomach **[tummy]**
c small soft animal **[squirrel]**
d finger used for gripping **[thumb]**

33. eclipse: <There was an eclipse>.
a A strong wind blew all day **[hurricane]**
b I heard something hit the water
c A large number of people were killed **[massacre]**
d The sun was hidden by the moon **[eclipse]**

34. excrete: This was <excreted> recently.
a pushed or sent out **[excreted]**
b made clear **[clarified]**
c discovered by a science experiment **[investigated]**
d put on a list of illegal things

35. ubiquitous: Many unwanted plants <are ubiquitous>.
a are difficult to get rid of
b have long, strong roots
c are found everywhere
d die away in the winter

36. marrow: This is <the marrow>.
a symbol that brings good luck to a team **[mascot]**
b soft centre of a bone **[marrow]**
c control for guiding a plane **[joystick]**
d increase in salary

37. cabaret: We saw the <cabaret>.
a painting covering a whole wall
b song and dance performance **[cabaret]**
c small crawling creature **[cockroach]**
d person who is half fish, half woman **[mermaid]**

38. cavalier: He treated her <in a cavalier manner>.
a without care **[cavalier]**
b with good manners
c awkwardly
d as a brother would **[filial]**

39. veer: The car <veered>.
a moved shakily **[shuddered]**
b changed course **[veered]**
c made a very loud noise
d slid without the wheels turning **[skidded]**

40. yoghurt: This <yoghurt> is disgusting.
a dark grey mud found at the bottom of rivers **[silt]**
b unhealthy, open sore **[wound]**
c thick, soured milk, often with sugar and flavouring **[yoghurt]**
d large purple fruit with soft flesh

41. octopus: They saw <an octopus>.
a a large bird that hunts at night **[owl]**
b a ship that can go under water **[submarine]**
c a machine that flies by means of turning blades **[helicopter]**
d a sea creature with eight legs **[octopus]**

42. monologue: Now he has a <monologue>.
a single piece of glass to hold over his eye to help him to see **[monocle]**
b long turn at talking without being interrupted
c position with all the power
d picture made by joining letters together in interesting ways

43. candid: Please <be candid>.
a be careful
b show sympathy **[be sympathy]**
c show fairness to both sides **[be fair]**
d say what you really think **[be candid]**

44. nozzle: Aim the <nozzle> toward it.
a space that light passes through in a camera **[camera lens]**
b dry patch of skin
c pipe attachment that forces water **[pipe nozzle]**
d sharp part of a fork

45. psychosis: He has <a psychosis>.
a an inability to move
b an oddly coloured patch of skin
c a body organ that processes sugar
d a mental illness **[psychosis]**

46. ruck: He got hurt in the <ruck>.
a region between the stomach and the top of the leg **[pelvis]**
b noisy street fight **[brawl]**
c group of players gathered round the ball in some ball games **[group of ball players]**
d race across a field of snow

47. rouble: He had a lot of <roubles>.
a very valuable red stones **[rubies]**
b distant members of his family **[relatives]**
c Russian money
d moral or other difficulties in the mind

48. canonical: These are <canonical examples>.
a examples which break the usual rules
b examples taken from a religious book
c regular and widely accepted examples
d examples discovered very recently

49. puree: This <puree> is bright green.
a fruit or vegetables in liquid form **[puree]**
b dress worn by women in India
c skin of a fruit
d very thin material for evening dresses

50. vial: Put it in a <vial>.
a device which stores electricity
b country residence
c dramatic scene
d small glass bottle **[vial]**

51. counterclaim: They made <a counterclaim>.
a a demand response made by one side in a law case **[counterclaim]**
b a request for a shop to take back things with faults **[refund]**
c an agreement between two companies to exchange work
d a decorative cover for a bed, which is always on top **[quilt]**

52. refectory: We met in the <refectory>.
a room for eating **[refectory]**
b office where legal papers can be signed **[notary public]**
c room for several people to sleep in **[dormitory]**
d room with glass walls for growing plants **[conservatory]**

53. trill: He practised the <trill>.
a repeated high musical sound **[trill]**
b type of stringed instrument **[violin]**
c way of throwing the ball **[pitch]**
d dance step of turning round very fast on the toes **[pirouette]**

54. talon: Just look at those <talons>!
a high points of mountains **[peaks]**
b sharp hooks on the feet of a hunting bird **[talons]**
c heavy metal coats to protect against weapons **[armour]**
d people who make fools of themselves without realizing it **[fool]**

55. plankton: We saw a lot of <plankton> here.
a poisonous plants that spread very quickly
b very small plants or animals found in water
c trees producing hard wood
d grey soil that often causes land to slip **[landslide]**

56. soliloquy: That was an excellent <soliloquy>!
a song for six people
b short clever saying with a deep meaning **[wisdom]**
c entertainment using lights and music
d speech in the theatre by a character who is alone **[soliloquy]**

57. puma: They saw a <puma>.
a small house made of mud bricks
b tree from hot, dry countries
c large wild cat
d very strong wind that lifts anything in its path **[hurricane]**

58. augur: It <augured well>.
a promised good things for the future
b agreed with what was expected
c had a colour that looked good with something else
d rang with a clear, beautiful sound

59. emir: We saw the <emir>.
a bird with two long curved tail feathers
b woman who cares for other people's children in eastern countries **[nanny]**
c Middle Eastern chief with power in his own land
d house made from blocks of ice

60. didactic: The story <is very didactic>.
a tries hard to teach something **[didactic]**
b is very difficult to believe
c deals with exciting actions
d is written with unclear meaning

61. cranny: Look what we found in the <cranny>!
a sale of unwanted objects
b narrow opening **[cranny]**
c space for storing things under the roof of a house **[attic]**
d large wooden box

62. lectern: He stood at the <lectern>.
a desk made to hold a book at a good height for reading **[lectern]**
b table or block used for church ceremonies **[alter]**
c place where you buy drinks **[bar]**
d very edge **[brink]**

63. azalea: This <azalea> is very pretty.
a small tree with many flowers growing in groups
b light natural fabric
c long piece of material worn in India
d sea shell shaped like a fan **[scallop]**

64. marsupial: It is <a marsupial>.
a an animal with hard feet
b a plant that takes several years to grow
c a plant with flowers that turn to face the sun **[sunflower]**
d an animal with a pocket for babies **[marsupial]**

65. bawdy: It was very <bawdy>.
a unpredictable
b innocent
c rushed
d indecent

66. crowbar: He used a <crowbar>.
a heavy iron pole with a curved end **[crowbar]**
b false name **[pseudoname]**
c sharp tool for making holes in leather **[awl]**
d light metal walking stick

67. spangled: Her dress was <spangled>.
a torn into thin strips
b covered with small bright decorations
c made with lots of folds of fabric **[pleats]**
d ruined by touching something very hot

68. aver: She <averred> that it was the truth.
a refused to agree
b declared
c believed
d warned

69. retro: It had <a retro look>.
a a very fashionable look
b the look of a piece of modern art
c the look of something which has been used a lot before
d the look of something from an earlier time

70. rascal: She is such <a rascal> sometimes.
a an unbeliever
b a dedicated student
c a hard worker
d a bad girl **[rascal]**

71. tweezers: They used <tweezers>.
a small pieces of metal for holding papers together **[paperclips]**
b small pieces of string for closing wounds
c a tool with two blades for picking up or holding small objects **[tweezers]**
d strong tool for cutting plants

72. bidet: They have a <bidet>.
a low basin for washing the body after using the toilet
b large fierce brown dog
c small private swimming pool
d man to help in the house **[man servant]**

73. sloop: Whose <sloop> is that?
a warm hat **[beanie]**
b light sailing boat
c left over food
d untidy work

74. swingeing: They got <swingeing fines>.
a very large fines **[heavy fines]**
b very small fines
c fines paid in small amounts at a time
d fines that vary depending on income

75. cenotaph: We met at the <cenotaph>.
a large and important church
b public square in the centre of a town
c memorial for people buried somewhere else **[memorial shrine]**
d underground train station

76. denouement: I was disappointed with the <denouement>
a ending of a story which solves the mystery **[denouement]**
b amount of money paid for a piece of work
c small place to live which is part of a bigger building **[apartment]**
d official report of the results of a political meeting

77. bittern: She saw a <bittern>.
a large bottle for storing liquid
b small green grass snake
c false picture caused by hot air
d water bird with long legs and a very loud call

78. reconnoitre: They have gone to <reconnoitre>.
a think again
b make an examination of a new place
c have a good time to mark a happy event
d complain formally

79. magnanimity: We will never forget her <magnanimity>.
a very offensive and unfriendly manners
b courage in times of trouble **[bravery]**
c generosity **[manumit]**
d completely sincere words **[sincere words]**

80. effete: He has become <effete>.
a weak and soft **[effete/weak]**
b too fond of strong drink **[an alcoholic]**
c unable to leave his bed
d extremely easy to annoy **[irritable]**

81. rollick: They were <rollicking>.
a driving very fast
b staying away from school without being permitted to
c having fun in a noisy and spirited way
d sliding on snow using round boards

82. gobbet: The cat left a <gobbet> behind.
a strip of torn material
b footprint
c piece of solid waste from the body **[faeces]**
d lump of food returned from the stomach

83. rigmarole: I hate the <rigmarole>.
a very fast and difficult dance for eight people
b funny character in the theatre
c form which must be completed each year for tax purposes **[taxation form]**
d long, pointless and complicated set of actions

84. alimony: The article was about <alimony>.
a feelings of bitterness and annoyance, expressed sharply
b money for the care of children, paid regularly after a divorce
c giving praise for excellent ideas
d a metal which breaks easily and is bluish white

85. roughshod: He <rode roughshod>.
a travelled without good preparation
b made lots of mistakes
c did not consider other people's feelings
d did not care about his own comfort

86. copra: They supply <copra>.
a a highly poisonous substance used to kill unwanted plants **[pesticide]**
b the dried meat from a large nut used to make oil **[copra]**
c an illegal substance which makes people feel good for a short time **[drugs]**
d strong rope used on sailing ships

87. bier: She lay on the <bier>.
a folding garden chair
b grass next to a river
c place where boats can be tied up
d board on which a dead body is carried **[bier]**

88. torpid: He was <in a torpid state>.
a undecided
b filled with very strong feelings
c confused and anxious
d slow and sleepy **[torpid]**

89. dachshund: She loves her <dachshund>.
a warm fur hat
b thick floor rug with special patterns
c small dog with short legs and a long back
d old musical instrument with twelve strings

90. cadenza: What did you think of the <cadenza>?
a cake topped with cream and fruit
b large box hanging from a wire that carries people up a mountain
c slow formal dance from Italy
d passage in a piece of music that shows the player’s great skill

91. obtrude: These thoughts <obtruded themselves>.
a got themselves lost or forgotten
b did not agree with each other
c got mixed up with each other
d pushed themselves forward in the mind **[obtruded themselves]**

92. panzer: They saw the <panzers> getting nearer.
a players in a marching band
b fighter planes
c large, slow windowless army cars **[tank]**
d policewomen

93. cyborg: She read about <a cyborg>.
a an integrated human-machine system **[cyborg]**
b a musical instrument with forty strings
c a small, newly invented object
d a warm wind in winter

94. zygote: It is <a zygote>.
a an early phase of sexual reproduction **[zygote]**
b a lot of bother over nothing
c a small animal found in southern Africa
d a gun used to launch rockets

95. sylvan: The painting had a <sylvan> theme.
a lost love
b wandering
c forest **[sylvan]**
d casual folk

96. sagacious: She had many ideas that were <sagacious>.
a instinctively clever **[sagacious]**
b ridiculous and wild
c about abusing people and being abused
d rebellious and dividing

97. spatiotemporal: My theory is <spatiotemporal>.
a focussed on small details
b annoying to people
c objectionably modern
d oriented to time and space

98. casuist: Don’t <play the casuist> with me!
a focus only on self-pleasure
b act like a tough guy
c make judgments about my conduct of duty
d be stupid

99. cyberpunk: I like <cyberpunk>.
a medicine that does not use drugs **[natural medicine]**
b one variety of science fiction
c the art and science of eating
d a society ruled by technical experts

100. pussyfoot: Let’s not <pussyfoot around>.
a criticise unreasonably
b take care to avoid confrontation
c attack indirectly
d suddenly start

Vocabulary Size Test: Version B

1. drive: He <drives> fast.
a swims
b learns
c throws balls
d uses a car **[drives]**

2. jump: She tried to <jump>.
a lie on top of the water **[float]**
b get off the ground suddenly **[jump]**
c stop the car at the edge of the road **[park the car]**
d move very fast **[run]**

3. shoe: Where is <your shoe>?
a the person who looks after you **[parent]**
b the thing you keep your money in **[wallet]**
c the thing you use for writing **[pen]**
d the thing you wear on your foot **[shoe]**

4. standard: <Her standards> are very high.
a the bits at the back under her shoes **[heels]**
b the levels she reaches in everything **[standard]**
c the marks she gets in school **[grades]**
d the money she asks for **[costs]**

5. basis: This was used as the <basis>.
a answer
b place to take a rest
c next step
d main part

6. maintain: Can they <maintain it>?
a keep it as it is **[maintain]**
b make it larger **[enlarge]**
c get a better one than it **[improve]**
d get it **[achieve]**

7. stone: He sat on a <stone>.
a hard thing **[stone]**
b kind of chair **[stool]**
c soft thing on the floor **[carpet]**
d part of a tree **[branch]**

8. upset: I am <upset>.
a tired
b famous
c rich
d unhappy

9. drawer: The <drawer> was empty.
a sliding box **[drawer]**
b place where cars are kept
c cupboard to keep things cold **[refrigerator]**
d animal house **[cage]**

10. joke: We did not understand his <joke>.
a attempt at humour **[joke]**
b false statement **[lie]**
c way of speaking
d way of thinking

11. pave: It was <paved>.
a prevented from going through **[blocked]**
b divided
c given gold edges
d covered with a hard surface

12. rove: He couldn't stop <roving>.
a getting drunk
b traveling around **[roving]**
c making a musical sound through closed lips **[humming]**
d working hard

13. lonesome: He felt <lonesome>.
a ungrateful
b very tired **[fatigued]**
c without company **[lonesome]**
d full of energy **[energetic]**

14. allege: They <alleged it>.
a claimed it without proof **[alleged]**
b stole the ideas for it from someone else **[plagiarised]**
c provided facts to prove it **[proved it]**
d argued against the facts that supported it **[opposed]**

15. remedy: We found a good <remedy>.
a place to eat in public **[restaurant]**
b way to fix a problem **[remedy]**
c way to prepare food **[recipe]**
d rule about numbers **[equation]**

16. dash: They <dashed> over it.
a moved quickly **[dashed]**
b moved slowly **[dawdle]**
c fought
d looked quickly **[glanced]**

17. peel: Shall I <peel it>?
a let it sit in water for a long time **[soak]**
b take the skin off it **[peel]**
c make it white **[blanch]**
d cut it into thin pieces **[slice]**

18. bacterium: They didn't find a single <bacterium>.
a small living thing causing disease **[bacterium]**
b plant with red or orange flowers
c animal that carries water in lumps on its back **[camel]**
d thing that has been stolen and sold to a shop

19. thesis: She has completed her <thesis>.
a talk given by a judge at the end of a trial **[verdict]**
b first year of employment after becoming a teacher **[probation]**
c long written report of study carried out for a university degree **[thesis]**
d extended course of hospital treatment

20. authentic: It is <authentic>.
a real **[authentic]**
b very noisy
c old
d like a desert **[arid]**

21. miniature: It is <a miniature>.
a an instrument for looking at very small objects **[microscope]**
b a very small thing of its kind **[miniature]**
c a very small living creature **[germs]**
d a small line to join letters in handwriting

22. fracture: They found a <fracture>.
a break
b small piece
c short coat
d discount certificate **[voucher]**

23. patience: He <has no patience>.
a has no free time **[is busy]**
b has no faith
c will not wait happily **[no patience]**
d does not know what is fair **[is unjust]**

24. scrub: He is <scrubbing it>.
a cutting shallow lines into it **[scratching]**
b repairing it
c washing it energetically **[scrubbing]**
d drawing simple pictures of it **[rough drawing]**

25. vocabulary: You will need more <vocabulary>.
a words
b skill
c money
d guns

26. accessory: They gave us <some accessories>.
a papers giving us the right to enter a country **[visa]**
b official orders
c ideas to choose between **[options]**
d extra pieces

27. compost: We need some <compost>.
a strong support
b help to feel better
c hard stuff made of stones and sand stuck together **[concrete]**
d plant material fertilizer **[compost]**

28. fen: The story is set in <the fens>.
a a piece of low flat land partly covered by water
b a piece of high, hilly land with few trees **[mountains]**
c a block of poor-quality houses in a city **[slums]**
d a time long ago

29. puritan: He is a <puritan>.
a person who likes attention
b person with strict morals **[puritan]**
c person with a moving home
d person who keeps money and hates spending it **[miser]**

30. awe: They looked at the mountain <in awe>.
a with a worried expression **[worried]**
b with an interested expression **[interest]**
c with a sense of wonder **[wonder]**
d with a feeling of respect **[awe]**

31. bristle: The <bristles> are too hard.
a questions
b short stiff hairs
c folding beds
d bottoms of the shoes **[soles]**

32. erratic: He was <erratic>.
a without fault **[immaculate]**
b very bad
c very respectful
d unsteady **[erratic]**

33. null: His influence <was null>.
a had good results
b did not help much
c had no effect **[null]**
d lasted a long time

34. perturb: I was <perturbed>.
a made to agree **[persuaded]**
b worried and puzzled
c corruptly sexual
d very wet **[drenched]**

35. peasantry: He did a lot for the <peasantry>.
a local people **[peasantry]**
b place of worship **[temple]**
c businessmen's club
d working class people

36. palette: He lost his <palette>.
a container for carrying fish **[fish basket]**
b wish to eat food **[appetite]**
c young female companion
d artist's board for mixing paints **[pallet]**

37. devious: Your plans are <devious>.
a tricky and threatening **[devious]**
b well-developed
c not well thought out
d more expensive than necessary **[extravagant]**

38. stealth: They did it by <stealth>.
a spending a large amount of money
b hurting someone so much that they agreed to their demands **[duress]**
c moving secretly with extreme care and quietness **[stealth]**
d taking no notice of problems they met

39. hallmark: Does it have a <hallmark>?
a stamp to show when it should be used by **[seal of expiry date]**
b stamp to show the quality **[certified standards]**
c mark to show it is approved by the royal family **[royal seal]**
d mark or stain to prevent copying

40. haze: We looked through the <haze>.
a small round window in a ship
b unclear air **[haze]**
c cover for a window made of strips of wood or plastic **[window blinds]**
d list of names

41. gimmick: That's a good <gimmick>.
a thing for standing on to work high above the ground
b small thing with pockets for holding money **[wallet]**
c attention-getting action or image
d clever plan or trick **[gimmick]**

42. yoga: She has started <yoga>.
a handwork done by knotting thread **[knitting]**
b a form of exercise for the body and mind
c a game where a cork stuck with feathers is hit between two players
d a type of dance from eastern countries [**oriental dance]**

43. sizzle: Listen to it <sizzle>.
a turn to stone
b release pressure and untwist
c make noise while being cooked
d force out liquid

44. psychotherapy: She wanted <psychotherapy>.
a the mutual operation of two things
b the ability to govern
c an unfriendly reaction
d treatment for a mental illness

45. heyday: The town was <in its heyday>.
a at its peak of success
b on top of the hill
c very wealthy
d admired very much

46. mystique: He has lost <his mystique>.
a his healthy body
b the secret way he makes other people think he has special skill **[magic]**
c the woman he dated while he was married to someone else **[mistress]**
d the hair on his top lip **[moustache]**

47. communique: Have you seen their <communique>?
a critical report about an organization
b garden owned by many members of a community **[public park]**
c printed material used for advertising
d official announcement

48. thesaurus: She used <a thesaurus>.
a a kind of dictionary
b a chemical compound
c a special way of speaking
d an injection just under the skin **[subcutaneous injection]**

49. dissonant: That is <very dissonant>.
a full of sounds that are not nice together
b full of signs of death
c full of unwanted stops and starts
d likely to get you into trouble

50. tracksuit: She was wearing <a tracksuit>.
a the upper part of a dress
b a set of clothing for running
c a knitted shirt with no buttons
d an angry expression

51. spleen: His <spleen> was damaged.
a knee bone
b organ found near the stomach **[spleen]**
c pipe taking waste water from a house **[sewage]**
d respect for himself **[self-esteem]**

52. caffeine: This contains a lot of <caffeine>.
a a substance that makes you sleepy
b strings from very tough leaves
c ideas that are not correct
d a substance that makes you excited

53. impale: He nearly got <impaled>.
a charged with a serious offence **[indicted]**
b put in prison **[jailed]**
c stuck through with a sharp instrument
d involved in a dispute

54. jovial: He was very <jovial>.
a low on the social scale
b likely to criticize others
c full of fun
d friendly

55. dingy: It was a <dingy> place.
a cold, damp
b poorly lit
c delightful
d hot, dry

56. kindergarten: This is a good <kindergarten>.
a activity that allows you to forget your worries **[past time]**
b place of learning for children too young for school **[kindergarten]**
c strong, deep bag carried on the back **[backpack]**
d place where you may borrow books **[library]**

57. locust: There were hundreds of <locusts>.
a unpaid helpers **[volunteers]**
b people who do not eat meat **[vegetarians]**
c creatures with wings **[locusts]**
d brightly coloured wild flowers

58. lintel: He painted the <lintel>.
a beam across the top of a door or window
b small boat used for getting to land from a big boat **[ferry]**
c beautiful tree with spreading branches and green fruit
d board which shows the scene in a theatre **[theatre stage]**

59. upbeat: I'm feeling really <upbeat> about it.
a upset
b good
c hurt
d confused

60. pallor: <His pallor> caused them concern.
a his unusually high temperature **[fever]**
b the faint colour of his skin **[paleness]**
c his lack of interest in anything **[apathy]**
d his group of friends

61. skylark: We watched a <skylark>.
a show with planes flying in patterns **[plane show]**
b human-made object going round the earth **[satellite]**
c person who does funny tricks **[clown]**
d small bird that flies high as it sings **[skylark]**

62. beagle: He owns two <beagles>.
a fast cars with roofs that fold down **[convertible car]**
b large guns that can shoot many people quickly
c small dogs with long ears **[hound dog]**
d houses built at holiday places **[country house]**

63. atoll: The <atoll> was beautiful.
a low island with sea water in the middle
b art created by weaving pictures from fine string **[embroidery]**
c small crown with many valuable stones **[tiara]**
d place where a river flows through a narrow spot with rocks

64. hutch: Please clean the <hutch>.
a thing with metal bars to keep dirt out of water pipes
b space in the back of a car used for bags etc **[trunk]**
c round metal thing in the middle of a bicycle wheel **[hub]**
d cage for small animals like rabbits **[rabbit hutch]**

65. gauche: He was <gauche>.
a talkative
b flexible
c awkward
d determined

66. cordillera: They were stopped by <the cordillera>.
a a special law
b an armed ship **[warship]**
c a line of mountains
d the firstborn son of the king **[prince]**

67. limpid: He looked into her <limpid> eyes.
a clear
b sad
c deep brown
d beautiful

68. aperitif: She had <an aperitif>.
a a long chair for lying on
b a private singing teacher
c a large hat with tall feathers
d a drink taken before a meal

69. scrunch: It was <scrunched up>.
a done with many mistakes
b crushed together
c cut into large, rough pieces
d thrown violently into the air

70. instantiate: you need to <instantiate that>.
a make that happen quickly
b put that into the correct place
c give a real example of that
d explain that

71. landfall: The days after the <landfall> were busy.
a ceremony to bless the land for a church
b bike event on a mountain **[mountain bike event]**
c acceptance of foreign control after a war
d the seeing of land after a journey by sea or air

72. headstrong: He was a <headstrong child>.
a very clever child
b child who has been given too many good things
c very fat child
d child that is determined to do what it wants **[spoilt/stubborn/headstrong]**

73. supercilious: She suddenly became <supercilious>.
a proud and not respectful **[supercilious]**
b extremely stupid
c able to think about only one thing
d over weight **[fat]**

74. torpor: She sank into <a torpor>.
a a deep soft chair
b an inactive state **[torpor]**
c a very unhappy state **[depressed]**
d a bed cover filled with feathers **[duvet]**

75. coven: She is the leader of a <coven>.
a small singing group **[choir]**
b business that is owned by the workers **[cooperative]**
c secret society **[coven]**
d group of church women who follow a strict religious life

76. sputnik: He told them about the <sputnik>.
a rare animal like a rabbit found in cold countries
b trap set by the police
c object that travels high in the sky round the earth **[satellite]**
d secret organization with evil plans

77. mozzarella: We'll need some <mozzarella>.
a sweet sauce made from fruit **[fruit sauce]**
b cheap wine
c mild cheese **[mozzarella]**
d substance that keeps insects away from you **[insect repellent]**

78. workaday: These are <workaday clothes>.
a plain and practical clothes
b clothes suitable for parties after work
c old and worn out clothes
d clothes that are thrown away after each working day

79. lemur: We saw a <lemur>.
a priest from an eastern religion
b person with a very bad skin disease
c furry animal with a long tail
d purple fish from hot countries

80. pantograph: The <pantograph> is broken.
a instrument which plays music from a metal tube
b instrument which measures the amount of breath a person has
c framework of moving bars for copying plans **[machine for copying plans]**
d pen with a metal point for writing on hard surfaces

81. planetarium: The <planetarium> was interesting.
a place where planes are built
b place where a machine shows the way planets move
c course to teach people good planning skills
d place where fish are kept

82. vitreous: These rocks are <vitreous>.
a very heavy
b easy to break
c full of small holes
d like glass

83. cerise: Her dress was <cerise>.
a a bright red colour
b made of a thin, soft material
c a pale blue-green colour
d made of expensive fabric with pretty patterns and small holes

84. frankincense: He brought some <frankincense>.
a sweet smelling white flowers
b soft cheese made in France
c food made from yellow coloured rice and shellfish
d good smelling substance that comes out of trees

85. feint: He made a <feint>.
a small cake with dried fruit **[dried fruit cake]**
b thing with wheels for moving heavy objects
c pretend attack to trick the enemy **[trick]**
d serious mistake

86. muff: This <muff> belonged to my mother.
a tube of animal hair for keeping the hands warm
b cover for a teapot
c long rope of feathers to wear around the neck **[feather scarf]**
d bed cover made from squares of material sewn together **[quilt]**

87. ablution: He <performed his ablutions>.
a did his exercises to stay healthy
b played his very difficult piece of music
c did all his duties as a church minister
d washed himself to get ready

88. exactitude: She was well known for her <exactitude>.
a courage under pressure
b sense of fairness
c habit of making unreasonable demands
d ability to be very accurate

89. speedometer: The <speedometer> stopped working.
a instrument that shows changes in the weather
b thing that measures how fast you go **[speedometer]**
c thing that keeps a room at an even temperature
d tube put into a person to let liquids in or out of their body

90. serviette: Where is my <serviette>?
a girl who helps in the house **[maid]**
b piece of glass which makes things look bigger **[magnifying glass]**
c large flat plate
d piece of cloth or paper for wiping your mouth **[serviette]**

91. scrumptious: This is <scrumptious>.
a extremely funny
b very expensive
c delightful in taste
d very dirty and untidy

92. poppadom: Did you put the <poppadoms> on the table?
a thin, slightly hard pieces of fried bread
b small pieces of food, usually raw, eaten before a meal
c cloths for protecting clothes while eating **[napkin]**
d small sweet baked cakes **[muffins]**

93. hydrofoil: He studies <hydrofoils>.
a crops produced from the sea **[seaweed]**
b devices that push boats clear of the water
c components of rocks
d amazing curls and twists

94. bylaw: They made a <bylaw>.
a publisher's list of older books
b secondary law
c code made of lines, read by machines
d law that morally condemns people

95. nymphomaniac: Don't be such <a nymphomaniac>!
a a person expressing uncontrolled sexual desire
b an antisocial person
c an innocent rural person
d a person who repeats the same crime after punishment

96. maladroit: He is <maladroit>.
a feeling sick to his stomach
b physically awkward
c rather silly but likeable
d quickly angry and easily depressed

97. taxon: I think it belongs in this <taxon>.
a tax category
b small and light container for fruit
c category of creature
d room for safely keeping valuables

98. canoodle: They're always <canoodling>!
a spreading false and evil ideas about others **[gossip]**
b looking for a free meal
c merging into the crowd
d stroking and kissing one another

99. stupa: Look at the <stupa>.
a tall hairstyle
b woman with a bad sexual reputation
c temporary platform for a dead person's body
d Asian religious memorial **[Asian shrine]**

100. dramaturgical: It has <a dramaturgical> effect.
a a theatrical
b a glorious
c a human-centring
d an oily and unpleasant

APPENDIX D

The full set of Australian English vowels were used in Experiment 1 (Chapter 6), and a subset of those vowels were employed in Experiment 5 (Chapter 8). The vowel measurements are presented in Table D.1. The pre-emphasis was applied from 50 Hz. To ensure the formant tracker accurately tracked the formant contours of the target vowel, formant settings in Praat were tuned for each individual token. The analysis frequency ranged from 5000-6200 Hz, with 4 or 5 formants being tracked, and the window length was 25 ms.

Table D.1: *Australian English mean vowel durations and the mean F1, F2, and F3 formant values at the 25%, 50%, and 75% points of the target vowel duration*

AusE Vowel	Vowel duration (ms)	F1 (Hz)			F2 (Hz)			F3 (Hz)		
		25%	50%	75%	25%	50%	75%	25%	50%	75%
ɐ	63	944	902	788	1477	1388	1306	2888	2880	2895
e	68	672	661	630	2199	2125	1886	2983	2937	2873
ɪ	55	401	436	439	2600	2505	2228	3113	3006	2863
ɔ	68	733	713	655	1091	1088	1048	2985	3000	2995
ʊ	64	432	437	416	919	888	865	2804	2815	2765
æ	74	978	958	880	1739	1703	1622	2838	2834	2848
ɐː	160	980	966	920	1495	1436	1381	2966	3068	3060
eː	148	592	616	645	2404	2358	2165	3051	3066	2992
iː	126	418	404	390	2703	2773	2755	3363	3305	3188
oː	149	512	528	536	898	849	861	2934	2965	2986
ʉː	121	415	410	397	1925	1889	1806	2623	2597	2597
ɜː	149	613	626	626	1876	1835	1781	2846	2888	2868
ɑe	156	976	976	837	1450	1681	1935	2924	2836	2838
æɔ	157	973	936	784	1696	1444	1178	2837	2922	3031
oɪ	153	600	520	446	1308	1967	2421	2847	2820	2923
ɪə	162	387	467	603	2710	2529	1992	3269	3097	2975
æɪ	143	755	605	479	2223	2465	2552	3001	3073	3136
əʉ	142	661	591	491	1568	1666	1709	2720	2732	2728
ə	60	601	606	546	1640	1597	1496	2859	2831	2791

APPENDIX E

The group mean percent categorisation responses and mean goodness-of-fit ratings for T0, T1, and T2 for the L1 perceptual assimilation task (i.e., L2 vowels assimilated to L1 Egyptian Arabic vowel category labels) and the L2 identification task (i.e., L2 vowels assimilated to L2 Australian English vowel category labels) in Experiment 5 (Chapter 8).

Tabe E.1: *Mean percent categorisation and goodness ratings out of 7 (in parenthesis) of Australian English vowels by Egyptian Arabic speakers at T0, with Egyptian Arabic allophonic vowel categories collapsed across appropriate main vowel categories*

Australian English	Egyptian Arabic vowel response category									
vowel stimulus	a	i	u	aː	eː	iː	oː	uː	aw	aj
æ	21			50	9					
ɐ	20			***51 (4.59)***	10		6			
e	23	11		15	28	9				5
ɪ	12	7		8	30	28				6
ʊ			15	5	6		27	24	14	
ɔ	11		17	6			28	16	13	
eː	15			31	24	11				7
iː	11			10	28	29				10
oː			10		6		32	23	17	
ʉː	7		5	7	13	8	23	21	8	
ɜː	12			20	22	10	13		6	5
æɪ	10			25	28	12	6			8
əʉ	9		7	11	8	5	30	14	11	
ɪə	12			10	26	27				15
ɑe	10			45	16	11	5			6

Numbers represent the percentage of each AusE vowel stimulus assimilated to an EA vowel category label, averaged across participants. The goodness-of-fit ratings are on a scale of 1 (very strange) to 7 (perfect), also averaged across participants, and are only displayed for the AusE vowels that were assimilated as categorised.
Numbers in bold and italics indicate the mean percent categorisation scores that have reached the 50% assimilation criterion, with the averaged goodness rating presented within parentheses.
Values ≥5% are displayed.

Table E.2: *Mean percent categorisations of Australian English vowels by Egyptian Arabic speakers at T0*

Australian English vowel stimulus	Australian English vowel response category																	
	æ	ɐ	e	ɪ	ʊ	ɔ	ɐː	eː	iː	oː	ʉː	ɜː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
æ	33						19	14		6			6			5		
ɐ	29	6					18	12					10					
e	16		10	5			6	13	9			14				10		
ɪ			12	13				10	22			8			8	8		
ʊ					34	11				13	14			5			9	5
ɔ					19	16				15	7			7			14	11
eː	13						11	27	7			10	6		5	7		
iː			8					9	35			6			12	13		
oː					24	9				20	12			10			7	9
ʉː					20				6	10	13			7		6	11	
ɜː	8						7	21	5	7		13				6	5	
æɪ	5						6	27	7			9	12		5	11		
əʉ					13	9		6		18				12		7	9	7
ɪə								13	18	6					28	12		
ɑe				9			8	22					5			35		

Numbers represent the percentage of each AusE vowel stimulus assimilated to an AusE vowel category label, averaged across participants. Values ≥5% are displayed.

Table E.3: *Mean percent categorisation and goodness ratings out of 7 (in parenthesis) of Australian English vowels by Egyptian Arabic speakers at T1, with Egyptian Arabic allophonic vowel categories collapsed across appropriate main vowel categories*

Australian English vowel stimulus	Egyptian Arabic vowel response category									
	a	i	u	aː	eː	iː	oː	uː	aw	aj
æ	26			***52 (4.32)***	6		5			
ɐ	26			***51 (4.28)***	5					
e	22	16		17	23	8	5			
ɪ	17	12		6	30	19				8
ʊ	8		17				26	22	19	
ɔ	11		13	6	5		32	16	13	
eː	13	7		32	21	13	6			5
iː	11			9	24	35				10
oː	4		10	5			32	18	22	
ʉː				9	12	7	25	22	10	
ɜː	18	7	6	17	19	6	10	7	8	
æɪ	16	6		23	27	10	6			8
əʉ	9		9	9	7	5	33	10	13	
ɪə	17			11	24	26				12
ɑe	12			44	20	10				5

Numbers represent the percentage of each AusE vowel stimulus assimilated to an EA vowel category label, averaged across participants. The goodness-of-fit ratings are on a scale of 1 (very strange) to 7 (perfect), also averaged across participants, and are only displayed for the AusE vowels that were assimilated as categorised.
Numbers in bold and italics indicate the mean percent categorisation scores that have reached the 50% assimilation criterion, with the averaged goodness rating presented within parentheses.
Values ≥5% are displayed.

Table E.4: *Mean percent categorisations of Australian English vowels by Egyptian Arabic speakers at T1*

Australian English vowel stimulus	Australian English vowel response category																	
	æ	ɐ	e	ɪ	ʊ	ɔ	ɐː	eː	iː	oː	ʉː	ɜː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
æ	35						21	9					6					
ɐ	29	10					22	8					6					
e	9		13	6				12	9			21	5			6		
ɪ			12	19				7	16			9			8	8		
ʊ					31	14				13	9			10			6	
ɔ					21	22				16				9			8	
eː	8						7	30	7			14	5			8		
iː			7	12					29			8			12	13		
oː					25	14				20	8			12			6	5
ʉː					26	5				8	13			9		6	9	
ɜː	8						6	10		10		24					5	
æɪ			6					20	7	5		10	15		5	13		
əʉ					13	7				18	6	6		15			10	6
ɪə								9	12	5		9			29	9		
ɑe				6			8	20					5			35	5	

Numbers represent the percentage of each AusE vowel stimulus assimilated to an AusE vowel category label, averaged across participants. Values ≥5% are displayed.

Table E.5: *Mean percent categorisation and goodness ratings out of 7 (in parenthesis) of Australian English vowels by Egyptian Arabic speakers at T2, with Egyptian Arabic allophonic vowel categories collapsed across appropriate main vowel categories*

Australian English vowel stimulus	Egyptian Arabic vowel response category									
	a	i	u	aː	eː	iː	oː	uː	aw	aj
æ	21	5		***55 (4.38)***	8					
ɐ	26			49	6					
e	21	18		14	26	9				
ɪ	14	9		5	33	23				7
ʊ	9		12				31	21	18	
ɔ	8		16		6		26	15	20	
eː	12			30	29	11				5
iː	13				36	29				8
oː	5		9		6		36	13	24	
ʉː	8				11		33	22	13	
ɜː	20			17	23	6	12	6	7	
æɪ	15	5		19	30	11				10
əʉ	14		8		9	5	31	9	12	
ɪə	18				33	25				10
ɑe	16			34	17	12	5			7

Numbers represent the percentage of each AusE vowel stimulus assimilated to an EA vowel category label, averaged across participants. The goodness-of-fit ratings are on a scale of 1 (very strange) to 7 (perfect), also averaged across participants, and are only displayed for the AusE vowels that were assimilated as categorised.
Numbers in bold and italics indicate the mean percent categorisation scores that have reached the 50% assimilation criterion, with the averaged goodness rating presented within parentheses.
Values ≥5% are displayed.

Table E.6: *Mean percent categorisations of Australian English vowels by Egyptian Arabic speakers at T2*

Australian English vowel stimulus	Australian English vowel response category																	
	æ	ɐ	e	ɪ	ʊ	ɔ	ɐː	eː	iː	oː	ʉː	ɜː	æɪ	əʉ	ɪə	ɑe	oɪ	æɔ
æ	35						16	9					8					
ɐ	30	7					15	8					5			6		
e	15		14	6			6	13	5			14				6		
ɪ			8	22					16	5		11			6	8		
ʊ					28	17				12	13			6			6	6
ɔ					20	26				15	5			5			9	6
eː							6	28				14	5		6	5		
iː			8	10				5	28			8			9	11	6	
oː					20	9				17	10			12			12	9
ʉː					26	5				10	15			9			12	
ɜː					6		5	18		10		17			5	8	6	
æɪ				6				21		7		8	12			9	5	
əʉ					15	6				14		7		13		6	11	7
ɪə				5				6	11	6					26	14	7	
ɑe				6				15		5			10			36	7	

Numbers represent the percentage of each AusE vowel stimulus assimilated to an AusE vowel category label, averaged across participants. Values ≥5% are displayed.

APPENDIX F

The table in Appendix F displays individual participants' perceptual assimilations for each L2 Australian English vowel across T0, T1, and T2 based on the data from Experiment 5 (Chapter 8). Australian English vowels that were assimilated as categorised in either the L1 or the L2 are marked with "C", and those that were uncategorised are indicated with "U". Where an L2 phone was uncategorised in the L1, but categorised in the L2, this was taken as indirect evidence to suggest that a new L2 phonological category had been acquired, and these are marked with "yes" in the "Acquired?" column. All other L1-L2 perceptual assimilation patterns (e.g., uncategorised in both the L1 and L2), are marked with "no". At T0, 14% (64 out of 465 observations) were of instances of an L2 vowel uncategorised in the L1 but categorised in the L2, 12% (56 out of 465 observations) at T1, and 13% (61 out of 465 observations) at T2.

Table F.1: *Individual participants' perceptual assimilation patterns at T0, T1, and T2 for each Australian English vowel (C = categorised; U = uncategorised) in the L1 and L2 assimilation tasks and the status of new phonological category formation*

T0					T1					T2				
L2 vowel	ID	L1 assim.	L2 assim.	Acquired?	L2 vowel	ID	L1 assim.	L2 assim.	Acquired?	L2 vowel	ID	L1 assim.	L2 assim.	Acquired?
ɐ	LS02	C	C	no	ɐ	LS02	C	C	no	ɐ	LS02	C	U	no
ɐ	LS03	C	C	no	ɐ	LS03	C	C	no	ɐ	LS03	C	C	no
ɐ	LS04	C	U	no	ɐ	LS04	C	U	no	ɐ	LS04	U	U	no
ɐ	LS05	C	U	no	ɐ	LS06	C	U	no	ɐ	LS05	C	C	no
ɐ	LS06	C	C	no	ɐ	LS07	C	U	no	ɐ	LS07	C	U	no
ɐ	LS07	C	U	no	ɐ	LS09	C	C	no	ɐ	LS09	C	C	no
ɐ	LS09	C	U	no	ɐ	LS10	C	U	no	ɐ	LS10	C	C	no
ɐ	LS12	U	U	no	ɐ	LS12	C	U	no	ɐ	LS13	C	U	no
ɐ	LS13	C	U	no	ɐ	LS13	C	U	no	ɐ	LS14	C	U	no
ɐ	LS14	U	U	no	ɐ	LS14	C	C	no	ɐ	LS15	U	U	no
ɐ	LS15	U	U	no	ɐ	LS15	C	U	no	ɐ	LS16	C	U	no
ɐ	LS16	C	C	no	ɐ	LS16	U	U	no	ɐ	LS17	C	C	no
ɐ	LS17	C	U	no	ɐ	LS20	U	U	no	ɐ	LS20	U	U	no
ɐ	LS20	U	U	no	ɐ	LS25	C	C	no	ɐ	LS23	C	C	no
ɐ	LS23	C	U	no	ɐ	LS27	C	U	no	ɐ	LS24	C	C	no
ɐ	LS24	C	U	no	ɐ	LS28	U	U	no	ɐ	LS25	U	U	no
ɐ	LS25	U	U	no	ɐ	LS29	U	U	no	ɐ	LS27	U	U	no
ɐ	LS27	C	U	no	ɐ	LS30	U	U	no	ɐ	LS28	U	U	no
ɐ	LS28	U	U	no	ɐ	LS34	C	C	no	ɐ	LS29	U	U	no
ɐ	LS29	U	U	no	ɐ	LS35	U	U	no	ɐ	LS30	U	U	no

ɐ	LS30	U	U	no	ɐ	LS37	C	U	no	ɐ	LS34	U	U	no
ɐ	LS34	C	U	no	ɐ	LS38	U	U	no	ɐ	LS35	C	U	no
ɐ	LS35	C	U	no	ɐ	LS41	C	U	no	ɐ	LS37	U	U	no
ɐ	LS37	U	U	no	ɐ	LS42	C	U	no	ɐ	LS38	U	U	no
ɐ	LS38	U	U	no	ɐ	LS43	C	U	no	ɐ	LS39	C	C	no
ɐ	LS39	C	C	no	ɐ	LS44	C	C	no	ɐ	LS41	U	U	no
ɐ	LS41	U	U	no	ɐ	LS05	U	C	yes	ɐ	LS42	C	U	no
ɐ	LS42	C	C	no	ɐ	LS17	U	C	yes	ɐ	LS43	U	U	no
ɐ	LS43	C	U	no	ɐ	LS23	U	C	yes	ɐ	LS06	U	C	yes
ɐ	LS44	U	U	no	ɐ	LS24	U	C	yes	ɐ	LS12	U	C	yes
ɐ	LS10	U	C	yes	ɐ	LS39	U	C	yes	ɐ	LS44	U	C	yes
æ	LS02	U	U	no	æ	LS02	C	U	no	æ	LS02	C	C	no
æ	LS03	C	C	no	æ	LS03	C	C	no	æ	LS03	C	C	no
æ	LS04	U	U	no	æ	LS04	U	U	no	æ	LS04	C	U	no
æ	LS05	U	U	no	æ	LS05	U	U	no	æ	LS05	C	C	no
æ	LS06	C	C	no	æ	LS06	C	C	no	æ	LS06	C	C	no
æ	LS07	C	U	no	æ	LS07	C	U	no	æ	LS07	C	U	no
æ	LS10	C	U	no	æ	LS09	C	C	no	æ	LS10	C	U	no
æ	LS12	U	U	no	æ	LS10	C	U	no	æ	LS12	U	U	no
æ	LS13	C	U	no	æ	LS12	U	U	no	æ	LS13	C	C	no
æ	LS14	C	C	no	æ	LS13	C	U	no	æ	LS14	C	U	no
æ	LS15	U	U	no	æ	LS14	C	U	no	æ	LS15	C	U	no
æ	LS16	C	C	no	æ	LS15	C	C	no	æ	LS16	C	C	no
æ	LS17	C	C	no	æ	LS16	C	U	no	æ	LS17	C	C	no
æ	LS20	U	U	no	æ	LS17	U	U	no	æ	LS20	U	U	no
æ	LS23	C	U	no	æ	LS20	U	U	no	æ	LS23	C	C	no
æ	LS24	C	U	no	æ	LS24	C	U	no	æ	LS24	U	U	no

æ	LS25	C	U	no	æ	LS25	C	C	no	æ	LS27	U	U	no
æ	LS27	C	U	no	æ	LS27	U	U	no	æ	LS28	U	U	no
æ	LS28	U	U	no	æ	LS28	U	U	no	æ	LS29	U	U	no
æ	LS29	U	U	no	æ	LS29	U	U	no	æ	LS30	C	U	no
æ	LS30	U	U	no	æ	LS30	C	U	no	æ	LS34	U	U	no
æ	LS34	C	U	no	æ	LS34	U	U	no	æ	LS35	C	U	no
æ	LS35	C	U	no	æ	LS35	C	U	no	æ	LS37	U	U	no
æ	LS37	U	U	no	æ	LS37	U	U	no	æ	LS38	U	U	no
æ	LS38	C	U	no	æ	LS38	U	U	no	æ	LS39	C	C	no
æ	LS39	C	C	no	æ	LS39	C	C	no	æ	LS41	U	U	no
æ	LS41	U	U	no	æ	LS41	U	U	no	æ	LS42	C	U	no
æ	LS43	C	U	no	æ	LS42	C	U	no	æ	LS43	C	U	no
æ	LS44	U	U	no	æ	LS43	C	C	no	æ	LS44	U	U	no
æ	LS09	U	C	yes	æ	LS23	U	C	yes	æ	LS09	U	C	yes
æ	LS42	U	C	yes	æ	LS44	U	C	yes	æ	LS25	U	C	yes
e	LS04	U	U	no	e	LS02	C	C	no	e	LS02	C	C	no
e	LS05	U	U	no	e	LS03	C	U	no	e	LS03	C	C	no
e	LS06	C	C	no	e	LS04	U	U	no	e	LS04	U	U	no
e	LS07	C	U	no	e	LS05	U	U	no	e	LS05	U	U	no
e	LS09	C	C	no	e	LS06	C	C	no	e	LS06	C	C	no
e	LS10	C	U	no	e	LS07	C	U	no	e	LS07	U	U	no
e	LS12	U	U	no	e	LS09	C	C	no	e	LS09	C	U	no
e	LS13	U	U	no	e	LS10	U	U	no	e	LS10	U	U	no
e	LS14	U	U	no	e	LS12	C	U	no	e	LS12	U	U	no
e	LS15	U	U	no	e	LS13	U	U	no	e	LS13	U	U	no
e	LS16	C	C	no	e	LS14	U	U	no	e	LS14	U	U	no
e	LS20	U	U	no	e	LS15	C	U	no	e	LS16	C	U	no

e	LS23	C	C	no	e	LS16	U	U	no	e	LS17	C	U	no
e	LS25	U	U	no	e	LS17	U	U	no	e	LS20	U	U	no
e	LS27	C	U	no	e	LS20	C	U	no	e	LS23	C	C	no
e	LS28	U	U	no	e	LS23	U	U	no	e	LS24	U	U	no
e	LS29	C	U	no	e	LS27	U	U	no	e	LS25	U	U	no
e	LS30	U	U	no	e	LS28	U	U	no	e	LS27	U	U	no
e	LS34	C	U	no	e	LS29	U	U	no	e	LS28	U	U	no
e	LS35	U	U	no	e	LS30	U	U	no	e	LS29	U	U	no
e	LS38	U	U	no	e	LS34	U	U	no	e	LS30	U	U	no
e	LS39	C	C	no	e	LS35	U	U	no	e	LS34	C	C	no
e	LS41	U	U	no	e	LS37	C	U	no	e	LS35	C	U	no
e	LS42	U	U	no	e	LS38	U	U	no	e	LS37	U	U	no
e	LS43	C	U	no	e	LS39	U	U	no	e	LS38	U	U	no
e	LS44	C	C	no	e	LS41	U	U	no	e	LS39	C	C	no
e	LS02	U	C	yes	e	LS42	U	U	no	e	LS41	U	U	no
e	LS03	U	C	yes	e	LS43	C	C	no	e	LS42	U	U	no
e	LS17	U	C	yes	e	LS44	U	U	no	e	LS43	U	U	no
e	LS24	U	C	yes	e	LS24	U	C	yes	e	LS15	U	C	yes
e	LS37	U	C	yes	e	LS25	U	C	yes	e	LS44	U	C	yes
ɪ	LS02	U	U	no	ɪ	LS02	U	U	no	ɪ	LS02	C	C	no
ɪ	LS03	U	U	no	ɪ	LS03	C	C	no	ɪ	LS03	C	C	no
ɪ	LS04	U	U	no	ɪ	LS04	U	U	no	ɪ	LS04	U	U	no
ɪ	LS05	C	U	no	ɪ	LS06	C	U	no	ɪ	LS05	C	C	no
ɪ	LS06	C	C	no	ɪ	LS07	U	U	no	ɪ	LS06	C	C	no
ɪ	LS07	U	U	no	ɪ	LS10	U	U	no	ɪ	LS07	C	U	no
ɪ	LS10	U	U	no	ɪ	LS12	C	U	no	ɪ	LS10	C	U	no
ɪ	LS12	C	U	no	ɪ	LS13	U	U	no	ɪ	LS12	U	U	no

ɪ	LS13	C	C	no	ɪ	LS14	C	U	no	ɪ	LS13	C	C	no
ɪ	LS14	U	U	no	ɪ	LS15	U	U	no	ɪ	LS14	U	U	no
ɪ	LS15	U	U	no	ɪ	LS16	C	U	no	ɪ	LS15	C	C	no
ɪ	LS17	U	U	no	ɪ	LS17	C	U	no	ɪ	LS16	U	U	no
ɪ	LS20	U	U	no	ɪ	LS20	U	U	no	ɪ	LS17	U	U	no
ɪ	LS25	U	U	no	ɪ	LS23	C	C	no	ɪ	LS20	U	U	no
ɪ	LS27	U	U	no	ɪ	LS24	U	U	no	ɪ	LS24	U	U	no
ɪ	LS28	U	U	no	ɪ	LS25	U	U	no	ɪ	LS25	U	U	no
ɪ	LS29	U	U	no	ɪ	LS27	U	U	no	ɪ	LS27	U	U	no
ɪ	LS30	U	U	no	ɪ	LS28	U	U	no	ɪ	LS28	U	U	no
ɪ	LS34	C	U	no	ɪ	LS29	U	U	no	ɪ	LS29	U	U	no
ɪ	LS35	U	U	no	ɪ	LS30	U	U	no	ɪ	LS30	U	U	no
ɪ	LS37	U	U	no	ɪ	LS34	C	U	no	ɪ	LS35	U	U	no
ɪ	LS38	C	U	no	ɪ	LS35	U	U	no	ɪ	LS37	U	U	no
ɪ	LS39	C	C	no	ɪ	LS37	U	U	no	ɪ	LS38	U	U	no
ɪ	LS41	U	U	no	ɪ	LS38	U	U	no	ɪ	LS41	U	U	no
ɪ	LS42	U	U	no	ɪ	LS39	U	U	no	ɪ	LS42	U	U	no
ɪ	LS44	U	U	no	ɪ	LS42	U	U	no	ɪ	LS43	U	U	no
ɪ	LS09	U	C	yes	ɪ	LS43	C	C	no	ɪ	LS44	C	U	no
ɪ	LS16	U	C	yes	ɪ	LS44	U	U	no	ɪ	LS09	U	C	yes
ɪ	LS23	U	C	yes	ɪ	LS05	U	C	yes	ɪ	LS23	U	C	yes
ɪ	LS24	U	C	yes	ɪ	LS09	U	C	yes	ɪ	LS34	U	C	yes
ɪ	LS43	U	C	yes	ɪ	LS41	U	C	yes	ɪ	LS39	U	C	yes
ɔ	LS03	C	U	no	ɔ	LS02	C	C	no	ɔ	LS03	C	C	no
ɔ	LS04	U	U	no	ɔ	LS03	C	C	no	ɔ	LS04	U	U	no
ɔ	LS06	C	C	no	ɔ	LS04	U	U	no	ɔ	LS06	C	C	no
ɔ	LS07	U	U	no	ɔ	LS05	U	U	no	ɔ	LS09	C	C	no

ɔ	LS09	C	U	no	ɔ	LS07	U	U	no	ɔ	LS10	U	U	no
ɔ	LS10	U	U	no	ɔ	LS09	C	U	no	ɔ	LS13	U	U	no
ɔ	LS13	U	U	no	ɔ	LS10	U	U	no	ɔ	LS14	U	U	no
ɔ	LS14	U	U	no	ɔ	LS12	U	U	no	ɔ	LS15	U	U	no
ɔ	LS15	U	U	no	ɔ	LS13	U	U	no	ɔ	LS16	U	U	no
ɔ	LS16	U	U	no	ɔ	LS14	U	U	no	ɔ	LS17	C	U	no
ɔ	LS17	C	U	no	ɔ	LS15	U	U	no	ɔ	LS24	C	C	no
ɔ	LS20	U	U	no	ɔ	LS16	C	U	no	ɔ	LS27	U	U	no
ɔ	LS23	U	U	no	ɔ	LS17	U	U	no	ɔ	LS28	U	U	no
ɔ	LS24	U	U	no	ɔ	LS20	U	U	no	ɔ	LS29	U	U	no
ɔ	LS25	U	U	no	ɔ	LS23	C	C	no	ɔ	LS30	U	U	no
ɔ	LS27	C	U	no	ɔ	LS24	U	U	no	ɔ	LS34	U	U	no
ɔ	LS28	U	U	no	ɔ	LS25	C	U	no	ɔ	LS35	C	C	no
ɔ	LS29	U	U	no	ɔ	LS27	U	U	no	ɔ	LS37	U	U	no
ɔ	LS30	U	U	no	ɔ	LS28	U	U	no	ɔ	LS38	U	U	no
ɔ	LS34	C	U	no	ɔ	LS29	U	U	no	ɔ	LS39	C	U	no
ɔ	LS35	U	U	no	ɔ	LS30	U	U	no	ɔ	LS41	U	U	no
ɔ	LS37	U	U	no	ɔ	LS34	C	U	no	ɔ	LS42	U	U	no
ɔ	LS38	U	U	no	ɔ	LS35	U	U	no	ɔ	LS43	U	U	no
ɔ	LS39	C	U	no	ɔ	LS37	C	U	no	ɔ	LS44	U	U	no
ɔ	LS41	U	U	no	ɔ	LS38	U	U	no	ɔ	LS02	U	C	yes
ɔ	LS42	U	U	no	ɔ	LS39	U	U	no	ɔ	LS05	U	C	yes
ɔ	LS43	C	U	no	ɔ	LS41	C	U	no	ɔ	LS07	U	C	yes
ɔ	LS44	C	U	no	ɔ	LS42	U	U	no	ɔ	LS12	U	C	yes
ɔ	LS02	U	C	yes	ɔ	LS44	C	C	no	ɔ	LS20	U	C	yes
ɔ	LS05	U	C	yes	ɔ	LS06	U	C	yes	ɔ	LS23	U	C	yes
ɔ	LS12	U	C	yes	ɔ	LS43	U	C	yes	ɔ	LS25	U	C	yes

ʊ	LS02	U	U	no	ʊ	LS02	C	U	no	ʊ	LS02	U	U	no
ʊ	LS03	U	U	no	ʊ	LS03	C	C	no	ʊ	LS03	C	U	no
ʊ	LS04	U	U	no	ʊ	LS04	U	U	no	ʊ	LS04	C	U	no
ʊ	LS05	U	U	no	ʊ	LS06	C	C	no	ʊ	LS06	C	C	no
ʊ	LS07	U	U	no	ʊ	LS07	U	U	no	ʊ	LS07	U	U	no
ʊ	LS10	U	U	no	ʊ	LS09	C	U	no	ʊ	LS09	C	C	no
ʊ	LS12	C	C	no	ʊ	LS10	U	U	no	ʊ	LS10	C	U	no
ʊ	LS14	U	U	no	ʊ	LS12	U	U	no	ʊ	LS12	C	C	no
ʊ	LS15	U	U	no	ʊ	LS13	U	U	no	ʊ	LS13	C	U	no
ʊ	LS16	C	C	no	ʊ	LS14	C	U	no	ʊ	LS14	U	U	no
ʊ	LS20	U	U	no	ʊ	LS15	C	C	no	ʊ	LS15	C	U	no
ʊ	LS23	C	C	no	ʊ	LS16	U	U	no	ʊ	LS16	U	U	no
ʊ	LS24	C	U	no	ʊ	LS17	C	U	no	ʊ	LS17	U	U	no
ʊ	LS25	U	U	no	ʊ	LS20	U	U	no	ʊ	LS20	U	U	no
ʊ	LS27	U	U	no	ʊ	LS24	U	U	no	ʊ	LS24	U	U	no
ʊ	LS28	U	U	no	ʊ	LS25	C	U	no	ʊ	LS25	U	U	no
ʊ	LS29	U	U	no	ʊ	LS27	U	U	no	ʊ	LS27	C	U	no
ʊ	LS30	C	U	no	ʊ	LS28	U	U	no	ʊ	LS28	U	U	no
ʊ	LS34	C	U	no	ʊ	LS29	U	U	no	ʊ	LS29	U	U	no
ʊ	LS37	U	U	no	ʊ	LS30	U	U	no	ʊ	LS30	C	U	no
ʊ	LS38	U	U	no	ʊ	LS34	U	U	no	ʊ	LS35	C	C	no
ʊ	LS39	U	U	no	ʊ	LS37	C	C	no	ʊ	LS38	U	U	no
ʊ	LS41	U	U	no	ʊ	LS38	C	U	no	ʊ	LS39	C	U	no
ʊ	LS42	U	U	no	ʊ	LS41	C	U	no	ʊ	LS41	U	U	no
ʊ	LS43	C	U	no	ʊ	LS42	U	U	no	ʊ	LS42	U	U	no
ʊ	LS06	U	C	yes	ʊ	LS43	U	U	no	ʊ	LS43	U	U	no
ʊ	LS09	U	C	yes	ʊ	LS05	U	C	yes	ʊ	LS44	U	U	no

ʊ	LS13	U	C	yes	ʊ	LS23	U	C	yes	ʊ	LS05	U	C	yes
ʊ	LS17	U	C	yes	ʊ	LS35	U	C	yes	ʊ	LS23	U	C	yes
ʊ	LS35	U	C	yes	ʊ	LS39	U	C	yes	ʊ	LS34	U	C	yes
ʊ	LS44	U	C	yes	ʊ	LS44	U	C	yes	ʊ	LS37	U	C	yes
e:	LS04	U	U	no	e:	LS04	U	U	no	e:	LS04	U	U	no
e:	LS05	U	U	no	e:	LS05	U	U	no	e:	LS05	U	U	no
e:	LS06	C	C	no	e:	LS06	C	C	no	e:	LS06	C	C	no
e:	LS07	U	U	no	e:	LS07	U	U	no	e:	LS07	U	U	no
e:	LS10	C	U	no	e:	LS10	C	U	no	e:	LS10	U	U	no
e:	LS12	U	U	no	e:	LS12	C	U	no	e:	LS12	U	U	no
e:	LS13	U	U	no	e:	LS13	C	U	no	e:	LS13	C	U	no
e:	LS14	C	U	no	e:	LS15	U	U	no	e:	LS14	U	U	no
e:	LS15	U	U	no	e:	LS16	U	U	no	e:	LS15	U	U	no
e:	LS16	U	U	no	e:	LS17	U	U	no	e:	LS16	U	U	no
e:	LS17	U	U	no	e:	LS20	U	U	no	e:	LS20	U	U	no
e:	LS20	U	U	no	e:	LS23	C	U	no	e:	LS24	U	U	no
e:	LS24	C	C	no	e:	LS24	U	U	no	e:	LS25	C	C	no
e:	LS25	C	U	no	e:	LS25	C	U	no	e:	LS27	U	U	no
e:	LS27	U	U	no	e:	LS27	U	U	no	e:	LS28	U	U	no
e:	LS28	U	U	no	e:	LS28	U	U	no	e:	LS29	U	U	no
e:	LS29	U	U	no	e:	LS29	U	U	no	e:	LS30	C	U	no
e:	LS30	U	U	no	e:	LS30	U	U	no	e:	LS34	C	C	no
e:	LS34	U	U	no	e:	LS34	U	U	no	e:	LS35	C	U	no
e:	LS35	U	U	no	e:	LS35	U	U	no	e:	LS37	U	U	no
e:	LS38	U	U	no	e:	LS37	C	U	no	e:	LS38	U	U	no
e:	LS41	U	U	no	e:	LS38	U	U	no	e:	LS39	C	U	no
e:	LS42	U	U	no	e:	LS41	U	U	no	e:	LS41	U	U	no

e:	LS43	U	U	no	e:	LS42	C	U	no	e:	LS42	U	U	no
e:	LS02	U	C	yes	e:	LS43	U	U	no	e:	LS43	U	U	no
e:	LS03	U	C	yes	e:	LS44	U	U	no	e:	LS02	U	C	yes
e:	LS09	U	C	yes	e:	LS02	U	C	yes	e:	LS03	U	C	yes
e:	LS23	U	C	yes	e:	LS03	U	C	yes	e:	LS09	U	C	yes
e:	LS37	U	C	yes	e:	LS09	U	C	yes	e:	LS17	U	C	yes
e:	LS39	U	C	yes	e:	LS14	U	C	yes	e:	LS23	U	C	yes
e:	LS44	U	C	yes	e:	LS39	U	C	yes	e:	LS44	U	C	yes
ɜ:	LS02	U	U	no	ɜ:	LS02	U	U	no	ɜ:	LS02	U	U	no
ɜ:	LS04	U	U	no	ɜ:	LS04	U	U	no	ɜ:	LS03	C	C	no
ɜ:	LS07	U	U	no	ɜ:	LS05	U	U	no	ɜ:	LS04	U	U	no
ɜ:	LS09	U	U	no	ɜ:	LS06	U	U	no	ɜ:	LS05	U	U	no
ɜ:	LS10	U	U	no	ɜ:	LS07	U	U	no	ɜ:	LS07	U	U	no
ɜ:	LS12	U	U	no	ɜ:	LS09	U	U	no	ɜ:	LS10	U	U	no
ɜ:	LS13	U	U	no	ɜ:	LS10	U	U	no	ɜ:	LS12	U	U	no
ɜ:	LS14	U	U	no	ɜ:	LS12	U	U	no	ɜ:	LS13	U	U	no
ɜ:	LS15	U	U	no	ɜ:	LS13	U	U	no	ɜ:	LS14	U	U	no
ɜ:	LS16	U	U	no	ɜ:	LS14	U	U	no	ɜ:	LS15	U	U	no
ɜ:	LS17	U	U	no	ɜ:	LS15	U	U	no	ɜ:	LS16	U	U	no
ɜ:	LS20	U	U	no	ɜ:	LS16	U	U	no	ɜ:	LS20	U	U	no
ɜ:	LS24	U	U	no	ɜ:	LS17	U	U	no	ɜ:	LS23	C	C	no
ɜ:	LS25	C	U	no	ɜ:	LS20	U	U	no	ɜ:	LS24	U	U	no
ɜ:	LS27	U	U	no	ɜ:	LS27	U	U	no	ɜ:	LS25	U	U	no
ɜ:	LS28	U	U	no	ɜ:	LS28	U	U	no	ɜ:	LS27	U	U	no
ɜ:	LS29	U	U	no	ɜ:	LS29	U	U	no	ɜ:	LS28	U	U	no
ɜ:	LS30	U	U	no	ɜ:	LS30	U	U	no	ɜ:	LS29	C	U	no
ɜ:	LS34	U	U	no	ɜ:	LS34	U	U	no	ɜ:	LS30	U	U	no

ɜ:	LS35	C	U	no	ɜ:	LS35	U	U	no	ɜ:	LS34	U	U	no
ɜ:	LS37	U	U	no	ɜ:	LS37	C	U	no	ɜ:	LS35	C	U	no
ɜ:	LS38	U	U	no	ɜ:	LS38	C	U	no	ɜ:	LS37	U	U	no
ɜ:	LS39	U	U	no	ɜ:	LS39	U	U	no	ɜ:	LS38	U	U	no
ɜ:	LS41	U	U	no	ɜ:	LS41	U	U	no	ɜ:	LS39	C	C	no
ɜ:	LS42	U	U	no	ɜ:	LS42	U	U	no	ɜ:	LS41	U	U	no
ɜ:	LS43	U	U	no	ɜ:	LS43	C	U	no	ɜ:	LS42	U	U	no
ɜ:	LS44	U	U	no	ɜ:	LS44	U	U	no	ɜ:	LS43	U	U	no
ɜ:	LS03	U	C	yes	ɜ:	LS03	U	C	yes	ɜ:	LS44	U	U	no
ɜ:	LS05	U	C	yes	ɜ:	LS23	U	C	yes	ɜ:	LS06	U	C	yes
ɜ:	LS06	U	C	yes	ɜ:	LS24	U	C	yes	ɜ:	LS09	U	C	yes
ɜ:	LS23	U	C	yes	ɜ:	LS25	U	C	yes	ɜ:	LS17	U	C	yes
i:	LS02	U	U	no	i:	LS02	U	U	no	i:	LS02	C	U	no
i:	LS03	C	C	no	i:	LS03	C	C	no	i:	LS03	C	C	no
i:	LS04	U	U	no	i:	LS06	C	U	no	i:	LS04	C	C	no
i:	LS05	C	C	no	i:	LS07	U	U	no	i:	LS05	U	U	no
i:	LS06	C	C	no	i:	LS09	C	U	no	i:	LS06	C	C	no
i:	LS07	U	U	no	i:	LS10	U	U	no	i:	LS07	U	U	no
i:	LS09	C	C	no	i:	LS12	U	U	no	i:	LS10	U	U	no
i:	LS10	U	U	no	i:	LS13	C	C	no	i:	LS12	U	U	no
i:	LS14	U	U	no	i:	LS14	U	U	no	i:	LS13	C	U	no
i:	LS15	U	U	no	i:	LS15	U	U	no	i:	LS15	C	U	no
i:	LS16	C	C	no	i:	LS16	U	U	no	i:	LS16	C	U	no
i:	LS17	U	U	no	i:	LS17	C	U	no	i:	LS17	U	U	no
i:	LS20	U	U	no	i:	LS20	U	U	no	i:	LS20	U	U	no
i:	LS24	U	U	no	i:	LS23	C	C	no	i:	LS24	U	U	no
i:	LS25	U	U	no	i:	LS24	U	U	no	i:	LS25	C	U	no

i:	LS27	U	U	no
i:	LS29	U	U	no
i:	LS34	C	U	no
i:	LS35	U	U	no
i:	LS37	U	U	no
i:	LS38	U	U	no
i:	LS41	U	U	no
i:	LS42	C	U	no
i:	LS43	C	U	no
i:	LS12	U	C	yes
i:	LS13	U	C	yes
i:	LS23	U	C	yes
i:	LS28	U	C	yes
i:	LS30	U	C	yes
i:	LS39	U	C	yes
i:	LS44	U	C	yes
o:	LS02	U	U	no
o:	LS03	U	U	no
o:	LS04	U	U	no
o:	LS06	U	U	no
o:	LS07	U	U	no
o:	LS09	C	C	no
o:	LS10	C	U	no
o:	LS12	U	U	no
o:	LS13	U	U	no
o:	LS14	U	U	no
o:	LS15	U	U	no

i:	LS25	U	U	no
i:	LS27	U	U	no
i:	LS28	U	U	no
i:	LS29	U	U	no
i:	LS30	C	U	no
i:	LS34	C	C	no
i:	LS35	U	U	no
i:	LS37	C	U	no
i:	LS38	U	U	no
i:	LS39	U	U	no
i:	LS41	U	U	no
i:	LS42	U	U	no
i:	LS43	C	U	no
i:	LS44	U	U	no
i:	LS04	U	C	yes
i:	LS05	U	C	yes
o:	LS02	C	U	no
o:	LS03	C	U	no
o:	LS04	U	U	no
o:	LS06	C	U	no
o:	LS07	U	U	no
o:	LS10	U	U	no
o:	LS12	U	U	no
o:	LS13	U	U	no
o:	LS14	U	U	no
o:	LS15	C	C	no
o:	LS16	U	U	no

i:	LS27	C	U	no
i:	LS28	U	U	no
i:	LS29	U	U	no
i:	LS30	U	U	no
i:	LS34	C	U	no
i:	LS35	U	U	no
i:	LS37	U	U	no
i:	LS38	U	U	no
i:	LS39	U	U	no
i:	LS42	U	U	no
i:	LS43	U	U	no
i:	LS44	C	U	no
i:	LS09	U	C	yes
i:	LS14	U	C	yes
i:	LS23	U	C	yes
i:	LS41	U	C	yes
o:	LS02	U	U	no
o:	LS03	C	C	no
o:	LS04	U	U	no
o:	LS07	U	U	no
o:	LS10	U	U	no
o:	LS12	U	U	no
o:	LS13	U	U	no
o:	LS14	U	U	no
o:	LS15	U	U	no
o:	LS16	C	U	no
o:	LS17	C	U	no

o:	LS16	C	U	no	o:	LS17	U	U	no	o:	LS20	C	U	no
o:	LS17	U	U	no	o:	LS20	U	U	no	o:	LS23	U	U	no
o:	LS23	U	U	no	o:	LS23	C	U	no	o:	LS24	U	U	no
o:	LS24	U	U	no	o:	LS24	C	C	no	o:	LS25	U	U	no
o:	LS25	U	U	no	o:	LS25	C	U	no	o:	LS27	U	U	no
o:	LS27	U	U	no	o:	LS27	U	U	no	o:	LS28	U	U	no
o:	LS28	U	U	no	o:	LS28	U	U	no	o:	LS30	U	U	no
o:	LS29	U	U	no	o:	LS29	U	U	no	o:	LS34	U	U	no
o:	LS30	U	U	no	o:	LS30	U	U	no	o:	LS35	U	U	no
o:	LS34	U	U	no	o:	LS34	U	U	no	o:	LS37	U	U	no
o:	LS37	U	U	no	o:	LS35	U	U	no	o:	LS38	U	U	no
o:	LS38	U	U	no	o:	LS37	C	U	no	o:	LS39	C	U	no
o:	LS39	U	U	no	o:	LS38	U	U	no	o:	LS41	U	U	no
o:	LS41	U	U	no	o:	LS39	U	U	no	o:	LS42	C	U	no
o:	LS42	C	U	no	o:	LS41	U	U	no	o:	LS44	C	U	no
o:	LS44	C	U	no	o:	LS42	C	U	no	o:	LS05	U	C	yes
o:	LS05	U	C	yes	o:	LS43	U	U	no	o:	LS06	U	C	yes
o:	LS20	U	C	yes	o:	LS44	C	C	no	o:	LS09	U	C	yes
o:	LS35	U	C	yes	o:	LS05	U	C	yes	o:	LS29	U	C	yes
o:	LS43	U	C	yes	o:	LS09	U	C	yes	o:	LS43	U	C	yes
ʉ:	LS02	U	U	no	ʉ:	LS02	C	U	no	ʉ:	LS02	U	U	no
ʉ:	LS03	C	C	no	ʉ:	LS03	C	C	no	ʉ:	LS03	C	C	no
ʉ:	LS04	U	U	no	ʉ:	LS04	U	U	no	ʉ:	LS06	C	C	no
ʉ:	LS05	U	U	no	ʉ:	LS05	U	U	no	ʉ:	LS07	U	U	no
ʉ:	LS06	C	C	no	ʉ:	LS06	C	C	no	ʉ:	LS09	C	C	no
ʉ:	LS07	U	U	no	ʉ:	LS07	U	U	no	ʉ:	LS10	U	U	no
ʉ:	LS10	U	U	no	ʉ:	LS10	U	U	no	ʉ:	LS12	U	U	no

ʉ:	LS12	U	U	no	ʉ:	LS12	U	U	no	ʉ:	LS13	C	U	no
ʉ:	LS13	U	U	no	ʉ:	LS14	C	U	no	ʉ:	LS14	U	U	no
ʉ:	LS14	U	U	no	ʉ:	LS15	U	U	no	ʉ:	LS15	U	U	no
ʉ:	LS15	C	U	no	ʉ:	LS16	U	U	no	ʉ:	LS16	U	U	no
ʉ:	LS16	U	U	no	ʉ:	LS17	U	U	no	ʉ:	LS20	C	U	no
ʉ:	LS17	U	U	no	ʉ:	LS20	U	U	no	ʉ:	LS23	C	C	no
ʉ:	LS24	U	U	no	ʉ:	LS23	U	U	no	ʉ:	LS24	U	U	no
ʉ:	LS25	U	U	no	ʉ:	LS27	U	U	no	ʉ:	LS25	U	U	no
ʉ:	LS27	U	U	no	ʉ:	LS28	U	U	no	ʉ:	LS27	U	U	no
ʉ:	LS28	U	U	no	ʉ:	LS29	U	U	no	ʉ:	LS28	U	U	no
ʉ:	LS29	U	U	no	ʉ:	LS30	U	U	no	ʉ:	LS29	U	U	no
ʉ:	LS30	U	U	no	ʉ:	LS34	U	U	no	ʉ:	LS30	U	U	no
ʉ:	LS34	U	U	no	ʉ:	LS35	U	U	no	ʉ:	LS34	U	U	no
ʉ:	LS35	U	U	no	ʉ:	LS37	U	U	no	ʉ:	LS37	U	U	no
ʉ:	LS37	U	U	no	ʉ:	LS38	U	U	no	ʉ:	LS38	U	U	no
ʉ:	LS38	U	U	no	ʉ:	LS39	U	U	no	ʉ:	LS39	C	U	no
ʉ:	LS39	C	C	no	ʉ:	LS41	U	U	no	ʉ:	LS41	U	U	no
ʉ:	LS41	U	U	no	ʉ:	LS42	C	U	no	ʉ:	LS42	U	U	no
ʉ:	LS42	U	U	no	ʉ:	LS43	C	U	no	ʉ:	LS43	U	U	no
ʉ:	LS43	U	U	no	ʉ:	LS09	U	C	yes	ʉ:	LS44	C	U	no
ʉ:	LS44	U	U	no	ʉ:	LS13	U	C	yes	ʉ:	LS04	U	C	yes
ʉ:	LS09	U	C	yes	ʉ:	LS24	U	C	yes	ʉ:	LS05	U	C	yes
ʉ:	LS20	U	C	yes	ʉ:	LS25	U	C	yes	ʉ:	LS17	U	C	yes
ʉ:	LS23	U	C	yes	ʉ:	LS44	U	C	yes	ʉ:	LS35	U	C	yes
æɪ	LS04	U	U	no	æɪ	LS02	C	C	no	æɪ	LS04	U	U	no
æɪ	LS05	C	U	no	æɪ	LS03	C	C	no	æɪ	LS05	C	C	no
æɪ	LS06	C	C	no	æɪ	LS05	U	U	no	æɪ	LS07	U	U	no

æɪ	LS07	U	U	no	æɪ	LS06	C	C	no	æɪ	LS09	U	U	no
æɪ	LS10	U	U	no	æɪ	LS07	U	U	no	æɪ	LS10	U	U	no
æɪ	LS13	C	U	no	æɪ	LS09	C	U	no	æɪ	LS12	U	U	no
æɪ	LS14	U	U	no	æɪ	LS10	U	U	no	æɪ	LS13	U	U	no
æɪ	LS15	U	U	no	æɪ	LS12	U	U	no	æɪ	LS14	C	U	no
æɪ	LS16	U	U	no	æɪ	LS13	U	U	no	æɪ	LS15	U	U	no
æɪ	LS17	U	U	no	æɪ	LS14	U	U	no	æɪ	LS16	C	U	no
æɪ	LS20	U	U	no	æɪ	LS15	U	U	no	æɪ	LS17	C	U	no
æɪ	LS23	U	U	no	æɪ	LS16	U	U	no	æɪ	LS20	U	U	no
æɪ	LS24	U	U	no	æɪ	LS17	U	U	no	æɪ	LS23	C	U	no
æɪ	LS25	U	U	no	æɪ	LS20	C	U	no	æɪ	LS24	U	U	no
æɪ	LS27	U	U	no	æɪ	LS23	U	U	no	æɪ	LS25	U	U	no
æɪ	LS28	U	U	no	æɪ	LS24	U	U	no	æɪ	LS27	U	U	no
æɪ	LS29	U	U	no	æɪ	LS25	C	U	no	æɪ	LS28	U	U	no
æɪ	LS30	U	U	no	æɪ	LS27	U	U	no	æɪ	LS29	U	U	no
æɪ	LS34	C	U	no	æɪ	LS28	U	U	no	æɪ	LS30	U	U	no
æɪ	LS35	U	U	no	æɪ	LS29	U	U	no	æɪ	LS34	U	U	no
æɪ	LS37	U	U	no	æɪ	LS30	U	U	no	æɪ	LS35	U	U	no
æɪ	LS38	U	U	no	æɪ	LS35	U	U	no	æɪ	LS37	U	U	no
æɪ	LS39	C	U	no	æɪ	LS37	C	U	no	æɪ	LS38	U	U	no
æɪ	LS41	U	U	no	æɪ	LS38	U	U	no	æɪ	LS39	C	C	no
æɪ	LS42	U	U	no	æɪ	LS39	U	U	no	æɪ	LS41	U	U	no
æɪ	LS43	U	U	no	æɪ	LS41	U	U	no	æɪ	LS42	U	U	no
æɪ	LS44	U	U	no	æɪ	LS42	U	U	no	æɪ	LS43	U	U	no
æɪ	LS02	U	C	yes	æɪ	LS43	C	U	no	æɪ	LS44	U	U	no
æɪ	LS03	U	C	yes	æɪ	LS44	U	U	no	æɪ	LS02	U	C	yes
æɪ	LS09	U	C	yes	æɪ	LS04	U	C	yes	æɪ	LS03	U	C	yes

æɪ	LS12	U	C	yes
ɑe	LS02	U	U	no
ɑe	LS04	U	U	no
ɑe	LS05	C	U	no
ɑe	LS06	C	C	no
ɑe	LS07	C	U	no
ɑe	LS10	C	C	no
ɑe	LS12	U	U	no
ɑe	LS13	C	U	no
ɑe	LS14	C	C	no
ɑe	LS15	U	U	no
ɑe	LS20	U	U	no
ɑe	LS24	C	U	no
ɑe	LS25	U	U	no
ɑe	LS28	U	U	no
ɑe	LS29	U	U	no
ɑe	LS30	U	U	no
ɑe	LS34	C	U	no
ɑe	LS35	U	U	no
ɑe	LS37	U	U	no
ɑe	LS38	U	U	no
ɑe	LS39	C	C	no
ɑe	LS41	C	U	no
ɑe	LS42	C	C	no
ɑe	LS43	C	U	no
ɑe	LS44	U	U	no
ɑe	LS03	U	C	yes
æɪ	LS34	U	C	yes
ɑe	LS02	C	U	no
ɑe	LS03	C	C	no
ɑe	LS04	C	U	no
ɑe	LS05	C	C	no
ɑe	LS07	C	U	no
ɑe	LS09	C	C	no
ɑe	LS10	C	U	no
ɑe	LS12	U	U	no
ɑe	LS14	U	U	no
ɑe	LS15	U	U	no
ɑe	LS16	U	U	no
ɑe	LS24	C	U	no
ɑe	LS27	C	C	no
ɑe	LS28	U	U	no
ɑe	LS29	U	U	no
ɑe	LS30	U	U	no
ɑe	LS34	C	C	no
ɑe	LS35	C	U	no
ɑe	LS37	C	U	no
ɑe	LS38	U	U	no
ɑe	LS41	U	U	no
ɑe	LS42	U	U	no
ɑe	LS44	C	U	no
ɑe	LS06	U	C	yes
ɑe	LS13	U	C	yes
ɑe	LS17	U	C	yes
æɪ	LS06	U	C	yes
ɑe	LS03	C	C	no
ɑe	LS04	C	C	no
ɑe	LS05	C	C	no
ɑe	LS06	C	C	no
ɑe	LS07	U	U	no
ɑe	LS10	C	C	no
ɑe	LS12	U	U	no
ɑe	LS15	C	U	no
ɑe	LS20	C	U	no
ɑe	LS24	C	U	no
ɑe	LS25	U	U	no
ɑe	LS27	U	U	no
ɑe	LS28	U	U	no
ɑe	LS29	U	U	no
ɑe	LS30	C	C	no
ɑe	LS34	U	U	no
ɑe	LS35	U	U	no
ɑe	LS37	U	U	no
ɑe	LS38	U	U	no
ɑe	LS39	C	C	no
ɑe	LS41	U	U	no
ɑe	LS42	U	U	no
ɑe	LS43	U	U	no
ɑe	LS02	U	C	yes
ɑe	LS09	U	C	yes
ɑe	LS13	U	C	yes

ɑe	LS09	U	C	yes	ɑe	LS20	U	C	yes	ɑe	LS14	U	C	yes
ɑe	LS16	U	C	yes	ɑe	LS23	U	C	yes	ɑe	LS16	U	C	yes
ɑe	LS17	U	C	yes	ɑe	LS25	U	C	yes	ɑe	LS17	U	C	yes
ɑe	LS23	U	C	yes	ɑe	LS39	U	C	yes	ɑe	LS23	U	C	yes
ɑe	LS27	U	C	yes	ɑe	LS43	U	C	yes	ɑe	LS44	U	C	yes
əʉ	LS04	U	U	no	əʉ	LS03	C	C	no	əʉ	LS02	U	U	no
əʉ	LS06	C	U	no	əʉ	LS04	U	U	no	əʉ	LS03	U	U	no
əʉ	LS07	U	U	no	əʉ	LS05	U	U	no	əʉ	LS04	C	U	no
əʉ	LS09	U	U	no	əʉ	LS06	U	U	no	əʉ	LS06	C	U	no
əʉ	LS10	U	U	no	əʉ	LS07	U	U	no	əʉ	LS07	U	U	no
əʉ	LS12	U	U	no	əʉ	LS10	U	U	no	əʉ	LS09	U	U	no
əʉ	LS13	U	U	no	əʉ	LS12	U	U	no	əʉ	LS10	C	U	no
əʉ	LS14	U	U	no	əʉ	LS13	U	U	no	əʉ	LS12	U	U	no
əʉ	LS15	U	U	no	əʉ	LS15	C	U	no	əʉ	LS13	U	U	no
əʉ	LS16	U	U	no	əʉ	LS16	U	U	no	əʉ	LS14	U	U	no
əʉ	LS17	C	U	no	əʉ	LS17	U	U	no	əʉ	LS15	U	U	no
əʉ	LS20	U	U	no	əʉ	LS20	U	U	no	əʉ	LS16	C	U	no
əʉ	LS23	U	U	no	əʉ	LS23	U	U	no	əʉ	LS17	U	U	no
əʉ	LS24	U	U	no	əʉ	LS24	U	U	no	əʉ	LS20	U	U	no
əʉ	LS25	U	U	no	əʉ	LS25	C	U	no	əʉ	LS24	U	U	no
əʉ	LS27	U	U	no	əʉ	LS27	C	U	no	əʉ	LS25	U	U	no
əʉ	LS28	U	U	no	əʉ	LS28	U	U	no	əʉ	LS27	U	U	no
əʉ	LS29	U	U	no	əʉ	LS29	U	U	no	əʉ	LS28	U	U	no
əʉ	LS30	U	U	no	əʉ	LS30	U	U	no	əʉ	LS29	U	U	no
əʉ	LS34	U	U	no	əʉ	LS34	U	U	no	əʉ	LS30	U	U	no
əʉ	LS35	U	U	no	əʉ	LS37	C	U	no	əʉ	LS34	C	U	no
əʉ	LS37	U	U	no	əʉ	LS38	U	U	no	əʉ	LS35	U	U	no

əʉ	LS38	U	U	no	əʉ	LS39	U	U	no	əʉ	LS37	U	U	no
əʉ	LS39	C	U	no	əʉ	LS41	C	U	no	əʉ	LS38	U	U	no
əʉ	LS41	U	U	no	əʉ	LS42	C	U	no	əʉ	LS39	C	U	no
əʉ	LS42	U	U	no	əʉ	LS43	U	U	no	əʉ	LS41	U	U	no
əʉ	LS43	C	U	no	əʉ	LS02	U	C	yes	əʉ	LS42	U	U	no
əʉ	LS44	U	U	no	əʉ	LS09	U	C	yes	əʉ	LS43	U	U	no
əʉ	LS02	U	C	yes	əʉ	LS14	U	C	yes	əʉ	LS44	C	U	no
əʉ	LS03	U	C	yes	əʉ	LS35	U	C	yes	əʉ	LS05	U	C	yes
əʉ	LS05	U	C	yes	əʉ	LS44	U	C	yes	əʉ	LS23	U	C	yes
ɪə	LS03	C	C	no	ɪə	LS03	C	C	no	ɪə	LS03	C	C	no
ɪə	LS04	U	U	no	ɪə	LS04	U	U	no	ɪə	LS04	U	U	no
ɪə	LS05	U	U	no	ɪə	LS06	C	C	no	ɪə	LS06	C	C	no
ɪə	LS06	C	C	no	ɪə	LS07	U	U	no	ɪə	LS07	U	U	no
ɪə	LS07	U	U	no	ɪə	LS09	C	C	no	ɪə	LS10	U	U	no
ɪə	LS10	U	U	no	ɪə	LS10	U	U	no	ɪə	LS12	C	U	no
ɪə	LS12	U	U	no	ɪə	LS12	U	U	no	ɪə	LS13	U	U	no
ɪə	LS13	U	U	no	ɪə	LS13	U	U	no	ɪə	LS14	U	U	no
ɪə	LS14	U	U	no	ɪə	LS14	U	U	no	ɪə	LS15	U	U	no
ɪə	LS15	U	U	no	ɪə	LS15	U	U	no	ɪə	LS16	U	U	no
ɪə	LS16	C	C	no	ɪə	LS16	U	U	no	ɪə	LS17	U	U	no
ɪə	LS17	U	U	no	ɪə	LS17	U	U	no	ɪə	LS20	U	U	no
ɪə	LS20	U	U	no	ɪə	LS20	U	U	no	ɪə	LS23	C	U	no
ɪə	LS24	C	U	no	ɪə	LS24	U	U	no	ɪə	LS24	U	U	no
ɪə	LS25	U	U	no	ɪə	LS25	U	U	no	ɪə	LS25	U	U	no
ɪə	LS27	U	U	no	ɪə	LS27	C	U	no	ɪə	LS27	U	U	no
ɪə	LS28	U	U	no	ɪə	LS28	U	U	no	ɪə	LS28	U	U	no
ɪə	LS29	U	U	no	ɪə	LS29	C	U	no	ɪə	LS29	C	U	no

ɪə	LS30	U	U	no	ɪə	LS30	U	U	no	ɪə	LS30	U	U	no
ɪə	LS34	C	U	no	ɪə	LS34	U	U	no	ɪə	LS34	U	U	no
ɪə	LS35	C	U	no	ɪə	LS35	U	U	no	ɪə	LS35	U	U	no
ɪə	LS37	U	U	no	ɪə	LS37	U	U	no	ɪə	LS37	U	U	no
ɪə	LS38	C	U	no	ɪə	LS38	U	U	no	ɪə	LS38	U	U	no
ɪə	LS39	C	U	no	ɪə	LS41	C	U	no	ɪə	LS41	U	U	no
ɪə	LS41	U	U	no	ɪə	LS42	U	U	no	ɪə	LS42	U	U	no
ɪə	LS42	U	U	no	ɪə	LS43	U	U	no	ɪə	LS43	U	U	no
ɪə	LS44	U	U	no	ɪə	LS44	U	U	no	ɪə	LS44	U	U	no
ɪə	LS02	U	C	yes	ɪə	LS02	U	C	yes	ɪə	LS02	U	C	yes
ɪə	LS09	U	C	yes	ɪə	LS05	U	C	yes	ɪə	LS05	U	C	yes
ɪə	LS23	U	C	yes	ɪə	LS23	U	C	yes	ɪə	LS09	U	C	yes
ɪə	LS43	U	C	yes	ɪə	LS39	U	C	yes	ɪə	LS39	U	C	yes

APPENDIX G

L2 vocabulary size has been shown to predict L2 speech perception in previous research by Bundgaard-Nielsen et al. (2011a, 2011b) and it is central to L2 category formation in PAM-L2. Therefore, based on the data from Experiment 5 (Chapter 8), an analysis was conducted in order to determine whether there were changes in L2 discrimination performance over time as a function of assimilation type and L2 vocabulary size at T0.

The average L2 vocabulary size at T0 for the 31 participants in Experiment 5 was 9232 words (Range: 4600 – 14200 words, *SD* = 2608 words). Using a median split, the Low-Vocabulary (LV) group consisted of 15 participants with an average L2 vocabulary size of 6987 words (Range: 4600 – 8600 words, *SD* = 361 words), and the average vocabulary for the 16 participants in the High-Vocabulary group was 11338 words (Range: 8800 – 14200 words, *SD* = 355 words). In a 2 x (3) x (9) mixed design ANOVA, *L2 Vocabulary Size* was a between-subjects factor with two levels (i.e., LV, HV). There were two within-subjects factors, namely, *Contrast* which was composed of nine levels (i.e., the nine AusE vowel contrasts under examination), and *Time* with three levels (i.e., T0, T1, T2).

Using a Huynh-Feldt adjustment for the degrees of freedom for main effects and interactions involving *Time* and *Contrast*, the main effect of *Time* was not significant, $F(1.74, 48.84) = 0.36$, $p = .672$, but there was a significant main effect of *L2 Vocabulary Size*, $F(1, 28) = 7.99$, $p = .009$, and *Contrast*, $F(5.50, 153.95) = 82.09$, $p < .001$. The only significant interaction that emerged was that involving *L2 Vocabulary Size* and *Contrast*, $F(5.50, 153.95) = 5.66$, $p < .001$.

This interaction was analysed by performing simple effects analyses conducted separately for the LV and HV groups using an adjusted alpha level of .025. The simple effect of LV was significant, $F(8, 104) = 28.66$, $p < .001$, and so was the simple effect of HV, $F(4.63, 69.50) = 67.30$, $p < .001$ (using a Huynh-Feldt adjustment for the degrees of freedom). These results suggest that both vocabulary size groups differed in their discrimination of the various AusE contrasts, but that discrimination performance did not differ significantly over time. Pairwise comparisons revealed that, overall, the HV group was better at discriminating between the vowel contrasts than the LV group. In each group, discrimination accuracy for certain contrasts varied, although there were no particularly striking patterns in the results. Descriptive statistics for the LV and HV groups are displayed in Table G.1.

Table G.1: *Mean percent discrimination accuracy (%), standard error, and 95% confidence intervals for the nine AusE vowel contrasts for both the Low-Vocabulary (LV) and High-Vocabulary (HV) groups*

Vocabulary size group	Contrast	Mean Discrimination accuracy %	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
LV	/æɪ/-/ɑe/	86	2.85	79.52	91.84
	/oː/-/ʉː/	87	3.12	79.99	93.45
	/oː/-/əʉ/	83	3.29	76.15	90.37
	/əʉ/-/ʉː/	79	3.74	70.86	87.03
	/ʊ/-/ɔ/	74	3.95	65.10	82.15
	/ɪə/-/iː/	73	4.33	63.39	82.11
	/ɪ/-/e/	72	3.73	63.52	79.64
	/eː/-/ɜː/	59	3.03	52.49	65.59
	/æ/-/ɐ/	58	1.63	54.85	61.90
HV	/æɪ/-/ɑe/	93	2.03	88.74	97.39
	/oː/-/ʉː/	94	1.95	89.69	97.99
	/oː/-/əʉ/	87	2.34	82.18	92.17
	/əʉ/-/ʉː/	88	3.32	81.18	95.32
	/ʊ/-/ɔ/	89	3.10	82.53	95.74
	/ɪə/-/iː/	90	2.55	84.25	95.12
	/ɪ/-/e/	90	2.40	85.06	95.28
	/eː/-/ɜː/	64	2.15	59.25	68.42
	/æ/-/ɐ/	63	2.29	57.74	67.52

APPENDIX H

The Appendix H displays the L1, L2, and preferred L1/L2 PAM assimilations, and the mean percent discrimination accuracy scores (columns labeled "%") for individual participants for each of the nine Australian English vowel contrasts across the three testing sessions (T0, T1, T2). The assimilation types displayed are: TC, UC, CG, SC, and UU.

Table H.1: *Individual participants' perceptual assimilations at T0 for each of the nine Australian English vowel contrasts*

ID	ʊ-ɔ				ɪ-e				ɪə-iː				æɪ-ɑe				əʉ-ʉː				oː-ʉː				oː-əʉ				æ-ɐ				eː-ɜː			
	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2
LS02	98	UU	UC	UC	98	UU	UC	UC	98	UU	UC	UC	97	UU	UC	UC	97	UU	UC	UC	97	UU	UU	UU	89	UU	UC	UC	58	UC	UC	UC	70	UU	UC	UC
LS03	95	UC	UU	UC	95	UU	UC	UC	98	SC	TC	TC	100	UU	TC	TC	100	UC	TC	TC	98	UC	UC	UC	91	UU	UC	UC	77	SC	TC	TC	67	UU	TC	TC
LS04	98	UU	UU	UU	98	UU	UU	UU	97	UU	UU	UU	100	UU	UU	UU	100	UU	UU	UU	100	UU	UU	UU	100	UU	UU	UU	78	UC	UU	UC	70	UU	UU	UU
LS05	89	UU	UC	UC	95	UC	UU	UC	95	UC	UC	UC	97	SC	UU	SC	97	UU	UC	UC	100	UU	UC	UC	98	UU	TC	TC	84	UC	UU	UC	53	UU	UC	UC
LS06	97	UC	TC	TC	81	UC	TC	TC	97	SC	TC	TC	98	TC	TC	TC	80	TC	UC	TC	95	UC	UC	UC	77	UC	UU	UC	53	SC	CG	CG	53	UC	SC	UC
LS07	86	UU	UU	UU	78	UC	UU	UC	75	UU	UU	UU	86	UC	UU	UC	73	UU	UU	UU	84	UU	UU	UU	73	UU	UU	UU	56	SC	UU	SC	55	UU	UU	UU
LS09	94	UC	UC	UC	100	UC	TC	TC	84	UC	TC	TC	98	UU	TC	TC	100	UU	UC	UC	100	UU	TC	TC	94	UC	UC	UC	61	UC	UC	UC	73	UU	UC	UC
LS10	94	UU	UU	UU	97	UC	UU	UC	100	UU	UU	UU	100	UC	UC	UC	95	UU	UU	UU	91	UC	UU	UC	75	UC	UU	UC	73	UC	UC	UC	83	UC	UU	UC
LS12	58	UC	SC	UC	77	UC	UU	UC	78	UU	UC	UC	83	UU	UC	UC	63	UU	UU	UU	98	UU	UU	UU	97	UU	UU	UU	61	UU	UU	UU	48	UU	UU	UU
LS13	97	UU	UC	UC	88	UC	UC	UC	78	UU	UC	UC	95	SC	UU	SC	94	UU	UU	UU	97	UU	UU	UU	73	UU	UU	UU	50	SC	UU	SC	52	UU	UU	UU
LS14	95	UU	UU	UU	95	UU	UU	UU	94	UU	UU	UU	98	UC	UC	UC	100	UU	UU	UU	98	UU	UU	UU	94	UU	UU	UU	80	UC	UC	UC	81	UC	UU	UC
LS15	78	UU	UU	UU	64	UU	UU	UU	81	UU	UU	UU	78	UU	UU	UU	89	UC	UU	UC	94	UC	UU	UC	89	UU	UU	UU	58	UU	UU	UU	56	UU	UU	UU
LS16	92	UC	UC	UC	95	UC	SC	UC	98	CG	SC	CG	98	UU	UC	UC	94	UU	UU	UU	100	UC	UU	UC	94	UC	UU	UC	73	SC	SC	SC	66	UU	UU	UU
LS17	92	UC	UC	UC	83	UU	UC	UC	86	UU	UU	UU	95	UU	UC	UC	95	UC	UU	UC	97	UU	UU	UU	97	UC	UU	UC	73	SC	UC	UC	64	UU	UU	UU
LS20	97	UU	UU	UU	81	UU	UU	UU	94	UU	UU	UU	100	UU	UU	UU	84	UU	UC	UC	94	UU	TC	TC	81	UU	UC	UC	56	UU	UU	UU	66	UU	UU	UU
LS23	100	UC	UC	UC	98	UC	TC	TC	100	UU	SC	SC	100	UU	UC	UC	100	UU	UC	UC	100	UU	UC	UC	89	UU	UU	UU	48	SC	UU	SC	41	UU	SC	SC
LS24	100	UC	UU	UC	98	UU	TC	TC	95	UC	UU	UC	100	UC	UU	UC	88	UU	UU	UU	100	UU	UU	UU	100	UU	UU	UU	80	SC	UU	SC	63	UC	UC	UC
LS25	83	UU	UU	UU	88	UU	UU	UU	86	UU	UU	UU	98	UU	UU	UU	97	UU	UU	UU	97	UU	UU	UU	84	UU	UU	UU	53	UC	UU	UC	75	SC	UU	SC
LS27	63	UC	UU	UC	81	UC	UU	UC	72	UU	UU	UU	75	UU	UC	UC	64	UU	UU	UU	80	UU	UU	UU	64	UU	UU	UU	55	SC	UU	SC	63	UU	UU	UU
LS28	70	UU	UU	UU	70	UU	UU	UC	56	UU	UC	UC	91	UU	UU	UU	64	UU	UU	UU	81	UU	UU	UU	88	UU	UU	UU	63	UU	UU	UU	61	UU	UU	UU
LS29	92	UU	UU	UU	77	UC	UU	UC	97	UU	UU	UU	97	UU	UU	UU	95	UU	UU	UU	98	UU	UU	UU	100	UU	UU	UU	70	UU	UU	UU	61	UU	UU	UU
LS30	72	UC	UU	UC	83	UU	UU	UU	67	UU	UC	UC	97	UU	UU	UU	89	UU	UU	UU	98	UU	UU	UU	98	UU	UU	UU	66	UU	UU	UU	61	UU	UU	UU
LS34	75	TC	UU	TC	83	SC	UU	SC	70	TC	UU	TC	91	TC	UU	TC	77	UU	UU	UU	84	UU	UU	UU	78	UU	UU	UU	73	SC	UU	SC	50	UU	UU	UU
LS35	47	UU	UC	UC	45	UU	UU	UU	70	UC	UU	UC	77	UU	UU	UU	83	UU	UU	UU	86	UU	UC	UC	91	UU	UC	UC	53	SC	UU	SC	48	UC	UU	UC
LS37	69	UU	UU	UU	66	UU	UC	UC	50	UU	UU	UU	78	UU	UU	UU	77	UU	UU	UU	84	UU	UU	UU	81	UU	UU	UU	50	UU	UU	UU	50	UU	UC	UC
LS38	50	UU	UU	UU	56	UC	UU	UC	63	UC	UU	UC	61	UU	UU	UU	64	UU	UU	UU	72	UU	UU	UU	59	UU	UU	UU	44	UC	UU	UC	52	UU	UU	UU
LS39	92	UC	UU	UC	91	TC	TC	TC	80	UC	UC	UC	98	SC	UC	UC	91	CG	UC	CG	97	UC	UC	UC	78	UC	UU	UC	69	SC	SC	SC	73	UU	UC	UC
LS41	67	UU	UU	UU	78	UU	UU	UU	64	UU	UU	UU	83	UC	UU	UC	80	UU	UU	UU	80	UU	UU	UU	80	UU	UU	UU	61	UU	UU	UU	55	UU	UU	UU
LS42	92	UU	UU	UU	97	UU	UU	UU	91	UC	UU	UC	63	UC	UC	UC	86	UU	UU	UU	71	UC	UU	UC	84	UC	UU	UC	59	UC	TC	TC	63	UU	UU	UU
LS43	50	TC	UU	TC	61	UC	UC	UC	61	UC	UU	UC	75	UC	UU	UC	66	UC	UU	UC	73	UU	UC	UC	69	UC	UC	UC	56	SC	UU	SC	44	UU	UU	UU
LS44	42	UC	UC	UC	48	UC	UC	UC	49	UU	UC	UC	60	UU	UU	UU	55	UU	UU	UU	72	UC	UU	UC	58	UC	UU	UC	47	UU	UU	UU	48	UU	UC	UC

Table H.2: *Individual participants' perceptual assimilations at T1 for each of the nine Australian English vowel contrasts*

	æ-ɐ				eː-ɜː				æɪ-ɑe				ɪə-iː				ɪ-e				ʊ-ɔ				əʉ-ʉː				oː-ʉː				oː-əʉ			
ID	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2
LS02	63	SC	UC	UC	80	UU	UC	UC	92	SC	UC	UC	92	UU	UC	UC	100	UC	UC	UC	97	SC	UC	UC	97	UC	UC	UC	98	TC	UU	TC	75	UC	UC	UC
LS03	61	SC	TC	TC	70	UU	TC	TC	100	TC	TC	TC	100	SC	TC	TC	100	SC	UC	UC	98	CG	TC	TC	100	TC	TC	TC	98	TC	UC	TC	97	CG	UC	CG
LS04	77	UC	UU	UU	63	UU	UU	UU	100	UC	UC	UC	97	UU	UC	UC	92	UU	UU	UU	91	UU	UU	UU	97	UU	UU	UU	98	UU	UU	UU	95	UU	UU	UU
LS05	80	UU	UC	UC	67	UU	UU	UU	97	UC	UC	UC	100	UU	TC	TC	91	UU	UC	UC	94	UU	UC	UC	94	UU	UU	UU	100	UU	UC	UC	100	UU	UC	UC
LS06	64	SC	UC	UC	63	UC	UC	TC	94	UC	TC	TC	78	SC	UC	UC	84	TC	UC	TC	88	UC	TC	TC	95	UC	UC	UC	98	TC	UC	TC	66	UC	UU	UC
LS07	72	SC	UU	SC	52	UU	UU	UU	94	UC	UU	UC	91	UU	UU	UC	83	UC	UU	UC	97	UU	UU	UU	56	UU	UU	UU	95	UU	UU	UU	75	UU	UU	UU
LS09	66	SC	SC	SC	67	UU	UC	UC	98	TC	UC	TC	97	TC	UC	TC	100	UC	TC	TC	97	SC	UU	UC	95	UU	TC	TC	97	UU	TC	TC	94	UU	SC	SC
LS10	72	UC	UU	UC	83	UC	UU	UC	100	UC	UU	UC	98	UU	UU	UU	97	UU	UU	UU	92	UU	UU	UU	97	UU	UU	UU	100	UU	UU	UU	92	UU	UU	UU
LS12	50	UU	UU	UU	47	UU	UU	UU	75	UU	UU	UU	58	UC	UU	UU	63	UC	UU	UC	53	UC	UU	UC	44	UU	UU	UU	66	UU	UU	UU	67	UU	UU	UU
LS13	53	SC	UU	SC	67	UC	UU	UC	98	UU	UC	UC	88	UU	UC	UC	77	TC	UU	TC	95	UU	UU	UU	84	UU	UC	UC	92	UU	UC	UC	73	UU	UU	UU
LS14	86	SC	UC	UC	83	UC	UC	UC	100	UU	UU	UU	94	UC	UU	UC	97	UU	UU	UU	100	UU	UU	UU	92	UU	UC	UC	100	UU	UU	UU	88	UU	UC	UC
LS15	58	SC	UC	UC	59	UU	UU	UU	77	UU	UU	UU	84	UU	UU	UU	80	UC	UU	UC	84	UC	UC	UC	77	UC	UU	UC	100	UC	UC	UC	95	UU	UC	UC
LS16	77	SC	UU	SC	59	UU	UU	UU	98	UU	UU	UU	100	UU	UU	UU	94	UC	UU	UC	100	UC	UU	UC	98	UC	UU	UC	100	UC	UU	UC	100	TC	UU	TC
LS17	70	UU	UC	UC	64	UU	UU	UU	95	UU	UC	UC	83	UU	UU	UU	98	UC	UU	UC	94	UC	UU	UC	97	UU	UU	UU	97	UU	UU	UU	97	UU	UU	UU
LS20	59	UU	UU	UU	66	UU	UU	UU	89	UC	UC	UC	94	UU	UU	UU	63	UC	UU	UC	91	UU	UU	UU	69	UU	UU	UU	89	UU	UU	UU	72	UU	UU	UU
LS23	53	UU	SC	SC	61	UC	UC	UC	100	UU	UC	UC	100	UC	SC	UC	100	UC	UC	UC	100	UC	TC	TC	100	UU	UU	UU	100	UC	UU	UC	95	UC	UU	UC
LS24	70	UC	UC	TC	86	UU	UC	UC	100	UC	UU	UC	100	UU	UU	UU	97	UU	UC	UC	95	UU	UU	UU	98	UC	UC	UC	100	UC	SC	UC	94	UC	UC	UC
LS25	55	SC	TC	UC	89	UC	UC	UC	98	UC	UC	UC	97	UU	UU	UU	88	UU	UC	UC	100	SC	UU	SC	98	UC	UC	UC	98	UC	UC	UC	95	SC	UU	SC
LS27	58	UC	UU	UC	41	UU	UU	UU	81	UC	UC	UC	80	UC	UU	UC	70	UU	UU	UU	64	UU	UU	UU	64	UC	UU	UC	70	UU	UU	UU	66	UC	UU	UC
LS28	55	UU	UU	UU	55	UU	UU	UU	91	UU	UU	UU	65	UU	UU	UU	59	UU	UU	UU	64	UU	UU	UU	89	UU	UU	UU	94	UU	UU	UU	89	UU	UU	UU
LS29	59	UU	UU	UU	61	UU	UU	UU	91	UU	UU	UU	95	UC	UU	UU	77	UU	UU	UU	92	UU	UU	UU	97	UU	UU	UU	100	UU	UU	UU	100	UU	UU	UU
LS30	59	UC	UU	UC	58	UU	UU	UU	77	UU	UU	UU	63	UC	UU	UC	61	UU	UU	UU	69	UU	UU	UU	45	UU	UU	UU	98	UU	UU	UU	97	UU	UU	UU
LS34	50	UC	UC	UC	44	UC	UU	UC	76	UC	SC	UC	50	UC	UC	UC	69	SC	UU	SC	59	UU	UU	UU	55	UC	UU	UU	67	UC	UU	UC	63	UU	UU	UU
LS35	73	SC	UU	SC	58	UU	UU	UU	92	UC	UU	UC	81	UU	UU	UU	84	UU	UU	UU	92	UC	UC	UC	89	UU	UC	UC	92	UC	UU	UC	95	TC	UC	TC
LS37	44	UU	UU	UU	56	UU	UU	UU	98	UU	UU	UU	52	UU	UU	UU	61	UU	UU	UU	75	UU	UC	UC	75	UU	UU	UU	95	UU	UU	UU	94	UU	UU	UU
LS38	50	UU	UU	UU	50	UC	UU	UU	77	UU	UU	UU	56	UU	UU	UU	56	UU	UU	UU	52	UC	UU	UC	91	UU	UU	UU	97	UU	UU	UU	91	UU	UU	UU
LS39	53	SC	SC	SC	75	SC	UC	UC	100	SC	UC	UC	88	UC	UC	UC	98	UC	UU	UC	84	SC	UC	UC	91	UC	UU	UC	100	UC	UU	UC	63	SC	UU	SC
LS41	58	UU	UU	UU	47	UU	UU	UU	94	UC	UU	UC	88	UU	UU	UU	88	UU	UC	UC	80	UU	UU	UU	95	UU	UU	UU	69	UU	UU	UU	95	UU	UU	UU
LS42	67	SC	UU	SC	55	UU	UU	UU	97	UC	UU	UC	91	UC	UU	UC	98	UC	UU	UC	84	UC	UU	UC	89	UU	UU	UU	100	UU	UU	UU	95	UU	UU	UU
LS43	50	SC	UC	UC	53	UU	UU	UU	76	UU	UC	UC	56	UC	UU	UC	42	UU	SC	SC	61	SC	UC	UC	67	UC	UU	UC	70	UU	UU	UU	58	UC	UU	UC
LS44	52	UC	SC	UC	45	UC	UU	UC	95	UU	UU	UU	42	UU	UU	UU	69	UU	UU	UU	55	UU	SC	SC	75	SC	SC	SC	98	TC	SC	TC	91	UC	SC	TC

Table H.3: *Individual participants' perceptual assimilations at T2 for each of the nine Australian English vowel contrasts*

	æ-ɐ				eː-ɜː				æɪ-ɑe				ɪə-iː				ɪ-e				ʊ-ɔ				əʉ-ʉː				oː-ʉː				oː-əʉ			
ID	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2	%	L1	L2	L1/L2
LS02	53	SC	UC	UC	84	UC	UC	UC	97	UU	TC	TC	100	UC	UC	UC	100	SC	TC	TC	98	UU	UC	UC	98	UU	UU	UU	98	UU	UU	UU	94	UU	UU	UU
LS03	63	SC	CG	CG	83	UC	TC	TC	98	UC	TC	TC	95	SC	TC	TC	98	SC	TC	TC	100	SC	UC	UC	100	UC	UC	UC	100	TC	TC	TC	95	UC	UC	UC
LS04	81	UC	UU	UC	77	UU	UU	UU	98	UC	UC	UC	100	UC	UC	UC	98	UU	UU	UU	97	UC	UU	UC	95	UC	UC	UC	97	UU	UC	UC	91	UC	UU	UC
LS05	77	TC	SC	TC	55	UU	UU	UU	95	SC	TC	TC	100	UU	UC	UC	92	UC	UC	UC	94	UU	SC	SC	92	UU	SC	SC	95	UU	TC	TC	95	UU	TC	TC
LS06	61	UC	SC	UC	67	UC	SC	UC	92	UC	TC	TC	92	SC	TC	TC	95	TC	TC	TC	98	SC	TC	TC	92	TC	UC	TC	100	UC	TC	TC	94	UC	UC	UC
LS07	66	SC	UU	SC	59	UU	UU	UU	98	UU	UU	UU	66	UU	UU	UU	78	UC	UU	UC	81	UU	UC	UU	81	UU	UU	UU	94	UU	UU	UU	69	UU	UU	UU
LS09	58	UC	SC	UC	80	UU	TC	TC	97	UC	UC	UC	97	UU	TC	TC	100	UC	UC	UC	100	SC	SC	SC	92	UC	UC	UC	98	UC	TC	TC	89	UU	UC	UC
LS10	58	CG	UC	CG	61	UU	UU	UU	100	UC	UC	UC	98	UU	UU	UU	97	UC	UU	UC	97	UC	UU	UC	95	UC	UU	UC	95	UU	UU	UU	89	UC	UU	UC
LS12	58	UU	UC	UC	58	UU	UU	UU	89	UU	UU	UU	75	UC	UU	UC	77	UU	UU	UU	48	UC	SC	UC	75	UU	UU	UU	92	UU	UU	UU	88	UU	UU	UU
LS13	47	SC	UC	UC	72	UC	UU	UC	97	UU	UC	UC	86	UC	UU	UC	97	UC	UC	UC	88	UC	UU	UC	95	UC	UU	UC	95	UC	UU	UC	66	UU	UU	UU
LS14	0	TC	UU	TC	81	UU	UU	UU	98	UC	UC	UC	97	UU	UC	UC	88	UU	UU	UU	100	UU	UU	UU	97	UU	UU	UU	100	UU	UU	UU	92	UU	UU	UU
LS15	45	UC	UU	UC	59	UC	UU	UC	97	TC	UU	TC	84	UC	UU	UC	84	UC	TC	TC	86	UC	UU	UC	75	UC	UU	UC	91	UU	UU	UU	91	UC	UU	UC
LS16	63	SC	UC	UC	70	UU	UU	UU	98	UC	UC	UC	98	UC	UU	UC	95	UC	UU	UC	91	UU	UU	UU	100	UC	UU	UC	98	UC	UU	UC	95	SC	UU	SC
LS17	64	SC	SC	SC	78	UU	TC	TC	97	UC	UC	UC	94	UU	UU	UU	95	UC	UU	UC	98	UC	UU	UC	91	UU	UC	UC	98	UC	UC	UC	94	UC	UU	UC
LS20	61	UU	UU	UU	61	UU	UU	UU	86	TC	UU	TC	83	UU	UU	UU	63	UU	UU	UU	73	UU	UC	UC	72	UC	UU	UC	78	CG	UU	CG	64	UC	UU	UC
LS23	55	SC	SC	SC	81	UC	SC	UC	100	UU	UC	UC	98	UC	UC	UC	100	UC	TC	TC	97	UU	TC	TC	97	UC	TC	TC	100	UC	UC	UC	92	UU	UC	UC
LS24	67	UC	UC	UC	63	UU	UU	UU	98	UC	UU	UC	86	UU	UU	UU	97	UU	UU	UU	92	UC	UC	UC	100	UU	UU	UU	100	UU	UU	UU	97	UU	UU	UU
LS25	67	UU	UC	UC	98	UC	UC	UC	97	UU	UU	UU	92	UC	UU	UC	83	UU	UU	UU	91	UU	UC	UU	100	UU	UU	UU	100	UC	UU	UC	97	UC	UU	UC
LS27	44	UU	UU	UU	48	UU	UU	UU	70	UU	UU	UU	58	UC	UU	UC	73	UU	UU	UU	77	UU	UU	UU	55	UU	UU	UU	70	UU	UU	UU	83	UU	UU	UU
LS28	50	UU	UU	UU	58	UU	UU	UU	70	UU	UU	UU	47	UU	UU	UU	63	UU	UU	UU	53	UU	UU	UU	86	UU	UU	UU	94	UU	UU	UU	91	UU	UU	UU
LS29	61	UU	UU	UU	44	UC	UU	UC	75	UU	UU	UU	86	UC	UU	UC	64	UU	UU	UU	80	UU	UU	UU	94	UU	UU	UU	98	UU	UC	UC	98	UU	UC	UC
LS30	52	SC	UU	SC	56	UC	UU	UC	89	UC	UC	UC	75	UC	UU	UC	44	UU	UU	UU	58	UC	UU	UC	39	UU	UU	UU	95	UU	UU	UU	92	UU	UU	UU
LS34	48	UU	UU	UU	55	UC	UC	UC	83	UU	UU	UU	66	UC	UU	UC	58	UC	SC	UC	53	UU	UC	UC	61	UC	UU	UC	72	UU	UU	UU	67	UC	UU	UC
LS35	69	SC	UU	SC	55	SC	UU	SC	97	UU	UU	UU	91	UU	UU	UU	77	UC	UU	UC	83	SC	SC	SC	83	UU	UC	UC	98	UU	UC	UC	97	UU	UU	UU
LS37	59	UU	UU	UU	53	UU	UU	UU	75	UU	UU	UU	55	UU	UU	UU	53	UU	UU	UU	61	UU	UC	UC	78	UU	UU	UU	77	UU	UU	UU	72	UU	UU	UU
LS38	53	UU	UU	UU	45	UU	UU	UU	64	UU	UU	UU	48	UU	UU	UU	59	UU	UU	UU	48	UU	UU	UU	42	UU	UU	UU	69	UU	UU	UU	61	UU	UU	UU
LS39	55	SC	SC	SC	75	SC	UC	UC	98	CG	SC	CG	84	UU	UC	UC	98	UC	TC	TC	97	SC	UU	SC	89	SC	UU	SC	97	SC	UU	SC	78	SC	UU	SC
LS41	64	UU	UU	UU	61	UU	UU	UU	97	UU	UU	UU	86	UU	UC	UC	78	UU	UU	UU	83	UU	UU	UU	97	UU	UU	UU	97	UU	UU	UU	95	UU	UU	UU
LS42	58	SC	UU	SC	58	UU	UU	UU	98	UC	UU	UU	97	UU	UU	UU	94	UU	UU	UU	77	UU	UU	UU	92	UU	UU	UU	100	UC	UU	UC	94	UC	UU	UC
LS43	47	UC	UU	UC	50	UU	UU	UU	61	UC	UU	UU	58	UU	UU	UU	47	UU	UU	UU	61	UU	UU	UU	41	UU	UU	UU	71	UU	UC	UC	58	UU	UC	UC
LS44	70	UC	UC	UC	58	UU	UC	UC	95	UU	UC	UC	78	UC	UU	UC	88	UC	UC	UC	84	UU	UU	UU	92	SC	UU	SC	78	SC	UU	SC	98	SC	UU	SC

APPENDIX I

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The Perceptual Assimilation of Danish Monophthongs and Diphthongs by Monolingual Australian English Speakers

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ABSTRACT

This study explores how experience with native language (L1) diphthongs influences the assimilation of non-native diphthongs. To obtain a comprehensive understanding of L1 attunement, native Australian English (AusE) speakers categorized and rated the Danish diphthongs, in addition to the monophthongs, in relation to their entire native vowel inventory. Short Danish vowels were assimilated to both lax and tense AusE vowels, and long Danish vowels were primarily categorized to tense AusE vowels. Only two of the Danish diphthongs were assimilated to an AusE diphthong, while the rest were either assimilated to an AusE tense vowel or were uncategorized. This suggests that the perceptual assimilation of non-native diphthongs is not based purely on sensitivity to vowel dynamics, but also on the perceived phonetic similarity between non-native diphthongs and L1 vowels. Implications for modelling cross-language speech perception are discussed.

Keywords: Cross-language speech perception, perceptual assimilation, vowels, diphthongs.

1. INTRODUCTION

Adults' perception of foreign consonants and vowels is influenced by their native language (L1) experience [2]. An adult's phonological system has often been likened to a 'sieve', which filters out phonetic information that is not phonologically meaningful in the L1 [12]. There have been no studies to date that have examined how experience with L1 diphthongs affects the perception of non-native diphthongs, so the primary focus of this study will be on the perceptual assimilation of non-native diphthongs by naïve listeners. Additionally, to gain a more complete understanding of perceptual attunement to the L1, the non-native listeners will also be asked to perceptually assimilate both diphthongs and monophthongs from a foreign language to their entire vowel inventory.

The Perceptual Assimilation Model (PAM; [2]) was developed to account for the effect of L1 attunement on speech perception. According to PAM, non-native phones may assimilate to an adult's phonological system in three different ways. A non-native phone may be *categorized* as an identical or deviant exemplar of an L1 category. If a non-native phone is perceived as speech but not as similar to any particular L1 category, it is considered *uncategorized*, and if it is not perceived as speech, it is deemed *non-assimilable*. PAM predicts discrimination accuracy of pairs of non-native phones based on these assimilation patterns. This study will only focus on the assimilation of individual non-native phones from an entire non-native vowel system in order to provide insight into how L1 attunement shapes the L1 phonological system.

The perception of non-native monophthongs has been shown to be influenced by L1 experience [13]. For instance, identifying and discriminating front rounded vowels is difficult for those who do not distinguish between front rounded versus unrounded vowels in their L1. In [11], American English (AE) listeners categorized and rated the North German vowels /yː, ʏ, øː/ and the Parisian French vowels /y, ø/ to L1 monophthongs. These vowels were primarily categorized to the AE back rounded vowels, despite being more acoustically similar to the front unrounded vowels. In [8], monolingual Spanish speakers categorized AE /i/ and /u/ to their /i/ and /u/, respectively, while the AE /ɛ, ɪ, æ/ were assimilated to Spanish /e/. Such studies demonstrate that listeners perceive non-native monophthongs in relation to those in their L1 inventory.

In contrast, little is known about the effect of L1 attunement on the perception of non-native diphthongs. Although diphthongs and monophthongs are both classified as vowels, they differ markedly from one another articulatorily and acoustically. While monophthongs are produced with the tongue and jaw in a relatively stable position throughout production, diphthongs are much more dynamic as they are produced with substantial movement of the tongue, jaw, or lips during articulation [6]. Diphthongs are often described as a combination of two monophthongs, but native diphthongs are nonetheless perceived as a single phone. It has been shown that listeners make fewer errors identifying diphthongs than monophthongs due to the rich dynamic information available in diphthongized vowels [1]. Given such differences, the perception of non-native diphthongs is likely to differ from monophthongs.

In the only study to date to investigate the perception of non-native/second-language (L2) diphthongs under a PAM framework, native Japanese speakers' perceptual assimilation of all the Australian English (AusE) monophthongs and diphthongs was examined [5]. Since diphthongs are not employed in Japanese, listeners were asked to identify the AusE vowels in terms of all the permissible combinations of the monomoraic vowels (/ie, ia, iu, io, ei, ea, eu, eo, ai, ae, au, ao, ui, ue, ua, uo, oi, oe, oa, ou/), in addition to their monomoraic (/a, e, i, o, u/) and bimoraic vowels (/aː, eː, iː, oː, uː/). As predicted, the majority of the AusE diphthongs were categorized to the Japanese bimoraic vowel combinations. The diphthongs /ɑe, æɪ, oɪ/ were categorized as /ai, ei, /oi/, respectively, while /æɔ, əʉ/ were uncategorized. However, the listeners identified the AusE diphthongs in terms of their monomoraic vowel combinations, which are not classified as diphthongs [10]. It is yet to be determined how experience with vowel dynamics shapes the perception of non-native diphthongs for speakers of languages with diphthongs in their vowel inventories.

For PAM to be a comprehensive model of cross-language speech perception, it must be able to account for the effect of L1 attunement on the perception of all types of speech sounds. Therefore, the current study assessed the perceptual assimilation of non-native monophthongs and diphthongs in listeners who have L1 experience with both types of vowels – Australian English (AusE) speakers. Danish is diphthong-rich, so it served as the stimulus language. The AusE speakers perceptually categorized and rated the goodness-of-fit of all the Danish vowels in relation to their full AusE vowel inventory. It was predicted that short and long Danish vowels would be assimilated to AusE lax and tense monophthongs, respectively. There are two possible scenarios for the assimilation of the Danish diphthongs. It may be that due to the AusE speakers' experience with vowel dynamics, Danish diphthongs will be assimilated only to L1 diphthongs. Alternatively, sensitivity to vowel dynamics may not necessarily result in the assimilation of Danish diphthongs to L1 diphthongs. That is, listeners may only assimilate Danish diphthongs to L1 diphthongs if they are perceived as being phonetically similar, as opposed to being based on vowel dynamics *per se*. The latter possibility is more consistent with PAM, which states that the perceptual assimilation of non-native phones depends on their perceived similarities and differences to L1 categories. Danish diphthongs that are not assimilated to L1 diphthongs may instead be categorized to L1 tense vowels or may be uncategorized.

2. METHOD

2.1. Participants

Forty monolingual Australian English speakers (31 females, M_{age} = 25 yrs, age range: 18-55) were recruited from the student pool at the University of Western Sydney and from the Greater Western Sydney community. Participants who were enrolled in Introductory Psychology courses received course credit for their participation and those recruited from the community received monetary reimbursement. All participants reported normal or corrected-to-normal vision and no hearing or language impairments.

2.2. Stimuli and Apparatus

2.2.1. Stimulus recording

Three native Danish female speakers were recorded in a sound-attenuated booth at The MARCS Institute. All three speakers were 24 years of age and were born and raised in Copenhagen, Denmark. The speakers produced the Danish short vowels /i, e, ɛ, ɑ, u, o, ɔ, y, ø, œ/, long vowels /iː, eː, ɛː, aː, uː, oː, ɔː, yː, øː, œː/, diphthongs /uj, iw, ew, ɛw, ɒw, yw, øw, œw, œw, iʌ̯, eʌ̯, æʌ̯, yʌ̯, øʌ̯, œʌ̯, uʌ̯, oʌ̯/, and /ə/ [9] in /ˈhVbə/ nonsense syllables.[1] They were instructed to speak in a natural, conversational manner, and to produce the tokens with a falling intonation. A female AusE speaker also produced all AusE vowels in /ˈhVbə/ context for a familiarization task. One auditory token per AusE vowel (18 in total) was selected.

Nonsense words were presented one at a time on a computer monitor situated in front of the speaker. The informants were instructed to speak in a normal, conversational manner, and to produce the nonsense words with a falling intonation. Approximately 8 randomized blocks of the 38 nonsense words were presented and speech production was recorded using a Shure SM10A headset microphone connected to a computer via an Edirol UA-25EX external USB sound card, with a sampling rate of 44.1 kHz.

Stimulus presentation and response collection was controlled using PsyScope X B57 on a MacBook laptop, Sennheiser HD 650 headphones, and an Edirol UA-25EX external USB sound card.

2.2.2. Stimulus preparation

Auditory recordings were high-pass filtered in Praat [3] at 70 Hz to attenuate any unwanted low-frequency rumble and to correct for the DC component. Each token was ramped so that there was a 10 ms fade-in for the token onset and a 20 ms fade-out for the token offset. Audible clicks were excised from the tokens using Praat.

To select the most suitable tokens for the final set of stimuli, five native Danish speakers verified all potential tokens in an identification task with goodness ratings. The tokens for the vowels /eʌ̯, ew, øʌ̯, œw, øw, ə/ were inconsistently and/or incorrectly identified, and were therefore excluded from the present study. Three tokens per speaker for each vowel were selected, resulting in 288 tokens in total. Table 1 displays the acoustic measurements.

Table 1: Mean Danish target vowel duration (ms), and F1, F2, and F3 at the 25%, 50%, and 75% of the vowel duration.

Danish vowel	Vowel duration	F1 (Hz)			F2 (Hz)			F3 (Hz)		
		25%	50%	75%	25%	50%	75%	25%	50%	75%
i	79	342	357	368	2384	2373	2310	3347	3277	2996
e	89	457	480	487	2341	2277	2143	3075	3039	2887
ɛ	87	512	537	540	2148	2074	1972	2930	2904	2760
a	107	915	910	854	1475	1452	1418	2754	2723	2700
y	93	362	377	382	2101	2079	1973	2609	2579	2422
ø	108	472	486	486	1852	1860	1784	2594	2568	2511
œ	113	508	529	523	1774	1754	1684	2605	2613	2566
u	96	418	425	424	923	899	839	2560	2555	2528
o	95	482	489	479	878	873	861	2681	2696	2690
ɔ	100	730	731	689	1208	1234	1229	2635	2629	2602
iː	169	330	325	338	2484	2498	2502	3536	3544	3473
eː	182	443	443	445	2465	2495	2505	3259	3308	3240
ɛː	176	476	482	503	2300	2289	2224	3039	3045	2950
aː	155	615	607	595	2214	2218	2171	2967	2975	2915
yː	171	348	339	345	2150	2150	2123	2534	2575	2548
øː	176	449	459	471	1890	1896	1866	2531	2537	2523
œː	178	484	490	498	1838	1840	1826	2607	2593	2591
uː	165	406	404	404	839	802	767	2490	2502	2511
oː	173	454	458	459	769	741	732	2740	2781	2802
ɔː	186	484	490	504	1088	1068	1048	2572	2603	2637
iw	157	377	427	428	2257	1751	1107	2825	2438	2508
uj	170	449	463	445	1036	1566	2040	2533	2489	2588
ɛw	166	511	545	514	2090	1632	1161	2759	2598	2597
yw	152	411	435	439	1919	1575	1112	2414	2370	2435
œw	162	535	534	500	1635	1352	1078	2496	2480	2539
ɒw	148	634	608	538	994	911	843	2692	2761	2822
iʌ̯	167	392	519	671	2345	2116	1723	3242	2965	2790
uʌ̯	176	466	530	691	770	1030	1221	2694	2653	2660
yʌ̯	176	390	502	615	2017	1797	1512	2541	2534	2611
oʌ̯	166	535	639	721	835	998	1151	2718	2738	2734
œʌ̯	164	689	751	773	1625	1505	1393	2602	2597	2606
æʌ̯	162	702	793	824	1985	1741	1543	2906	2765	2707

2.3. Procedure

Participants were tested in groups of up to three at the University of Western Sydney. They first completed a familiarization task to help make them aware of the vowel sounds in the English keywords. On a given trial, participants heard an AusE vowel in /ˈhVbə/ context. A 6 x 3 grid was displayed containing the AusE vowels /ɐ, e, ɪ, ɔ, ʊ, æ, ɐː, eː, iː, oː, ʉː, ɜː, ɑe, æɔ, æɪ, əʉ, ɪə, oɪ/ [7] presented in the English keywords *up*, *bet*, *hid*, *hot*, *hood*, *had*, *hard*, *hair*, *heed*, *hoard*, *boot*, *her*, *hide*, *how*, *bay*, *boat*, *here*, and *hoist*, respectively, with the target vowel sound highlighted in red. They were asked to select a keyword containing the same vowel that they had heard. If the incorrect label was selected, the correct response was given as feedback. The familiarization ended when they reached a score of 60 or they completed 100 trials. Each participant was presented with a different randomized order of the trials.

Participants then completed a category assimilation task with goodness rating using the Danish vowels. On a given trial, participants heard a /ˈhVbə/ nonsense word and were again asked to attend to the first vowel. The same grid from the familiarization task was presented and participants used a computer mouse to select an English keyword containing the closest sounding vowel to the one they heard. The same auditory token was presented a second time for participants to rate how well it matched the chosen vowel on a 7-point scale (1 = sounds very poor to 7 = sounds perfect). No feedback was provided. There were 288 trials (32 vowels x 3 speakers x 3 repetitions) in total, and each participant received a different randomized order of the trials. They were given 6 s to select a category label and 3.5 s to rate the vowel, and if no response was registered for either part of the trial, that same trial was randomly repeated later. The ITI was 480 ms. The session duration was 50 min.

3. RESULTS

Table 2 displays the mean percent categorization and goodness ratings of each Danish vowel to an AusE category label. Using a 50% assimilation criterion (following [5]), two of the Danish short vowels were uncategorized, while the remaining short vowels were categorized, with the responses split between the AusE lax and tense vowels. For example, the Danish /e/ and /i/ were both categorized to the AusE lax vowel /ɪ/, while /œ/ and /ø/ were both categorized to the AusE tense vowel /ɜː/.

All Danish long vowels were assimilated to tense AusE vowels except for three long vowels that were uncategorized. Similar to the assimilation pattern observed for some Danish short vowels, there were instances where two Danish tense vowels were categorized to a single AusE vowel. For instance, /eː/ and /iː/ were both assimilated to AusE /iː/, and /œː/ and /øː/ were both categorized to /ɜː/. In some instances, Danish vowels differing only in length were categorized to the same AusE vowel. For example, /y/ and /yː/ were both categorized to /ʉː/, and /œ/ and /œː/ were both categorized to AusE /ɜː/. The only Danish diphthongs that were assimilated to AusE diphthongs were /uj/ and /iʌ̯/, which were categorized as /oɪ/ and /ɪə/, respectively. Five Danish diphthongs were categorized to an AusE tense vowel, while the remainder of the diphthongs were uncategorized. Some of the Danish long vowels and diphthongs were categorized to the same L1 category. For instance, the Danish long vowels /œː/ and /øː/, and the diphthongs /œʌ̯/ and /œw/ were all categorized as AusE /ɜː/. Similarly, /ɛː/ and /æʌ̯/ were assimilated to AusE /eː/.

Table 2: Mean percent categorization (%) and goodness rating (GR), both averaged across participants, of Danish vowels by Australian English speakers. The top three responses (R) are presented for the uncategorized vowels.

Danish	1			2			3		
vowel	R	%	GR	R	%	GR	R	%	GR
ɔ	ɔ	57%	5.64						
e	ɪ	55%	5.40						
i	ɪ	57%	5.43						
u	ʊ	63%	5.15						
a	ɐː	53%	5.52						
œ	ɜː	89%	5.87						
ø	ɜː	60%	5.26						
y	ʉː	58%	5.01						
ɛ	e	40%	5.10	eː	23%	4.90	ɜː	12%	3.79
o	ɔ	33%	4.32	ʊ	22%	4.90	oː	21%	4.82
eː	iː	51%	5.30						
iː	iː	59%	5.58						
ɛː	eː	51%	5.28						
œː	ɜː	86%	5.83						
øː	ɜː	53%	5.07						
yː	ʉː	58%	5.35						
uː	ʊ	56%	5.04						
aː	eː	48%	5.42	æɪ	24%	5.46	e	14%	5.14
ɔː	oː	36%	4.61	əʉ	15%	4.45	ɔ	15%	3.73
oː	oː	44%	5.08	ʊ	21%	4.81	əʉ	9%	4.24
uj	oɪ	78%	4.63						
iʌ̯	ɪə	80%	6.14						
æʌ̯	eː	55%	5.36						
œʌ̯	ɜː	68%	5.37						
œw	ɜː	54%	4.19						
uʌ̯	oː	57%	4.77						
oʌ̯	oː	74%	5.24						
ɒw	ɔ	36%	4.59	oː	23%	3.93	əʉ	18%	4.66
ɛw	ɜː	28%	3.69	e	18%	4.22	eː	18%	3.78
iw	ɐ	19%	3.41	ɪ	16%	4.04	ʉː	16%	3.41
yʌ̯	ʉː	20%	3.44	ɜː	18%	3.26	ʊ	16%	3.72
yw	ʉː	37%	3.83	ɐ	16%	2.79	ʊ	13%	4.06

4. DISCUSSION

This study examined how AusE listeners perceptually assimilate the Danish monophthongs and diphthongs to their entire vowel inventory. It was predicted that short and long Danish vowels would be assimilated to AusE lax and tense vowels, respectively. This prediction was largely upheld for the assimilation of long Danish vowels, but it was not the case for the short Danish vowels as many of them were also assimilated to tense AusE vowels.

If listeners assimilated Danish diphthongs to AusE diphthongs purely based on dynamic vowel quality, the majority of the Danish diphthongs would be expected to have been categorized to AusE diphthongs. However, this prediction was not supported as only two of the Danish diphthongs were assimilated to an AusE diphthong. This finding is more consistent with our alternate hypothesis that despite experience with L1 vowel dynamics, non-native listeners do not assimilate Danish diphthongs to L1 diphthongs purely because of their sensitivity to vowel dynamics. According to PAM, this finding may be explained in terms of the perceived phonetic similarity between the native and non-native phones. For Danish diphthongs assimilated to AusE tense vowels, non-native listeners appear to have detected one of the targets in the Danish diphthongs and assimilated it based on the most similar AusE tense vowel. For instance, the Danish monophthong /œ/ and the diphthongs /œw/ and /œʌ̯/ were assimilated to AusE /ɜː/. It seems that listeners were sensitive to the rounded /œ/ element of both diphthongs. Similarly, the Danish vowels /oʌ̯/ and /uʌ̯/, both of which involve lip rounding during the first vowel target, were categorized to the rounded AusE /oː/. Additional studies within a PAM framework are required to further explore the factors determining assimilation of non-native diphthongs to the L1 phonological system.

While the current study has demonstrated the way in which non-native diphthongs assimilate to listeners' L1 phonological system, little is known about the extent to which PAM's discrimination predictions are applicable to diphthongs, particularly since studies testing PAM's predictions have been conducted using non-native consonants and monophthongs. As PAM was developed to account for all types of speech segments, it is necessary to examine PAM discrimination predictions for diphthongs. The only study to assess PAM's discrimination predictions using diphthongs is that by [4]. Native Japanese speakers were assessed on their perception of the AusE vowels. In a discrimination task, the two contrasts tested involving diphthongs were /iː/-/ɪə/ which were assimilated as single category, and /əʉ/-/oː/ which were assimilated as uncategorized-categorized. Consistent with PAM predications, the single-category contrast was discriminated poorly and discrimination for the uncategorized-categorized contrast was fair. These contrasts were composed of a tense vowel and a diphthong. But, it is still not known how well listeners are able to discriminate *between* non-native diphthongs. On the basis of these results, future studies will be able to test PAM discrimination predictions for contrasts where both phones are diphthongs. Also, given that the current study has established the assimilation of the Danish vowels by AusE speakers, there is also the opportunity for testing PAM discrimination predictions for various assimilation types within the same stimulus language.

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L2 phonological category formation and discrimination in learners varying in L2 experience

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Abstract

Non-native phones that are perceived as speech-like, but do not closely resemble any single first-language (L1) category, are assimilated as uncategorised. The Perceptual Assimilation Model for Second-Language (L2) Speech Learning [1] predicts that such phones are likely to be acquired as L2 categories, which should result in improvements in discrimination. This study investigated the acquisition of uncategorised L2 phones and discrimination performance in L1 Egyptian-Arabic learners varying in L2 Australian-English experience. While no firm conclusions can yet be drawn about L2 category formation, age of acquisition and L2 vocabulary size predicted discrimination accuracy, but this was dependent upon assimilation type.

Index Terms: vowel perception, L2 immersion, individual variability

1. Introduction

Research on L2 speech perception has demonstrated that, unlike young children, adult learners experience difficulty in discriminating and acquiring certain L2 phones [2]. It is well known, for example, that the discrimination of L2 phones varies as a function of both L1 attunement and the specific contrasts tested. For instance, German and Spanish learners of English differ on their discrimination of the English vowels /ɛ/ and /æ/ [3]. The Spanish listeners were able to successfully discriminate between these two English vowels, which they perceived as two contrasting L1 vowel categories (Spanish /e/ and /a/, respectively). The German listeners, on the other hand, discriminated this English contrast poorly, which they may have perceived as instances of a single L1 vowel category (German /ɛ/ or /ɛː/). Similarly, Japanese learners experience varying degrees of perceptual difficulty in discriminating between certain Australian-English vowel contrasts [4]. Good discrimination was observed for the L2 contrast /iː/-/ɪ/, which they perceived as two separate L1 vowel categories, namely, /iː/ and /i/, respectively. The L2 contrast /iː/-/ɪə/ was discriminated poorly, however, since they perceived both phones within the contrast as the single L1 phoneme /iː/.

Several models on L2 speech perception have been developed to account for the variations in discrimination performance on L2 contrasts by L2 learners. One of the most prominent models of L2 speech acquisition is the Perceptual Assimilation Model for L2 Speech Learning [PAM-L2; 1]. PAM-L2 predicts the likelihood of establishing new L2 categories, which would result in changes in discrimination performance over L2 learning time. According to PAM-L2, L1 attunement shapes L2 speech acquisition in ways that imply a shared L1-L2 phonological system. PAM-L2 makes various predictions about L2 speech learning based on the way in which L2 phones are initially assimilated to the L1 phonological system. An L2 phone that is perceived as somewhat similar to an existing L1 phoneme will be assimilated as categorised and may vary in its goodness-of-fit to the native ideal. If, however, it is perceived as speech-like, but does not closely resemble any of the L1 categories, then it will be assimilated within the L1 phonological space as uncategorised. However, phones that are perceived as non-speech will not be assimilated within the phonological space. When considered as pairs of phones, various predictions about L2 learning are possible. Consider assimilation types where one or both phones are uncategorised, namely, Uncategorised-Categorised and Uncategorised-Uncategorised assimilations. According to PAM-L2, a new L2 category is likely to be formed for phones assimilated as uncategorised. This is predicted to result in improvements in discrimination over L2 learning time. It is the discrimination and acquisition of those contrasts that are of interest in the present study.

New L2 category formation is influenced not only by the different ways in which pairs of L2 phones assimilate to the L1 phonological system, but there are also a number of factors that have been shown to affect L2 speech acquisition. High discrimination accuracy is associated with a longer length of residence [LOR; 5], a younger age of acquisition [AOA; 6] and age of immersion in the L2 speaking environment [AOI; 7], use of the L2 is relatively more than the L1 [proportion L2 use; 2], a higher L2 vocabulary size [L2 VS; 4], and a longer period of L2 training prior to L2 immersion [EFL; 8]. Given the variability among L2 learners, the effect of these factors on L2 perception will be considered in the current study. While the PAM-L2 predictions are based on beginner learners who are immersed in the L2 speaking environment, its principles are also applicable to other learning situations.

This study is part of a larger project that aims to test the PAM-L2 predictions of new L2 phonological category acquisition and to track the changes in discrimination performance over L2 learning time in learners varying in L2 experience for contrasts assimilated as Uncategorised-Categorised and Uncategorised-Uncategorised. Here we present data from the first testing session of the longitudinal study to investigate how variations in L2 experience influence L2 category acquisition and discrimination, and to test PAM contrast assimilation predictions. The PAM-L2 predictions were examined in Egyptian-Arabic (EA) learners of Australian-English (AusE) who had been exposed to the L2 prior to immersion. Based on the perceptual assimilation results in [9], two Uncategorised-Categorised (/ʊ/-/ɔ/, /ɪ/-/e/) and seven Uncategorised-Uncategorised (/ɪə/-/iː/, /æɪ/-/ɑe/, /əʉ/-/ʉː/, /oː/-/ʉː/, /oː/-/əʉ/, /æ/-/ɐ/, /eː/-/ɜː/) AusE vowel contrasts were selected for the current study.

1. Method

1.1. Participants

Thirty-eight native adult EA speakers participated in the study (20 females, M_{age} = 41 years, age range: 17 – 73 years). They were recruited from the Greater Western Sydney community and through snowball sampling. Participants varied to some extent on each of the six factors (see Table 1). They indicated that they were native-born speakers of EA, with no hearing or language impairments, and normal or corrected-to-normal vision. None of the participants had had any extended stay in an English-speaking country prior to immersion in Australia. English instruction in Egypt was typically from non-native speakers of British or American English. They received monetary reimbursement for their participation.

Table 1. *Characteristics (means and ranges) of the learners on each of the six factors.*

Variable	Mean	Range	
		Min.	Max.
Length of residence	1.41 years	0.03 years	6.34 years
Age of acquisition	13 y/o	2 y/o	52 y/o
Age of immersion	40 y/o	16 y/o	71 y/o
Proportion of L2 use	0.37	0.06	0.61
L2 vocabulary size	9200 words	4600 words	14200 words
English as a foreign language	10.03 years	0 years	23 years

1.2. Stimulus and Apparatus

The stimuli were the same as those used in [9]. Briefly, the auditory stimuli were produced in a sound-attenuated booth at the Western Sydney University by two female speakers of AusE (34 and 44 years old) recruited from the Greater Western Sydney region. All AusE monophthongs /ɐ, e, ɪ, ɔ, ʊ, æ, ɐː, eː, iː, oː, ʉː, ɜː/, diphthongs /ɑe, æɔ, æɪ, əʉ, ɪə, oɪ/, and /ə/ [10] were produced in /ˈhVbə/ nonsense words. Selected tokens were those produced with a falling intonation and spoken with a consistent speaking rate across talkers. The tokens containing the vowels /æ, ɐ, ɪ, e, ʊ, ɔ, eː, ɜː, iː, oː, ʉː, æɪ, ɑe, ɪə, əʉ/ were selected for the current study.

The stimuli were recorded at a 44.1 kHz sampling rate using a Shure SM10A headset microphone connected to an Edirol UA-25EX external USB sound card. The recordings were high-pass filtered at 70 Hz to attenuate low-frequency noise and to correct for the DC component. Tokens were ramped such that the onset and offset of each token had a 10 ms fade-in and 20 ms fade-out, respectively. Four tokens per vowel category were selected from both speakers resulting in a total of 120 tokens (15 vowels x 4 repetitions x 2 speakers). Any audible clicks detected in the tokens were excised.

L2 vocabulary size was assessed using a bilingual version of the Nation and Beglar L2-English Vocabulary Size Test [11]. It is an assessment of decontextualised knowledge of written receptive vocabulary presented in a multiple-choice format. As the English version of the test requires grammatical knowledge and fair reading abilities, a bilingual version of the test was developed by the first author. The bilingual version of the test required participants to select one out of four translated definitions that best match the test word or phrase. They were given one of two equivalent versions of the test, each containing 100 multiple-choice questions. The readability of the test and the accuracy of the translations were checked by native EA speakers prior to the administration of the test.

1.3. Procedure

Participants first completed an AXB categorial discrimination task for each of the nine AusE vowel contrasts. Participants indicated whether the vowel in the middle token (X) belonged to the same phonemic category as the vowel in either the first (A) or last (B) token. To encourage phonological perception, all three tokens per trial were physically different, with tokens A and B produced by a different speaker than token X. The interstimulus interval was 1 s. Participants were asked to attend to the first vowel in the nonsense syllable and to select one of two keys on a computer keyboard. If a response was not collected within 2 s, the trial was repeated a random number of trials later. No feedback was provided. Participants were first familiarised with the procedure on three practice trials with feedback, and the tokens were produced by a different female AusE speaker than those from the experimental trials. For each AXB task, there were 64 trials, which were randomised for each participant. All four trial types (i.e., AAB, ABB, BAA, BBA) were presented an equal number of times per contrast. As there were three tokens per speaker, using a Latin-square design, each token was presented an equal number of times in each position (i.e., A, X, B). The order of presentation of each AXB contrast was pseudorandomised.

Participants then completed an L1 perceptual assimilation task with goodness-of-fit ratings. On a given trial, they were presented with a /ˈhVbə/ nonsense syllable over headphones and were instructed to attend to the target vowel. A grid was then presented containing all L1 core phonemic (/a, i, u, aː, iː, uː, eː, oː, aw, aj/) and allophonic ([æ, æː, ɑ, ɑː, ɛː, ɛ̃ː, e, o, ɪ, ɪː, ʊ, ʊː, ə]) vowel categories, and /ʔ/ presented in Arabic CVC or CV keywords, with the vowels highlighted in red. Using a computer mouse, participants selected an L1 keyword containing the vowel closest to the auditorily presented AusE vowel. After the token was presented again, they rated its goodness-of-fit to their chosen EA vowel using a scale from 1 (strange) to 7 (perfect). No feedback was provided. A keyword selection and rating response were required to be made within 6 s and 3.5 s, respectively, otherwise the entire trial was reinserted into the random sequence. There were 120 trials (15 vowels x 2 speakers x 4 repetitions), the intertrial interval was 500 ms, and the presentation order of the trials was randomised for each participant.

In addition to the L1 perceptual assimilation task, an L2 perceptual assimilation task was administered in order to allow for inferences to be made about new L2 phonological category formation. The procedure was similar to that of the L1 task except that participants categorised the L2 vowels to L2 AusE vowel category labels. All 18 AusE vowels were presented in CVC or CV English keywords, with the vowels highlighted in red. The order of presentation of the two perceptual assimilation tasks was counterbalanced. Stimulus presentation and response collection for the AXB task and both perceptual assimilation tasks were controlled using PsyScope X B57 on a MacBook laptop, Sennheiser HD 650 headphones, and an Edirol UA-25EX external USB sound card.
Participants were given the vocabulary size test, and a language background information questionnaire in order to

collect information on the participants' AOA, AOI, LOR, EFL, and proportion of L2 usage.

1. Results

1.1.1. New L2 phonological category formation

Inferences about new L2 phonological category formation were made based on the perceptual assimilation patterns from both L1 and L2 perceptual assimilation tasks. For a given L2 phone, if it was uncategorised in the L1 but categorised in the L2, then this was taken as indirect evidence that a new L2 phonological category had been formed. Phones were deemed categorised if an L1 category label was consistently selected more than 50% of the time, otherwise it was deemed uncategorised. No systematic differences were found in whether an AusE vowel was categorised to an L1 core phonemic versus allophonic category, so the allophonic vowel categories were collapsed into the appropriate main phonemic categories [see 9]. The only two AusE vowels that were categorised to an L1 category were /æ/ and /ɐ/, which were categorised to the EA /aː/ 53% and 54% of the time, respectively, while none of the AusE vowels were categorised to an L2 vowel category label.

The individual perceptual assimilation patterns revealed a high degree of variability in terms of whether a given L2 phone was categorised or uncategorised, both in the L1 and L2 tasks. Given the high degree of interindividual variability, for each individual participant instances were identified where an L2 AusE vowel was uncategorised in the L1, but categorised in the L2. A binomial logistic regression was conducted with each of the six variables (i.e., AOA, AOI, LOR, L2 VS, proportion of L2 usage, and EFL) to determine whether any of those factors are related to the likelihood of forming a new L2 phonological category. An L2 phone was uncategorised in the L1 but categorised in the L2 in 21% of instances. The logistic regression was not statistically significant, $\chi^2(6) = 3.339$, $p > .05$, suggesting that none of the six factors reliably predicted the likelihood of new L2 phonological category acquisition for this first testing session of the longitudinal project.

1.1.2. Assessing PAM's predictions of discrimination

PAM assimilation types were determined in the same way as in [12]. When the L2 phones were considered as contrasts, there was a high degree of interindividual variability in the PAM assimilation patterns. For example, while the contrast /oː/-/əʉ/ was assimilated as Uncategorised-Uncategorised in the L1 perceptual assimilation task at the group level, individual participants assimilated it either as Uncategorised-Uncategorised or Uncategorised-Categorised. Given this high degree of variability, to analyse the discrimination results, we adopted the same approach as in [12]. Specifically, each individual's assimilation type for each of the nine contrasts was determined. The mean discrimination accuracy scores were then grouped according to individual assimilation type rather than on vowel contrast. For example, the discrimination accuracy scores for Uncategorised-Uncategorised assimilations were grouped together, regardless of the contrast in which they occurred. Individual assimilation patterns were determined per individual for both the L1 and L2 tasks.

Individual assimilation types were compared across the L1 and L2. There were cases where a contrast was assimilated as a Single-Category in the L1, but as a Two-Category contrast in the L2, suggesting that the participant was able to discern phonological differences between the pair of contrasting L2 phones, *and* that they had learned the new L2 contrast. Therefore, it may be more meaningful to consider both L1 and L2 perceptual assimilation patterns than either one alone. Taking into account both L1 and L2 assimilation types, we created a composite L1-L2 assimilation type by selecting the L1 or L2 assimilation type that was predicted to result in the more accurate discrimination across the two. For instance, for an individual participant, if a given contrast was assimilated as Uncategorised-Uncategorised in the L1, but as a Two-Category in the L2, then the L2 perceptual assimilation type was selected. Similarly, if a contrast was Uncategorised-Categorised in the L1, but Single-Category in the L2, then the L1 perceptual assimilation type was selected. Eight percent of cases were Single-Category assimilations, another 8% were Two-Category, 40% were Uncategorised-Categorised, and 42% were Uncategorised-Uncategorised. Since only 1% of cases were of Category-Goodness assimilations (comprised of two data points), they were excluded from further analyses.

A one-way between-subjects analysis of variance was conducted to determine if the discrimination accuracy scores vary as a function of assimilation type. There was a significant difference in the discrimination accuracy scores among the assimilation types, $F(3, 336) = 5.446$, $p = .001$. A Bonferroni post-hoc comparison revealed Two-Category assimilations were discriminated more accurately than Single-Category, $M_{\text{diff}} = 15.92\%$, $p = .001$, $SE = 4.27\%$. Uncategorised-Categorised assimilations were discriminated more accurately than Single-Category assimilations, $M_{\text{diff}} = 10.68\%$, $p = .009$, $SE = 3.34\%$. The results are displayed in Figure 1.

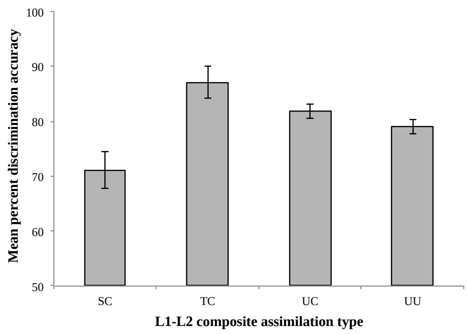

Figure 1: *Mean percent discrimination accuracy for the composite L1-L2 assimilations. Error bars represent standard error of the mean*

1.1.3. Effect of the six factors on discrimination accuracy

The relationship between the six predictors on discrimination accuracy was assessed using the composite L1-L2 assimilation types. Bivariate Pearson correlations were conducted between the mean percent discrimination accuracy score for a given assimilation type with each of the six factors. The correlations are presented in Table 2, with significant bivariate Pearson correlation coefficients presented in bold, which ranged from .202 to -.490. A younger age of acquisition was associated with more accurate discrimination for all assimilation types, except for Single-Category. Uncategorised-Categorised and Uncategorised-Uncategorised contrast assimilations each yielded a larger number of significant correlations than Single-Category and Two-Category assimilations combined.

To determine whether any of the factors predicted discrimination performance, a separate standard multiple regression was conducted for each composite L1-L2 assimilation type. A high L2 vocabulary size predicted poorer discrimination accuracy for Single-Category assimilations (i.e., a negative correlation), $F(6, 21) = 4.114$, $p = .007$, and accounted for approximately 47% of the variance ($R^2 = .540$, adjusted $R^2 = .409$). A younger age of acquisition was a significant predictor of better discrimination accuracy for Uncategorised-Categorised assimilations, $F(6, 131) = 10.90$, $p < .001$, and accounted for approximately 32% of the variance ($R^2 = .333$, adjusted $R^2 = .303$). Similarly, a younger age of acquisition significantly predicted higher discrimination accuracy scores for Uncategorised-Uncategorised assimilations, $F(6, 138) = 2.560$, $p = .022$, and accounted for approximately 8% of the variance ($R^2 = .100$, adjusted $R^2 = .061$). None of the factors significantly predicted discrimination accuracy for Two-Category assimilations.

Table 2. *Bivariate Pearson correlations between the mean percent discrimination accuracy scores for each composite L1-L2 assimilation type with each of the six factors.*

Composite L1-L2	Mean discrimination accuracy	LOR	AOI	AOA	EFL	Prop. L2 use	L2 VS
SC	71	-.122	**-.407***	.001	.221	-.077	**-.476***
TC	87	-.296	-.142	**-.490****	.164	.352	.231
UC	82	**-.376****	-.146	**-.480****	**.445****	**.202***	**.364****
UU	79	**-.205***	-.123	**-.266****	**.248****	.036	.116

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

1. Discussion

This study aimed to examine new L2 category formation and discrimination accuracy in learners varying in L2 experience. Vowel perception was shown to be highly variable [e.g., 12]. Despite this variability, PAM's predictions of discrimination were upheld such that both Two-Category and Uncategorised-Categorised assimilations were discriminated more accurately than Single-Category assimilations.

By accounting for variability within individual participants who differed on factors related to L2 experience, we have shown that, to some extent, differences in L2 discrimination accuracy may be explained by such factors. A high L2 vocabulary size predicted poor discrimination accuracy. According to PAM-L2, a steadily expanding L2 vocabulary size is beneficial for L2 learners as it forces them to attend to important phonetic details in the L2 that are not employed in the L1, and in turn, help learners distinguish between minimally contrasting L2 words. But, a rapidly expanding L2 vocabulary may be detrimental for L2 learners as it may cause them to fossilise, or settle on a suboptimal common L1-L2 phonological category, thus curtailing further L2 development. At this initial stage of testing, the learners' L2 vocabulary size was high, averaging 9200 words. The current study did not assess the rate of L2 vocabulary acquisition. However, the acquisition of English vocabulary and grammar are normally the key focuses of L2 acquisition in schools and universities in Cairo. It may be tentatively inferred that the L2 vocabulary was acquired rapidly prior to L2 immersion. As this study forms part of a larger longitudinal study, there will be an opportunity to track how changes in L2 vocabulary size affect discrimination accuracy over L2 learning time. Vocabulary size for an average native English speaker is roughly 20,000 words [13], so there remains room for vocabulary expansion.

While discrimination accuracy was affected to some extent by some of the factors, none of the factors reliably predicted discrimination accuracy for Two-Category assimilations. It is unsurprising given that it is L1 attunement that helps the listener distinguish between phones assimilated as Two-Category, which is consistent with PAM's framework.

Individual differences may also play a role in new L2 phonological category formation. The results revealed that none of the factors significantly predicted the likelihood of new L2 phonological category formation. However, as only 21% of cases were of an L2 phone that was uncategorised in the L1 but categorised in the L2, there may not be sufficient statistical power to detect those influences. Consequently, no firm conclusions may be made at this stage of the longitudinal study. The effect of the six factors on category formation will be examined longitudinally as a function of changes in L2 immersion experience. This should in turn be reflected in changes in discrimination performance over L2 learning time.

The next stage of this project will be to examine the developmental changes over a 12-month period of L2 immersion by tracking changes in discrimination performance as a function of perceptual assimilation, and how discrimination performance is affected by the six factors.

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Conference abstract AMLaP (2015)

FACTORS AFFECTING SECOND LANGUAGE VOWEL DISCRIMINATION IN LEARNERS IN AN IMMERSION SETTING

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BACKGROUND L2 speech perception and acquisition in adults has been shown to be affected by length of residence (LOR) in the L2 speaking environment, age of immersion (AOI), age of acquisition (AOA), length of time the L2 had been studied before L2 immersion (EFL), amount of L1/L2 usage, and L2 vocabulary size (VS). However, previous studies have primarily examined a subset of those factors in isolation. This study investigated the influence of each of these factors on the discrimination of L2 Australian English (AusE) vowel contrasts by L1 Egyptian Arabic (EA) learners who vary on each of these measures. It forms the first part of a larger longitudinal project investigating changes in L2 speech perception in an L2 immersion setting. Vowel contrasts were selected based on a study by Faris, Best, and Tyler (submitted), in which EA speakers residing in Egypt perceptually categorised and rated all AusE vowels in relation to their full vowel inventory. To test category formation and discrimination predictions of the Perceptual Assimilation Model of Second Language Speech Learning (Best & Tyler, 2007), we selected two uncategorized-categorized (UC: /ʊ-ɔ/, /ɪ-e/) and seven uncategorized-uncategorized contrasts (UU: /ɪə-iː/, /æɪ-ɑe/, /əʉ-ʉː/, /oː-ʉː/, /oː-əʉ/, /æ-ɐ/, /eː-ɜː/). Over the course of L2 learning, discrimination accuracy is predicted to decline for the last three contrasts as they may form single category assimilation but is likely to become excellent for the other six contrasts.

METHOD 37 EA learners of AusE (20 females) were recruited from Sydney. The AusE vowels were presented in /ˈhVbə/ syllables. To test L2 VS, an Arabic version of the Nation and Beglar (2007) L2-English Vocabulary Size Test was used. Participants completed a discrimination task for each of the nine contrasts. On a given trial, they indicated whether the vowel in the second auditory token was the same category as the vowel in the first or the last auditory token. Participants then completed the VS test followed by a background information questionnaire that measured the other L2 factors: LOR, AOI, AOA, L1/L2 use, EFL.

RESULTS A One-way ANOVA revealed significant differences in discrimination accuracy scores across the nine contrasts, $F(8, 324) = 22.95$, $p < .001$. Tukey HSD post hoc comparisons showed poorer accuracy for /æ-ɐ/ and /eː-ɜː/ than for the other seven contrasts. Bivariate correlations compared discrimination accuracy for the seven factors (Table 1).

Table 1. Average discrimination accuracy scores and the bivariate correlations

Contrast	Av. disc. accuracy (%)	L2 VS	L1 use	L2 use	AOA	AOI	LOR	EFL
/æ, ɐ/	62	.015	.189	.105	-.370*	-.328*	-.301	.307
/eː, ɜː/	61	.047	.110	.245	-.228	-.258	-.268	.279
/æɪ, ɑe/	89	.271	-.195	.307	-.729**	-.305	-.253	.599**
/ɪə, iː/	82	.480**	-.051	.149	-.404*	-.110	-.307	.504**
/ɪ, e/	83	.371*	-.037	.311	-.534**	-.402*	-.485**	.635**
/ʊ, ɔ/	82	.392*	-.023	.151	-.570**	-.323	-.392*	.585**
/əʉ, ʉː/	85	.236	.042	.108	-.515**	-.235	-.347*	.486**
/oː, ʉː/	89	.232	-.312	.121	-.608**	-.207	-.308	.515**
/oː, əʉ/	84	-.042	-.128	-.132	-.455**	.051	-.295	.275

** Correlation is significant at the .01 level; * Correlation is significant at the .05 level (2-tailed).

DISCUSSION Discrimination accuracy is consistent with PAM UC and UU predictions. As in previous research, AOA was the most consistent predictor of discrimination accuracy for all but one contrast, suggesting that the younger the AOA, the better the discrimination accuracy. For all but three contrasts, a longer EFL was associated with better discrimination accuracy. Interestingly, it was those three contrasts that we predicted would show a decline in discrimination performance over the course of L2 learning, while discrimination accuracy for the six other contrasts would improve. Future analyses will determine the relative influences of each factor, and test whether the pattern of influence is stable over variations in immersion.

Conference abstract New Sounds (2016)

Perceptual assimilation and discrimination of L2 Australian-English vowels by Egyptian-Arabic learners varying in L2 experience

This study investigated the perceptual assimilation and discrimination of second-language (L2) Australian-English (AusE) vowels by Egyptian-Arabic (EA) learners in an immersion setting. Thirty-eight EA learners of AusE were tested on their perceptual assimilation and discrimination of nine AusE vowel contrasts (/ʊ-ɔ/, /ɪ-e/, /ɪə-iː/, /æɪ-ɑe/, /əʉ-ʉː/, /oː-ʉː/, /oː-əʉ/, /æ-ɐ/, /eː-ɜː/). An AXB discrimination task was completed for each of the contrasts, where participants indicated whether the second of three tokens belonged to the same category as the first or last token. Participants also categorised and rated the goodness-of-fit of the AusE vowels to their L1 vowel categories, and then they attempted the task again using L2 AusE vowel categories to allow inferences to be made about L2 category formation. Participants differed substantially on factors known to affect L2 category formation (e.g., age of acquisition, length of residence), so assimilation types were determined separately for each individual. In line with the Perceptual Assimilation Model (Best, 1995), discrimination accuracy was higher, on average, for contrasts assimilated as two-category or uncategorized-categorized assimilations, as compared to single-category assimilations. Based on the individual assimilations, there were instances where contrasting phones were single-category assimilations when using L1 category labels but uncategorized-categorized or two-category assimilations when using L2 labels. In those cases, discrimination accuracy was correspondingly high, suggesting that the learners had established a new L2 category for one or both vowels in the contrast. There were also many instances where individuals assimilated the contrasts as uncategorized-categorized or uncategorized-uncategorized in both languages. Using those contrasts as a baseline, future research will track L2 category formation longitudinally over a 12-month period.