L2 visual word processing in L1 Arabic L2 English learners : beyond vowel blindness

L2 VISUAL WORD PROCESSING IN L1 ARABIC L2 ENGLISH LEARNERS - BEYOND VOWEL BLINDNESS

Emina Tuzović

Birkbeck College, University of London

Declaration

Declaration I hereby declare that, except where explicit attribution is made, this thesis represents my own work and has not been previously submitted to this or any other institution for any degree, diploma or other qualification.

Signature: …………………………………………..

Acknowledgements

First of all, I would like to thank my supervisor Marjorie for her invaluable advice, for her patience and understanding, especially when things were tough. I would also like to thank Jean-Marc for his words of encouragement and his guidance, and a big thanks to Iti and Sally for assisting me with the statistics. Last but not least, many thanks to my lovely students who kindly took their time to take part in this study.

On a personal level, a big thank you to my friends and family who have offered me unwavering support over this decade. I could not have done it without you. Thank you Antony, my rock, and thank you A*ngels* (my girls) for all your wise and kind words, which kept me going. Hvala ti Atvija na tvojoj podršci.

Finally, I would like to dedicate this thesis to my dad who had always encouraged me to do it! Hvala tata, ovo je za tebe! I would also like to dedicate this thesis to my best friend Alenka, who has been by my side and cheering me on all the way. Tole je zate, da vse zmoremo draga!

Abstract

L1 Arabic L2 English learners tend to underperform in L2 word recognition in English compared to other L2 learners. Prior studies have explained this by the vowel blindness phenomenon, which stems from L1 Arabic word processing techniques (focusing on consonant skeletons; non-linear processing), which are inadequate when processing L2 English (linear processing). This study investigated whether vowel blindness can account for specific reading difficulties found in these L2 learners by assessing their performance in L2 word recognition. Two experimental tasks were conducted on a group of intermediate L1 Arabic L2 English learners. The study also aimed to explore whether other factors, such as word length and letter position have an effect on the choice of the processing route employed. Both of these factors (word length and letter position) were found to have an impact on how these L2 learners process words in L2 English. While shorter words mainly elicited the use of the orthographic route, longer words attracted the use of the phonological route.

Overall, the findings in this study indicate that vowel blindness is still present in the L2 word processing in intermediate L1 Arabic L2 English learners, however, it is only a partial explanation for their L2 word recognition difficulties. Instead, the results suggest difficulties in processing syllables in L2 English, rather than in processing vowel letters in isolation. Secondly, at the intermediate L2 proficiency level, there is evidence that L1 Arabic L2 English learners are starting to process L2 words sequentially, i.e., implementing linear processing. This raises question marks over the role of vowel blindness and non-linear processing, especially in intermediate and higher L2 proficiency learners. In order to acquire a better understanding of how L1 Arabic L2 English learners read in L2 English, future research needs to go beyond this processing phenomenon. This has an impact on the design and future iterations of L2 word recognition models in this L2 learner group, based on various factors, such as word length, letter position and the choice of the processing route employed.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

This chapter will provide the general theoretical background related to the areas of L1 and L2 word processing and outline some of the main factors in L1 and L2 word recognition. This will be followed by introducing the key concept of vowel blindness and presenting the current research on L2 word processing with its limitations and identified gaps which informed the rationale for this study. Finally, select areas connected to the phenomenon of vowel blindness and pertinent to this study will be presented prior to providing the overview of this study.

1.1 Introduction to the Study

This study investigated visual word processing in L2 English, focusing on the performance of adult participants whose first language is Arabic (L1) learning English as a second language (L2). The level of L2 English proficiency of the tested participants in this study was [1]broadly intermediate. L2 learners are typically competent readers in their L1, but show evidence of L1 reading transfer on L2 reading that has been widely-researched (e.g., Koda, 1990). L1 Arabic L2 English learners are known to frequently exhibit specific reading difficulties when processing and recognising words in L2 English (e.g., Al-Sulaimani, 1990).

Word recognition is a vast and well-researched area in L1 English (e.g., Castles, Rastle, & Nation, 2018). In contrast, L2 English word recognition has only started receiving attention in the last two decades (e.g., Jiang & Wu, 2022; for an overview, see Koda 2016), particularly evident in the bilingual context (e.g., Mor & Prior, 2019). This study aimed to contribute to the research field of L2 word recognition by investigating specific L2 word processing difficulties found in non-proficient L1 Arabic L2 English learners.

[1] To assess the participants' proficiency level in English, IELTS (International English Language Testing System) exam scores ranging from 3.0 (lower-intermediate) to 6.0 (higher-intermediate) was used. According to the Common European Framework of Reference for Languages (CEFR), IELTS score 3.0 corresponds to A2, 5.0 to B1 and 6.0 to B2. Elementary and advanced L2 English learners did not participate in this study. For more detail on L2 proficiency scales, see *Appendix* A.

Special emphasis was placed on difficulties processing vowels typically found in these L2 learners. The aim of this study was to test the phenomenon referred to in literature as *vowel blindness*, which will be discussed in more detail below. The study also explored whether other factors connected to vowel blindness, such as word length, letter position and the processing route, contribute to how intermediate L1 Arabic L2 English learners process and recognise words in L2 English. This will further our understanding of the L2 reading difficulties typically found in these L2 learners and help provide adequate solutions for these.

1.2 Theoretical Framework and Determining Scope

[2]Reading - as part of a broader research area of literacy - is a complex cognitive and linguistic skill that requires careful coordination between a number of reading components in order to access text meaning and enable comprehension (Yamashita, 2013). Reading-related components tend to be divided into two main processing levels. Higher level processes, i.e., top-down reading at text level, include various cognitive and metacognitive processes, e.g., the use of semantic and syntactic context to obtain comprehension, discourse, inference, activating background knowledge, etc. Conversely, lower-level processes, i.e., bottom-up reading, operate at word and sub-word level. These include word decoding (parsing words into smaller elements, such as syllables), processing ortho-tactic patterns (frequent letter sequences), phonological recoding (applying grapheme-to-phoneme rules to pronounce unknown words), encoding and retaining information in working memory (Brown & Haynes, 1985; Nassaji, 2003).

Reading research in L2 English still tends to focus on higher levels of processing despite a vast body of research now suggesting that lower-level processing is crucial to

[2]Reading is a vast interdisciplinary area which is of interest to many research angles. The literature consulted for this study mainly derives from the area of psycholinguistics, especially regarding reading in L1 English (see 2.1). Conversely, English as a Second Language (ESL) terminology was borrowed to refer to certain aspects of reading in L2 English, e.g., to determine the L2 proficiency level of the participants (IELTS scores; CEFR framework), and to outline the L2 practical outcomes of this study which have predominantly been borne out of theoretical research.

become a fluent reader (e.g., Koda, 2016). This was the principal motivation to adopt the latter approach, i.e., investigating word-level reading in L1 Arabic L2 English learners in this study.

This behavioural study investigated *visual* word processing which encompasses the mechanisms enabling the analysis of predominantly orthographic features (Rastle, 2016). An exhaustive body of research on visual word processing has been conducted on L1 English and is based on complex computational reading models (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Seidenberg & McClelland, 1989). In traditional Dual-Route Reading Models, words are represented as being processed through two main processing routes. The *orthographic route* entails whole-word processing, which is crucial for recognising [3]sight words in English. Conversely, the *phonological route* is employed to process words segmentally, especially unfamiliar words (e.g., Forster & Chambers, 1973). In Dual-Route Reading Models, this is done via a succession of activities (phonology-orthography-semantics). Alternatively, Connectionist Reading Models posit that words are processed via a network of simultaneous activities (phonology-orthography-semantics), i.e., though parallel processing (Seidenberg & McClelland, 1989). Apart from whole-word processing, words can also be recognised through smaller constitutional elements within a word as part of sublexical processing, by processing vowel and consonant graphemes/phonemes, grapheme/phoneme sequences, syllables, etc. This study used the principles of word recognition proposed by the reading models outlined above to inform the interpretation of the findings from the current study on L2 English learners.

In the literature, *word processing* is frequently used interchangeably with the term *word recognition*. In this study, word recognition refers to a specific stage within word processing, which denotes the moment a printed letter sequence is identified as a unique word. A word is accessed and successfully retrieved from the [4]mental lexicon, which occurs prior to lexical access. It is also noteworthy that processing word *form* was of primary interest in this study while word meaning was considered beyond its scope.

[3] These are high-frequency regular words (e.g., *and, go*) as well as irregular words (e.g., *talk, does*).

[4] Part of our language system, i.e., a mental dictionary where word forms are stored (Aitchison, 2012).

1.2.1 The Effect of Various Factors on L1 and L2 Word Recognition

Within the realms of L1 and L2 word processing and word recognition, various areas require consideration to gain an in-depth understanding of their complex workings. In order for a word to be processed successfully and thus acquire fluent reading at word level**,** the principal metalinguistic sublexical processing skills, i.e., [5]orthographic and phonological processing skills are of the essence (Koda, 2016). Other factors include various word properties (e.g., word frequency and familiarity), as well as other external factors, such as exposure to print and orthographic knowledge. These factors will be discussed in more detail below.

Orthographic processing refers to the knowledge of frequent letter sequences (e.g., <str> in word initial positions in English, in words such as *strike*, *strain*, etc.) and the knowledge of orthotactic constraints (e.g., a letter sequence <str> cannot feature in the word-final position in English). Orthographic structure also extends towards the knowledge of ortho-phonological mappings (e.g., mapping graphemes onto phonemes and dividing words into [6]ortho-syllables). For instance, in the word *cat*, the grapheme <c> corresponds to the phoneme /k/, <a> to /æ/, and <t> to /t/, and this word consists of 1 syllable. Phonological processing is defined as the ability to access, store and manipulate various sublexical units, such as phonemes and syllables (Ziegler & Goswami, 2005). Compared to orthographic processing, phonological processing has been more widely researched and is considered a crucial metalinguistic processing skill to become a fluent reader in L1 English (Wagner & Torgesen, 1978).

In contrast to orthographic *processing*, [7]orthographic *knowledge* refers to the knowledge of the whole-word forms. These are mental representations of lexical items which can be readily accessed and retrieved from the mental lexicon (e.g., Deacon,

[5] Grainger and Ziegler (2011) combined the Dual Route and Connectionist Reading Models; these were employed as a framework to discuss orthographic/phonological processing. Orthographic/phonological processing refer to the sublexical processing of grapheme and phoneme sequences, and are typically tested with pseudowords (e.g., *tiece*) and nonwords (e.g., **stroughve).*

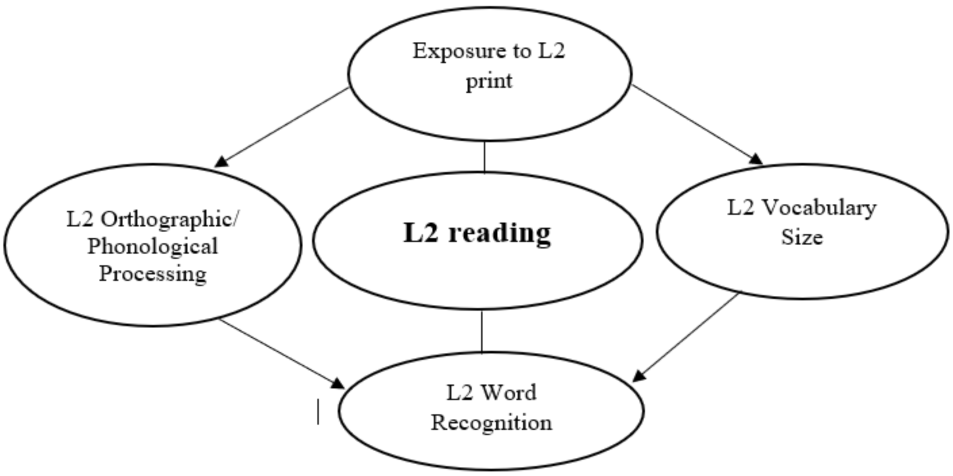
[6] Syllables are typically considered phonological units. In this study syllables were referred as an orthographic category as well. For ortho-syllables, see Perry (2013) and Taft (1979).

[7] See Nassaji (2003) for the difference between orthographic *processing* and orthographic *knowledge*.

Pasquarella, Marinus, Tims, & Castles, 2019). As a result of more exposure to print, the readers' lexical representations in their mental lexicons increase, which ultimately leads to faster word recognition.

Compared to L1 word recognition, L2 word recognition also depends on additional factors, such as L1-L2 orthographic distance, L1-L2 orthographic regularity and consistency, L2 proficiency, etc. (Allmark, 2022; Koda, 2016). However, in the same way as with L1, where exposure to print expands the orthographic knowledge, the exposure to L2 print also contributes to a larger L2 vocabulary size. As there is a higher likelihood of the recurring orthographic letter combinations being detected, the speed/automaticity and accuracy of orthographic as well as phonological processing in L2 improve (Stæhr, 2008). This, in turn, increases the likelihood of successful L2 word recognition (Figure 1) and ultimately leads to efficient L2 reading skills.

Figure 1: Effect of Various Factors on L2 Reading



Turning to word properties, these play an important role in word recognition, as mentioned earlier. Another word property closely related to word frequency and familiarity is *word length* which has not been as widely researched, and the findings in this area of research are rather fragmented (Bunton, 2014). Overall, performance in lower-frequency words is typically poorer than higher-frequency words. Furthermore, skilled readers tend to have extensive exposure to print which means they process high-frequency words successfully regardless of their length (Mason, 1978). Conversely, word length effects were found in higher-frequency words in young L1 readers and in *unskilled* L1 adult readers, specifically regarding response times (Bunton, 2014; Nazir, 1999).

With regard to adult readers in L2 English, these typically have lower exposure to L2 print compared to adult L1 readers, therefore L2 word length effects tend to be more pronounced. Words containing more letters/syllables can add to the processing load and might require longer processing times in L2 learners (Kramer & McLean, 2019).

1.3 Vowel Blindness in L1 Arabic L2 English Learners

In the L2 English classroom, L1 Arabic L2 English learners demonstrate specific reading and spelling difficulties which indicates differentiating L2 word processing compared to other L2 learner groups. This could be due to a number of factors which will be outlined below.

Arabic has a consonant-led writing system, which is a key factor in how L1 Arabic L2 English learners access words in L2 English. Arabic also employs a non-Roman script and a right-to-left reading direction, which also play a significant role in L2 processing in L1 Arabic L2 English learners. Reading in English, which uses the Roman alphabet, involves letter-by-letter (linear) processing as each letter is explicitly stated. Conversely, reading in Arabic involves non-linear word processing as only consonant letters and long vowels are explicitly represented while short vowels are indicated by diacritics (see non-vowelised form in Figure 2; also see the difference between of linear and non-linear processing illustrated in Figure 3).

Figure 2: Arabic Word *darb* ('path') in a Non-Vowelised and a [8]Vowelised Form

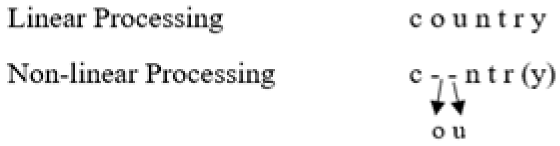
درب	Non-vowelised form
دَربْ	Vowelised form (diacritics below and above the letters)

Non-linear processing refers to extrapolating a consonant root to access a word from the mental lexicon. This L1 processing technique transfer can explain unusual reading and spelling errors in L2 English, such as confusing a target word *century* for *country* (Al-Sulaimani, 1990). In this example, the consonant skeleton *c-n-t-r (y)* is preserved while the vowels are assigned incorrectly. Investigating this phenomenon further, the commonly observed word confusion can be either based on the orthographic similarity between words (*subtle-subtitle*) or phonological similarity (*basket-biscuit*) (Al-Sulaimani 1990). As expected, this error also frequently occurs with short, monosyllabic words containing matching consonants and vowel modifications (e.g., *but, bit, bat, bought, beat*).

Due to the Arabic consonantal writing system, these L2 learners tend to overfocus on the consonants while vowels are processed superficially. This widely observed phenomenon is referred to in the literature as *vowel blindness,* and will be the focal point of this study. This phenomenon indicates that the whole-word, orthographic route normally employed in accessing sight words in English is not employed fully. Instead, words are accessed by extrapolating consonants which resembles how words are processed in Arabic (non-linear processing). Vowel blindness is an L2 processing phenomenon typically found in lower-L2-proficiency L1 Arabic L2 English learners, and it is expected to become less pertinent with L2 proficiency and more exposure to L2 print.

[8] Vowelised forms are predominantly used in texts for pedagogical purposes (for children leaning to read) and for religious purposes (reading Quran). The texts adult readers would normally access are non-vowelised.

Figure 3: Differences in Linear and Non-linear Processing



Vowel blindness has received a considerable amount of attention in the last 30 years and the literature on L2 visual word processing in L1 Arabic L2 English learners has primarily relied on this phenomenon to explain specific reading difficulties found in this L2 learner group (e.g., Alhazmi, Milton, & Johnston, 2019; Alsadoon & Heift, 2015; Bowen, 2011; Ryan & Meara, 1991). However, more recent studies warn that this processing phenomenon has not been systematically researched and there are concerns over its validity. To illustrate, the existing studies on vowel blindness demonstrate numerous methodological limitations and exhibit mixed findings ([9]Allmark, 2022). These points will be further addressed below.

One of the first and most influential studies investigating this phenomenon was Ryan and Meara (1991) who administered an identity judgment task to 2 intermediate L2 English learner groups (L1 Arabic and L1 Non-Arabic). A pair of stimuli were presented in quick succession and required [10]same/different judgement. The non-identical stimuli contained deleted vowels in different positions. The results revealed double the error rate in the L1 Arabic group compared to the L1 Non-Arabic group, demonstrating noticeable L2 word processing difficulties in L1 Arabic L2 English learners compared to other L2 learners. The authors concluded that these difficulties stem from inadequate L1 word processing transfer, where consonants are prioritised over vowels.

Based on this seminal article, studies subsequently investigating L2 word recognition in L1 Arabic L2 English learners mainly focused on testing vowels as the main source of their processing difficulties, and assumed superior processing of consonants over

[9] See this study for a critical review of the literature on vowel blindness.
[10] same: *possession-possession*; different: *autograph-*autogrph*

vowels in these L2 learners without comparing both letter types (Alsadoon & Heift, 2015; Martin, 2011; Saigh & Schmitt, 2012). Therefore, it is not clear whether the processing difficulties occurred due to the vowel or *letter* (consonant/vowel) processing. If the latter is the case, the L2 word processing difficulties might not entirely stem from superficial vowel processing but might be due to letter position effects. This has not been explored a great deal in the L2 word recognition literature, and will further be discussed below (1.3.1).

A small number of studies addressed this methodological issue by employing consonants alongside vowels to test this phenomenon in L1 Arabic L2 English learners. By employing identical target stimuli and task design as Ryan and Meara (1991), Ryan (1997) reported superior performance in consonant deletions over vowel deletions compared to other L2 groups. These results exhibited vowel blindness in their intermediate L1 Arabic L2 learners, which was expected. However, Hayes-Harb (2006) employed the same task design as the studies beforehand but did not find superior performance in consonant deletions compared to vowel deletions in their L1 Arabic L2 English participants. The author raised a number of methodological limitations to explain these results (sample size, task design, stimuli length), but also added that other factors apart from vowel blindness might contribute to the L2 word processing difficulties in intermediate L1 Arabic L2 English learners. This was echoed by a more recent eye-tracking study by Alhazmi et al., (2019), who tested pre-advanced/advanced L1 Arabic L2 English learners (IELTS:6.0-8.0;CEFR:B2/C1) and also found no significant difference in the processing consonants over vowels in these L2 learners.

The unexpected results failing to demonstrate vowel blindness in intermediate and higher L2-proficiency L1 Arabic L2 English learners presented above might have occurred due to small sample sizes (fewer than 20 participants), and shorter words employed, which were found to facilitate same-different judgement (Grainger, 2008). The results might also have occurred due to non-homogenous L2 groups, i.e., participants coming from a variety of L1 backgrounds, which might have confounded the data. Furthermore, lack of methodological detail in these studies created difficulties in analysing the results and also means opportunities for replications were limited.

The studies presented above employed the identity judgment task as well as eye tracking to test vowel blindness. Ryan (1993), on the other hand, focused on testing *word confusion* as part of the test battery investigating vowel blindness. The author employed phonologically-matched words in a multiple-choice task (e.g., *last, lest, least, lost*). Alongside these stimuli, semantically-related words were included (e.g., *make, brand, mark, use*). A sentence was read and the learners were asked to select the word they heard. The results revealed an equal error rate between the two stimuli types. As the sentences were read out, the errors with semantic distractors should not have occurred, meaning the task was methodologically flawed. Instead of semantic distractors, it was of interest to employ orthographic distractors (e.g., *subtle-subtitle*) as these were expected to provide evidence whether the erroneous processing occurred due to phonological or orthographic factors.

More fine-grained research into vowel blindness in L1 Arabic L2 English learners has been under way in the last decade, predominantly building on the vowel blindness approach and focusing on particular vowel qualities and their effects (e.g., vowel length and vowel position; see Bowen, 2011; Martin, 2011; Saigh & Schmitt, 2012). A growing number of studies explored consonants in their investigations as well (Stein, 2010). In this vein, the consonant/vowel letter transposition (*mobile -*mboile*) was found to be one of the most frequent spelling errors in L1 Arabic L2 English learners (Abu-Rabia & Sammour, 2013; Bowen, 2011), indicating difficulties processing syllables. To my knowledge, no other studies investigated these findings further. It was of interest to see whether these specific errors only manifested themselves in recall or whether they stemmed from inaccurate processing to begin with.

To rectify the methodological shortcomings outlined above, the present study employed a larger and a more homogenous intermediate L1 Arabic L2 English group (N=26). This study aimed to test the pertinence of vowel blindness in *intermediate* L1 Arabic L2 English learners, by testing vowels as well as consonants, and investigate whether this phenomenon can account for the specific reading errors found in these L2 learners. Furthermore, this study aimed to exploit some of the gaps within the literature on L2 word recognition (e.g., letter position, the use of the processing routes and syllable effects), which were believed to be significant in how these L2 learners process words in English. For the word length effects and the preferential processing route in L1 Arabic L2 English learners, see below.

1.3.1 The Impact of Word Length and the Processing Routes on L2 Word Processing in L1 Arabic L2 English Learners with Reference to Vowel Blindness

Due to the findings presented above, vowel blindness might not be the sole or even a predominant factor in the L2 processing difficulties found in intermediate L1 Arabic L2 English learners. As the L2 processing difficulties still persist at this L2 proficiency level, this study aimed to go beyond vowel blindness and explore other avenues within this phenomenon.

Starting with word length, there is little evidence from research concerning the impact of this word property on L2 word processing in L1 Arabic L2 English learners (1.2.1).

Fender (2008) tested vowel blindness in recall in high-intermediate L1 Arabic L2 learners (IELTS:5.5/6.0;CEFR:B1+/B2) and reported lower error rate in spelling *shorter*, monosyllabic words (featuring short and long vowels), compared to longer, multisyllabic words. These findings were expected as longer words contain more letters, and therefore they tend to be more challenging to recall than shorter words (Baddeley, Thomson & Buchanan, 1975; Neath & Nairne, 1995). However, it is not clear whether longer words would yield higher error rate and demonstrate stronger vowel blindness effects also in the processing stage (not just recall) in intermediate L1 Arabic English L2 learners.

Word length might also have an impact on the *processing route* employed in these L2 learners (for the orthographic and phonological processing routes, see 1.2). The L2 word recognition research has reported mixed findings regarding the preferential route employed in L2 word processing in sL1 Arabic L2 learners.

Compared to other L2 groups, L1 Arabic L2 English learners were found to have well-developed phonological skills and tend to over-rely on the phonological route in L2 English (Brown & Haynes, 1985). In contrast to the expected overuse of the phonological route, Taylor (2008) concluded that these L2 learners might predominantly employ the orthographic route when processing L2 English. The author concluded that this is due to L1 transfer, and might therefore involve an attempt to extrapolate the consonant root in processing L2 English words as well (1.3). Similarly, Bowen (2011) also found no evidence of overreliance on the phonological route in the spelling errors of their L1 Arabic L2 English participants. In fact, the majority of spelling errors reported in this study involved adjacent letter transpositions (*mobile*-**mboile*), which are orthographic and not phonological errors. This again indicates that these L2 learners might not over-rely on the phonological route when processing words in English.

The selection of the L2 processing route employed also bears implications on the phenomenon of vowel blindness. The overuse of the phonological route in L1 Arabic L2 English learners in L2 English diverges from its concept. Using the phonological route denotes [11]linear, letter-by-letter processing. Conversely, vowel blindness postulates orthographic, non-linear processing as it indicates that consonant letters are processed fully, while vowel letters are processed only superficially. Therefore, the L2 processing in L1 Arabic L2 English learners in terms of their preferential processing route requires further investigation.

Investigating the preferential processing route also requires testing the processing of different letter positions within a word. In this vein, Ryan and Meara (1991) investigated the effects of the vowel letter deletion in different word positions in longer words, however, no firm conclusions regarding the processing of these were reported. To my knowledge, no other studies attempted to further investigate this and combine it with the preferential processing route employed in L1 Arabic L2 English learners.

To summarise, exploring word length effects, the processing of vowel/consonant letters in different positions within a word, and investigating the preferential processing route employed in these L2 learners sprung from the gaps in the existing literature. These were considered important avenues to pursue in order to further explore the vowel

[11] In this study, terminology referring to orthographic (non-linear) and phonological (linear) processing was employed. Strictly speaking, not all linear processing is phonological; successful word recognition in English involves employing the orthographic route - a 'snapshot' of the whole word which means processing consonant and vowel letters serially as well. As this study focuses on L2 word processing difficulties in L1 Arabic L2 English learners, which involve specific L1 transfer of consonant extrapolation, the word processing terminology outlined here was considered optimal.

blindness phenomenon and L2 word recognition difficulties in L1 Arabic L2 English learners.

1.6 Thesis Overview

The remaining chapters in this study will describe and discuss the two experimental tasks conducted on L1 Arabic L2 English learners testing L2 word processing with the specific focus on the phenomenon of vowel blindness.

Chapter 2 will present a review of the relevant literature for the present study. Chapter 3 will provide an overview of the current research introducing the experiments and the general methodology employed in this study. Chapter 4 will present the Auditory-Visual Word Matching task investigating the vowel blindness effects in shorter and longer words in intermediate L1 Arabic L2 English learners while chapter 5 will test the impact of letter transposition on how L2 words are processed in these L2 learners (Letter Transposition Task). Chapters 4 and 5 will also provide the rationale and the specific methodology employed in these tasks, the results and the discussion of those. Chapter 6 will provide the discussion based on the findings obtained from both experiments while Chapter 7 will present a summary and a conclusion of the thesis. Subsequently, the limitations of the study will be laid out before elaborating on the contributions of this study to the wider field of L2 English literacy. Finally, ideas for the future research will be discussed.

1.7 Chapter Summary

In this introductory chapter, the theoretical framework of word recognition in L1 and L2 English was presented prior to introducing the phenomenon of vowel blindness and other important terminology for this study. Subsequently, difficulties in L2 word recognition in L1 Arabic L2 English learners were elaborated on, informed by the research literature and its findings. The main methodological limitations of previous investigations were outlined and improvements were presented alongside identifying the gaps in the literature. Next, select areas connected to the phenomenon of vowel blindness and pertinent to this study were presented prior to providing the overview of this study. Lastly, the thesis overview by chapter was laid out.

The following chapter will provide a critical review of the research pertinent to this study.

Chapter 2: Literature Review

This chapter will provide a summary of the research literature relevant to the current study. In the first part, the evidence from L1 English word recognition research relevant to this study will be presented (reading models; word properties) followed by the evidence from the word recognition in Semitic languages. In the second part, L2 English word recognition will briefly be discussed before focussing on L2 word recognition in L1 Arabic L2 English learners. This consideration of the current research landscape will be used to motivate the research questions and the rationale for the present study.

2.1 Word Recognition in L1 English

Regarding reading at word level, successful visual word recognition is the paramount step which leads to fluent reading (Rastle, 2016). Under normal reading conditions, eyes will fixate on most of the words in the text, enabling the extraction of their visual features. This constitutes early visual processing, which will subsequently lead to orthographic, phonological, and eventually semantic processing (Grainger, 2008). Word recognition as such consists of two stages: First, the visual (orthographic) and phonological forms are matched. Afterwards, other properties, such as morphological specifications and meaning allow the full lexical access from the mental lexicon. In the broad sense, both stages may be considered to constitute full word recognition, however, the present study will only employ the first, prelexical stage (De Groot, 2011). The lexical and post-lexical processing stages concern the *meaning*, which is beyond the scope of this study.

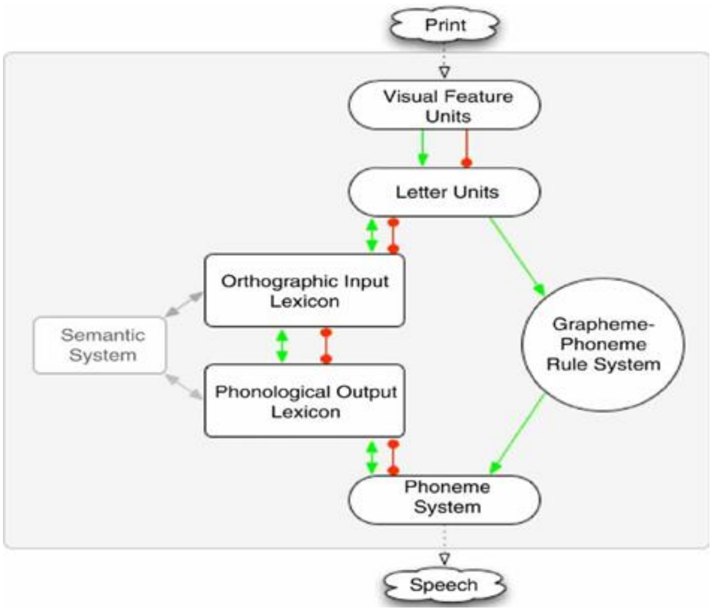
2.1.1 Computational Reading Models in L1 English

2.1.1.1 Dual-Route Reading Models

In the past 50 years, various reading models of word recognition have been proposed predicting how words are recognised. One of the most influential reading models was the *Interactive Activation Model* (McClelland & Rumelhart, 1981) which posited that words are recognised in a hierarchical manner depending on their mutually interacting constituents through cascaded and interactive processing. This is the main aspect of word reading that modern reading theories today agree on (e.g., Rastle, 2016). Successors of the Interactive Activation Model involved various Dual Route models (e.g., Houghton & Zorzi, 2003; for an overview, see Coltheart, 2005) and started to focus on orthography, phonology and semantics as well as on the pre-lexical and post-lexical processes (Frost, 2005). On the whole, earlier Dual Route models posited that familiar and high-frequency irregular words are processed through the faster (direct/whole-word) orthographic route while unfamiliar, low-frequency regular words are processed through the slower (indirect), phonological route by means of assembling letters and employing grapheme-to-phoneme mappings (Grainger, 2008).

The most widely-cited Dual Route model to date is the *Dual Route Cascaded Model* (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). According to this reading model, the visual features are extracted as letter units from print. The pronunciation is subsequently extracted from letter units via two different procedures - a lexical and a non-lexical procedure. The former involves accessing an orthographic representation in the mental lexicon which activates a phonological structure of the target word. In contrast, the non-lexical (phonological) procedure involves the mapping of grapheme-phoneme rules to the visual letter sequence, applying sequential, left-to-right processing. At the outset, the first letter of the letter string is processed before identifying the first two letter sequences, etc. until the ultimate letter in the visual input is processed (Coltheart, 2005).

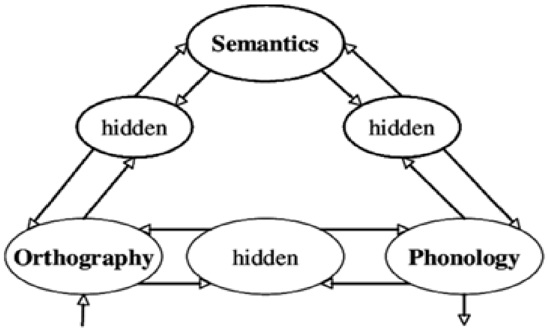
Figure 4: Dual Route Cascaded Model (Coltheart, 2005)



2.1.1.2 Connectionist Reading Models

In recent years, an alternative to these models has emerged based on associative networks and distributed-connectionist principles that stem from computer science. In these so-called *triangle* models, orthography, phonology and semantics do not work separately as in the Dual Route models but simultaneously as one process. Connectionist reading models (e.g., Seidenberg & McClelland, 1989) focus on the formation of between-letter associative networks which occur through repeated processing experience in a writing system. According to these reading models, processing words successfully depends on a degree to which readers consolidate between-letter relationships in word items. The more frequent the letter sequence combination, the stronger the connections between them (Koda, 1996). The Connectionist reading models highlight specific processes which start by word items being a vague representation to becoming clear and consolidated entities, and spanning from deliberate processing to acquiring the skills for automatic processing (Koda, 1996). For instance, when letter <t> appears in word-initial position, the subsequent letter most likely to be activated is <h> (h being the next letter is 50 percent higher than any other letter) (Adams, 1990). The awareness of these strong between-letter connections facilitates reading fluency (Ehri, 2014).

Figure 5: The Standard Connectionist ''Triangle'' Model (Seidenberg & McClelland, 1989)



2.1.1.3 Consonant/Vowel Reading Models

According to this reading model, the processing of consonants and vowels differs considerably (Caramazza, Chialant, Capasso, & Miceli, 2000; Carreiras & Price, 2008; New, Araujo & Nazzi, 2008) as they vary in processing automaticity (Berent & Perfetti, 1995). Consonants have also been found to be phonologically as well as orthographically more prominent than vowels (Carreiras & Price, 2008; Martin, 2017; New et al., 2008). However, regarding the grapheme-phoneme relations, vowels have a considerably more complex bi-directional mapping than consonants in English (Venezky, 1970).

Based on this, Berent and Perfetti (1995) proposed a two-cycle reading model which highlights a representational as well as computational distinction between consonants and vowels. According to their reading model, consonants are processed in the first cycle which constitutes a rapid and automatic process while vowels are accessed in the second cycle through a slower and a more controlled process (Lee, Rayner, & Pollatsek, 2002). In the same vein, another non-linear, consonant/vowel reading model was proposed by Caramazza and Miceli (1990). Unlike Berent and Perfetti's two-cycle model (phonological in nature), theirs is orthographic, and posits that graphemic representations are divided into various multidimensional structures, one of them being the consonant and vowel status of the graphemes. It is noteworthy that both consonant/vowel reading models postulate that consonants/vowels operate on differently assigned planes and not in a linear fashion. For non-linear reading models in Semitic Languages, see 2.2.2.

2.1.2 Word Properties

The literature on word recognition has argued that for a theory to be adequate, it must be able to account for the effect of different word properties of printed letter strings.

Some of the most typically investigated word properties in word recognition research include word frequency and familiarity followed by sublexical properties, such as the frequency of letter combinations measured by bigram and trigram frequencies (Solso, Barbuto, & Juel, 1979), neighbourhood effects (Adams, 1990; Van Heuven, Dijkstra, & Grainger, 1998), word length (measured in the number of letters or syllables; see New, Ferrand, Pallier, & Brysbaert, 2006), as well as [12]pronounceability (Frankish & Turner, 2007) and regularity (Wang, Castles, & Nickels, 2012). The research evidence on the most important word properties for this study will be considered in detail in this section.

Common interactions exist between various word properties and many of them are task-dependent (e.g., employed in a lexical decision or a naming task). It is also noteworthy that some word properties yield more reliable results than others, which will be outlined below.

2.1.2.1 Word Frequency and Word Familiarity

Two of the most important word properties are word frequency and word familiarity, which are also highly correlated (Connine et al., 1990). Both of these word properties reveal a complex interaction with bigram frequencies (2.1.2.2), neighbourhood size, word length as well as at what age an item is acquired (Bryasbert et al., 2018). Compared to word frequency, word familiarity is a subjective variable (Connine

[12] Word regularity and pronounceability effects were not investigated in this study as they were beyond its scope.

et al., 1990), and is closely connected to orthographic knowledge and vocabulary size (see 3.3.1.1).

Word frequency effects have been extensively studied to determine their role in lexical access (Connine, Mullenix, Shernoff, & Yelen, 1990; New et al., 2006). In lexical decision tasks, high-frequency and high-familiarity words tend to yield faster response times than lower-frequency words, however this seems to be dependent on the testing mode. Lower-frequency words generally result in better performance in word recognition tasks but tend to yield poorer results in recall tasks (Brysbaert, Mandera, & Keuleers, 2018; Connine et al., 1990).

2.1.2.2 Orthographic Patterns

Apart from word frequency and familiarity, the recognition of sublexical orthographic patterns also impacts the automaticity of responses. Early readers are expected to internalise various types of orthographic regularities alongside grapheme-phoneme mapping, which build connections with ortho-syllabic units (Ehri, 2014). These include statistically-measurable bigram and trigram frequencies of the spelling patterns based on the co-occurrence of graphemes in English (Treiman & Kessler, 2006). As conceived in Connectionist Reading Models (2.1.1.2), letters frequently encountered with other letters will result in 'positive excitation' whereas rare letter combinations will receive 'negative excitation' (Adams, 1990). Consequently, various orthotactic features consisting of illegal letter combinations will be detected (e.g., **ghl*). Many of these orthographic patterns are acquired implicitly over a period of time. As readers' lexical representations in their orthographic lexicon increase as a result of more exposure to print, there is a higher likelihood of the recurring patterns being detected (Ehri, 2014). For instance, in order to attain rapid word recognition, initial letter combinations and high-frequency initial syllables are crucial. These activate whole-word presentations which subsequently compete with the target words for final identification, i.e., for lexical access and retrieval from the mental lexicon (Conrad, Grainger, & Jacobs, 2007).

2.1.2.3 Neighbourhood Effects

A word property closely connected to word frequency, familiarity and letter combination sequences is neighbourhood size (Coltheart et al., 1977; Perea & Rosa, 2000) which measures a target word's similarity to other words. Neighbourhood size consists of a number of words that can be formed by substituting one letter of a target word, either a consonant (e.g., *night, light, might)* or a vowel (e.g., *bit, bat, but*).

Apart from letter substitutions, stimuli containing transposed letters can also be classified as neighbours (Andrews, 1996; Norris, 2013). Neighbours where two adjacent word-internal letters are transposed (*judge- *jugde*) were commonly found to be misclassified as real words in the lexical decision task (Chambers, 1979) and revealed large [13]priming effects in various masked priming tasks (Perea & Lupker, 2003a; 2003b).

Word properties, such as word length and neighbourhood size were found to have an effect on letter transposition. Regarding word length (Acha & Perea, 2008; Buchwald & Rapp, 2006; see 2.1.2.4), long transposed letter primes (*revoultion-revolution)* were easily confused with the target word (see Lupker, Perea, & Davis, 2008) while transposed letter priming effects seem to disappear with shorter words. Stronger transposed letter effects were found in internal transpositions in 7-letter than 5-letter words (Grainger, 2008) whereas no transposed letter effects were found in 4-letter words (Humphreys, Evett, & Quinlan, 1990). With regard to the neighbourhood effects, neighbourhood size was also found to have an effect on the letter transposition. Robust transposed letter effects were found in longer words containing 5 and more letters (Grainger, 2008), which tend to have fewer neighbours than shorter words (Jalbert et al., 2011). Therefore, the bigger the neighbourhood size (typically in shorter words), the less pronounced the transposed letter effects. In other words, letter transpositions are more detectable in shorter words.

Other subcategories found to have an effect on letter transposition are the *type* and the *position* of transposition. In terms of the type of transposition, factors such as the

[13] *Priming* involves presenting a word (a prime) before a target word to which participants respond to. *Masked* priming refers to the prime masked by the symbols, such as ###. These are presented before or after the prime.

number of letters in common and the degree the shared letters match the position/slot in relation to the target item were found to affect the performance in the same-different (identity judgement) task (e.g., **jugde* is more similar to *judge* than **jupte*). Therefore, the smaller the number of letters two items have in common, and the further the transposition from the target (e.g., positions 2 and 5), the easier the letter transposition is detected (Grainger, 2008). Secondly, the letter type (consonant/vowel) transposition also demonstrates transposed letter priming effects. CC letter transitions (*judge*-**jugde*) alongside CV transpositions (*management*-**manaegment*) were reported to be the most effective, while VV transposition primes (a*ppearance*-**appaerance*) were found to be the least effective (Lupker, Perea, & Davis, 2008). This is convergent with the findings regarding the superiority of consonants over vowels in word processing (Berent & Perfetti, 1995; Caramazza & Miceli, 1990; New et al., 2008; see 2.1.1.3).

Regarding the position of transposition in the lexical decision task, letter transpositions have been found to yield faster response times in the word-initial and word-final positions. Conversely, the internal transpositions amounted to slower response times and lower accuracy in shorter words (Chambers, 1979) as well as in longer words (Guerrera & Forster, 2008), which is in line with the superior processing found in external letters (e.g., Hammond & Green, 1982).

2.1.2.4 Word Length

Alongside word frequency/familiarity, orthographic patterns and neighbourhood size, word length is another word property of importance. Word length effects are closely connected to word frequency (Bunton, 2014), i.e., stronger word length effects were found for lower- than higher-frequency words and word length effects in higher-frequency words were mainly found in unskilled L1 English readers. Word length and word frequency were found to be closely related to the exposure to print. Reading increases the exposure to lower-frequency words and at the same time word length effects were found to diminish with the exposure to print (Mason, 1978).

In this vein, Zipf’s universal law of abbreviation (1935) posited that there is a negative correlation between word length and word frequency; the longer the word, the less frequent it is. This has specific implications for English as lower-frequency words are predominantly found in print (Milton & Hopkins, 2006). Therefore, through reading, the exposure to longer words increases as well, which facilitates their recognition.

Unlike some other word properties outlined earlier, word length has not always yielded consistent findings when measured either by the number of letters (Acha & Perea, 2008; Beyersmann, Grainger, & Taft, 2020; Martens & De Jong, 2006) or by the number of syllables (Guitard, Saint-Aubin, Tehan, & Tolan, 2018; Jalbert et al., 2011; see New et al., 2006 for employing both).

With regard to word length measured by letters, New et al. (2006) reported faster response times in 3-5 letter words and slower response times for 8-13 letter words in the lexical decision task. Surprisingly, no significant effects were found for 5-8 letter words which are also of highest frequency in English. It was concluded the word length effects are not straightforward and require more investigation. In the same vein, Acha and Perea (2008) did not find any significant word length effects in their fluent L1 English adult readers. In terms of the syllable count, further inconsistencies regarding word length were reported by Jalbert et al. (2011). Neighbourhood size demonstrated more substantial effects on word recognition than word length in the oral recall task; i.e., when one- and three-syllable words were controlled for the same neighbourhood size, the word length effect disappeared.

Therefore, as word length measured by letters and syllables yielded inconsistent results, Jalbert et al. (2011) suggested classifying words into *short* and *long* words as more effective than employing the letter/syllable count.

2.1.3 English Orthography

Orthography plays a crucial role in word recognition and therefore requires specific attention.

English orthography uses the Roman alphabet and is *linear*, i.e., consonants and vowels are processed in a serial manner (e.g., CVCV). English orthography distinguishes between 26 letters, and its graphemic system of orthographic patterns is complex. The functional units can be comprised of numerous orthographic combinations, e.g., <th>, <ch>, <oo>, etc. which subsequently map onto phonemes. English distinguishes between 24 *consonant* phonemes and 20 *vowel* phonemes (8 of those are diphthongs) (Venezky, 1970). For the impact of orthographic patterns on word recognition, see 2.1.2.2.

As in most alphabetic systems, a single grapheme in English orthography may represent a single phoneme. For instance, the word *dog* /dɒg/ is comprised of 3 graphemes - <d>, <o>, <g>, which map onto 3 phonemes - /d/, /ɒ/, /g/. Conversely, in the word *ditch,* the phoneme /ʧ/ is represented by 3 graphemes - <tch> (Cook & Bassetti, 2005).

Complex grapheme-phoneme mappings can be further illustrated with the vowel diagraph <ea> which is pronounced as /e/ in head, /i:/ in heat and /ɜ:/ in search. The phoneme associated with a particular grapheme to some extent depends on the neighbouring graphemes. Therefore, <ea> in search is pronounced as /ɜ:/ as it is followed by letter <r>. It is noteworthy that many orthographic patterns have exceptions. For instance, <ea> in ear is not affected by <r> in the same way as in the word search. Long vowel phonemes and diphthongs are predominantly encoded by vowel digraphs (e.g., <au> mapped onto /ɔ:/ in caught and <oa> mapped onto /əʊ/ in *coat*).

As the grapheme-phoneme correspondences are many-to-many in both directions, the phonemes can be ambiguous as well. For instance, the long phoneme /i:/ can be written in a variety of ways: <i> + consonant + <e> (e.g., *pike*), <ay> (*quay*), <ey> (*whey*), <ie> (*grief*), etc. (Caplan, 1987). In the same vein, short vowel phonemes (especially the schwa /ə/ in unstressed syllables) can also have many grapheme representations (e.g., *captain, teacher*).

Therefore, due to its complex grapheme-phoneme correspondences, English orthography is classified as a *deep* orthography according to the [14]*Orthographic Depth Hypothesis* (Katz & Frost, 1992). See 2.2.1 for Arabic orthography.

[14] Conversely, Italian and Spanish are examples of shallow orthographies due to having regular 1:1 grapheme-phoneme correspondences.

2.2 Word Recognition in Semitic languages

Word recognition in L1 Semitic languages (bottom-up processing) as well as reading at text level (top-down processing) differ markedly from L1 English. In terms of top-down processing, adult readers of Semitic languages will predominantly be exposed to unvowelised Arabic/unpointed Hebrew texts. Due to vowel underrepresentation in Semitic languages, skilled readers are more reliant on sentences and wider textual context clues to facilitate their word processing (Koriat, 1985; see 2.2.1) than skilled readers in English where only poorer readers rely more on the context (Stanovich & West, 1989). For differences in word access in Semitic languages based on the reading mode, [15]see footnotes.

2.2.1 Arabic orthography

Regarding reading/writing, Arabic differs from typical alphabetic languages in four different aspects: writing system (consonantal), script/letter architecture (cursive), reading direction (right-to-left), and the [16]diglossic situation (Funder Hansen, 2014). The specificity of the consonantal orthography is heavily reflected in the processing beyond word level. To become a fluent reader in Arabic, substantial knowledge of Modern Standard Arabic (MSA) including a high degree of morphological, syntactic, lexical and contextual awareness is required in order to process words successfully (Abu-Rabia, 2002; Saiegh-Haddad, 2018).

Compared to English, Arabic is comprised of more consonant phonemes (28) and fewer vowel phonemes (6); Arabic has 3 short vowel phonemes, /i/, /u/, /a/ which contrast with their long counterparts /ī/, /ū/, /ā/, as well as 2 diphthongs, /aj/ and /aw/ (Al-Ani, 1970). As Arabic has a smaller number of vowel phonemes than English, it does not

[15] In silent reading, a word root is identified which allows initial lexical access and leads to the general comprehension of the sentence. Utilising exact phonological representations is not required as phonological and syntactic clues are provided by the sentence context. Conversely, reading aloud demands more reliance on phonology and syntax (Abu-Rabia, 2002).

[16] Two varieties of Arabic; the high variant is standardised Arabic (MSA) used in schools and other formal contexts; the low variant is the vernacular used in everyday conversation (Funder Hansen, 2014).

distinguish, for example, between the vowel phonemes /e/ and /ɪ/ (Kharma & Hajjaj, 1997).

Arabic orthography encodes consonant root morphemes (approximately 3000 in total), long vowels and a certain number of short vowels which form the so-called *word patterns*. Arabic orthography mainly relies on consonants, while short vowels, marked with diacritics, can be omitted as they can be predicted from context (Campbell, 1997). Diacritics are perceived as unnatural and are mainly only retained for religious and pedagogical purposes; e.g., in Quran, dictionaries, children's books, and some literary materials to avoid ambiguity. Diacritics mainly bear phonological cues (functioning as vowels) and signal grammatical functions (Azzam, 1989). For instance, the word pattern *a-a-a* can be applied to a variety of different consonant roots to signal the third person singular as well as the past tense (e.g., /*kataba*/ means 'He wrote').

The absence of short vowels in everyday texts can be illustrated by a word *darb* (meaning 'path') - in its most common, unvowelised form and in its vowelised form (Table 1). The arrow in the tables demonstrates the right-to-left reading direction.

Table 1: An Example of an Arabic Word Containing a [17]Short Vowel:

Unvowelised word: *darb* (path)	Vowelised word: *darb* (path)
درب	دَربْ
د - ر - ب b r d ←	دَ - ر- بْ a b r d ←

[17] Whenever a consonant is not followed by a vowel, it receives a mark called a *sukūn* (a small circle placed above the letter), which represents the end of a closed syllable (CVC or CVVC).

In contrast to short vowels, long vowels are encoded in Arabic. This is illustrated by the word *nahaar* (meaning 'day') in its most common, unvowelised form and in its vowelised form (Table 2).

Table 2: An Example of an Arabic Word Containing a Short Vowel /a/ and a Long Vowel /aa= ā/:

Unvowelised word: *nahaar* (day)	Vowelised word: *nahaar* (day)
نهار	نَهَار
ن - ه - ا - ر	نَ - هَ - ا - ر
r aa h n	a a r aa h n

As far as different parts of speech are concerned, Arabic verbs, nouns, and adjectives are a combination of root letters and word patterns. Consonant roots are primarily comprised of 3-4 consonants, called the tri-/quadrilateral root, and rarely of 2 or 5 (Abu-Rabia, 2001). There is a limited number of consonant roots, many of which bear an identical consonant sequence (e.g., *k-t-b*). This alongside the lack of vowelisation result in a large number of homographs which are difficult to disambiguate therefore reliance on context is essential (Abu-Rabia, 2001; 2002).

Arabic boasts complex morphology where the process of derivation plays a crucial role. The majority of words are derived from roots to which affixes are added (word patterns), e.g., /*kataba*/ is a derivative of the root /k/, /t/, and /b/+infixes /a/, /a/ + the suffix /a/. Regarding the syllabic structure, Arabic words consist of open syllables (CV/CVV) and closed syllables (CVC/CVVC). A [18]consonant cluster is only allowed in the word-final position (CVCC). Syllables start with a consonant and follow regular

[18] CCC clusters are typically not found in Arabic. In contrast, English allows CCC and CCCC clusters and has overall a more varied syllable structure (e.g., *strength* is a one-syllable word with CCCVCCCC structure).

grapheme-phoneme patterns (/*kataba*/ follows the CV-CV-CV structure). From the k-t-b consonant root, many different forms can be derived: /*kitābah*/ (writing), /*kitāb*/ (book), /*maktab*/ (office), /*kātib*/ (writing/writer), /*maktūb*/ (written/a letter) (Ryding, 2005). Therefore, words containing the identical consonant sequence (e.g., *k-t-b*) belong to the same word family.

This could be further illustrated by another consonant sequence (f - [19]ʕ - l) in the typically unvowelised form (see Table 3), which an Arabic reader can find in a text. Contextual information ought to be employed to decode fiʕl which means ‘verb’ (vowelised text 1) or the semantically related subject and verb faʕala meaning ‘He did’ (vowelised text 2*)*.

Table 3: [20]An Example of Semantically-related Words Derived from a Consonant Sequence (f - ʕ - l)

Unvowelised text: consonant sequence f - ʕ - l	Vowelised text 1: fiʕl (meaning *verb*)	Vowelised text 2: faʕala (meaning *He did*)
فعل	فِعل	فَعَلَ
ف - ع - ل	فِ - ع - ل	فَ - عَ - لَ
l - ʕ - f	l - ʕ - if	al aʕ af
←	←	←

2.2.1.1 Classification of the Arabic Writing System

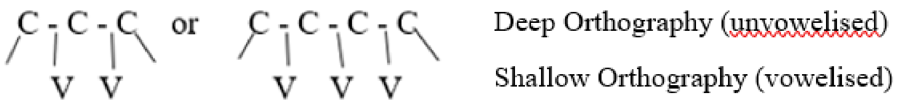
A substantial body of literature classifies Arabic writing system as consonantal (Caplan, 1978; Cook & Bassetti, 2005; Fatihi, 2001), alphabetic (Abu-Rabia, 2002; Al-Sulaimani, 1990; Azzam, 1989), as well as phonological/phonographic (Cook & Bassetti, 2005) depending largely on the categorisation adopted (Henderson, 1982).

[19] Voiced pharyngeal fricative

[20] The example of the consonant root and its derivations were taken from Hayes-Harb (2006).

According to the *Orthographic Depth Hypothesis (*Katz & Frost, 1992), Arabic orthography is categorised as a *shallow* orthography as it has a predictable grapheme-phoneme correspondence in its fully-vowelised form, whereas in its common, unvowelised form it is considered a *deep* orthography (also see 2.1.3 for English), and is non-linear.

Figure 6: Arabic as a Non-Linear (unvowelised-deep) and Linear (vowelised-shallow) Orthography



2.2.2 Computational Reading Models in Semitic Languages

Word recognition in Semitic languages poses numerous challenges for computational reading models due to the nature of consonantal writing systems. According to the Dual-Route Reading Models (see 2.1.1.1), word recognition is attached to the root-based entries in the mental lexicon. When the reader identifies an unknown or ambiguous word (a homograph), they primarily identify the root before attaching a suitable vowel pattern to it, based on the context. If no context is available, the most high-frequency word will be retrieved (Funder Hansen, 2014). Conversely, the Connectionist approach (2.1.1.2) can also explain the top-down reading in Semitic languages (Abu-Arabia, 2001; Funder Hansen, 2014; Shimron & Sivan, 1994; see 2.2). Here orthographic and phonological processes are not separate but constantly intertwined (Seidenberg & McClelland, 1989). The prior exposure to various sublexical structures is crucial under this approach allowing the activation of relevant resources, such as context, frequency, and vowel information. Roots and word patterns might not be acting separately but can be processed based on frequency, i.e., a limited number of word patterns allows combining with a limited number of word structures stored in *hidden units* (mental lexicon in Dual-Route Models). This would signify the starting point of decoding a word in Arabic and Hebrew (Funder Hansen, 2014).

A significant number of scholars believe that the current Dual-Route and Connectionist Reading Models based on L1 English are not fully applicable to Semitic languages. Therefore, morphology- rather than orthography-led, [21]root-based reading models have been proposed.

2.2.3 Word Properties in L1 Arabic

When comparing words in Semitic languages to words in English, there are some striking differences worth highlighting. Arabic and Hebrew words are more compact in terms of the orthographic, phonological and morphological information they carry which is encoded in a 3-4 literal word root and its word pattern. As they are visually considerably less diverse than words in English, decoding words in Semitic languages requires more visuo-spatial awareness (Abu-Rabia, 2001; Ibrahim, Eviatar, & Aharon-Peretz, 2007). Regarding word length, words in Semitic languages are generally shorter than words in English and are composed of approximately 6 graphemes (Randall & Meara, 1988).

Lexical space in two languages is also organised differently, and is denser in Arabic. The difference in lexical space can be further illustrated by the transposed letter effect (**jugde-judge*). While in English robust transposed letter priming effects have been widely reported (2.1.2.3), transposed letters in Arabic and Hebrew have demonstrated [22]strong inhibitory effects. Compared to English word structure where letters (consonants/vowels) are encoded in a linear fashion, words in Semitic languages are non-linear morphological structures - consonant roots and word patterns present separate cognitive entities (Abu-Rabia & Awwad, 2004). Therefore, linear processing of word properties, such as letter sequences, neighbourhood effects (Boudelaa & Marslen-Wilson, 2001) and syllables cannot be directly applicable to Arabic and

[21] for Arabic, see Abu-Rabia, 2002; Saiegh-Haddad, 2018; for Hebrew see Velan & Frost, 2009; for *Consonant/vowel reading models*, see 2.1.1.3.

[22] For Hebrew, see Velan & Frost, 2007; 2009; for Arabic, see Perea, Mallouh, & Carreiras, 2010.

Hebrew (Funder Hansen, 2014). Conversely, knowledge of word-pattern frequency, a vital source of vowel information, and the word frequency itself are word properties which are alongside the *context* of the utmost importance in visual word processing in Semitic languages (Funder Hansen, 2014).

2.2.4 Phonological/Orthographic Processing, Vowelisation and the Processing Routes in L1 Arabic

Similarly to other L1s with shallow alphabetic orthographies, phonological processing skills in L1 Arabic were also found to be a strong predictor of successful reading and spelling in beginner readers (Elbeheri & Everatt, 2007; Taibah & Haynes, 2011). In the same vein, *orthographic* processing skills were also found to be an important predictor of fluent word and pseudoword reading (Maroun, Ibrahim, & Eviatar, 2019).

Orthographic and phonological processing skills are also connected to the processing route employed and the processing of vowels in L1 Arabic readers. Although the effects of vowelisation still require a great deal of investigation in the future, there seems to be a consensus that vowelised texts in Arabic rely on the phonological processing and employing the phonological route while unvowelised texts rely more on the orthographic route (Abu-Rabia, 2001; 2002).

Overall, vowelisation has been found to have facilitatory effects on reading in Arabic across all reading conditions in young as well as adult readers (Abu-Rabia, 2001). Furthermore, Arabic readers were also found to pay attention not only to long vowels, which are encoded in Arabic, but also to short vowels, represented by diacritics ([23]Abu-Rabia, 1998). This has important implications for the processing of vowels in L2 English in L1 Arabic L2 English learners (1.3). As vowels were found to have a more prominent role in the processing of words in L1 Arabic, this indicates that the concept of vowel blindness might play a much smaller role in L2 processing in these L2 learners than previously assumed (Allmark, 2022; for more detail, see 2.5).

[23] For the review of the vowelisation in Arabic, see Abu-Rabia (2019).

2.3 Word Recognition in L2 English

While L1 English word recognition has been extensively investigated in the last 50 years, L2 English word recognition is still largely under-researched. Similarly to L1 English word processing, L2 English word processing is influenced by a multitude of factors and additionally involves complex cross-linguistic interactions (Koda, 2016).

L1 word recognition has a significant effect on L2 word recognition (Birch, 2014; Wade-Wolley, 1999). The development of L2 reading is also heavily influenced by L1 orthography (Koda, 2016); the difference in L2 word recognition performance can be explained by the cross-linguistic constraints specifically related to different writing systems. The most crucial factor in this respect is the similarity/distance between the L1 and L2 orthographies (Akamatsu, 1999; Hamada & Koda, 2008). As there is a large L1-L2 orthographic distance between Arabic and English (see 2.3), this was found to have an adverse effect on their L2 visual word processing (Muljani, Koda, & Moates, 1998) and is considered one of the crucial factors contributing to their L2 reading difficulties.

Secondly, well-developed phonological and orthographic processing skills enable efficient L2 word recognition which, in turn, facilitates the development of L2 reading comprehension (Koda, 1996; Nassaji, 2003). In this vein, L1 Arabic L2 English learners were found to have superior phonological processing skills while less developed orthographic processing skills compared to L1 Japanese L2 English learners (e.g., Brown & Haynes, 1985). Poorer performance in orthographic processing in L1 Arabic L2 English learners might have inhibitory effects on their L2 processing as these were also found to be crucial for successful word processing in L2 English (Martin, 2017).

Lastly, other factors such as L2 language proficiency and L2-specific word properties (e.g., word frequency/familiarity, word length, etc.) were also found to be significant in how words are recognised in L2 English (Koda, 2016; Kramer & McLean, 2019).

2.4 L2 Word Recognition in L1 Arabic L2 English Learners

Within the area of L2 word recognition, the research in L1 Arabic L2 English learners is considerably smaller in scope compared to the research found in some other L2 learner groups (e.g., L1 Chinese). While earlier studies in L2 word recognition in L1 Arabic L2 English learners were mainly cross-linguistic (e.g., Brown & Haynes, 1985; Ryan & Meara, 1991), the last decade has seen an increasing research activity in the investigation of reading difficulties specific to this L2 group (Alhazmi, et al., 2019; Alhazmi & Milton, 2015; Alsadoon & Heift, 2015). The key research articles which provide a foundation for the current investigation will be considered in greater detail in the following section.

2.4.1 Key Research on L2 Word Recognition in L1 Arabic L2 English Learners - Focus on Vowel Blindness

The key research in L2 word recognition in L1 Arabic L2 English learners was conducted by Ryan and Meara (1991) who aimed to investigate the vowel blindness phenomenon by administering an identity judgment (same-different) task. Two L2 English groups were tested (L1 Arabic and L1 Non-Arabic) alongside the L1 English control group. The participants were presented with 100 10-letter item pairs in rapid succession (e.g., same condition: *possession-possession*; different condition: *department-*dpartment)* and were asked to judge the stimuli the same or different. The non-identical stimuli featured vowel deletions in the 2nd, 4th, 6th and 8th position (**dpartment*; **expriment; *managment; *photogrph*); the error rate and response times were measured. As expected, the results revealed superior L2 word processing in the L1 Non-Arabic L2 English group in both error rate and response times, i.e., L1 Arabic group made twice as many errors as the L1 Non-Arabic group (the L1 English control group performed at ceiling). Significant effects of the stimuli condition were found for error rate and response times as well; deletions in word-initial positions (2 and 4) were detected significantly faster in all the groups. The authors concluded that this points towards left-to-right reading direction typical of processing Roman alphabet.

Conversely, when exploring [24]letter position results in Ryan and Meara (1991) in more detail, there are also some indications of possible L1 transfer. For instance, L1 Arabic L2 English group demonstrated differential visual processing pattern in mid- and end-word vowel manipulations compared to the other groups (L1 Non-Arabic and L1 English). While the latter demonstrated the slowest response times in vowel deletions in position 8 (in a 10-letter word), the L1 Arabic group demonstrated the slowest vowel deletions in a mid-word position (position 6). This indicates that these participants might have employed the L1 Arabic processing technique of consonant extrapolation which might also include right-to-left processing.

The differential word processing found in L1 Arabic L2 English learners is broadly convergent with an earlier study by Randall and Meara (1988) who investigated visual letter search in their advanced L1 Arabic L2 English learners by employing [25]5-letter arrays. These L2 learners were found to process Roman letters identically to Arabic letters (U shape) which differs to how L1 English readers processed Roman letters (upward M shape). This indicates that even at higher L2 English proficiency levels, Arabic learners still employ L1 Arabic visual search techniques, which might also involve some features of right-to-left processing (Allmark, 2022; Hamada, 2017). At the same time, Randall (2009) noted that the results of both studies might not be directly comparable, as Randall and Meara (1988) employed 5-letter arrays (not words) while Ryan and Meara (1991) employed words consisting of 10 letters.

In the same vein, Hamada (2017) conducted a word search task in L1 Arabic, L1 Chinese L2 English learners, and L1 English speakers employing longer, polysyllabic words. All the groups yielded the lowest error rate and the fastest responses in the initial position (for similar results, see Ryan & Meara, 1991). However, unlike the other groups, L1 Arabic L2 English learners demonstrated a lower error rate in the mid-word and word-final positions. This ties in with the differential processing patterns in these L2 learners reported in the studies above (Randall & Meara, 1988; Ryan & Meara, 1991). The authors concluded that L1 Arabic L2 English learners most likely employed the L1 processing technique which involves consonant root extrapolation and elements of right-to left processing.

[24] which part of the word is processed faster and more accurately

[25] These consist of 5 random letters; the participants are asked to locate a letter; response times are measured.

It is noteworthy that all the studies presented above made tentative conclusions regarding consonant extrapolation and the right-to-left reading direction in *longer* words in these L2 learners. Letter position effects can better be observed in longer words (see Hamada, 2017; Ryan & Meara, 1991), however, it is less clear what processing patters occur in *shorter* words in these L2 learners.

Stein (2010) tested the processing of mid-word vowels in relation to the adjacent consonants in the monosyllabic [26]pseudowords in 3 different groups (L1 Arabic L2 English, L1 Non-Arabic L2 English, and L1 English). The participants were asked to silently read a pseudoword (e.g., *spant*) and match it to one of the two words they heard in terms of rhyme (*font*/*rant*). The L1 Arabic L2 English learners performed even more poorly than anticipated in utilising surrounding consonants to pronounce vowels compared to the other groups. This suggests that L1 Arabic L2 English learners do not only process vowels superficially but consonants as well. Poor performance was reported particularly in word-final positions while better performance was recorded in word-initial positions. This indicates left-to-right processing which is overall in line with the vowel letter position effects found in Ryan and Meara (1991). It is noteworthy, that this study employed short, monosyllabic words while other studies presented above employed longer words. This suggests that word length might have an effect on how L2 words are processed in L1 Arabic L2 English learners and therefore requires further investigation.

There are also some methodological concerns regarding this study which need addressing. The task design and stimuli administered in Stein (2010) were based on Treiman, Kessler and Bick (2003), and were originally designed for testing L1 English children. Their stimuli set require high-level phonological/orthographic processing (Koda, 2016) as well as a large vocabulary size to draw analogies between the tested pseudowords (e.g., **spant*) and real words (e.g., *rant*). As only some minor changes to the original study had been applied, the task and the stimuli were considered to be too challenging for L2 English learners. Secondly, the L1 Arabic L2 English group in Stein (2010) was rather small (N=15). Therefore, the results obtained in this study ought to be approached with caution.

[26] These are pronounceable stimuli which are designed to look like real words (e.g., **tiece* is constructed through the analogy with *piece* and *niece*).

It is noteworthy that Stein (2010) did not report L2 proficiency levels for their groups. Instead, they provided reading/writing assessment conducted prior to the experiment; those not reaching the threshold were subsequently excluded from the study. However, as a one-time assessment, reading/writing assessment might not reflect the participants' exact proficiency L2 level. A combination of external testing and the assessment conducted by experienced English teachers are believed to provide a more accurate assessment of the participants' L2 proficiency level.

Turning back to Ryan and Meara (1991), some methodological concerns need addressing regarding this study. Firstly, their sample size was rather small, with only 10 participants in each group (also see Hayes-Harb, 2006). In psycholinguistic quantitative analysis research, sample sizes of at least 30 participants per group are recommended (Lazaraton, 2005). This might be indicative of results failing to yield sufficient statistical power which limits the results as they cannot be generalised for the whole population (Hayes-Harb, 2006).

Secondly, the participants' L2 English proficiency level in Ryan and Meara (1991) was assessed as lower-intermediate/intermediate. However, it is not clear whether this proficiency assessment refers to the participants' oral competency only. This is significant as L1 Arabic L2 learners were reported to have more advanced oral than reading and writing skills in L2 English (Thompson-Panos & Thomas-Ružić, 1983). Therefore, selecting this L2 groups' participants on oral proficiency alone can overestimate this L2 group's reading/writing aptitude in English. Thirdly, the L1 Arabic participants' countries of origin were not specified alongside whether they were proficient in any other L2s. Maghrebi L1 Arabic learners might have a good command of L2 French. Due to their exposure to the Roman alphabet, the word processing in L2 English in these learners has very different implications to the L2 word processing in L1 Arabic L2 English learners from the Gulf, who are not assumed to have had extensive exposure to the Roman alphabet. Lastly, the study did not specify the apparatus employed to calculate response times, which makes the possibilities of replication limited.

Regarding the stimuli utilised in Ryan and Meara (1991), these were controlled for length, vowel deletion position and frequency. However, it is not clear whether the stimuli were piloted on other intermediate L2 English learners or verified by English language teachers. Unlike in the lexical decision task, knowing the stimuli is not a prerequisite for successful performance in the identity judgment task where two items are presented and require orthographic comparison. Therefore, the participants' performance was not dependent on the word-frequency or their L2 proficiency level per se. Nevertheless, a consolidated representation of a target word in the mental lexicon was expected to facilitate the participants' responses.

The stimuli employed in *other* studies testing L2 word recognition in L1 Arabic L2 English learners mostly [27]manipulated only vowel letters to test the vowel blindness phenomenon. Hayes-Harb (2006) pointed out that introducing one letter type condition (a vowel or a consonant) is ambiguous as it is not clear whether processing difficulties occurred due to a missing vowel or a missing letter in general. Therefore, adding consonant manipulations was vital to resolve this ambiguity. Ryan (1997) extended the study by Ryan and Meara (1991) and rectified this issue. Four intermediate L2 learner groups were tested with an identical set of stimuli in the deleted vowel as well as deleted consonant condition on larger participant groups (N=30) compared to Ryan and Meara (1991) (N=10). As expected, L1 Arabic L2 English learners demonstrated fewer errors and faster responses in the deleted consonant than deleted vowel conditions. This consolidated the vowel blindness phenomenon as the principal reason for their L2 reading difficulties.

In her unpublished dissertation, Ryan (1993) also administered a multiple-choice task by employing phonologically-matched (consonant-matched) and semantically-related foils, which were presented in sentences: *'I'm sorry I couldn't eat anymore. I'm ………'*. The sentences were read out and the learners were asked to select between 4 options to complete a gapped sentence: *a) fed up b) full up c) filled up d) satisfactory* (p.100).

The task was administered to L1 Arabic and L1 Non-Arabic L2 English learner groups. As expected, the L1 Arabic L2 English learners attained a higher errors rate, which means they found the stimuli more easily confusable than other L2 learners.

[27] For vowel deletion, see Ryan and Meara (1991) and Ryan (1993). For vowel deletion and substitution, see Saigh and Schmitt (2012).

As the sentences were read out, employing semantically-related foils was believed to be redundant as these would be too easily eliminated (e.g., *satisfactory* is not phonologically/orthographically-matched to *full/filled/fed* up). Moreover, as the results demonstrated similar error rate in phonologically-matched and semantically-related stimuli, this signals that the task was most likely misunderstood by the participants and therefore methodologically flawed. Thus, it would be of interest to see how these L2 learners performed if tested with orthographically-matched words (*subtle-subtitle*) alongside phonologically-matched words rather than semantically-related words. Some of the *target* words employed by Ryan (1993) were of low-frequency and therefore probably unknown to the intermediate L2 learners, which might have had a detrimental effect on the participants' performance. It is also not clear whether the target stimuli had been piloted beforehand. This is of importance as L1 Arabic L2 English learners tend to have smaller L2 vocabulary size to other L2 learner groups (e.g., Coderre & Van Heuven, 2014).

Turning back to administering the identity judgment task, Hayes-Harb (2006) replicated the study by Ryan and Meara (1991) by employing vowel as well as consonant deletions. The results revealed no significant group or condition effects regarding error rate. This was unexpected as in the previous studies, error rate was found to be significantly higher in L1 Arabic L2 English learners (Ryan & Meara, 1991; Ryan, 1993). Regarding response times, Hayes-Harb recorded faster responses for deleted *vowels* than deleted consonants across the groups which the author attributed to the "greater visual salience of [28]vowels relative to consonants" (p. 329).

While vowels have a prominent role in processing syllables, it is *consonants* that have been found to be more visually as well as phonologically salient in L1 and L2 English (Share 1995; New et al., 2008; for L2 English, see Martin, 2017). Overall, the unexpected results reported in Hayes-Harb (2006) most likely occurred due to shorter stimuli employed (6-10 letters). For instance, a letter deletion in 6-letter words is expected to be more easily detected compared to letter deletions in longer stimuli (see Ryan & Meara, 1991; Ryan, 1993). Furthermore, this study demonstrates that adding consonants to test vowel blindness reveals a more complex picture in how these

[28] Notably, the findings in vowel/consonant deletion manipulations in L1 *Non*-Arabic L2 English learner groups and L1 English groups have been inconsistent (Ryan, 1993; cf., Martin, 2017).

learners process vowels in L2 English. Therefore, both letter types should be employed to test this processing phenomenon.

Subsequent to obtaining unexpected results in their first experiment, Hayes-Harb (2006) conducted a letter detection task where the participants were asked to read a text for comprehension and locate a letter (vowel/consonant). No letter effect was found in the L1 Arabic L2 English group. Although these L2 learners were found to process vowels less accurately than consonants in this task, the effect sizes were very small, therefore the author warned these results should be approached with caution. As unexpected results were found in both, methodologically different tasks in Hayes-Harb (2006), the potential task type effects were eliminated. In line with Ryan and Meara (1991), Hayes-Harb (2006) also reported *differential* visual processing in the L1 Arabic L2 English group compared to the L1 Non-Arabic and L1 English groups.

While the factors outlined above (sample size, stimuli length), most likely contributed to the contradictory results, Hayes-Harb also allowed the possibility of *no* significant difference in consonant and vowel processing in intermediate L1 Arabic L2 English learners. This raises a question mark over the prevalence of vowel blindness in these intermediate L2 learners. Allmark (2022) noted that most of the studies on L2 word recognition in L1 Arabic L2 English learners were published prior to the more extensive research conducted on L1 Arabic vowels. For example, Abu-Rabia (1998) found that Arabic readers do pay attention to diacritics encoding short vowels in Arabic (for more detail, see 2.2.4). This has important implications for the vowel processing in L2 English and suggests that the phenomenon of vowel blindness in L1 Arabic L2 English learners requires a great deal of further investigation.

The unexpected results reported by Hayes-Harb (2006) were not followed-up in subsequent research until Alhazmi et al. (2019) administered an eye-tracking study investigating vowel blindness in higher-L2-proficiency L1 Arabic L2 English learners. They tested the number and the length of consonant and vowel fixations in these L2 learners and in L1 English readers.

As expected, the L1 English control group demonstrated fewer and shorter fixations. This suggests accessing the stimuli through the orthographic route which is faster and more efficient in English than employing the phonological route (e.g., Ryan & Meara, 1991; Taylor, 2008). Conversely, the L1 Arabic L2 English participants displayed longer dwell times and more fixations than the L1 English readers (for similar results, see Martin, 2011). Based on this, the authors concluded that L1 Arabic L2 English learners predominantly accessed the stimuli through the phonological route (letter-by-letter processing). This ties in with a large body of literature where L1 Arabic L2 learners were found to over-rely on the phonological route in L2 English word processing, which makes their reading slower and less efficient (Alhazmi & Milton, 2015; Fender, 2003; Koda, 1988; 1996; Masrai, 2021). However, most importantly, no evidence of superior processing of consonants in relation to vowels was found in this study which converges with the findings in Hayes-Harb (2006). This indicates that vowel blindness might not be prevalent in intermediate and higher-L2-proficiency L1 Arabic L2 English learners and again requires further investigation.

Although this study is considered methodologically more robust compared to other studies testing L2 word recognition in L1 Arabic L2 English learners (Allmark, 2022), there are some methodological shortcomings that need addressing. The authors pointed out that insufficient word familiarity was likely to have had a detrimental effect on the L2 word processing in their L1 Arabic L2 English participants as these were found to have a smaller L2 vocabulary size compared to other L2 learner groups (also see Ryan, 1993). The study provided no detail on the piloting the stimuli for word familiarity, which would have largely eliminated the unknown stimuli and increased the validity of the task. Processing unfamiliar stimuli could have also resulted in the predominant use of the phonological route, which was also demonstrated by more fixations compared to L1 English participants. The phonological processing route is employed for unknown words as they need to be parsed to be processed successfully. New words do not have lexical representations in the mental lexicon and therefore cannot be directly retrieved, which is required for the processing via the orthographic route (1.2).

Turning to word length, Alhazmi et al. (2019) employed [29]shorter words than Ryan and Meara (1991). As neither a word item list nor an item error analysis was provided, it is difficult to determine whether word length had an effect on the participants' responses. It would have been of interest to see whether word length served as a factor

[29] (*M*=6.72); Ryan and Meara (1991) employed 10-letter words.

in selecting a processing route. Lastly, a minor methodological concern related to the procedure also needs raising. The participants were asked to read the stimuli aloud, rather than silently to verify successful word recognition. The reading mode was found to affect processing in L1 Arabic (2.2.3) and might also have an effect on their L2 word processing. Administering silent reading in this study would have avoided any confounding task factors coming into play.

It is noteworthy the participants' L2 English proficiency level in their study was [30]higher than in most other studies testing L2 word recognition in L1 Arabic L2 English learners. Although their participants were assumed to have had more exposure to L2 print, they still used inefficient processing techniques, i.e., predominantly the phonological route, when processing words in English (for similar results in higher L2-proficiency L1 Arabic L2 English learners, see Randall & Meara, 1988).

Apart from the L2 word recognition studies, the spelling research has also contributed a valuable insight into how L1 Arabic L2 English learners process words in L2 English. Bowen (2011) analysed spelling errors in lower-proficiency L2 learners and found that the transposition of adjacent consonant/vowel letters (**viatl* for *vital*; **mboile* for *mobile*) to be one of the most frequent orthographic errors (Abu-Rabia & Sammour, 2013; Haggan, 1991). These findings demonstrate that both - consonants and vowel positions were recalled incorrectly. Hence, it would be worth investigating whether letter transposition occurs due to inaccurate word processing in the first place, i.e., prior to recalling the word.

In terms of the letters in isolation, Bowen (2011) also recorded twice as many vowel errors (89%) compared to consonant errors (43%) in their L1 Arabic L2 English participants, which supports difficulties in recalling vowels in these L2 English learners (also see Saigh and Schmitt (2012) below). It is noteworthy, however, that this study tested L1 Arabic L2 learners with [31]lower levels of L2 English proficiency. These learners were assumed to have received less exposure to L2 print, therefore their difficulties with vowel spelling might have been more pronounced compared to the higher-L2-proficiency learners. Arising from the findings from this study, the

[30] IELTS:6.0-8.0;CEFR:B2/C1

[31] For vowels blindness in *lower*-L2-proficiency L1 Arabic L2 English learners, see Alsadoon and Heift (2015).

pertinence of vowel blindness in learners of *higher* L2 proficiency also needs investigation by testing the consonant and vowel transposition effects on their L2 processing.

2.4.1.1 Key Research Focusing Exclusively on Vowels

After the original study by Ryan and Meara (1991), the majority of studies on L2 English word recognition in L1 Arabic L2 learners explored vowels and did not aim to challenge the concept of vowel blindness. Nevertheless, focusing exclusively on vowels allowed a more detailed investigation of vowel qualities (e.g., vowel length).

Saigh and Schmitt (2012) investigated the differences in vowel length processing in L1 Arabic L2 English learners. The participants were asked to locate misspelled words presented in sentences and to correct their spelling. Three separate conditions were employed by manipulating an equal number of *short* and *long* vowels (identical condition- e.g., *dinner*, deleted vowel condition -**conclsion* and a substituted vowel condition-**imprave*).

As expected, the results revealed lower accuracy rates in the word recognition task than in the spelling task as the latter requires a more complex process of retrieving consolidated word form representations (Burt & Tate, 2002; Abbott, Berninger, & Fayol, 2010). As expected, higher accuracy was found in [32]*long* vowels, which will be discussed below.

Firstly, overall lack of overt graphemic representation of short vowels in Arabic leads to difficulties processing short vowels in L2 English. Secondly, short vowels in English frequently fall on unstressed syllables. These frequently feature the schwa phoneme (/ə/) which has a multitude of grapheme mappings (*teacher*, *captain*). The graphemic representations create processing difficulties as the syllables containing /ə/ are mispronounced; an incorrect grapheme-phoneme link is stored and subsequently an erroneous word form is retrieved from the mental lexicon. Conversely, longer vowels tend to be more easily recognisable in English as they are frequently encoded by

[32] For similar results in testing long/short (tense/lax) diphthongs, see Al Juhani, 2015; Alzahrani, 2014.

digraphs and therefore visually more salient than shorter vowels (e.g., /ɪ/ and /i:/ in *increase*). Furthermore, Arabic distinguishes between short and long vowels and the latter are encoded in writing (2.2.1). This contributes to the vowel processing awareness and is expected to facilitate the processing of long vowels in English. Therefore, this further demonstrates the complexity of the concept of vowel blindness found in L1 Arabic L2 English learners.

Saigh and Schmitt (2012) also reported higher accuracy in the deleted than substituted vowel condition. These findings complement the results reported in Ryan and Meara (1991) as presenting fewer letters (**objctive*) is more visually salient and more easily detectable than substituting a letter (**imprave*). The authors also pointed out that the participants might have developed specific knowledge of consonant clusters resulting from vowel deletion (**complx*) which reduced the error rate. This seems likely as the words containing letter substitution (**imprave*) could not be compared against the target words (*improve*) in this experimental task. Conversely, in the [33]identity judgment task, two items are presented in quick succession for comparison. These results might also depend on the learners' L2 proficiency: As the L2 learners in Saigh and Schmitt (2012) were of high- and upper-intermediate proficiency (IELTS:4.5-5.5+;CEFR:B1+), they were expected to have been sufficiently exposed to L2 print to recognise errors containing [34]illegal consonant clusters in English (**complx)*.

While Saigh and Schmitt (2012) found higher accuracy in words containing consonant clusters, spelling difficulties containing consonant clusters have otherwise been widely reported in the spelling studies conducted on L1 Arabic L2 English learners (Bowen, 2011). For instance, vowel elision resulting in a consonant cluster (**complx*) is one of the most common errors in these L2 learners. Notably, this error type might also be more prevalent in *lower*-L2-proficiency learners (Bowen, 2011) compared to the L2 learners tested in Saigh and Schmitt (2012).

Some minor methodological weaknesses have been noted in this study. Firstly, the task was not administered in real time but had been assigned for homework. Despite explicit instruction given to participants not to consult dictionaries and suggesting a slot of 20-30 minutes, this is difficult to verify and might have resulted in higher accuracy rates.

[33] used in Hayes-Harb, 2006; Ryan & Meara, 1991; Ryan, 1993.
[34] letter sequences which break the phono-/ortho-tactic rules of English (**plx*)

Secondly, although the stimuli were controlled for familiarity and frequency, the stimuli length ranged from 4-letter to 13-letter stimuli (*ugly*; *responsibility*), yet word length effects were not taken into consideration in this study. Longer words might require longer processing times than shorter words in L2 learners (Kramer & McLean, 2019), which might have had an impact on how words were recognised and recalled in this study. Categorising stimuli based on their length (e.g., short vs long) would provide an additional insight into how L1 Arabic learners process words in L2 English (2.1.2.4).

Thirdly, in terms of the stimuli difficulty, vowel deletions in word-initial positions in several shorter words were expected to be easier to detect (*jmbo, *scret, *scond) due to the remaining consonant clusters. This converges with the results in Ryan and Meara (1991) where the fastest responses in their L1 Arabic L2 English learners were found in the vowel manipulations in the initial positions (2 and 4). However, as Saigh and Schmitt only tested vowels, it is not clear whether *consonant* manipulations in the word-initial positions would also be detected faster than in other word positions. Lastly, although the importance of word stress has been acknowledged in their study, a number of vowel deletions still fell on the stressed syllables (*automtic, *objctive, *expnsive), which was again expected to facilitate error detection. It would be of interest to see whether vowel manipulations in unstressed syllables attracted high error rate as these manipulations are overall considered more difficult to detect.

Alsadoon and Heift (2015) conducted one of the rare [35]longitudinal studies in L1 Arabic L2 English learners with lower L2 English proficiency levels by administering eye tracking method. Additionally, special training software was employed to help learners process vowels by visually enhancing them. Their stimuli manipulations featured letter substitutions rather than deletions and provided three items to select from (e.g., *wanter, winter, *wentir). The possibility of unknown target words was eliminated by testing its meaning ([36]translation into Arabic). The results comparing pre- and post-tests revealed a lower error rate in vowel recognition in the experimental group who had been exposed to the enhanced input training. These results were attributed to longer fixations on target words which suggests more in-depth processing of the vowels in

[35] For a longitudinal study testing higher-level L1 Arabic L2 English learners, see Taylor (2008). For a longitudinal study employing qualitative research methods in these L2 learners, see Keller (2020).

[36] Translation rarely features in L2 word recognition research (Al-Hazemi, 1993), as it tests vocabulary knowledge rather than word processing/recognition.

these words. Therefore, vowel blindness could be considered a transitional phenomenon, which improves through implementing specific intervention practice as well as with L2 proficiency and with more exposure to L2 print (Khan, 2013).

It is noteworthy that Alsadoon and Heift (2015) tested a group of L1 Arabic L2 English learners with the L2 proficiency levels ranging from beginners (IELTS:1.0-2.0;CEFR:A1) to lower-intermediate L2 learners (IELTS:4.0;CEFR:B1-). While the former were expected to have had little exposure to L2 print, the latter were expected to have had more of it. This implies large differences in the L2 processing accuracy and speed, which may have confounded the results. Therefore, drafting a more homogenous group in terms of the L2 proficiency level is of the essence as it increases the validity of the study.

2.4.1.2 Evidence from Studies Focusing on the Processing Routes and Letter Position in the context of Vowel Blindness

L1 Arabic L2 learners were found to have superior phonological processing skills (e.g., Brown & Haynes, 1985) and therefore tend to overuse the phonological route when processing words in L2 English. However, in order to be a fluent reader in English requires an extensive use of the orthographic route (e.g., Ehri, 1995).

While the research in L2 word processing in L1 Arabic L2 English learners strongly indicates over-reliance on the phonological route, spelling research in these L2 learners does not entirely support that. Abu-Rabia and Sammour (2013) found the majority of spelling errors in their Arabic participants to be phonological in nature only in L1 Arabic, while in L2 English these were reported to be semi-phonological, i.e., retaining some orthographic features as well, such as letter transposition. Similarly, Bowen (2011) found almost double the spelling errors in their L1 Arabic L2 English learners to be orthographic (37%) (e.g., **sikills* for *skills*) rather than phonological (17%) (**deleshous* for *delicious*).

Letter position research also provides a valuable insight into the word processing patterns. For instance, as mentioned earlier, Ryan and Meara (1991) found superior vowel letter processing at the beginning of long words in their L1 Arabic L2 English participants which suggests the use of the phonological, letter-by-letter processing route. However, they also found a different vowel processing pattern in the word-final positions compared to the other groups. This might suggest consonant extrapolation or an attempt to process a word right-to-left, rather than left-to-right processing (see the beginning of the section 2.4.1).

As evidence regarding the preferential processing route in these L2 learners is more fragmented than previously assumed, it requires further investigation.

2.4.1.3 Evidence from Studies focusing on Word Length in the Context of Vowel Blindness

Word length is a word property that has not been extensively investigated in the L1 and L2 visual word processing research. With regard to the L2 word recognition and recall in L1 Arabic L2 English learners, Fender (2008) is one the rare studies that included this word property in their analysis within the context of vowel processing in these L2 learners.

Fender (2008) tested a group of L1 Arabic L2 English learners (N=16) and a group of proficiency-matched Non-Arabic L2 learners (N=26) on their listening, spelling and reading comprehension (IELTS:5.5;CEFR:B1+). While their listening skills were found to be comparable, L1 Arabic L2 English learners, as expected, attained a significantly higher error rate in the spelling and reading tasks (also see Thompson-Panos & Thomas-Ružić, 1983). In the spelling task, L1 Arabic L2 English learners overall performed well with vowels, which indicates that vowel blindness might not be as pertinent in intermediate and higher L2-proficiency level L1 Arabic L2 English learners. As expected, these learners demonstrated more difficulties with more complex and less frequent vowel grapheme-phoneme correspondences (e.g., [37]*flew, shout)*.

Regarding word length, they performed well in shorter, monosyllabic words which contained short and long vowels. Conversely, a higher error rate was recorded in longer, polysyllabic words (e.g., *customer, bottle, success*). These findings were tested in a spelling task, however, it is not clear whether shorter, monosyllabic words would also yield lower error rate compared to longer, polysyllabic words in the processing stage.

[37] /u:/ mapping onto <ew> and /aʊ/ mapping onto <ou>

Furthermore, Fender (2008) addressed the performance regarding the vowel accuracy in their L1 Arabic L2 English participants only in their analysis. Therefore, controlling the stimuli for vowel qualities more systematically with regard to word length, and administering a more detailed item error analysis would provide a valuable insight into the complex nature of the vowel blindness phenomenon.

Another avenue exploring word length effects in L1 Arabic L2 English learners came from the L2 vocabulary acquisition research. However, these studies did not explore the potential vowel processing difficulties in connection with word length. Alsaif and Milton (2012), and Masrai and Milton (2015) investigated the effect of word length on acquiring new vocabulary in these L2 learners. They conducted [38]correlations and multiple regression analyses testing the effect of word length on the participants' responses.

Alsaif and Milton (2012) found moderate effects of word length on L2 word acquisition in L1 Arabic L2 English learners. In the first analysis, word length alone demonstrated 36% of the variance in scores compared to other variables and a medium correlation ($r = -.599$); longer words were more difficult to acquire than shorter words. Conversely, Masrai and Milton (2015) did not find significant word length effects in their study, however, a weak correlation was reported between word length and the participants' responses ($r = -.357$). They attributed the inconclusive results to shorter stimuli employed compared to the stimuli found in Alsaif and Milton (2012), and confirmed that shorter words (1 to 3 syllables) might be easier to acquire than longer words. It would be of interest to see whether controlling for vowels had a significant effect when processing shorter and longer words in L1 Arabic L2 English learners and whether differential processing routes were employed depending on word length.

As these studies tested L2 vocabulary acquisition, translation was employed to test their knowledge of the stimuli. It would be interest to see whether word length effects were also found when administering L2 word processing tasks, e.g., a word matching or

[38] Other word properties were also included, e.g., repetition, concreteness, translation equivalence, part of speech.

identity judgment task, which test recognising L2 word form rather than L2 vocabulary knowledge.

2.5 Rationale for the Present Study

The literature review chapter has critically examined the relevant studies in the area of L2 visual word recognition in L1 Arabic L2 English learners over the last 30 years and a gradual progress that has been achieved in understanding how this learner group recognise words in L2 English. L1 Arabic L2 English learners have specific difficulties with word recognition in L2 English. These are characterised by inaccurate processing particularly in relation to vowels. This processing phenomenon is frequently referred to as *vowel blindness* in the literature.

The majority of the studies presented in the literature review assumed vowel blindness to be a deciding factor in causing difficulties in L2 word recognition in L1 Arabic L2 English learners. However, this phenomenon has recently started accumulating criticism due to a lack of systematic research, which points towards issues regarding its validity (Allmark, 2022). After consonant manipulations were gradually introduced alongside vowel manipulations to test vowel blindness, mixed results started emerging; consonant manipulations did not necessarily yield more accurate and faster responses in intermediate and [39]higher-L2 proficiency L1 Arabic L2 English learners (Alhazmi et al., 2019; Hayes-Harb, 2006). This poses a question mark over the prominence of vowel blindness phenomenon typically associated with the L2 processing difficulties found in L1 Arabic L2 English learners.

The literature review has demonstrated that vowel blindness in L1 Arabic L2 English learners requires more research for several other reasons. Firstly, these L2 learners were found to typically over-rely on the phonological route when processing words in English (Brown & Haynes, 1985). This suggests letter-by-letter processing where consonants and vowels are equally processed, i.e., in a linear manner. Conversely, vowel blindness postulates incomplete orthographic processing in English where consonants are accurately processed while vowels tend to be processed superficially.

[39] IELTS:6.0-7.0;CEFR:B2+

This would signify non-linear processing by employing L1 Arabic processing techniques of consonant root extrapolation. Secondly, L1 Arabic readers have been found to demonstrate sensitivity not only towards long vowels (encoded in L1 Arabic), but also towards short vowels (normally represented by diacritics; 2.2.3). Therefore, L1 Arabic L2 English learners are likely to demonstrate more vowel awareness in L2 English than previously assumed. Finally, consonants are universally considered to be more salient than vowels (New et al., 2008; see 2.1.1.3), therefore the prominence of consonants over vowels in word processing is not specific to L1 Arabic.

The literature reviewed has also demonstrated that this phenomenon tends to be more pronounced in the L2 learners of lower L2 proficiency (Alsadoon & Heift, 2015; Bowen, 2012) typically due to insufficient exposure to L2 print. Intermediate learners were selected for this study as they are at a transitory stage of L2 learning, i.e., they are assumed to have had more exposure to L2 print than lower L2 proficiency learners but less than higher L2 proficiency learners. Therefore, they are expected to have adopted linear processing of consonants and vowels, rather than employing consonant extrapolation when processing L2 words in English. Based on this, this study aimed to investigate whether vowel blindness is still as prevalent in intermediate L1 Arabic L2 English learners and the principal cause for their L2 word processing difficulties.

This study also aimed to go beyond this phenomenon by exploring other factors which might have a decisive impact on how these L2 learners process words in English. One of the largely unexplored word properties in L2 word processing in L1 Arabic L2 English learners is word length and its potential effects on the vowel blindness phenomenon (2.4.2.3). Word length is of specific importance for these L2 learners as Arabic words tend to be shorter compared to words in English (2.2.3), which might have an effect of their L2 processing. Processing longer L2 words might add to the processing load and might trigger a differential processing route to the processing of shorter words. In this vein, the Auditory-Visual Word Matching Task (4.1) tested the effects of vowel blindness on L2 word recognition in intermediate L1 Arabic L2 English learners in phonologically- and orthographically-matched shorter and longer words.

Apart from word length effects, the impact of letter position on L2 processing in L1 Arabic L2 English learners had also been largely underexplored. This word recognition factor was investigated through letter transposition in this study.

Letter transposition was found to be one of the most frequent spelling errors in L1 Arabic L2 English learners (Bowen, 2011). This study aimed to investigate whether letter transposition effects already occur in the processing stage, and thus cause subsequent errors in recall. Based on the literature reviewed, both letter types (consonants and vowels) were employed to test letter transposition, and the impact of vowel blindness in different word positions in these L2 learners. See 5.1 for the Letter Transposition Task.

The investigation of the letter position is also of great importance as it can confirm the preferential processing route employed (e.g., the potential overreliance of the phonological route over the orthographic route in these L2 learners). A conclusion could be drawn from the literature review that there is a complex interplay between the use of the phonological and orthographic processing routes in both, English and Arabic (see 1.2; 2.3; 2.2.4). This is amplified by the fact that the processing via the orthographic route differs between the two L1s. Arabic has a regular and a consistent orthography, which requires the processing via the phonological route. However, in order for the L1 readers to access a word in Arabic, the use the orthographic, (whole-word) route to extrapolate the consonant root is also of the essence (non-linear processing). English has irregular orthography and therefore requires the predominant use of the orthographic route. However, in contrast to Arabic, English encodes all the letters and requires linear processing. Therefore, the use of the orthographic routes in the two languages differs, which, in turn, has complex implications on how L1 Arabic learners access words in L2 English. This was addressed in this study as well via exploring the word length and letter position effects in L2 word processing in these L2 learners.

2.5.1 Methodological Gaps and Planned Methodological Enhancements

Through the analysis and consideration of the relevant research literature, there are several methodological limitations that have been identified. These mainly include stimuli control, task design, participant sizes and the selection characteristics of the participants employed in the study.

Regarding the participants, the studies investigating L2 English word recognition in L1 Arabic L2 English learners began with small numbers (e.g., N=10 in Ryan & Meara, 1991) but have started garnering somewhat larger sample sizes only relatively recently. This study included a larger number of participants to ensure sufficient statistical power is achieved. Furthermore, instead of conducting a comparative study with other L2 English learner groups (e.g., Ryan & Meara, 1991), this study only focused on the L1 Arabic L2 English learners. This approach enabled investigating the performance in this L2 English group in greater depth, following the trends in the most recent research testing L1 Arabic L2 English learners (e.g., Alhazmi et al., 2019). Secondly, while some studies presented in the literature review tested learners with a range of L2 proficiencies, this study tested L2 proficiency range only within the intermediate L2 proficiency level (IELTS:4.0-6.0; CEFR:B1/B2).

A number of [40]studies did not report detailed information regarding their participants' L2 proficiency level as well as other methodological detail, such as L1 background; instruments employed, etc. In addition, these studies employed different means of assessment of L2 proficiency (e.g., self-assessment; reading/writing/spelling pre-test; L2 English exam scores). As it is externally validated and therefore widely considered one of the most reliable tools for assessing L2 proficiency, IELTS exam scores were provided to validate the intermediate L2 level requirements set by this study. This was accompanied by other background information on the participants, obtained via a detailed background questionnaire (3.3). All the participants in this study were from Saudi Arabia (not from other L1 Arabic backgrounds), which also added to the homogeneity of the tested L2 group.

In a number of studies, the *stimuli* have not been found to be thoroughly controlled and word properties, such as word length as well as frequency/familiarity not sufficiently specified (e.g., Alhazmi et al., 2019). This study attempted to rectify this by specifying this detail in both experimental tasks. Secondly, the stimuli administered in the key studies outlined above were frequently not piloted. This study tested stimuli for

[40] Martin, 2017; Milton & Hopkins, 2006; Ryan & Meara, 1991; Stein, 2010; Taylor, 2008.

familiarity beforehand, which is especially vital for L1 Arabic L2 English learners as this L2 group frequently demonstrate a smaller L2 vocabulary size than other L2 English learners (e.g., Coderre & Van Heuven, 2014). For the findings of the L2 vocabulary size baseline test conducted on the L1 Arabic L2 English participants, see 3.3.1.1.

Regarding the task types, testing words in isolation was selected in this study rather than employing contextualised tasks. These were not selected due to their facilitative effects on the L2 word recognition (Ryan, 1993; Shillaw, 1996) as well as dependence on word familiarity. Silent reading tasks were selected due reading aloud/oral task effects found in processing L1 Arabic (2.2.3)

Both experimental tasks in this study tested processing accuracy. The Letter Transposition Task also tested response times (Hayes-Harb, 2006; Ryan & Meara, 1991), otherwise a noticeably absent measurement tool in L2 psycholinguistic research (Jiang, 2011). Reporting response times is considered of great importance as to become a fluent reader, words not only require accurate but also automatised word processing. This study also featured detailed item error analyses, which equally do not commonly feature in L2 psycholinguistic studies (McDowell, 2011). Error analyses by item further helped pinpoint difficulties in L2 word processing in these L2 learners, which is believed to be more complex than previously believed and goes beyond the notion of vowel blindness.

For the methodological enhancements regarding the stimuli in this study, see the *Rationale for the Stimuli Employed* (4.1.1.2 and 5.1.1.2). For more detail on methodology, see Chapter 3.

2.6 Research Questions to be Addressed regarding L2 Visual Word Processing in L1 Arabic L2 English Learners – Beyond Vowel Blindness

Based on the critique of the core literature and the gaps identified (see 2.5.1) - the *general research questions* posed in the present study were as follows:

1. How can the data in this study inform our understanding of the nature of L2 visual word processing in intermediate L1 Arabic L2 English? Is *vowel blindness* still the pertinent factor in L2 word recognition difficulties typically found in *intermediate* L1 Arabic L2 learners of English? Can this phenomenon account for the specific L2 word recognition difficulties found in these L2 learners?

2. Are L2 words in these intermediate L2 learners primarily conducted through the process of consonant extrapolation (non-linear processing), which implies the use of the orthographic route, through the phonological route (linear processing) or through the use of both routes?

3. Do *word length* and *letter position* have an effect on how L2 words are processed in L1 Arabic L2 English learners (and do these inform the use of the phonological or orthographic route)?

2.7 Chapter Summary

This chapter provided a review of the literature which addresses the research area of word processing and word recognition. First, this area was presented in relation to L1 English. The principal computational reading models predicting word recognition were presented. This was followed by identifying the main word properties as crucial factors which have an impact on word recognition. Next, English orthography was presented. Subsequent to word recognition in L1 English, word recognition in Semitic languages was addressed including Arabic orthography, the computational reading models employed in Semitic languages, and the word properties in L1 Arabic. In the second part, word recognition in *L2* English was outlined before presenting key L2 word recognition research in L1 Arabic L2 English learners with the emphasis on vowel blindness. Finally, the rationale for the present study was presented including methodological gaps and methodological enhancements prior to outlining the research questions.

The following chapter will provide the methodological overview of the current research.

Chapter 3: Methodology

This chapter will provide the overall methodology employed in the experimental tasks in this study. The pilot studies conducted will be presented prior to the main experimental tasks. Subsequently, the questionnaire administered to the L1 Arabic L2 English participants will be presented before discussing its results alongside the results from the L2 Vocabulary Size Test. Next, methods concerning the data analysis will be elaborated on as part of the research design, before outlining the testing procedures employed in this study.

3.1 Pilot Studies

Two experimental tasks were piloted in 2 stages on 2 different sets of participants. None of these participants took part in the main experimental task.

The Letter Transposition Task administered in this study was based on an earlier, letter *deletion* study which I conducted as part of my Master's degree. This study was based on a paper by Ryan and Meara (1991) who also provided the stimuli in their target form. The results revealed that the L1 Arabic L2 English group were outperformed by the L1 Non-Arabic L2 English group; the L1 Arabic L2 English learners performed better in the deleted consonant stimuli than deleted vowel stimuli. This was expected due to the vowel blindness phenomenon typically found in these L2 learners. For more detail, see the *Pilot Study* in 5.1.1.2.

As some of the most typical spelling errors in L1 Arabic L2 English learners entail letter transpositions (Bowen, 2011), it was of interest to see whether this L2 learner group already had demonstrated difficulties detecting transposed letters in the processing stage. In the first piloting stage, the stimuli provided by Ryan and Meara were manipulated by transposing adjacent consonant and vowel letters (e.g., *difficulty* -**difficutly*). These stimuli were subsequently piloted on experienced English language teachers (N=10) to determine the task demand.

In the second piloting stage, the stimuli in The Auditory-Visual Word Matching Task were piloted on 8 experienced English language teachers for familiarity to intermediate

L2 English learners. Subsequently, the task was piloted on a group of L2 English learners (N=7). The entire task including the stimuli were piloted as these were designed by me and had not been administered beforehand. In this way the pilot demonstrated that the task was suitable for L2 learners and its demand was not too high. This task was initially designed to test L1 Arabic as well as L1 Non-Arabic L2 English learners. It was piloted on the L1 *Non*-Arabic L2 learner group due to the availability of these participants (see 7.3 for *Limitations*).

3.2 The Main Experimental Tasks

The experimental part of this study consists of 2 forced-choice tasks; i.e., the Auditory-Visual Word Matching Task and the Letter Transposition Task. For more methodological detail on each of the experimental tasks, see 4.1.1 and 5.1.1.

3.2.1 Presentation of the Experimental Tasks

The experimental tasks will be presented in the subsequent 2 chapters testing the impact of vowel blindness on L2 word recognition in intermediate L1 Arabic L2 English learners. In chapter 4, the Auditory-Visual Word Matching Task investigated the effect of this phenomenon in shorter and longer words. In chapter 5, the Letter Transposition Task tested the effect of vowel blindness by employing adjacent vowel and consonant letter transpositions in different word positions (e.g., *difficulty -*difficutly; parliament-* **parlaiment*).

The *Methodology* sections in Chapter 4 and Chapter 5 will first present the *Rationale for Employing the Experimental Tasks* before presenting the *Materials* and *Testing Procedures*; the *Hypotheses* and *Analytical Procedures* will precede the presentation of the results. The *Results* section in Chapters 4 and 5 will be presented in the following manner: First, the overall results will be outlined and afterwards presented in greater depth. Subsequently, the *Item Error Analysis* will be provided. The *Results* section will be followed by the *Discussion* section. In Chapter 6, the results from both experimental tasks will be synthesised and discussed in greater detail.

To access the stimuli for the experimental tasks, see *Appendix* B.

3.3 Questionnaire on Participant Variables

A background questionnaire was administered in the form of a semi-structured interview at the beginning of the session. The aim of the questionnaire was to collect the information on various participant variables and test the suitability of the L1 Arabic L2 English learners to participate in this study. The first part focused on the participants' gender, age, length of stay in the UK and participant background details for L2 English (education history). The second part focused on the participants' L1 and L2 literacy practices. The details on these participant variables are presented below.

The questionnaire aimed to identify the participants who did not meet the inclusion criteria, e.g., that none of the participants lived in any other countries apart from the UK at the moment of testing (confirming none of them were part of a mainstream education that uses the Roman alphabet) as well as that none of them had learnt any other L2s apart from English. The second part of the questionnaire aimed to collect information on the participants' L1/L2 reading experiences. The participants were asked to evaluate how much they read in Arabic and English on a 5-point scale (*1. very often 2. often 3. sometimes 4. almost never 5. never*) in L1 Arabic and L2 English. This information was considered of great importance as L1 reading habits and exposure to print have a major influence on L2 reading habits (e.g., Alderson, 1984) and consequently on L2 word recognition, and may vary greatly between individuals (for more detail, see 3.3.1). Lastly, the participants were also asked to report any known educational or reading impairments.

Based on the results of the questionnaire, none of the tested learners were eliminated from the study.

3.3.1 Participants

In total, 26 Saudi Arabian L2 English learners from an [41]English language college in London were recruited to participate in this study (16 female and 10 male participants). I taught English to most of the participants at the college.

All the participants were between the ages of 18 and 44 (*M*=24.56; *SD*=8.42). All had been studying English in Saudi Arabia and had recently travelled to the UK; none reported studying any other L2s. The majority of the participants started learning English in primary school between the ages of 9 and 14 as part of the [42]mainstream education whereas a smaller number of participants started learning English at the age of 6, as an extra-curricular activity (*M*=10.68, *SD*=3.36). Prior to the testing session, these L2 learners reported learning English between [43]3 and 18 years with intermittent gaps (*M*=9.8; *SD*=4.17). Regarding the exposure to English in an English-speaking country, the participants had been in the UK prior to the testing between 2 months and 13 months. Only 2 participants reported spending a longer period of time in the UK, i.e., 2 years (*M=8; SD=5.7*). The participants' stay in the UK predominantly overlapped with the same period of time receiving instruction in English in the UK.

In terms of the education level, more than half of the participants already held a university degree from Saudi Arabia (14 out of 26 (53.8%)) prior to this study and were planning to enrol on a Master's programme in the UK, while 1 participant was planning to apply for a place on a PhD course in the UK. The remainder of the participants (12 out of 26 (46.1%)) had finished secondary school in Saudi Arabia and were planning to pursue their undergraduate university studies in the UK. They all reported receiving reading and writing instruction simultaneously with speaking and listening activities in their English classes in school in Saudi Arabia.

[41] An institution where English courses are provided to students aged 18+ whose L1 is not English. Learners attend different classes based on their L2 English proficiency level (see *Appendix* A) in order to access graduate and post-graduate education in an English-speaking country or to improve their career prospects. The learners participating in this study attended mid-length courses (1-6 months) or long courses (up to one year).

[42] Saudi students start learning English as part of the mainstream education in the 4th grade, at the age of 9 (Alasmi, 2016).

With regard to determining their level of L2 English proficiency, all the participants in this study were required to have taken the [44]IELTS exam before being enrolled. Only the learners who scored overall in the intermediate range (between 3.0 and 6.0 on the IELTS scale) were included as participants in this study. Their [45]overall IELTS score was approaching level 5.0 (standard intermediate) with small individual differences in score across the group (*M*=4.58; *SD*=0.73). This means that the majority of participants were between the low-intermediate (IELTS:4.0;CEFR:B1) and intermediate (IELTS:5.0;CEFR:B1) levels. The overall IELTS scores can be interpreted as an average between reading/writing scores and speaking/listening scores. The former scores tend to be typically lower in L1 Arabic L2 English learners compared to their speaking/listening scores (e.g., Thompson-Panos & Thomas-Ružić, 1983). For more detail, see 3.4.1.1.

Turning to L1/L2 literacy, the participants were all fully literate in Modern Standard Arabic (MSA). When asked to evaluate how much they read in Arabic and English, the results demonstrated they read more in Arabic than in English. To illustrate, while 6 out of 26 of them (23%) stated they *very frequently* read in Arabic, 10 out of 26 (38%) said they *often* read in English. Conversely, 9 out of 26 (35%) of them reported they *almost never* or *never* read in English. Lesser exposure to L2 print is expected at lower levels of L2 proficiency while the exposure to print is assumed to increase with the L2 proficiency (Alderson, 1984). Nevertheless, the questionnaire results demonstrated that more than one third of the participants almost never read in English despite residing in the UK when the testing was undertaken. Such low exposure to print is expected to lead to poor L2 word recognition in these L1 Arabic L2 English participants and converges with the literature on low exposure to print in these L2 learners in general. This can be attributed to a large orthographic L1-L2 distance

[44] *International English Language Testing System* is an internationally recognised test measuring English proficiency. For the scoring system, see *Appendix* A.

[45] The *overall* scores were considered in this study as only 14 IELTS reading/writing scores were retrieved (N=26). The available mean reading/writing scores were lower than their overall IELTS scores. The participants' mean reading score was higher than their mean writing score (*M*=4.26; *SD*=0.67; *M*=3.92; *SD*=0.73).

between L1 Arabic and L2 English (2.3) as well as to educational differences between the home and Anglophone countries (Al-Mahrooqi & Denman, 2016).

Regarding the inclusion/exclusion criteria, none of the participants reported to have any known educational or reading impairments and consistently achieved satisfactory results in their academic studies.

3.3.1.1 L2 Vocabulary Size

Exposure to L2 print also has an impact on L2 vocabulary size, which is a crucial factor in successful L2 word recognition (1.2.1). L1 Arabic L2 English learners are frequently found to have a smaller L2 vocabulary size compared to other L2 English learner groups (e.g., Coderre & Van Heuven, 2014). Therefore, the X-Lex Test measuring L2 vocabulary size was conducted as a baseline test to investigate whether a potentially smaller L2 vocabulary size is a contributing factor in L2 word recognition difficulties typically found in L1 Arabic L2 English learners.

The results of the X-Lex Test revealed that this group of L1 Arabic L2 English learners have an L2 vocabulary size of approximately 2,500 words in English (M = 2527.27, SD = 3.15). This is more than a threshold of 2,000 words required for baseline reading comprehension and basic L2 oral communication (McCarthy, 2006). According to the assessment provided by Meara and Milton (2003), this score is comparable with the L2 vocabulary size typically found in L2 *pre*-intermediate/*lower*-intermediate learners (IELTS:3.0-4.5;CEFR:A2/B1-).

Overall, the L2 vocabulary size in the tested L1 Arabic L2 English learners was assessed to be broadly intermediate. However, the L2 vocabulary size demonstrated by the tested participants was still expected to have some detrimental effects on their performance. For instance, they might not have been familiar with some of the [46]lower-frequency words employed in this study.

Overall, smaller L2 vocabulary size was expected to be found in the tested participants due to poor L2 reading habits reported in the questionnaire (3.3).

[46] See *Stimuli constraints* in 4.1.1.2 for the lower-frequency stimuli employed in the Auditory-Visual Word Matching Task.

3.4 Research Design

This study followed the quantitative approach of analysing the data and employed the within-subjects design, i.e., all the participants in this study - representing only one group - were tested with the same stimuli. In the Letter Transposition Task, the *L2 proficiency* was used as a between-subjects factor; i.e., the participants were divided into higher-intermediate and lower-intermediate L2 proficiency learner groups. For more detail, see *Analysis* in 5.1.1.3.

For methodological enhancements arising from the literature review, see 2.5.1.

3.4.1 Data Analysis

In both experimental tasks inferential statistical methods were employed to obtain the group error rates (analysis by participant). The Letter Transposition Task also measured response times. For parametric and non-parametric tests employed in this study, see the *Analysis* sections in 4.1.1.3 and 5.1.1.3.

Both experimental tasks also included an in-depth item error analysis employing the [47]descriptive statistical method. A detailed analysis by item was conducted as a complementary analysis to the analysis by participant to provide an additional insight into the L2 processing difficulties found in L1 Arabic L2 English learners. As this study investigated the prominence of the vowel blindness phenomenon, the item error analyses predominantly focused on [48]vowels. However, the analyses also included the processing of [49]consonants as these were also considered vital in testing this processing phenomenon in greater depth (2.5).

[47] Descriptive statistics focuses on summarising the key features of a dataset and is focused on stating facts. Conversely, inferential statistics makes generalisations about a larger population based on a representative sample of that population. It focuses on making predictions in the form of probability.

[48] For the Auditory-Visual Word Matching Task, see 4.1.2.1; for The Letter Transposition Task, see VV transposition in 5.1.2.2.

[49] For the Auditory-Visual Word Matching Task, see consonant sequences in 4.1.2.1; for the Letter Transposition Task, see CC transposition in 5.1.2.2.

Imposing time restrictions and/or measuring response times was considered of importance in this study as the automaticity of responses is another crucial factor in successful word recognition. Time restrictions were imposed in the Auditory-Visual Word Matching Task, i.e., a cut-off point was presented between the target stimuli, however, response times were not measured in this task. Conversely, as time restrictions were not imposed in the Letter Transposition Task, response times were measured.

3.4.1.1 L2 English Proficiency and Individual Variability in Performance

In terms of the data analysis, *L2 English proficiency* and individual variability in performance require specific attention in this study.

L2 English Proficiency, as an independent variable, was measured on the IELTS and CEFR scales (see *Appendix* A). The participants were recruited based on having attained an overall *intermediate* score in the IELTS test (3.3.1). Furthermore, both experimental tasks attempted to verify any potential variation within the intermediate L2 proficiency in the drafted participant pool (IELTS:3.0-6.0;CEFR:A2-B2) which might have had an effect on the participants' performance. In order to monitor for this, the participants were divided into 2 groups in the Letter Transposition Task: lower-intermediate and higher-intermediate. Subsequently, exploratory data analyses were conducted: In the Letter Transposition Task a Spearman's Rank Correlation Coefficient was conducted to examine the relationship between L2 proficiency and error rate in the Same/Different conditions (see Analysis in 5.1.1.3; 5.1.2.1). In the same vein, the Pearson Correlation Coefficient was also measured to examine a relationship between L2 proficiency and error rate in the Auditory-Visual Word Matching Task (4.1.2).

Testing for this was of importance not only regarding potentially significant differences in reading skills between lower-intermediate and higher intermediate L2 learners but also due to high individual differences in performance that might not be necessarily related to the L2 proficiency level. The latter was found in previous studies testing L2 word recognition in L1 Arabic L2 English learners (Ryan & Meara, 1991; Ryan, 1993).

Due to time constraints, a more homogenous group within the intermediate L2 proficiency could not be recruited (see 7.3 for *Limitations*).

Turning to more detail with regard to measuring L2 proficiency, the overall IELTS scores included the scores from all 4 skills, i.e., speaking/listening/reading/writing rather than reading and writing only, which would be a more accurate measurement of the participants' L2 word processing skills. With regard to the L2 reading and writing difficulties found in L1 Arabic L2 English learners, some of the overall IELTS scores in this study were expected to be higher than their reading and writing scores as they include speaking and listening, i.e., areas L1 Arabic L2 English learners are typically stronger in (Thompson-Panos & Thomas-Ružić, 1983).

To rectify this, a baseline X-Lex Vocabulary Size Test was selected as it was found to correlate strongly with reading and writing skills as well as with IELTS reading and writing scores (Alhazmi & Milton, 2015). The results obtained in this study demonstrated a L2 vocabulary size in the tested participants on a par with the L2 vocabulary size typically found in L2 learners of *lower*-intermediate L2 proficiency. However, the L2 vocabulary size in this study still exceeds the vocabulary knowledge required for baseline reading comprehension in English. Therefore, the tested L1 Arabic L2 English participants were considered to have broadly intermediate reading and writing skills as well, without taking their speaking and listening into account (for more detail, see 3.3.1.1).

3.4.2 Testing Procedure

As part of the materials and testing procedure, The Auditory-Visual Word Matching Task was administered as a pencil-and-paper task on an A4 sheet while The Letter Transposition Task was administered on the communal PCs at the college.

The participants were tested either individually or in smaller groups after the official school hours in a quiet classroom; [50]the whole session lasted for approximately 30

[50] Initially, 5 experimental tasks were administered testing L2 vocabulary size, orthographic awareness and orthographic/phonological processing. As these tasks were too broad in scope and not

minutes. No feedback was voluntary and unpaid. The protocol for this study received approval according to the Ethics procedures set out by the Birkbeck College, University of London. I approached the potential participants, explained the purpose of the study and outlined the procedure. If the participants accepted to take part in the study, a signed document of consent was obtained. In order to invite the potential participants to this study, the following text was devised and handed in (Invitation to this study):

> You're invited to take part in a university study which will be done by Emina, one of the teachers in our school. She's doing this research to try to understand better how Arabic students *read and write words* in *English*. As a result of the research, teachers can help Arabic students to improve their reading and their spelling in English.

Informed consent from all the participants was obtained (see *Appendix* D).

3.4 Chapter Summary

This chapter provided the overall methodology employed in this study. First, the pilot studies were introduced prior to presenting the experimental tasks. Subsequently, the questionnaire administered and its results were discussed before describing the participants recruited for this study and discussing the results acquired from the L2 Vocabulary Size X-Lex Test. Next, the research design was outlined including the methods employed for the data analysis and the testing procedure employed in this study.

The subsequent chapter will present the first experimental task (Auditory-Visual Word Matching Task) which measured the effects of vowel blindness on L2 word recognition in shorter and longer words in intermediate L1 Arabic L2 English learners.

directly related to testing vowel blindness, they were eliminated from this study. The Auditory-Visual Word Matching Task and the Letter Transposition Task were administered within approximately 20-25 minutes while the whole session (including the other 3 experiments) lasted for approximately 1 hour.

Chapter 4: The Impact of Vowel Blindness on L2 Word Recognition in L1 Arabic L2 English learners with Reference to Word Length

This chapter will introduce the first experimental task in this study (Auditory-Visual Word Matching Task) investigating the vowel blindness effects on L2 word recognition in intermediate L1 Arabic L2 English learners. The L2 word processing will be tested in shorter and longer orthographically and phonologically-matched stimuli.

4.1 Auditory-Visual Word Matching Task

In this section, the methodology is detailed to present the rationale for the test employed. The rationale for the stimuli employed and the constraints attached to those will be laid out. The next section will outline the materials including the pilot study and the testing procedure. Subsequently, the hypotheses and the analytical procedures will be provided before presenting the results and a detailed item error analysis. Finally, the results obtained in this task will be discussed.

4.1.1 Methodology

4.1.1.1 Rationale for the Test Employed

As an L2 word processing phenomenon in L1 Arabic L2 English learners, vowel blindness has received a considerable amount of attention. This term is employed to provide a partial account for the unusual errors produced by this L2 learner group characterised by specific types of word confusion (e.g., *century* for *country*). A more detailed error analysis reveals that the consonant sequence is preserved while vowels seem to be arbitrarily assigned. Word confusion in L1 Arabic L2 English learners can be either based on orthographic similarity (*subtle-subtitle*) or on phonological similarity (*basket-biscuit*) (Al-Sulaimani, 1990). Both of these aspects were examined in this experimental task. These errors are frequently found in spelling in these L2 learners (Bowen, 2011), however, it is not clear whether they already occur in the processing stage.

The literature on vowel blindness suggests that this phenomenon is more pronounced in lower levels of L2 English proficiency (e.g., Khan, 2013), however, L2 word recognition difficulties can still be found in intermediate and even higher L2 proficiency L1 Arabic L2 English learners. This experimental task was designed to test the effects of inaccurate vowel processing in intermediate L2 learners. This experimental task investigated whether these reading difficulties persist predominantly due to this phenomenon, which postulates non-linear processing (consonant extrapolation) or whether there are other factors at play. In this vein, word length was identified as an under-researched and yet a very important word property to understand how L2 words in English are processed in non-fluent L2 English readers. Word length was also selected as it was expected to contribute to a processing route selected (orthographic or phonological). Additionally, a comprehensive item error analysis helped reveal prevalent factors in inhibiting L2 word recognition in these learners.

The Auditory-Visual Word Matching Task in this study was inspired by [51]Ryan (1993) with some modifications, particularly regarding the stimuli selection and task design. Their study employed phonologically-matched and semantically-related words, which were presented in sentences: *'I'm sorry I couldn't eat anymore. I'm ………'.* The participants were asked to select between 4 options to complete the gapped sentence: *a) fed up b) full up c) filled up d) satisfactory* (Ryan, 1993, p.100). As the sentences were read out, the author remarked the semantic foils were redundant. Moreover, as some participants selected those foils, it signals the task was misunderstood and was therefore considered methodologically flawed. Secondly, due to stimuli design constraints, Ryan (1993) reported employing some lower-frequency items (not likely to be familiar to intermediate L2 learners), which were likely to have had a detrimental effect on their performance. For more detail on this study, see 2.4.1.

Based on the limitations of the original study, the following methodological enhancements were adopted in the present study. Firstly, orthographically-matched items were added as the knowledge of orthographic patterns is one of the vital aspects of successful word recognition (2.1.2.2) while semantically-related items were excluded. Secondly, the stimuli were presented in isolation rather than embedded in

[51] Three consecutive experimental tasks were conducted. Each task was an iteration of the previous task. Two L2 intermediate groups (L1 Arabic; L1 Non-Arabic) were tested in the ultimate experiment presented here. There were 22 participants in each group (N=44).

sentences, and the target item was read out. By not employing [52]contextualised and semantically-related word items, the word familiarity was not a prerequisite; the participants' performance was not dependent on the word-frequency, their L2 vocabulary size or L2 proficiency level per se.

4.1.1.2 Materials and Testing Procedure

Rationale for the Stimuli Employed

Regarding the stimuli in this task, I had previously collected a list of examples of oral and written word confusion produced by L1 Arabic L2 English learners. These words were used as the basis for designing the stimuli for this experimental task. The stimuli were not only designed to adhere to the same or matched consonant skeleton criteria but were carefully controlled for a number of other variables outlined below (e.g., number of syllables/consonants), which subsequently enabled a detailed item error analysis.

This task employed [53]word items, largely selected on the basis of word frequency and familiarity wherever that was possible (see *Stimuli Constraints* below). The target words were verified for frequency in the [54]British National Corpus (BNC), and were found to occur at least 20 times per million (high-frequency words). This means that they were expected to be familiar to intermediate L2 learners. The stimuli were also verified for familiarity by experienced English language teachers.

When constructing the stimuli for this task, consonant sequences were preserved while vowels were subjected to modification. As the purpose of this investigation was to explore the vowel blindness in L2 word recognition in intermediate L1 Arabic L2 English learners, vowel modifications were of primary interest. Specific English orthographic vowel features which do not exist in Arabic were tested (e.g., silent word-final vowel letter <e>; /e/ and /ɪ/ sounds differentiation and their grapheme-phoneme

[52] See Shillaw (1996) for the facilitative effects of presenting contextualised stimuli to L1 Arabic L2 English learners.

[53] High-frequency words are expected to be more familiar. Therefore, they are expected to be processed faster and more accurately (Connine et al., 1990).

[54] Retrieved from http://sara.natcorp.ox.ac.uk

mapping). In contrast to vowels, the effect of processing consonants in L1 Arabic L2 English learners has been researched to a [55]lesser extent. Thus, this experiment also aimed to explore whether the *number* of consonants has an effect on L2 word recognition in these L2 learners. This variable was selected as words in L1 Arabic predominantly consist of 3-4 consonant letter roots (2.2.1) while English can have many more. Furthermore, non-adjacent consonant transposition (e.g., *spill* - *slip*) was employed to test the sensitivity of intermediate L1 Arabic L2 learners to the manipulation of consonant sequences in English, as these are considered vital in decoding words in L1 Arabic. If the changes in the consonant sequences in L2 words are no detected, this might point towards potential reading direction effects. For differential processing directions in Arabic and English, see Farid & Grainger, 1996; also see 2.2.1.

This task employed 30 target word items which consist of *Consonant Sequences* (see rows in Table 4 below) and 3 different foils for each target word, i.e., *Word Categories* (see columns in Table 4 below). All the items across Word Categories attempted to preserve an identical or matched consonant sequence of the target word (e.g., m-n target word: *man*; followed by three foils: *men, mane, many*) and were subjected to vowel variation. In total, 120 word items were presented.

The items employed in this task varied in length (3-10 letters) and followed regular grapheme-phoneme mappings. [56]Inflectional and derivational morphemes were avoided wherever possible. The items were divided into 3 stimuli *Groups*. Each Group consisted of 10 Consonant Sequences (C-sequence); there were 24 C-sequences in total. Each of them consisted of 4 Word Categories which varied based on the Group (1 target word + 3 foils). Word categories were comprised of *the vowel modifications* (changes in vowel quality, short vs long vowels, adding silent final letter <e>), *number of syllables* (1-4 syllables), *number of consonants* (2-6 consonants) and *non-adjacent consonant transposition* (e.g., *spill-slip*). Table 4 below displays examples of the stimuli and the types of manipulations employed to construct the target words and the foils.

[55] For employing consonants alongside vowels, see Hayes-Harb (2006) and Ryan (1993).

[56] For example: *appeared*; derivational morphemes (*revolution*) featured in Group III (see *Appendix* C).

Table 4: [57]Example of Word Categories by Group

Monosyllabic C-C Sequence

Group I	(C-C)	Target word	Modified V	Final silent <e>	2-syllable
	b/p – n	bun [6](S)	ban (S)	bone	open
	b/p – n	bean [7](L)	pawn (L)	pane	upon

Monosyllabic C-C-C+ Sequence

Group II	C-C-C+	Target word	Modified V	2-syllable	C Transposition
	s-t-r	star (L)	steer (L)	satire	sort
	s-t-r	stair (L)	stir (L)	sitar	assert

Polysyllabic C-C-C+ Sequence

Group III	C-C-C+	Target word	Modified V	Modified V	C Transp
	b-t-r	better	bitter	battery	ba(r)ter
	r-v/f-l-t-n	revolution	revelation	reflection	irrelevant

Each Group was divided into a number of syllables and a number of consonants. Group I was comprised of target items with 2 non-adjacent consonants (C-C) while Groups II and III presented target items with 3 or more adjacent/non-adjacent consonants (C-C-C+). As regards the *number of syllables*, Groups I and II contained monosyllabic target items while Group III employed polysyllabic target items.

Group I was the easiest to control for the selected variables. In contrast, word items in Groups II and III proved to be more challenging in order to meet all the criteria imposed by the variables. Items with matched consonantal sequences were selected on the basis

[57] For all the stimulus items, see *Appendix* C.

of the phonological principles which entailed [58]substituting and adding graphemes/phonemes. See *Stimuli Constraints* below; for more detail, see *Appendix* C.

Stimuli constraints

The items were selected to meet the experimental criteria based on the *number* and *sequence* of *consonants*, *number* of *syllables*, and various *vowel modifications*, which will be outlined in more detail below. In this respect, a number of stimuli constraints occurred. English offers a limited number of words comprising of the identical consonant sequences. To control for different variables mentioned above, matched (similar rather than identical) consonant combinations had to be employed in some instances. For instance, <b-n>/<p-n> consonant letter combinations were employed as matched consonant sequences as /b/ and /p/ sounds are allophonic in Arabic and they frequently result in L2 word confusion in L1 Arabic L2 English learners. Conversely, in English /p/ and /b/ are mapped onto <p> and <b> letters, respectively (<b-n> in *bean*; <p-n> in *upon*). Designing the stimuli resulted in employing some lower-frequency word items (e.g., *bean-pawn-pane-upon*), however only in the minority of the word items, and not as target items. For employing lower-frequency stimuli in L1 Arabic L2 English learners, see Ryan (1993).

Approximately one-quarter of the word items presented in this task were either lower-frequency or did not feature predominantly in the cultural schema of the Arab world, therefore the intermediate L1 Arabic L2 learners would not be expected to be familiar with them. However, these items appeared predominantly as foils and not [59]target items. Furthermore, to minimise any detrimental effects of unfamiliar words, all the stimulus items followed regular grapheme-phoneme mappings which bears facilitative effects on L2 word processing. Although word familiarity was expected to result in

[58] These included letter-doubling (*strap – stirrup*), silent digraphs (<gh> in *caught* vs *cot*), and semi-vowels as part of a diphthong (<ow> pronounced as /aʊ/ in *clown* or <aw> pronounced as /ɔ:/ in *pawn*). Other examples using matched consonant sequences included the phoneme /s/, employed due to its multiple mappings in English, i.e., <s> and <c> (*soul-cell; salary-celery*) whereas phoneme /k/ was employed to map onto <c> and <k> (*colon-kennel*). Consonant substitutions also featured voiced and voiceless plosives (e.g., /p/-/b/ distinction).

[59] Four lower-frequency target words *moan, cot, strap,* and *terrain were* employed due to the limitations of available words in English to meet the stimuli criteria. To counterbalance this, high-frequency foils were employed alongside these target words; e.g., *moan* (target word) alongside *mean-mine-money* (foils).

faster word recognition, knowing a word was not a prerequisite to successful word recognition (see above).

Pilot Study

The task was piloted on [60]7 intermediate L2 Non-Arabic learners (Russian (2); French (2); Romanian (1) Polish (1); German (1)) to test the task's effectiveness by focusing on the low-frequency foils outlined above (see *Stimuli Constraints*). For more detail, see 3.1.; see 7.3. for *Limitations*.

The results of the pilot study revealed that the L1 *Non*-Arabic L2 English learners performed at ceiling (M = 1.86 (6.2 %), SD = 0.69); a very small number of target words were matched incorrectly. Furthermore, the lower-frequency foils identified earlier were not found to have a significant effect on the overall performance of the pilot group. The subsequent item error analysis revealed there were no errors involving those word items. Therefore, all the words from the pilot study were included in the final experimental task.

The participant debriefing session after completing the task revealed that the presentation speed of the recorded items was rather fast. Based on this, the target items were recorded again for the main experimental task utilising longer gaps between the presented items (see below).

Testing procedure

The participants listened to the [61]recording of the 30 target word items (recorded on an Iphone device) presented in a randomised order. Each target word was heard twice

[60] The L2 participants from the selected L1 backgrounds were chosen due to the L1-L2 orthographic similarity with English. Due to the L1-L2 orthographic distance between Arabic and English involving differences in the vowel representations (2.2.1), this task was expected to present more difficulties for L1 Arabic L2 English learners. All L1s in the pilot study employ alphabetic orthographies.

[61] A speaker with a standard SE England accent was used to present 30 target words for the task presentation recording. This accent was selected to maximise the participants' ability to process the phonological input. The participants tested were mostly exposed to this accent as they were based in London during the testing period, and they largely received instruction in this accent. According to the British English Received Pronunciation, syllable-final and word-final /r/ were not pronounced in items such as *barter* /ba:tə/ and *lustre* /lʌstə/; the vowel in the word *caught* was pronounced as /ɔ:/. Spelling of the stimuli followed the standard British English spelling rules (*colour*).

with a two-second pause between them and a four-second pause before the next target item. The participants were asked to select 1 of the 4 items on the task sheet which corresponded to the spoken word they had heard on the recording. I pointed at an example on the sheet: *(a) drink b) drank c) drunk d) drunken):*

> Read these four words a), b), c), d). They look similar. You're going to hear one of these words twice. Listen carefully and circle the word you hear. Now do the same with each set of four words. There will be 30 sets of words. There will be some words which will be new for you but don't worry about those. Tell me when you are ready to start.

4.1.1.3 Hypotheses and Analytical Procedures

The Auditory-Visual Word Matching Task was constructed to test the effects of vowel blindness in intermediate L1 Arabic L2 English learners. Performing at ceiling would have pointed against vowel blindness in these L2 learners, which was not expected. Regarding the L2 proficiency level, higher-intermediate L2 learners were assumed to have had more exposure to L2 print compared to lower-intermediate L2 learners. This contributes to a larger L2 vocabulary size and typically better L2 word processing skills in higher-L2-level learners. In this vein, these learners were expected to attain fewer errors than lower-intermediate L2 English learners. Furthermore, based on previous research in L2 word processing in L1 Arabic L2 English learners, considerable individual variation in performance was expected (Ryan & Meara, 1991; Ryan, 1993).

Word length was expected to have an effect on how words with vowel modifications were processed in these L2 learners. In terms of the stimulus items, words comprised of more letters, i.e., longer, polysyllabic words with C-C-C+ structure, were predicted to attract more errors as they typically require longer processing time in lower L2 proficiency learners (Fender, 2008; Kramer & McLean, 2019). With regard to various Stimuli Groups, the participants were expected to attain the highest error rate in Group III which contained longer, polysyllabic stimuli, followed by Group II containing shorter stimuli. Group I was expected to attract the lowest error rate as it employed the shortest, monosyllabic (C-C) stimuli.

Regarding the vowel processing, poorer performance was expected in the stimuli containing vowel phonemes /e/ and /ɪ/ as these are allophonic in Arabic. Secondly, as diphthongs are more limited in Arabic than in English (2.2.1), these were expected to be confused with long vowels (e.g., /əʊ/ in *boat*; /ɔ:/ in *bought*). Thirdly, regarding silent letters, the word-final <e> (e.g., *plan* vs *plane*) was also expected to attract high error rate as Arabic does not have silent letters. With regard to the consonants, the *number* of consonants was also expected to have an effect on these L2 learners' performance. Longer items, containing more than 4 consonants (e.g., *revolution*) were expected to incur high error rate. Arabic words are overall shorter and consist of only 3-4 consonant sequences (2.2.3). Thus, longer words in English, especially those containing more than 4 consonants were expected to add to the processing load and lead to failing to process the whole word, especially under [62]time restrictions.

In terms of the non-adjacent consonant transposition (*spill -slip)*, the participants were expected to perform at ceiling. In L1 Arabic consonant sequences are paramount in successful word processing. Therefore, these L2 learners were expected to demonstrate a high level of sensitivity to consonant sequences in English as well.

Analysis

A normality test was conducted to determine whether the data obtained in this experimental task is normally distributed. Visual inspection of distributions revealed satisfactory approximations of normality for all variables. These met the required normality assumption for [63]parametric testing.

The Pearson correlation coefficient was computed to assess a potential relationship between the participants' L2 English proficiency and error rate; the L2 proficiency level was inputted as ranging from levels 3.0 to 6.0 on the IELTS scale (CEFR:A2-B2) for individual participants. This analysis was conducted to test whether there is a difference in vowel processing accuracy between the participants of higher- and lower-intermediate L2 proficiency, and whether there is a large individual variability in performance typically found in L1 Arabic L2 English learners (see M*ethodology* in 3.4.1.1). The higher-intermediate L2 learners were expected to have had more exposure

[62] a two-second pause between presenting the next target item
[63] All variables in this task were analysed using parametric tests.

to L2 print and were therefore expected to perform better than the lower-intermediate L2 learners.

In this experiment *word length* was introduced as one of the main variables. Two main stimuli conditions measuring word length were introduced - the number of syllables and the number of consonants. The number of syllables were selected over the number of letters as the former was found a more reliable measurement of word length (Jalbert et al., 2011). It was also considered the optimal categorisation of distinguishing between *shorter*, mainly monosyllabic words representing minimal pairs (e.g., *bit-bet*) from *longer*, polysyllabic words in this experiment (2.1.2.4). Secondly, the number of syllables were selected as CV letter transpositions (*mobile-*mboile*) were found to be one of the highest-frequency spelling errors in L1 Arabic L2 learners, signalling difficulties with the L2 syllabic structure (Bowen, 2011).

The other stimulus condition, i.e., the number of consonants, was divided into C-C words (consisting of 2 non-adjacent consonants; e.g., *bit* and mainly represented by short, monosyllabic words), and C-C-C+ words (consisting of 3 or more consonants; e.g., *coral; better* and represented by polysyllabic words).

A two-way within-subjects ANOVA was conducted to compare the effects of the two stimulus conditions on error rate. Syllable condition and consonant condition were inputted as independent variables and error rate as a dependent variable. Syllable condition was divided into two levels, based on the number of syllables (*monosyllabic* and *polysyllabic* words). Consonant condition was divided into two levels as well, based on the number of consonants (*C-C words* and *C-C-C+* words). Regarding the syllable condition, 20 monosyllabic items and 10 polysyllabic items were inputted while regarding the consonant condition, 10 C-C items and 20 C-C-C+ items were inputted.

Item Error Analysis

First, the item error analysis was conducted by [64]Stimuli Group (how many participants made an error with the items in a particular Group). Subsequently, the error analysis was conducted by target item and [65]by foil. Analysing the selection of a particular foil was significant as it pinpointed the areas of L2 word processing difficulty in the tested L2 learners (4.1.2.1). Finally, errors by word item were analysed for vowel modifications as well as consonant transposition sequences.

4.1.2 Results

In this section, the overall results regarding error rate will be presented before proceeding to the results obtained from the statistical analysis which measured the effects of L2 proficiency and the number of syllables/consonants (word length) on the error rate (analysis by participant). Finally, the item error analysis will be presented.

In the Auditory-Visual Word Matching Task, the participants were presented with 30 target items and were asked to select an item they heard (selecting between 4 items).

The Auditory-Visual Word Matching Task tested the sensitivity to processing vowels in shorter and longer words in intermediate L1 Arabic L2 English learners. The participants did not perform at ceiling and a fifth of their responses were still incorrect. This indicates that vowel blindness is still a processing phenomenon which is present in intermediate L1 Arabic L2 English learners.

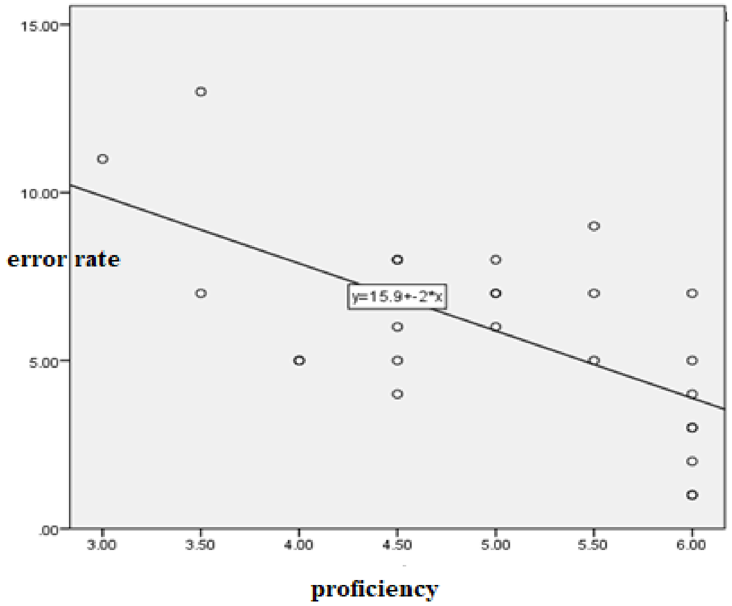
Looking at the results in more detail, the mean group number of errors in the tested L2 learners in this task was approximately 6 out of 30 items in total ($M = 5.92$; $SD = 2.81$) amounting to a 20% error rate.

[64] Group I consisted of monosyllabic C-C words. Group II consisted of monosyllabic C-C-C+ words whereas Group III consisted of polysyllabic C-C-C+ words. The categories consisted of word items with modified vowels, and with the final silent letter <e>, 2-syllable words and consonant transposition sequences.

[65] marked with an asterisk (*) in this study

The Pearson correlation coefficient was computed to assess the relationship between the participants' L2 proficiency and the error rate. An individual error rate was recorded for each participant (N=26). There was a medium negative correlation between the two variables (r = - .65, n = 26, p < .001). The higher the participants' L2 English proficiency, the significantly lower the error rate. As expected, higher-L2-proficiency learners demonstrate more sensitivity processing the vowels, which means that vowel blindness effects are less prominent in these L2 learners compared to L2 learners of lower L2 proficiency. A scatterplot below summarises the results (Figure 7).

Figure 7: Relationship between the Participants' [66]L2 Proficiency and Error Rate



The results did not reveal significant individual variability in processing orthographically and phonologically-matched stimuli in this L1 Arabic L2 English group, which diverges from the findings reported in a number of studies testing L2

[66] L2 proficiency ranges from lower-intermediate (IELTS:3.0;CEFR:A2) to higher-intermediate (IELTS:6.0;CEFR:B2). Error rate refers to the number of incorrect responses.

word recognition in these L2 learners (Alsadoon & Heift, 2015; Hayes-Harb, 2006; Ryan & Meara, 1991; Ryan, 1993).

A two-way within-subjects ANOVA was conducted to compare the effects of two stimulus conditions - syllable condition and consonant condition - on error rate. Syllable condition was divided into monosyllabic and polysyllabic words while consonant condition was divided into C-C words and C-C-C+ words. The results revealed there was a significant effect of the *syllable* condition on error rate, Wilks' Lambda = .81 (F (1,25) = 5.50, p = .028, partial η^2 = .009).

No significant effect of the consonant condition on error rate was found, Wilks' Lambda = .93 (F (1,25) = 1.80, p = .19, partial η^2 = .17). This will further be elaborated on in the *Discussion* section (4.1.3).

Table 5: The Effect of Syllable Condition on [67]Error Rate

Syllable condition	*M*	*SD*
Monosyllabic	4.2 (21%)	2.71
Polysyllabic	1.77 (17.7%)	2.60

Regarding the effects of the syllable condition on error rate, the results revealed a significantly higher error rate in shorter, monosyllabic words than in longer, polysyllabic words (see Table 5 above). This suggests that shorter, monosyllabic words were more difficult to process accurately in these L2 learners than longer, polysyllabic words, despite having fewer visual cues to process compared to longer words.

These results were not expected but could be explained by the fact that shorter words in English tend to have a larger number of orthographic and phonological neighbours, i.e., orthographically/phonologically-matched stimuli with vowel variations (e.g., *cot*,

[67] The number of incorrect responses (percentage of errors in brackets; out of the total of 20 monosyllabic words and out of the total of 10 polysyllabic words).

coat, caught, cut, cute) and are therefore more easily confused (2.1.2.3*)*. Therefore, these items are not as distinctive orthographically as longer word items (*revolution-revelation-reflection*). Longer words tend to share fewer letters and are therefore easier to discriminate between (for more detail, see 4.1.3).

4.1.2.1 Item Error Analysis

First, errors by Stimuli Group will be presented before addressing the errors by target item and by foil. Finally, errors containing vowel modifications and consonant transpositions will be elaborated on.

Stimuli Group

This error analysis revealed errors in all the items in Group III, which contained longer word items. Surprisingly, no errors were recorded with the following monosyllabic word items, which featured in Groups I and II: *bean, moan, heel, star, port*. This signals that intermediate L1 Arabic L2 English learners are starting to process vowels in shorter words more successfully despite the results in this study demonstrating high error rate in shorter, monosyllabic words.

Analysing Groups I and II (monosyllabic words), items containing short vowels (*cot, hell, strap, spill, frost*) attracted [68]more errors than items containing long vowels (e.g., *caught*). This was expected as longer vowels are more visually salient; i.e., they are frequently represented by vowel digraphs. Conversely, short vowels tend to have more irregular grapheme-phoneme mappings (e.g., the schwa phoneme /ə/ can have many grapheme representations). Items in Group III (polysyllabic) were not controlled for vowel length, therefore they were not included in this analysis.

Analysing Group III, items containing more than 7 letters accounted for the majority of the errors (e.g., *revolution, appeared, century, percent*). This confirms that these intermediate L1 Arabic L2 English learners still make many errors with longer stimuli, despite the analysis by participant demonstrating lower error rate in longer words. Furthermore, although no significant effects of the number of consonants were found

[68] For similar results, see Saigh and Schmitt (2012).

in this task, the item error analysis revealed that word items with 4 or more consonants yielded the highest error rate in these L2 learners (*strap, cruel, frost, list, appeared, century, percent, revolution*). Fore more detail, see 4.1.3.

For more detailed individual item error analysis, see below.

Errors by Target Item

Analysing error rate by target item, words *cot* and *caught* yielded the highest error rate. More than half of the participants (15 out of 26 (57.7%)) made an error with *cot*. As a lower-frequency word, it was expected to be unfamiliar to the intermediate L1 Arabic L2 English learners which contributed to the fact it was not processed accurately. *Caught* attracted errors in just under half of the participants (12 out of 26 (46%)). This was expected as this grapheme-phoneme pattern (a long monophthong /ɔː/ mapping onto a vowel digraph <au>) generally poses difficulties for L2 English learners due to its irregular grapheme-phoneme mapping and the lower-frequency of the grapheme-phoneme pattern. In this vein, it would be of interest to compare the performance of Arabic and Non-Arabic L2 learners in terms of less common grapheme-phoneme mappings.

The following word items also attracted a large number of errors: *frost* (11), *hell, boat, spill* (10), *list, century, appeared* (7), *strap, revolution, colony, percent* (6), *bun, coral, man, bit* (4). For errors with the word-final silent letter <e>, see *Vowel Modifications* below.

Errors by Foil

The foils presented alongside the target word *cot* were high-frequency words (**cut*-**cute*-**actor*) and were expected to be familiar to intermediate L2 learners. However, they were still not eliminated by half of the participants; 13 out of 26 of them selected **cut* over the target word *cot*.

The target word *caught* was presented alongside the foils **coat*-**kite*-**acute*. *Selecting* the foil **coat* over the target item *caught* demonstrates that the vowel phoneme /ɔː/ in *caught* was confused with the diphthong /əʊ/ in *coat* and mapped onto the vowel digraph <*oa*>. *Caught* was most likely not selected due to its irregular grapheme-phoneme mapping. The consonant digraph <gh> in *caught* is silent, and the mapping of the vowel digraph <au> onto the phoneme /ɔ:/ is of lower frequency. Conversely, the word item *coat* contains a more regular grapheme-phoneme mapping, i.e., the vowel digraph <oa> maps onto a diphthong /əʊ/, which facilitates the processing of this word.

Ten out of 26 participants (28.5%) made errors selecting **bought,* **hill* and **spell* over the target stimuli *boat, hell, spill*. *Boat* /bəʊt/ was confused with the foil **bought* /bɔ:t/, which follows the same orthographic pattern as the foil **coat* (selected over the target item *caught*). In both cases, the vowel sound /ɔ:/ (*caught, bought*) was confused with the diphthong /əʊ/ and mapped onto the vowel digraph *<oa> (coat, boat).*

Foils **hill* and **spell* were selected over the target items *hell* and *spill.* These words contrast the /e/ and /ɪ/ sounds, which are allophonic in Arabic. For that reason, these were expected errors (see *Vowel Modifications* and *Consonant Transpositions* below).

**Forest* was selected by 11 out of 26 participants (42.3%) over the target item *frost.* This processing error is an example of an adjacent vowel/consonant transposition as well as an example of [69]*epenthesis* (vowel insertion). The same error type was also found in **stirrup* for *strap* in 6 out of 26 participants (23%). *Strap* and **stirrup* are lower-frequency words and were therefore expected to be largely unfamiliar to intermediate L2 English learners. However, the number of participants selecting this foil was still considered high. This error points towards difficulties processing CCC clusters in English which is a typical word processing difficulty found in L1 Arabic L2 learners (e.g., Haggan, 1991).

In contrast to epenthesis, errors containing *elision* (letter deletion) were also found albeit to a lesser extent. *****Crawl* was selected for *coral* generating errors in 4 out of 26 participants (15.3%). High error rate involving epenthesis and elision indicates difficulties processing syllables in L1 Arabic L2 English learners, which ties in with the syllabic effects found in this experimental task (see 4.1.2 for *Results*).

[69] Epenthesis means adding a syllable. Instead of the target word *frost*, **forest was selected* (the phoneme /ɒ/ was added and mapped onto the letter <o>).

Longer stimuli also attracted a high error rate. Six out of 26 participants (23%) selected ***parade*** (foil) over *appeared* (target word), which indicates the initial schwa phoneme /ə/ in *appeared* was not processed successfully (for difficulties mapping the schwa /ə/ phoneme onto a grapheme, see 2.4.1.1). Six participants also chose *revelation* for *revolution.* This might have occurred as the five-consonant sequence <r-v-l-t-n> alongside the suffix -*tion* contribute to their visual similarity, and they only differ in two vowel graphemes.

Five out of 26 participants selected **present* for the target item *percent*; the sound /s/ in *percent* was mapped onto the letter <s> (**present*) instead of the letter <c> (*percent*). More importantly, the adjacent vowel/consonant letter transposition <re> in *present* over <er> in *percent* again indicates difficulties in processing syllables. Furthermore, it is also likely that *present* was selected over *percent* also as it is higher-frequency and therefore more familiar (the first lexical items activated in the mental lexicon).

The word item *century* attracted errors in 7 participants (4 selected **contrary*, 2 **country* and 1 **certainty*). The target word c*entury* and the foil **country* feature the same consonant skeleton. These are again expected errors due to L1 transfer. Errors with foils **contrary* and **certainty* were more surprising as these word items contain additional consonant letters (<r>, <n>, <t>) compared to the target item *century.* This indicates the word items might not have been processed fully due to the time restrictions imposed.

- *Vowel modifications*

Due to the vowel blindness phenomenon, the highest number of errors involved items with vowel modifications. The items attracting the highest error rate included phonemes /e/ and /ɪ/ (e.g., **spell for spill; *hill* for *hell;* see *Errors by Foil* above). Almost one third of the participants (28.5%) confused these items. This was expected as /e/ and /ɪ/ sounds are allophonic in Arabic, which signals a phonological error. Conversely, only 3 participants (11.5%) made errors with the high-frequency words *bitter* (target) and **better (*foil). This suggests that at the intermediate level in L2 English, Arabic learners do seem to be developing sensitivity towards successfully differentiating between the /ɪ/ and /e/, especially in words which are higher-frequency (*bitter/better* compared to *spill* and *hell*).

Finally, the foils with the final vowel letter <e> (e.g., **mane* for *man; *bite* for *bit*), also attracted high error rate (in 4 out of 26 participants (15.3%)). This error type indicates this prominent [70]grapheme-phoneme mapping pattern has not been consolidated yet. For similar results, see 5.2.2.

- *Consonant transpositions*

A significantly smaller number of errors occurred with the items featuring a [71]non-adjacent consonant transposition. L1 Arabic L2 English learners were expected to focus on processing the consonant sequences and therefore perform at ceiling. Altogether 4 out of 26 participants (15.3%) made errors with the following stimuli: **pristine* for *percent*, **certainty* for *century,* **colour* for *coral*, **patter* for *appeared*. These types of error are not commonly found in L1 Arabic L2 English learners due to L1 Arabic where a consonant sequence is vital to successfully process a word. Furthermore, transposed letters in Arabic were found to have strong inhibitory effects in the word processing in L1 Arabic readers (2.2.3). Therefore, these errors might have occurred in longer stimuli as they were not processed fully due to time restrictions imposed (i.e., before the next target word was heard). Errors which include not detecting the transposed consonants might also indicate right-to-left processing, which was reported in some of the L2 processing literature in L1 Arabic L2 English learners (e.g., Randall & Meara, 1988; see 2.4.1).

For the effects of the adjacent letter transposition, see 5.1; for right-to-left processing in L1 Arabic L2 English learners, see 6.1.2.

[70] final silent letter <e> lengthening the preceding vowel

[71] In total, the participants were presented with 20 foils containing consonant transpositions (e.g., *coral*- **colour*).

4.1.3 Discussion

In this section, the results from the Auditory-Visual Word Matching Task will be analysed, and conclusions drawn from those discussed.

Overall, the intermediate L1 Arabic L2 English learners did not perform at ceiling, indicating that vowel blindness is still present in their L2 processing, which was expected. The findings from this experimental task also confirmed that the errors resulting in word confusion (*basket-biscuit*) already occur at the processing stage where the erroneous lexical item is accessed in the mental lexicon, which is subsequently also manifested in an erroneous recall of the word form.

The mean group error rate amounted to 20%, which suggests that at the intermediate level of L2 proficiency, these learners still process vowels more superficially than consonants, frequently resulting in word confusion. These results tie in with the poor reading habits typically found in L1 Arabic L2 English learners, which was reported by the tested L2 learners in this study as well (3.3.1). This contributed to a smaller L2 vocabulary size found in the tested L2 cohort, corresponding to a vocabulary size typically found in pre-intermediate/lower-intermediate L2 learners (3.3.1.1). Furthermore, it is not only the size of orthographic knowledge that has an adverse effect on their L2 processing and L2 word recognition but also a poor quality of the stored word forms (Aitchison, 2012).

On the other hand, there are signs that vowel blindness is starting to diminish in L1 Arabic L2 English learners of intermediate L2 proficiency. The results obtained from the item error analysis revealed that the vowels typically causing difficulties are starting to be processed more accurately. These include the differentiation between the /e/ and /ɪ/ phonemes, short vowels including the mapping of the schwa /ə/ phoneme, the word-final grapheme <e> lengthening the preceding vowel, and various lower-frequency and irregular grapheme-phoneme mappings, such as the phoneme/ɔː/ mapping onto the digraph <au> (Bowen, 2011; Haggan, 1991; Ibrahim, 1978; Saigh & Schmitt, 2012). This means that these intermediate L2 learners are at a transitory stage in terms of their orthographic/phonological processing where they are starting to acquire a larger number of orthographic sequences (2.1.2.2). Therefore, they are developing more fine-grained word recognition techniques which help them discriminate between orthographically and phonologically-matched lexical items.

Overall, although vowel blindness has been found to be present in intermediate L1 Arabic L2 English learners, it does not seem to be a pertinent factor in their L2 processing, and it does not fully explain their typical reading errors, such as word confusion. This means that other areas which might contribute to their reading difficulties ought to be explored. These are not expected to only address letters in isolation as is the case with the phenomenon of vowel blindness (e.g., for word length, see 4.1.3.1).

Turning to the L2 proficiency differences in this experimental task, marginal L2 proficiency effects were found in the tested L2 learners. The participants with lower-intermediate L2 proficiency were not as successful in disambiguating between phonologically and orthographically-matched stimuli as the participants with higher-intermediate L2 proficiency. This indicates that even within the intermediate L2 proficiency level, there are significant differences in L2 processing, which is, as mentioned earlier, most likely due to the differences in the exposure to L2 print. Higher-L2-proficiency intermediate learners are assumed to read more in L2 English and therefore process vowels more accurately, i.e., they are less likely to confuse words with a similar vowel structure. It is noteworthy that the Auditory-Visual Word Matching Task was specifically designed for L1 Arabic L2 English learners as it focused on a reading phenomenon typically not found in other L2 learner groups. This might explain the fact that this experimental task managed to tap into the differences in fine-tuned processing within a single L2 proficiency level.

Regarding the individual differences in performance regardless of their L2 proficiency, this experimental task did not yield a large variability in the learners' performance. This suggests that a [72]homogenous group of intermediate L2 learners was recruited, which adds to the validity of this experimental task. The results obtained in this study diverge from Ryan and Meara (1991) and Ryan (1993), who reported a large variability in performance in their intermediate L1 Arabic L2 English learner groups. The difference in the results might once again be attributed to the fact that the Auditory-Visual Word

[72] Also see *Limitations* in 7.3

Matching Task was designed to tackle specific reading difficulties found in these learners.

4.1.3.1 Word Length

As a measurement of word length, the number of syllables was found to have a significant effect on how these L1 Arabic L2 English learners process L2 words. This is of importance as evidence regarding word length effects in these L2 learners was found to be inconsistent (for word length effects, see Fender, 2008; for the absence of these effects, see Alsaif & Milton, 2012; Masrai & Milton, 2015). It is noteworthy that this study employed different methodology to the studies above measuring word length, therefore caution should be applied drawing direct comparisons.

While syllables were found to have an effect on the processing of these L2 learners, no significant effects were found for the number of consonants. The results suggest that the word recognition technique of accessing the 3-4 consonant root in processing L1 Arabic words does not seem to have a direct effect on the processing of the same number of consonants in L2 word processing in intermediate L1 Arabic L2 English learners. These results might also be tentatively interpreted as diverging from the vowel blindness phenomenon; i.e., intermediate L1 Arabic L2 English learners might not be extensively utilising consonant extrapolation when processing phonologically- and orthographically-matched words.

It is noteworthy that the number of consonants might not be the optimum word length measurement compared to the syllable count, which was found to have an effect on the L2 word processing in these L2 learners. However, in contrast to the error analysis by participant, the *item* error analysis of polysyllabic words (Group III) demonstrated the highest error rate in words containing more than 4 consonants (C-C-C-C+). This indicates that intermediate L1 Arabic L2 English learners might be processing words with more than 4 consonants in English more inaccurately due to L1 transfer, as words containing more than 4 consonants are rare in Arabic (2.2.3). If the number of consonants is of importance after all, this might indicate an attempt of consonant root extrapolation in L2 word processing in intermediate L2 English in these L2 learners.

The tested intermediate L1 Arabic L2 English participants demonstrated to be overall more accurate at processing [73]longer, polysyllabic words than shorter, monosyllabic words, which was not expected. These results diverge from the findings reported in spelling and vocabulary acquisition studies in these L2 learners where longer words were partially found to be more difficult to learn and recall (Fender, 2008; Masrai & Milton, 2015). The obtained results in this study can be explained by the fact that longer words are more likely to be more visually salient, i.e., easier to distinguish as orthographically-similar longer words share fewer letters. On the other hand, shorter, monosyllabic words tend to have many orthographic neighbours which feature a vowel as the only distinguishing feature (e.g., *bit/bet/but/bat*). Therefore, these words can be confused more easily than longer words (for neighbourhood effects, see 2.1.2.3). Secondly, as mentioned earlier, the difference in the findings regarding the word length effects might be attributed to different methodologies employed. This study tested L2 word processing and L2 word recognition while other studies tested L2 vocabulary acquisition and L2 recall. These are more complex than L2 word recognition as they involve additional processing stages, such as retrieving a letter string from the mental lexicon and connecting it to its meaning (e.g., Ehri, 1995).

Lower error rate found in longer words might seem counterintuitive as these contain more visual cues to process, especially under time restrictions (see below). Furthermore, longer words also tend to be of lower-frequency in English where they mostly occur in writing (Miller, Newman, & Friedman, 1958). As the tested intermediate L1 Arabic L2 English learners were reported to lack exposure to L2 print (3.3.1), they are more likely to be unfamiliar with these words. Unfamiliar words are not stored in the mental lexicon, therefore they cannot be accessed directly through the whole, orthographic route. Instead, letters have to be assembled sequentially, i.e., processed in a linear manner (1.2).

Naturalistic observations from the L2 English classroom demonstrate that L1 Arabic L2 English learners frequently process longer stimuli based on the initial letter

[73] Overall, lower error rate was found in longer, polysyllabic words. However, the difference in the performance between shorter and longer words was not large. This was supported by both analyses - by participant and by item. For example, when breaking down the error analysis of the polysyllabic words, (Group III) demonstrated that the longest words employed (7+letters) attracted the highest error rate.

sequences only. This is not sufficient to disambiguate a word in English as it would most likely activate the most familiar, high-frequency lexical item containing the same or matched letter sequence rather than the target word. To illustrate, processing the target word *precedent* <*pres*-d-n-t> would frequently activate a higher-frequency word *president* <*prez*-d-n-t>, based on the matched initial grapheme/phoneme sequence. For more detail processing the word-initial positions, see 6.1.2. For stimuli prediction in L1 Arabic L2 English learners, see Bowen (2011), and Milton and Hopkins (2006).

Taking all of the findings into account, the results which measured word length by syllable indicate that intermediate L1 Arabic L2 English learners are starting to process particularly longer, polysyllabic words in English in a linear manner. Conversely, processing words in a non-linear manner would indicate consonant extrapolation, which is postulated by the phenomenon of vowel blindness. Linear processing found in the word processing in these L2 learners suggests the use of the phonological route, which is crucial for processing unfamiliar, lower-frequency words in English. When errors occur in longer words, this indicates the incorrect use of the phonological route, i.e., the processing of the word-initial syllables/letter sequences rather than the processing of the whole word (see above).

At the same time, these intermediate L2 learners demonstrated more difficulties disambiguating shorter, monosyllabic words (e.g., *bit/bet*), which signals they also employed the orthographic route inaccurately when processing words in L2 English. These errors are likely to occur due to an attempt to extract a consonant root, where vowels are not processed as accurately as consonants (Martin, 2011; Stein, 2010). Therefore, the findings in this study overall demonstrate that intermediate L1 Arabic L2 English learners employ both processing routes, however, they are frequently utilised inefficiently. For the difference in utilising the orthographic route in Arabic and English, see 2.5.

4.1.3.2 Item Error Analysis

Turning to item error analysis, the results in this study revealed important findings in terms of vowels and consonants as well as regarding the processing preferences in these intermediate L1 Arabic L2 English learners.

With regard to vowels, the majority of vowel errors in this experimental task were found to stem from the [74]differences in L1/L2 phonology. This could be illustrated by the errors in words containing the front vowel phonemes /e/ and /ɪ/, which are allophonic in Arabic.

As mentioned at the beginning of this section, distinguishing between the long monophthong /ɔ:/ and the diphthong /əʊ/, and mapping them appropriately onto the vowel digraphs <au> and <oa> (*caught* vs *coat*), was more pronounced than distinguishing the vowel length (e.g., /ɔ:/ in *caught* vs /ɒ/ in *cot*). Regarding orthographic errors, the Auditory-Visual Word Matching Task also demonstrated intermittent difficulties in the processing the word-final silent vowel letter <e>. This means that certain high-frequency grapheme-phoneme mappings have not been consolidated yet. This is reminiscent of a transitory reading stage found in young L1 English readers, which will be discussed in more detail in 6.1.3.

With regard to consonants, the L1 Arabic L2 English learners were expected to be more sensitive to consonant letter sequences and more prone to rejecting them in English as consonant clusters are considerably more restricted in Arabic (Kharma & Hajjaj, 1997). Therefore, this error type might have occurred due to the overcompensation strategies employed. As expected, the Auditory-Visual Word Matching Task revealed a tendency in these L2 learners to separate the CCC clusters, which resulted in vowel insertion (epenthesis). To illustrate, instead of a target stimulus (*strap*), **st**i**rrup* was selected which indicates difficulties with the processing of syllables in intermediate L1 Arabic L2 English learners. Furthermore, some unexpected errors regarding the non-adjacent consonant sequences were recorded as well (**colour-coral*), which will be further investigated in the subsequent chapter (see 5.1 for CC transposition).

[74] Arabic does not feature silent letters and has a small number of diphthongs (2.2.1) but it differentiates between long and short vowels.

4.2 Chapter Summary

This chapter presented the Auditory-Visual Word Matching Task. The rationale for the test employed was discussed prior to outlining the materials and the procedure employed. This also included the hypotheses and analytical procedures. Subsequently, the results and the item error analysis were presented.

The following chapter will investigate the impact of the letter transposition on L2 word recognition with special emphasis on vowel blindness in intermediate L1 Arabic L2 English learners.

Chapter 5: The Impact of Letter Transposition on L2 Word Recognition in L1 Arabic L2 English learners

This chapter will introduce the second experimental task in this study investigating the letter transposition effects on the L2 word recognition with a specific emphasis on vowel blindness in intermediate L1 Arabic L2 English learners.

5.1 Letter Transposition Task

In this section, the methodology is detailed to present the rationale for the test employed. This will include a critical review of the original study by Ryan and Meara (1991), which was the inspiration for this experiment. The rationale for the stimuli employed and the constraints attached to those will be laid out prior to addressing the design constraints. The next section will outline the materials and the testing procedure alongside the pilot study. Subsequently, the hypotheses and the analytical procedures will be provided before presenting the results and a detailed item error analysis. Finally, the results obtained in this task will be discussed.

5.1.1 Methodology

5.1.1.1 Rationale for the Test Employed

In the previous chapter, the Auditory-Visual Word Matching Task investigated the impact of vowel blindness on word length resulting in word confusion in intermediate L1 Arabic L2 English learners. This was tested in shorter and longer words by mapping phonological form onto the orthographic form. The results demonstrated that this phenomenon is not only found in written recall in these L2 learners (Al-Sulaimani, 1990; Bowen, 2011; Fender, 2008; Haggan, 1991; Ibrahim, 1978) but already in the L2 word processing stage when words are being decoded.

The most frequent vowel spelling errors do not only involve omitting, substituting and adding the vowels (tested in the Auditory-Visual Word Matching Task), but also transposing adjacent letters. Consonant/vowel (CV) transpositions (*goes-*gose; destroy-*destory)* were found to be one of the most persistent types of transposition errors in these L2 learners (Bowen, 2011). The Auditory-Visual Word Matching Task demonstrated that even non-adjacent consonant-consonant (CC) transposition errors *(spill-slip)* can occur sporadically, especially in lower-intermediate L1 Arabic L2 English learners (4.1.2.1).

The present experimental task employed an identity judgement (same-different) task to investigate whether spelling errors involving letter transposition outlined above can also be once again a result of an earlier word processing stage. Furthermore, this task examined whether other fine-grained sublexical processing factors, such as syllabic structure and frequent letter combinations (2.1.2.2) contribute to the letter transposition errors rather than the vowel blindness phenomenon as the principal factor.

Lastly, the Auditory-Visual Word Matching Task revealed that intermediate L1 Arabic L2 English learners frequently access particularly shorter words by extrapolating a consonant root which frequently results in word confusion. Conversely, regarding the longer stimuli, naturalistic observations from the L2 English classroom anecdotally record the use of the slower, phonological processing route in such instances. This experiment only employed longer, 10-letter words to verify whether the use of the phonological processing route was indeed prevalent in these learners in processing longer words in L2 English. In this vein, vowel as well as consonant letters might be processed differently in different positions of the word. This has not been explored extensively in the L2 word recognition research (but see Ryan & Meara, 1991). The processing of a specific letter position (adjacent letter transposition in this experiment) was expected to inform a preferential processing route employed, which is crucial in understanding specific L2 word recognition difficulties found in L1 Arabic L2 English learners.

The Original Study by Ryan & Meara (1991)

In order to test the phenomenon of vowel blindness in L1 Arabic L2 English learners, Ryan & Meara (1991) administered an identity judgment task on 2 experimental L2 groups ranging between lower-intermediate and intermediate proficiency in L2 English

([75]L1 Arabic; L1 Non-Arabic; L1 English control group). One hundred10-letter stimuli pairs were employed in the *same/identical* condition (*sufficient-sufficient)* and in the *different* condition, i.e., vowel deletions were assigned in four positions (**dpartment*, **expriment, *managment *photogrph).* The stimuli pairs were presented in quick succession and the participants were asked to judge them as same or different. Error rate and response times were measured. The results revealed that the L1 Arabic L2 English learners made twice as many errors and was significantly slower than the Non-Arabic L2 learners. For more detail, see 2.4.1.

Four major methodological limitations have been identified in this study. These predominantly involved the criteria for drafting participants and the group size. A considerable amount of underspecified methodological detail was also noted, particularly regarding the L2 groups and the apparatus utilised to measure response times. For instance, the L1 Arabic participants' countries of origin were not specified alongside whether they were proficient in any other L2s. Maghrebi L1 Arabic learners might have a good command of L2 French. Due to their exposure to the Roman alphabet, the word processing in L2 English in these learners has very different implications to the L2 word processing in L1 Arabic L2 English learners from the Gulf, who are not assumed to have had extensive exposure to the Roman alphabet. Secondly, it is not clear whether the participants' L2 English proficiency was based on their oral or reading/writing proficiency skills. This is significant as L1 Arabic L2 learners have been reported to have more advanced oral than reading and writing skills in L2 English (e.g., Thompson-Panos & Thomas-Ružić, 1983). Therefore, selecting this L2 groups' participants on oral proficiency alone can overestimate this L2 group's reading/writing aptitude in L2 English. Lastly, only 10 participants were drafted in each tested group which could have resulted in low statistical power.

In order to rectify the methodological shortcomings outlined above, this experimental task provided more detailed background on the participants and methodological tools employed. This is considered essential in understanding the rationale for selecting methodology and participants for this study. Secondly, with regard to the selected participants, efforts were made to recruit L2 learners who were controlled more closely for country. For this study only participants from Saudi Arabia had been recruited.

[75] There were 10 participants in each group.

Thirdly, in this study, the participants had been selected based on the overall scores attained in the IELTS exam, not solely based on their oral skills. The learners who obtained overall IELTS scores between 3.0 and 6.0 (CEFR:A2-B2; M=4.58; SD=0.73) participated in this study. As the participants' L2 proficiency level ranged from lower to higher-intermediate, potential effects of the L2 proficiency range were tested as well.

The present study also gathered a larger pool of L1 Arabic L2 English learners (N=26) than reported in the majority of previous studies testing L2 word recognition in L1 Arabic L2 learners. For instance, both Ryan and Meara (1991) and Hayes-Harb (2006) employed 10 participants in their participant groups. Lastly, this study aimed to provide detailed information on the apparatus used to measure response times.

5.1.1.2 Materials and Testing Procedure

Rationale for the Stimuli Employed

The present experiment modifies and extends the methodology of Ryan and Meara (1991) who also supplied the stimuli for this experiment. The original study employed vowel deletions (see above), where the non-identical item in a pair is shorter than the target item (**deprtment/ department*). This is significant specifically in the identity judgment task where items are presented in rapid succession and can easily be compared in terms of their length. This is especially evident in the vowel deletion in the position 2 (*distribute-*dstribute)*, which would be [76]easier to detect than deletions in other positions. Thus, the vowel deletion stimuli design might not be sufficiently sensitive to assess the L2 word processing difficulties in L1 Arabic L2 English learners. For superior performance in deleted vowel condition over the vowel substitution condition (*improve-*imprave*) in the recall tasks, see Saigh and Schmitt (2012).

The vowel deletions provided in the original study also resulted in [77]CCCC consonant clusters in certain items (*distribute-*dstribute).* Vowel manipulations in these might be easier for L1 Arabic L2 English learners to detect as orthotactic rules in L1 Arabic do not allow more than 2 consonant clusters in the majority of word positions (Kharma & Hajjaj, 1997). Lastly, the vowel deletions in Ryan and Meara (1991) frequently fell on

[76] For facilitative letter recognition effects at word boundaries, see Green and Meara (1987).

[77] Also see spelling errors containing epenthesis and elision, which signal difficulties processing consonant clusters in L2 English in L1 Arabic L2 English learners (e.g., Ibrahim, 1978).

stressed syllables *(experiment-*expriment)* which was also predicted to have major facilitatory effects on the L2 learners' performance.

The target lexical items provided by Ryan and Meara (1991) were selected due to their length (10 letters). Studies testing word recognition in this context typically employ shorter stimuli (e.g., Masrai & Milton, 2015). While word length does not typically affect word recognition in [78]fluent L1 readers (Jalbert et al., 2011), it was found to have a greater impact on L1 Arabic L2 English learners as well as other L2 groups (Alsaif & Milton, 2012; Kramer & McLean, 2019); i.e., longer words might take longer to process. Furthermore, longer stimuli also provided more insight into the sublexical processing in L1 Arabic L2 English learners, i.e., which letter positions were processed the fastest/most accurately. Word length also has specific implications for L1 Arabic L2 English learners as words in Arabic are shorter than words in English (2.2.3). For more detail on word length, see 2.1.2.4.

This study employed letter transpositions instead of deletions in order to avoid the stimuli constraints outlined above. Alongside vowel transpositions, *consonant* transpositions were also included in the present study for several reasons. As outlined earlier, CV transpositions hold particular prominence with regard to spelling errors in L1 Arabic L2 English learners (Bowen, 2011). Furthermore, [79]CC transpositions were employed to test whether the sensitivity to consonant sequences required in processing L1 Arabic words is utilised as well when processing longer stimuli in L2 English.

Consonant manipulations were assumed to be processed more quickly and accurately than vowels in this L2 group, therefore their performance in processing consonants has been largely underexplored (for no significant differences in processing consonant and vowel manipulations in L1 Arabic L2 English learners, see Alhazmi et al., 2019; Hayes-Harb, 2006). This indicates a more complex interaction between consonant and vowel processing in these learners, which was further explored in this experiment.

[78] For word length effects found in response times, see Bunton (2014).

[79] CC transpositions were also found to have the strongest priming effects in L1 English readers (see 2.1.2.3).

To further rectify the limitations of the original stimuli outlined above, the stimuli in this study were controlled to eliminate any CCCC clusters and minimise the number of CCC clusters. To avoid recency and latency effects, the present study did not employ stimuli with letter transpositions at word boundaries (1/2 and 9/10 letter positions) and avoided manipulations in suffix positions. No transpositions were assigned to stressed syllables as these are considered easier to detect (Green & Meara, 1987).

The Letter Transposition Task in this study employed 90, 10-letter, 3 to 5-syllable items. These consisted of various open-class stimuli; nouns (57), followed by adjectives (23), adverbs (11) and verbs (8). The majority of the stimuli contained a derivational morpheme (e.g., *-ment, -ence, -ion, -al* for nouns; *-able; -ous; -ent* for adjectives; -ly for adverbs; *-ish* for verbs) while a smaller number contained inflectional morphemes (*-ing* for an adjective). All the stimuli contained regular grapheme-phoneme mappings.

The stimulus items were subsequently manipulated in terms of adjacent letter transposition in 6 different *positions*. The letters were transposed in the following positions: 2/3 (**sruprising*), 3/4 (**esepcially*), 4/5 (**favuorable*), 5/6 (**freqeuntly*), 6/7 (**tremednous*), 7/8 (**confernece*) and 8/9 (**altogetehr*). The items were additionally controlled for the *type* of transposition; CV (**inivtation*), VV (**expereince*), and CC (**ditsribute*) transpositions.

Ninety pairs of words were subsequently uploaded to [80]*Compleat LexTutor* software/ *Same-Diff (*seq).* Forty-five of those were presented in the Same (identical) condition while the other 45 in the Different condition, featuring adjacent letter transposition (see above).

Stimuli constraints

Despite avoiding transpositions in suffixes, consonant clusters and on syllable boundaries for the reasons described above, it was not possible to entirely exclude stimulus items with these features. This was due to a limited number of words in English which fulfil the word parameters listed above and contain other relevant features subject to testing (e.g., consonant and vowel transpositions).

[80] *Compleat LexTutor (Reaction Timer);* see *Analysis*.

Creating a list with an equal number of manipulated items for each set of parameters also proved challenging. For instance, regarding the *type* of transposition, CC and VV transposition conditions contained fewer items (10 each) than the CV/VC condition (12 and 13 respectively) (N=45). Regarding the *position* of transposition, the majority of transpositions fell on mid-word position (N=23) while 11 items on the initial or word-final positions (see 7.3 for *Limitations*).

The target words in this study were verified for frequency in the British National Corpus. They were found to occur at least [81]20 times per million and were considered high-frequency words, expected to be familiar to intermediate L2 learners (also verified for familiarity by experienced English language teachers). At the same time, certain lower-frequency stimuli (*expedition, throughout, thoroughly, tremendous*) might also not have been familiar to [82]intermediate L1 Arabic L2 English learners, which was remarked by one of the English teachers verifying the stimuli. However, these were not eliminated as word familiarity is not considered paramount for successful performance in the identity judgment task.

Design constraints

The identity judgment task was conducted on the computer which involved the participants familiarising themselves with the apparatus. Most participants tested were considered to be highly computer-literate. However, some of them required more time to navigate the keys which might have adversely affected their performance regarding the response times. Secondly, when testing error rate and response times, a trade-off between the two was expected (Bruyer & Brysbaert, 2011). However, as this experiment measured accuracy as well automaticity, the participants were explicitly instructed not to spend excessive amounts of time on their responses. This might have led to rushed responses contributing to a higher error rate than normal. Thirdly, despite reducing the number of item pairs tested, the duration of the testing session (approximately 15 minutes) and the fatigue effects might have had a detrimental effect on the participants' performance. For more detail, see the *Pilot study* below.

[81] This was also reported in the original study by Ryan and Meara (1991) who provided the stimuli for this task.

[82] For typically smaller L2 vocabulary size found in L1 Arabic L2 English learners compared to other L2 learner groups, see Coderre and Van Heuven (2014).

Lastly, letter transposition tasks are typically conducted on L1 readers (Lerner, Armstrong, & Frost, 2014; Perea & Carreiras, 2008) suggesting this type of an experimental task might bear high task demand on L2 learners. This is particularly pertinent to L1 Arabic L2 English learners, who have known L2 word processing difficulties in English. Furthermore, the Letter Transposition Task could be construed as a specific cognitive task rather than a linguistic task indicating that the performance would be more individual-based rather than L2 language/proficiency-based. Therefore, the performance in these L2 learners might be a task artefact rather than revealing how they truly process words in L2 English.

Pilot Study

The Letter Transposition Task was based on a previous study which formed part of my Master's degree. None of the participants presented in this pilot study took part in the experimental task (for more detail, see 3.1).

An identity judgement task with the same set of 100 target stimuli pairs as in the original experiment (Ryan & Meara, 1991) was administered to 3 participant groups (L1 Arabic L2 English group (N=14); L1 [83]Non-Arabic L2 English group (N=10); L1 English control group (N=10)). The stimuli were manipulated by deleting vowels and consonants (see Ryan, 1993). Error rate was measured.

As expected, the results revealed a highly significant group effect (F (2,31) = 67.47, p <.01, partial η^2= .81). L1 Arabic L2 English group yielded the highest error rate, followed by the L1 Non-Arabic L2 English group while the L1 English control group performed at ceiling. More importantly, a [84]marginally significant interaction of group and stimulus condition was found (F (4,62=2.51, p=.051, partial η^2 =.14). In the light of these findings, the main experimental task in this study included stimulus manipulations involving both, vowels and consonants.

In a debriefing session after this preliminary study, the participants reported lack of concentration after 10 minutes into the session. Therefore, 90 out of 100 target word

[83] all from L1 Roman-alphabet literacy backgrounds
[84] No significant stimulus effect was found (F (2,62) = 1.21, p>.05; partial η^2=.04).

items were [85]included in the final Letter Transposition Task. Ten item pairs were subsequently used for trial testing. Secondly, the participants reported they found the instructions ambiguous; there was uncertainty whether to focus on the meaning. To avoid this, the instructions for the main task presentation were subsequently changed to "Are they [words] *spelled* the same or differently?"

Testing procedure

The Letter Transposition Task was administered on the communal computers at the college. Software was accessed to measure error rate and response time through the [86]*Compleat Tutor* website. A message 'wait' appeared on the screen for approximately 2 seconds until the next pair of stimuli loaded. This message served as a fixation point for the participants to focus on the right part of the screen and to concentrate on the task itself.

The participants saw two words in rapid succession and were asked to determine whether the two words were identical or not. The first item was presented for 1 second. There was approximately a 1 second pause before the second item was presented. The first item was in its correct form (e.g., the target word *automobile*) while the second item was either identical to the target word or in the different/non-identical condition (**automoblie*). The second item remained on the screen until the participant pressed the key to display the next item pair; i.e., there was no cut-off point for the responses.

For practice purposes, they were given a trial of 10 word-pairs prior to being presented with 90 pairs of words in randomised order. The trials were randomised anew for each participant. The participants were given the following instructions:

> In this task, I would like you to read the words on screen as quickly as possible. You're going to see one word very quickly followed by the same word or a word that is almost the same. I would like you to tell me if the words are spelled exactly the same or differently. Don't think about the meaning, only focus on the spelling. Let's do the first example together. Are they spelled the same or differently? (a)

[85] More item pairs were not removed as this was expected to have a significant impact on the statistical power of the task.

[86] http://www.lextutor.ca/ > RT Builder > Same-Diff (*seq*)

transport b) *trasnport*). If you think they're the same, press 1. If you think they're different, press 3. To move to the next pair, press 2.

I waited for a reply to the practice example (different) and gave the following instructions: "Now you try to do 10 examples yourselves." After they had completed all of them, I asked: "How did it go? Shall we try and do some more now?" and answered any questions asked. "You're going to see 90 pairs of words. Try not to take too much time to decide. Focus on the screen, keep your hands on the keyboard and whenever you're ready, you can press start."

5.1.1.3 Hypotheses and Analytical Procedures

When taking the Stimuli Condition into account (Same/Different), the L1 Arabic L2 English learners were expected to yield lower error rate and slower response times in the Same condition which signals a speed/accuracy trade-off (see Ryan & Meara, 1991). Slower responses here might occur due to stronger working memory demands when comparing two stimulus items (recalling and matching the second item to the first one). Conversely, the Different condition was expected to induce higher error rate and faster response times as many transpositions were not expected to be detected.

As in the Auditory-Visual Word Matching Task, the participants of lower-intermediate L2 proficiency were expected to yield higher error rate and slower response times compared to the participants of higher-intermediate L2 proficiency. Furthermore, high variability in individual responses was expected as this was also reported in the original study by Ryan and Meara (1991). Differences in individual performance were also expected as the authors provided the stimuli in its target form for this study.

As L1 Arabic L2 English learners have a tendency to prioritise consonants over vowels in L2 word processing, they were expected to perform faster and have more accurate responses in the CC transposition condition. Conversely, the highest error rate was expected in the VV transposition condition (signalling vowel blindness), followed by the CV transposition condition (for difficulties processing syllables, see Bowen, 2011). At the same time, vowel blindness was expected to be less pertinent in intermediate L1 Arabic L2 learners than previously assumed. As these learners were expected to start processing letters in a linear manner, VV transposition was also tentatively expected to attract lower error rate.

Regarding the position of transposition in longer stimuli, the word-initial positions were expected to attract the fastest and most accurate responses (Stein, 2010) compared to the mid-word and word-final positions. This would indicate left-to-right processing and the use of the phonological route in longer words.

In terms of the individual items, better performance was expected with the transpositions falling on a syllable boundary (**enthusaism*) and occurring in CC and CCC clusters (******ditsribute*). For more detail on L1 Arabic learners processing consonant clusters in L2 English, see Saigh and Schmitt (2012).

Analysis

To administer the Letter Transposition Task, the *Compleat LexTutor (Compleat Reaction Timer)* software was utilised. The analysis was conducted by participant (N=26). The individual error rate and response times (dependent variables) were automatically collected by the computer software. The individual error rate and response times by *stimulus item* were also included. Response times were analysed for correct responses only and the [87]outliers had not been eliminated. The latter was not considered vital as L2 proficiency and variation in individual performance were additionally tested in this study. [88]Error rate was presented as the number of incorrect responses (see Figures 8, 10 and 11), while response times were presented in seconds (see Figure 9; see Tables 8 and 10).

The *Stimulus Condition* was added as an independent variable and was divided into identical item pairs - *Same* Condition (*appearance-appearance*) and into non-identical pairs - *Different* Condition (*difficulty-*difficutly*). The Different Condition was further divided into two categories based on the transposition of adjacent letters. The *Type* of Transposition consisted of CC (**ditsribute*), VV (**freqeuntly*) and CV (**automoblie*) letter transpositions while the *Position* of Transposition featured the word-initial (2/3,

[87] For eliminating outliers in L2 word recognition studies, see Milton & Hopkins, 2006; Hayes-Harb, 2006; Martin, 2017.

[88] Error rate was *not* presented in percentages in the graphs; percentages were added in the Tables (see 7 and 9).

3/4), mid-word (4/5, 5/6 and 6/7) and (7/8 and 8/9) word-final positions. The participants' L2 proficiency levels were inputted ranging from 3.0 to 6.0 on the IELTS scale. The learners with the L2 proficiency levels between 3.0 and 4.5 (CEFR:A2-B1) were placed into the lower L2 proficiency group while the learners between the levels of 5.0 and 6.0 (CEFR:B1-B2) were placed in the higher L2 proficiency group.

A normality test was conducted to determine whether the data obtained in this experimental task was normally distributed. Visual inspection of distributions revealed satisfactory approximations of normality for all variables *except* the Stimulus Condition regarding the error rate. Within the Stimulus Condition, only the Same Condition failed to meet the required normality assumption for parametric testing, therefore non-parametric testing was performed. All other variables were analysed using parametric tests, including the error rate and response times in the Different Condition.

A Wilcoxon signed-ranks test was conducted to evaluate the difference in *error rate* between words presented in the Same Condition compared to those in the Different Condition. As a non-parametric test was used, the medians instead of means were reported. As there is no non-parametric equivalent for the mixed ANOVA, the relationship between the Stimulus Condition (Different/Same) and the L2 Proficiency (High/Low) was assessed by employing Spearman's Rank Correlation Coefficient (for more detail, see 3.4.1.1).

Regarding the Different Condition, 3 3x2 mixed ANOVAs with Proficiency as the between-subjects factor were conducted to measure the effects of the Stimulus Condition (independent variable) on response times, as well as the effects of the Type of Transposition (independent variable) and the Position of Transposition (independent variable) on error rate and response times.

Item Error Analysis

Subsequent to the analysis by participant (above), an in-depth error analysis by item was conducted. An in-depth item error analysis regarding the letter transpositions in the Different Condition was performed as this could pinpoint specific L2 word processing difficulties in L1 Arabic L2 English learners, such as linear/phonological processing effects, reading direction effects, etc. The items in the *Same* condition were employed as control items, i.e., to investigate whether there are significant differences in processing between the Same and Different stimulus conditions. Therefore, the items in the Same Condition were not included in the item error analysis.

In the results by stimulus condition (see Different Condition), 3 different transpositions were used; i.e., CC, CV and VV transposition conditions. In the item error analysis, CV condition was divided into CV and VC transposition conditions. This allowed for a more fine-grained item error analysis as the two conditions indicate two opposite mechanisms taking place during the word processing; i.e., epenthesis (vowel insertion) and elision (vowel deletion).

Turning to word length, all the items in this experiment were categorised as longer words due to a uniform 10-letter stimuli in this task. For the number of syllables as a measurement of word length, see 2.1.2.4.

5.1.2 Results

In this section, the overall group results obtained from the tested L1 Arabic L2 English participants will be presented. Subsequently, the results obtained in the Stimulus Condition (Same and Different Transposition Condition) will be provided prior to focusing on the Different Condition. Within this condition, the results obtained from the Type of Transposition (CC, VV, CV) will be presented before analysing the results obtained from the Position of Transposition (word-initial, mid or word-final positions) in terms of error rate and response times.

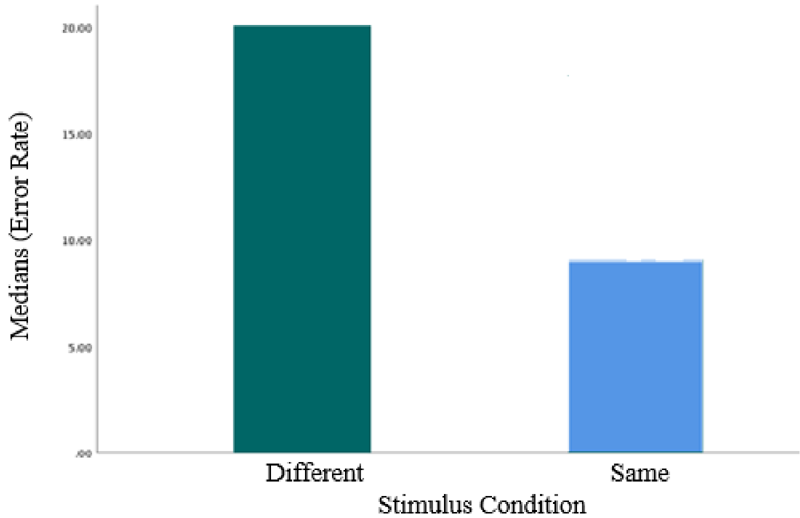
The Letter Transposition Task was conducted as an identity judgment (same-different) task. Ninety stimuli pairs in either Different or Same Transposition Condition were tested on intermediate L1 Arabic L2 English learners (N=26).

The results revealed that the tested intermediate L1 Arabic L2 English learners made errors with approximately one third of the stimuli (*M* = 15.5 (34.4%), *SD* = 10.45). As expected, the standard deviation scores demonstrated high variability in individual performance. Regarding response times, the results revealed that these L2 learners took almost 4 seconds to respond to whether the stimuli pairs were the same or different (*M* = 3.80, *SD* = .80). This study demonstrated poorer performance in both - error rate and response times compared to the original study by Ryan and Meara (1991). This most likely occurred due to a higher task demand in this experimental task which employed transposed letters rather than deleted letters (see 5.1.3 for *Discussion*).

5.1.2.1 Stimulus (Same/Different) Condition

A Wilcoxon signed-ranks test was conducted to evaluate the difference in error rate between the words presented in the Same Condition (no letter transposition) compared to those in the Different Condition (words containing a letter transposition). This analysis indicated that error rate for words in the Same Condition (*Mdn* = 9, *Range* = 21) was significantly lower compared to the words in the Different Condition (*Mdn* = 20, *Range* = 29), $Z = -3.66$, $p < .001$, $r = .51$ (see Figure 8 below). These results diverge from the results in Ryan and Meara (1991) who reported lower error rate in the Different Condition employing vowel deletions. For more detail on Ryan and Meara, (1991), see 2.4.1.

Figure 8: Effects of Stimulus Condition on [89]Error Rate



[89] Number of incorrect responses

A [90]Spearman's rank correlation was conducted to examine the relationship between L2 Proficiency and the error rate in the Stimulus Condition. This analysis revealed a non-significant association between L2 Proficiency and the error rate in the Different Condition [*rs* (26) = .34, *p* = .08] as well as a non-significant association between L2 Proficiency and the error rate in the Same Condition [*rs* (26) = -.11, *p* = .61].

Turning to how fast the responses were, a 2x2 mixed ANOVA was conducted to test the effect of Stimulus Condition (Same/Different) and L2 Proficiency on the response times.

A significant main effect of the Stimulus Condition on response times was found (F (1,24) = 9.30, p = .006, partial η^2 = .28). Specifically, response times were slower when the words were presented in the Different Condition (*M* = 3.96, *SD* = .87) compared to the Same Condition (*M* = 3.65, *SD* = .73). See *total* scores in Table 6 below. These results again diverge from the results reported in Ryan and Meara (1991) who found faster responses in the Different Condition. For more detail, see 5.1.3.

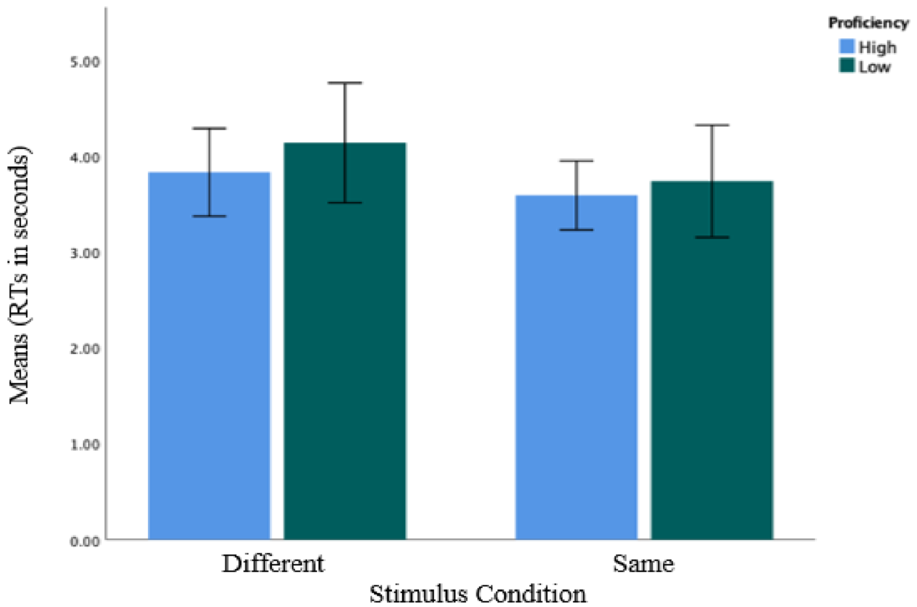
The effect of the L2 Proficiency was not found to be significant (F (1,24) = .55, p = .46, partial η^2 = .02), and neither was the interaction between the Stimulus Condition and L2 Proficiency (F (1,24) = .58, p = .45, partial η^2 = .02). See Table 6/Figure 9 below.

[90] The data for error rate was not normally distributed (see *Analysis*), therefore a non-parametric test was conducted. The data for response times was normally distributed, therefore ANOVA was conducted (see Table 6/Figure 9).

Table 6: Effects of Stimulus Condition on Response Time by L2 Proficiency

Stimulus condition	*M*			*SD*		
	High	Low	*Total*	High	Low	*Total*
Different	3.83	4.14	3.96	.82	.92	.86
Same	3.59	3.74	3.65	.65	.87	.73
Total			3.80			.79

Figure 9: Effects of Stimulus Condition on Response Time by L2 Proficiency



The error bars represent 95% confidence intervals

Different Condition

This section will present the analysis of the performance of the L1 Arabic L2 English learners regarding error rate and the response times in the Different Condition. The results obtained in the *Type* of Transposition will be provided prior to presenting the results obtained in the *Position* of Transposition.

Overall, these intermediate L1 Arabic L2 English learners made errors with almost half of the stimuli in the Different Condition which contained a letter transposition ([91]*M* = 20.61 (45.8%); *SD* = 1.53).

Type of Transposition

A 3x2 mixed ANOVA was conducted to test the effect of Type of Transposition and L2 Proficiency on Error Rate.

A significant main effect of the Type of Transposition was found on error rate [Greenhouse–Geisser corrected: F (1.613, 38.713) = 102.73, $p < .001$, partial $\eta^2 = .81$]. Subsequent post-hoc analyses employing the Bonferroni adjustment demonstrated that the error rate was higher in the CV Transposition Condition (M = 12.19, SD = 4.58) compared to the VV Transposition Condition (M = 5.60, SD = 2.92, $p < .001$) and the CC Transposition Condition (M = 3.18, SD = 1.50, $p < .001$). As expected, the error rate was also found to be higher in the VV Transposition Condition compared to the CC Transposition Condition ($p < .001$). The largest variability in performance was found in the CV condition (SD=4.58). See *total* scores in Table 7 and Figure 10 below.

The highest error rate was expected to be found in the VV transposition condition which would demonstrate the presence of vowel blindness in these L2 learners. Conversely, the highest error rate in the CV letter transposition indicates that the vowel blindness might be present to a lesser degree in intermediate L1 Arabic L2 English learners. For more detail, see 5.1.3.

The effect of L2 Proficiency was not found to be significant (F (1,24) = 1.97, p = .14, partial η^2 = .08). Despite the non-significant results, the participants with the higher-intermediate L2 proficiency were found to make fewer errors compared to the participants of the lower-intermediate L2 proficiency. Notably, the difference between these two L2 learner groups was very small in the CC transposition condition. See Table 7 below.

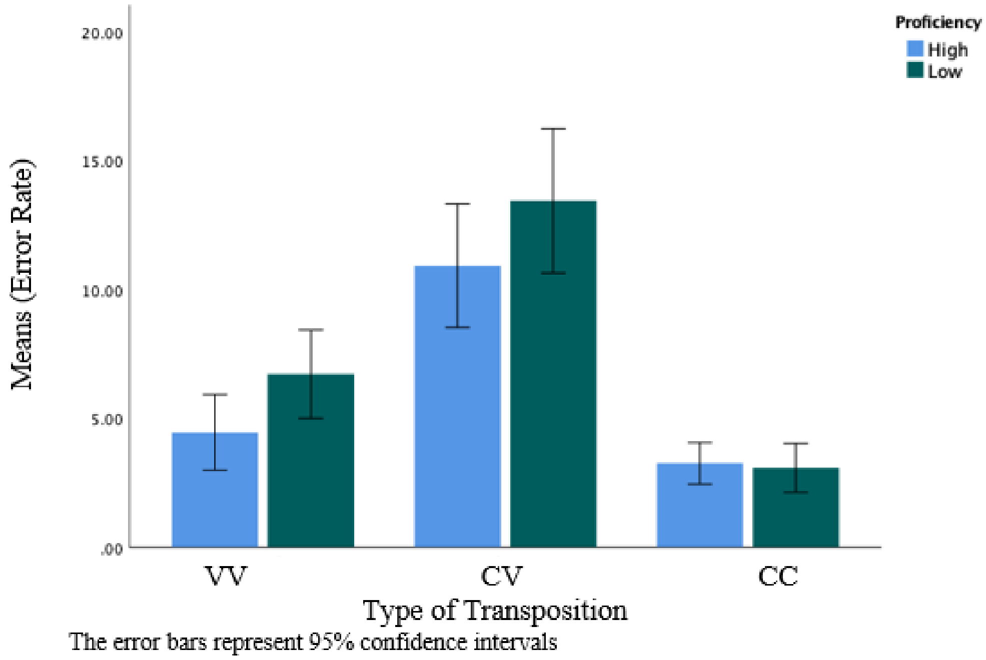
[91] Means were reported in the Different Condition as its data was normally distributed. As the data was *not* normally distributed in the Same condition, medians instead of means were reported.

There was also a non-significant Type of Transposition by L2 Proficiency interaction [Greenhouse–Geisser corrected: F (1.613, 38.713) = .26, p =.09, partial η^2 = .09].

Table 7: Effects of Type of Transposition on Error Rate

Type of Transposition	*M*			*SD*		
	High	Low	*Total*	High	Low	*Total*
VV	4.45	6.72	5.60 (21.54 %)	3.40	2.42	2.92
CC	3.26	3.09	3.18 (12.23 %)	1.38	1.70	1.50
CV	10.93	13.45	12.19 (46.88 %)	4.07	5.02	4.58

Figure 10: Effects of Type of Transposition on [92]Error Rate by L2 Proficiency



[92] Number of incorrect responses

Turning to how fast their responses were, a 3x2 mixed ANOVA was conducted to test the effect of the Type of Transposition and L2 Proficiency on the response times.

There was a non-significant main effect of the Type of Transposition on response times (*F* (2,[93]48) = .64, *p* = .53, partial η^2 = .03). The effect of L2 Proficiency was also not found to be significant (*F* (1,24) = .57, *p* = .46, partial η^2 = .02). Despite the non-significant results, the participants with the higher-intermediate L2 proficiency responded faster in all the transposition conditions compared to the participants of the lower-intermediate L2 proficiency. See Table 8 below.

No interaction was found between the Type of Transposition and L2 Proficiency (*F* (2,48) = .53, *p* = .59, partial η^2 = .02).

Table 8: Effects of Type of Transposition on Response Time (in seconds)

Type of Transposition	*M*			*SD*		
	High	Low	*Total*	High	Low	*Total*
CC	3.84	4.13	3.97	.86	.92	.88
VV	3.80	3.89	3.84	1.11	1.20	1.13
CV	3.82	4.23	3.99	.89	1.00	.94

Position of Transposition

A 3x2 mixed ANOVA was conducted to test the effect of the Position of Transposition and L2 Proficiency on error rate. There was a significant main effect of the Position of Transposition on error rate [Greenhouse–Geisser corrected: *F* (1.420, 34.084) = 85.93, *p* < .001, partial η^2 = .78].

[93] In mixed designs, the degrees of freedom error refers to errors x2; one for the between-subjects variable (i.e., L2 proficiency), and one for the within-subject variables.

Subsequent post-hoc analyses employing the Bonferroni adjustment demonstrated a higher error rate in the words with the letter transposition occurring in middle position (*M* = 11.36, *SD* = 4.61) compared to words with the letter transposition at the beginning of the word (*M* = 4.62, *SD* = 2.25, $p < .001$) and the end of the word (*M* = 4.97, *SD* = 1.60, $p <.001$). However, no difference regarding error rate was found in the words containing letter transposition at the beginning compared to the words containing a transposition at the end of the word ($p = .97$).

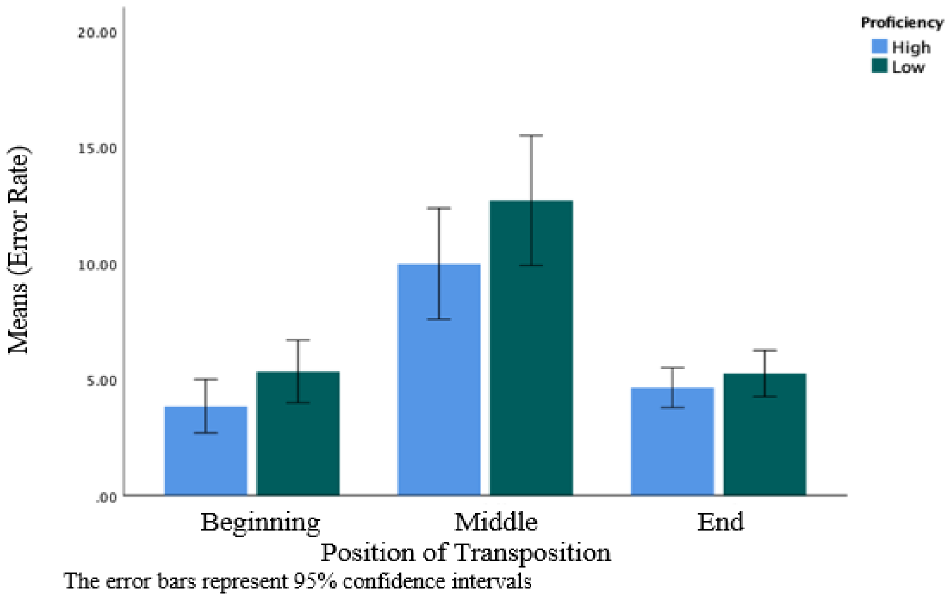
The effect of L2 Proficiency was once again not found to be significant F (1,24) = 2.61, $p = .12$, partial $\eta^2 = .09$. Despite the non-significant results, the participants with higher-intermediate L2 proficiency were found to make fewer errors in all the transposition conditions compared to the participants of lower-intermediate L2 proficiency. See *total* scores in Table 9/Figure 11 below.

The interaction between the Type of Transposition and Proficiency was also not found to be significant [Greenhouse–Geisser corrected: F (1.420, 34.084) = 1.69, $p = .20$, partial $\eta^2 = .06$].

Table 9: Effects of Position of Transposition on Error Rate

Pos of Transposition	*M*			*SD*		
	High	Low	*Total*	High	Low	*Total*
Beginning	3.86	5.36	4.62 (17.77%)	2.23	2.06	2.25
Middle	10.00	12.72	11.36 (43.70%)	4.14	4.94	4.61
End	4.66	5.27	4.97 (19.11%)	1.29	1.95	1.60

Figure 11: Effects of Position of Transposition on [94]Error Rate by L2 Proficiency



Turning to how fast the participants' responses were, a 3x2 mixed ANOVA was conducted to test the effect of the Position of Transposition and L2 Proficiency on the response times.

There was a non-significant main effect of the Position of Transposition on the response times (F (2,48) = .50, p = .61, partial η^2 = .02). The effect of L2 Proficiency was also not found to be significant (F (1,24) = .69, p = .41, partial η^2 = .03). Despite the non-significant results, the participants with higher-intermediate L2 proficiency responded faster in all the transposition conditions compared to the participants of lower-intermediate L2 proficiency. See Table 10 below.

No interaction was found between the Position of Transposition and the L2 Proficiency (F (2,48) = 1.23, p = .30, partial η^2 = .05).

[94] Number of incorrect responses

Table 10: Effects of Position of Transposition on Response Time (in seconds)

Pos of Transposition	*M*			*SD*		
	High	Low	*Total*	High	Low	*Total*
Beginning	3.63	4.28	3.91	.71	.94	.86
Middle	3.86	4.06	3.95	.88	1.09	.96
End	3.69	3.95	3.80	.99	.96	.97
Total			3.88			.93

5.1.2.2 [95]Item Error Analysis (Different Condition)

First, the stimuli in the Different Condition will be presented in terms of the overall error rate mainly by target item, followed by errors by the *Position* of Transposition (word-initial, mid-word or word-final positions) and the *Type* of Transposition (CC, VV, VC and CV transpositions). Finally, the most pertinent findings in terms of error analysis by item will be outlined.

Overall, the results of the item error analysis revealed a high error rate by target item. Half of the participants (13 out of 26) made errors with more than half of the item pairs presented in the Different Transposition Condition (in 24 out of 45 items (53% of items in total)). Errors were found in all the item pairs in the Different Condition.

[95] The error analyses by *item* and by *participant* were overall found to converge regarding error rate. However, the error analysis by item provided additional detail and demonstrated a marginally different processing pattern in the tested L1 Arabic L2 English learners compared to the analysis by participant. For example, the error analysis by item demonstrated prominent left-to-right processing in longer words while error analysis by participant demonstrated lower error rate in word-final positions.

Table 11: Error Rate by Stimulus Item

Stimulus item pairs	Number of errors by stimulus item	*Type* of error (transposition)	*Position* of error (transposition)
*difficulty-*difficutly*	24	CC	end (8/9)
*accomplish-*accompilsh*	20 (76.92%)	CV	end (7/8)
*frequently- *freqeuntely*	19 (73.07%)	VV	middle (5/6)
*instrument-*insturment*	19	CV	middle (5/6)
*conference-*confernece*	18 (69.23%)	VC	end (7/8)
*automobile-*automoblie*	17 (65.38%)	VC	end (8/9)
*difference-*differnece*	17	VC	end (7/8)
*impression-*imperssion*	17	CV	middle (4/5)
*afterwards-*aftrewards*	16 (61.53%)	VC	middle (4/5)
*resolution-*resloution*	16	VC	middle (4/5)
*delightful-*delihgtful*	16	CC	middle (5/6)
*industrial-*indusrtial*	16	CC	middle (6/7)
*distribute-*ditsribute*	16	CC	beginning (3/4)

The word item which yielded the highest error rate was *difficulty-*difficutly* where almost none of the participants noticed the transposition in the 8/9 letter position (found in 24 out of 26 participants (92.3%)). For other item pairs attaining high error rate, see Table 11 above.

The highest error rate occurred in word items containing the transpositions in the mid- and word-final positions (apart from *distribute-*distribute*; see Table 11). To provide more detail, in the 8 items attracting the highest error rate (found in 17 or more participants out of 26 (65.3%)), 5 items contained a transposition in the word-final position, 3 in the mid-word position and none in the word-initial position. This indicates strong left-to-right visual processing preference; the word-initial positions attracted the fewest errors while the error rate [96]increased with letter position (see 5.1.2.1 for the *Position* of Transposition). It can be deduced that the word-initial positions were processed successfully but the word items were not processed fully. This means some responses regarding the mid- and final position transpositions might have been guessed, which resulted in high error rate in these transposition positions.

As far as the number of syllables are concerned, the 24 items attracting the highest error rate predominantly comprised of three-syllable words (17 out of 24 items (70.8%)) while only 7 of them (29.1%) were four-syllable words. These errors were expected as 10-letter words containing only 3 syllables are more likely to map onto a large number of consonants clustered around the vowels. This has important implications for L1 Arabic L2 English learners as consonant clusters are more limited in Arabic, which typically creates difficulties in processing CCC and CCCC clusters in L2 English (2.2.1). It would be of interest to verify the performance of L1 Arabic L2 English learners regarding the consonant clusters with the performance in L1/L2 English readers (see 7.3 for *Limitations*).

Type of Transposition

In this section CC transposition errors will be presented first, followed by the VV and CV/VC transposition errors. These will be further elaborated on in 5.1.3.

- *CC condition*

Relatively high error rate involving CC transpositions obtained in this experimental task was not expected as L1 Arabic L2 English learners have a tendency to focus excessively on consonants compared to vowels. Nevertheless, the results by participant still support the prominence of consonants in L2 word processing in this L2 learner group as CC transpositions yielded the lowest error rate compared to VV and CV transpositions.

[96] In contrast, the error analysis by participant revealed lower error rate in the word-final than in the mid-word position. This will be further discussed in section 5.1.3 and 6.1.2.

Error analysis by item revealed that 3 instances of mid-word transpositions embedded in CCC clusters were also processed inaccurately by half or more of the participants (*industrial-*indusrtial* (16 out of 26 participants), *conclusion-*conlcusion* (14), *atmosphere-*atmoshpere* (13)). This once again indicates a left-to-right reading direction pattern. For difficulties processing CCC and CCCC clusters in L1 Arabic L2 English learners, see CV/VC condition below.

Analysing the CC transposition errors in more detail, those occurring in the 2/3 letter positions (*absolutely-*asbolutely* (11), *impossible-*ipmossible* (8)) as well as in 3/4 letter positions (*distribute-*ditsribute* (16)) are rather unusual. These examples of errors fail to support left-to-right reading direction and also do not tie in with the vowel blindness phenomenon where consonant manipulations are expected to be detected.

As mentioned earlier, the CC transposition errors in the word-initial positions might also be a result of employing the L1 Arabic word processing technique of consonant extrapolation where the initial fixation occurs in mid-word positions rather than in initial word positions, typical of processing the Roman alphabet (Randall, 2009). This explanation is plausible as L1 Arabic L2 English learners were found to process Roman alphabet letters and words in L2 English differently to L1 English readers (Randall & Meara, 1988). This, however, once again requires further investigation which would require a comparison to L1 English readers (7.3).

The findings in this study are interpreted in terms of reading strategies and processing routes but errors found in the word-initial positions containing consonants may also be a result of the visuo-perceptual processing factors, i.e., concerning the word position where the fixation landed. In English, the fastest and most accurate word recognition normally occurs when the fixation lands left-to-the-centre of the word while in Semitic languages (e.g., Hebrew and Arabic), this was frequently found to be right of the centre of the word as words are read right-to-left (Deutsch & Rayner, 1999; Farid & Grainger, 1996). Therefore, not noticing the CC transposition in word-initial positions might have occurred as the attention was allocated to the right of the fixation (Deutsch & Rayner, 1999). For more detail, see 6.1.2.

Finally, this error type might also be explained by the fact that *intermediate* L1 Arabic L2 English learners are starting to process consonant as well as vowel letters in a linear manner rather than overfocusing on consonants, which would allow for this error type (see *partial alphabetic reading stage* in L1 young readers in 6.1.3). This explanation diverges from the vowel blindness phenomenon at the intermediate L2 proficiency, which could, once again, be more attributed to the L2 processing in the learners of the lower L2 proficiency in L2 English.

- *VV condition*

VV transpositions involved high-frequency vowel digraphs mainly set in the mid-word positions. Mid-word VV transpositions were employed as they were considered more difficult to detect compared to word-initial positions. Mid-word VV transpositions were also employed due to a limited number of possible VV transpositions in word-initial and word-final positions (see *Analysis*). As L1 Arabic L2 English learners generally underperform in processing vowels in English, VV transpositions were expected to yield a high error rate.

The results revealed that the vowel digraph which was affected the most was <ue> in *frequently-*freqeuntly* where 19 out of 26 participants (73%) failed to notice the transposition. Approximately half of the participants performed poorly with <ia> digraph in *parliament-*parlaiment* (13), *enthusiasm-*enthusaism* (12) as well as with <ie> in *experience-*expereince* (13). These words were checked for frequency and verified by L1 English teachers to be familiar to intermediate L2 learners. At the same time, the L1 Arabic L2 English learners in this study were found to have L2 vocabulary size expected of *lower*-intermediate L2 learners (3.3.1.1). Therefore, the participants in this study might not have been familiar with some of the stimuli (*enthusiasm*, *parliament),* which was more likely to result in an erroneous processing of those (see *Stimuli constraints* in 5.1.1.2). Notably, due to irregular grapheme-phoneme mappings of some of the stimuli containing VV transpositions (*parliament-*parlaiment*), some L1 English readers might also process the items incorrectly. In order to test whether these errors only occur in L1 Arabic L2 English learners, L1 and/or L2 readers ought to be tested as well (see 7.3 for *Limitations*).

Overall, the majority of the vowel digraphs in the VV transposition condition could be mapped onto diphthongs which demonstrates 1:1 grapheme-phoneme mapping. For instance, in *frequently-*freqeuntly* the diagraph <ue> directly maps onto the diphthong

/ʊe/. This was expected to have facilitatory effects on the L2 word processing, and could explain lower error rate found in the VV transposition condition.

- *CV/VC condition*

L2 English spelling research suggests that CV/VC transpositions are the most frequent spelling errors in L1 Arabic L2 English learners (Bowen, 2011), which is supported by the results obtained in this experimental task. Typical examples of this type of transposition error included: *instrument-*insturment* (19 out of 26 participants), *procession-*porcession* (13) *invitation-*inivtation* (11), *especially-*esepcially* (9) and *mysterious-*msyterious* (9). CV transpositions indicate vowel insertion (epenthesis) which is an error that frequently occurs due to Arabic L1 transfer. As Arabic syllabic structure is regular (CVCV) and does not allow CC+ clusters, these L2 learners tend to break the consonant clusters in English by inserting a vowel (2.2.1).

A high error rate also occurred in CV transpositions resulting in CCC clusters: *accomplish-*accompilsh* (20), *impression-*imperssion* (17). These errors were, on one hand, unexpected as it was assumed intermediate L1 Arabic L2 learners would be more sensitive to consonant clusters in English, as they were assumed to have had sufficient exposure to L2 print at the intermediate L2 proficiency level (for the sensitivity to consonant clusters in these L2 learners, see Saigh & Schmitt, 2012). On the other hand, difficulties in the processing and recall of CCC and CCCC clusters in English in L1 Arabic L2 English learners have been extensively reported (e.g., Haggan, 1991; see 2.2.1). At the same time, as these transpositions occurred in the mid-word and word-final positions, the errors might be an indication of slow processing speed; i.e., the items were not processed fully. For more detail on the processing of word-initial positions in L1 Arabic L2 English learners, see 6.1.2.

In contrast to the CV transposition, the VC transposition indicates the opposite process of epenthesis, i.e., *elision* (vowel deletion), which is another frequent spelling error in L1 Arabic L2 English learners. This can be illustrated with the following item errors: **resloution* (found in 16 out of 26 participants), **unviersity* (12), **mangaement* (9), **genreation* (8). VC transposition errors are less frequent in L1 Arabic L2 English learners compared to CV transpositions. In items following CVCV structure (*management*), VC transpositions (**mangaement*) are predicted to be detected more easily by L1 Arabic L2 English learners as L1 Arabic has a regular CVCV syllable structure (2.2.1). The VC transposition errors therefore indicate a possible overcompensation strategy when processing words in L2 English.

The following examples of error were rather unexpected as the CCC cluster in the initial positions was expected to be detected: _*aftrewards_ (16), _*cnostantly_ (15), _*cnovenient_ (14). The errors with _*cnostantly,_ and _*cnovenient_ contain an illegal *<cno> sequence in the word-initial position which once again indicates lack of knowledge of common orthographic patterns in English (2.1.2.2) in L1 Arabic L2 English learners. See CC condition above for the visuo-perceptual factors, and for more detail, see 6.1.2.

CV/VC transposition errors are significant as they indicate difficulties processing syllables. Furthermore, the item error analysis demonstrated that the error rate was lower in the items containing a CV/VC transposition on a syllable boundary: _en-thu-si-asm-*enthusaism_ (12), _com-plete-ly-*completley_ (12), _u-ni-ver-si-ty-*unviersity_ (12), _in-vi-ta-tion-*inivtation (_11), _pro-tec-tion-*portection_ (10). These results indicate that intermediate L1 Arabic L2 learners have acquired a certain level of awareness regarding the syllabic structure in English. However, high error rate was still found in some items where the transpositions fall on the syllable boundary: _dif-fi-cul-ty- *difficutly (_24), _dis-trib-ute-*ditsribute_ (16), _con-fer-ence-*confernece_ (18), _re-so-lu-tion-*resloution_ (16), etc.

Position of transposition

- _Word-initial positions_

Despite the overall error rate being the lowest in word-initial transpositions, more than half of the participants failed to notice a letter transposition in 3 items in 2/3 letter positions (_*cnostantly_ found in 15 out of 26 participants, _*cnovenient_ (14), _*porcession_ (13)). What is more, 11 participants failed to notice the word-initial 2/3-letter CC transposition in the items _*asbolutely_ and 8 of them in _*ipmossible. *Ditsribute_ (3/4 letter transposition) yielded even a higher error rate (16). These errors were already mentioned previously in the CC transposition section above. They indicate that L1 Arabic L2 English learners might attempt to access words via mid-word fixations rather than through word-initial positions, which indicates an attempt of extrapolating the consonant root (Randall, 2009). This can be explained by the attention being allocated to the right of the centre of the word, which is due to L1 processing transfer (Deutsch & Rayner, 1999), and will be further elaborated on in 6.1.2.

- *Mid-word positions*

The results revealed a high error rate in mid-word transpositions, especially in the 5/6 letter positions (**freqeuntly; *insturment* (19)). These errors suggest left-to-right reading direction and slow word processing in these L2 learners. Sixteen participants made errors in the 4/5 letter position (**afterwards; *resloution*), in the 5/6 letter position in **delihgtful* and in the 6/7 letter position in *indusrtial**. Although mid-word CC transpositions were not expected to yield high error rate, the following did: In positions 4/5 in **conlcusion* (14), in 5/6 in **delihgtful* (16), in 6/7 in **indusrtial* (16) and in **atmoshpere* (13)). For more detail, see 5.1.3.

- *Word-final positions*

Word-final transpositions also attracted a high error rate**.** Overall, the error rate in the tested L2 English learners was marginally higher in the 8/9 than in the 7/8 letter positions, which once again illustrates the performance gradually deteriorating towards the end of the word. This demonstrates the left-to-right processing direction; superior word-initial and mid-word letter processing at the expense of the word-final positions.

The item error analysis also revealed that a considerable proportion of errors in word-final positions involved transpositions in suffix positions. To illustrate this, the transposition in the noun suffix *-ence* (7/8 letter position) was not detected by more than half of the participants (**confernece* (18), **differnece* (17)). The same pattern could also be extracted in the letter positions 8/9 with the noun suffix *-ty* (**difficutly* (24), and the adverb suffix *-ly* (**completley* (12)). These results were not expected as it was assumed that the *intermediate* L1 Arabic L2 English learners have developed sensitivity to processing suffixes in English also due to Arabic being a highly-inflectional language (2.2.1). Regarding CC transpositions, these already yielded a high number of errors in the word-initial and mid-word positions thus this trend was expected in the word-final positions as well (**difficutly* (24)).

5.1.3 Discussion

In this section, the error rate and response times obtained by testing intermediate L1 Arabic L2 English learners will be discussed prior to elaborating on the error rate and response times in the Same and Different conditions.

5.1.3.1 Error rate and Response Time by Group

The results obtained from the Letter Transposition Task revealed that the error rate was higher and the responses were found to be slower compared to the original study by Ryan and Meara (1991) who provided the stimuli in its target form. Similarly to Ryan and Meara, the variability in individual performance was found to be large regarding error rate while the difference regarding response times in individual participants was not found to be large. In other words, while some participants in this study were more inaccurate in their responses, they were not necessarily slower.

Looking at the results in more detail, this experiment revealed errors in one third of the stimuli in the tested intermediate L1 Arabic L2 English learners (34.4%), while the original study by Ryan and Meara (1991) reported error rate twice as low in their intermediate L1 Arabic L2 English learners (17.23%) (also see Ryan, 1993). This can be explained by the differences in the stimuli manipulation employed in both studies. Ryan and Meara (1991) utilised a deleted vowel letter condition (also see Hayes-Harb, 2006; Ryan, 1993) while this experiment employed an adjacent consonant and vowel letter transposition. The latter is considered to be less visually salient as it contains the same number of letters in both presentations in the identity judgment task (*conclusion-*conlcusion*). Therefore, an item containing letter transposition is more easily confusable with the target word. This is especially the case for longer words, which were employed in this study (10 letters). For large priming effects in longer stimuli, see 2.1.2.3.

Turning to response times, in the same vein, the mean response times in this study amounted to 3.8 msec. The response times in Ryan and Meara (1991) were more than 1 second faster while Hayes-Harb (2006) reported mean response times of just over 1 second. Notably, some of the target stimuli in Hayes-Harb consisted of 6 letters only, which was expected to facilitate the letter deletion being detected as letter manipulations were found be less effective in shorter words (Grainger, 2008). Compared to Ryan and Meara (1991) and Hayes-Harb (2006), slower responses found in this study can be again attributed to the difficulty of the task as each stimuli pair contained the same number of letters (2.1.2.3).

5.1.3.2 Error rate and Response Time by Stimulus Condition (Same/Different)

A significant effect of the Same/Different condition on error rate and response times was also found, which again converges with the results reported in other studies investigating L2 word recognition in L1 Arabic L2 English learners (Ryan & Meara, 1991; Ryan, 1993; 1997; see Hayes-Harb, 2006 for response times only).

Regarding error rate, the L2 learners in this study produced double the errors in the Different Condition (e.g., not noticing the transposition in *convenient -*cnovenient)* compared to the Same Condition *(possession-possession)* (for similar results, see Ryan & Meara, 1991; Ryan, 1993; Hayes-Harb, 2006). Error rate in the Different Condition obtained here (45.8%) was twice as high as the error rate reported by Ryan and Meara (19.35%). This can once again be accounted for by the nature of stimuli manipulation in both studies (deletion vs transposition).

In contrast, this study found faster response times in the Same Condition than in the Different Condition. This diverges from the findings in Ryan and Meara (1991), Ryan (1993) and Hayes-Harb (2006) where slower response times were reported in the Same Condition. Jiang (2011) states that "a longer RT in one condition than in another may reflect [firstly] the involvement of *more* mental operations, [secondly] a higher level of *complexity* of operations, or [thirdly] a higher degree of difficulty encountered by the *language processor*" (p.2). The participants in Ryan and Meara (1991) and Hayes-Harb (2006) were exposed to letter deletion stimuli considered easier to reject as identical due to their visual salience compared to the letter *transpositions* (see above). However, it is likely that when the letter deletion was not detected, the process of verifying this increased the response times (Ryan, 1997).

In contrast, stimuli in the Letter Transposition Task required more in-depth processing as both stimuli in the Same and Different Conditions were the same length. Once the

Same Condition was encountered, verification of the items was not necessary, which resulted in faster response times. The verification process was more pertinent in the Different Condition once the letter transposition was detected. This, in turn, increased the response times. Secondly, the “language processor” (Jiang, 2011), which includes word properties, such as word frequency and word familiarity, might also have had an effect on the response times. The higher the word frequency, the more likely the lexical item will be familiar, which leads to a faster response.

With regard to L2 proficiency, this variable was not found to have a significant effect on the participants’ performance. However, it is noteworthy that higher-intermediate L2 learners consistently outperformed lower-intermediate L2 learners. The identity judgment task includes short presentation intervals between the 2 items. This puts a great deal of demand on the working memory as the second stimulus requires matching to the first stimulus. Furthermore, the item length (10-letters) might require longer processing times compared to shorter word items, especially in L2 learners (Kramer & McLean, 2019).

Secondly, the L1 Arabic L2 English learners in this study were found to have an L2 vocabulary size of approximately 2,500 words (3.3.1.1), which is still smaller compared to the L2 vocabulary size expected of an intermediate L2 learner. Therefore, some participants might not have been familiar with some of the lower-frequency words presented (e.g., *lieutenant*) while some word forms (especially with irregular phoneme-phoneme correspondences) might not have been well consolidated in the mental lexicon (Aitchison, 2012). The factors outlined above (task demand; L2 vocabulary size) may have contributed to incorrect as well as slower responses, not only in the learners at the lower end of intermediate L2 proficiency but also in the higher-intermediate L2 learners (for individual differences in performance in L1 Arabic L2 English learners, see Ryan, 1993).

5.1.3.3 Different condition

In this section the Type of Transposition will be discussed before the Position of Transposition. The analysis by the participant and by item will be discussed together.

Type of Transposition

Regarding the Type of Transposition, L1 Arabic L2 English learners would be expected to attain the highest error in the VV transposition condition due to the vowel blindness phenomenon. Instead, the L2 learners in this study incurred the highest error rate in the CV transposition condition which converges with the findings from the L2 English *spelling* research conducted in L1 Arabic L2 Arabic learners. CV transposition errors were found to be one of the most frequent spelling errors in these L2 learners. To illustrate, Bowen (2011) reported that 60 out of 92 orthographic spelling errors constituted a transposition of adjacent vowels and consonants. Therefore, [97]spelling errors featuring CV transposition reported in their study could be directly attributed to the inaccurate CV decoding already at the word processing stage, which was demonstrated in this study.

The results obtained by testing consonants alongside vowels regarding error rate are of great importance. The findings obtained from this task only partially support the vowel blindness phenomenon, which postulates non-linear processing focusing on consonants while vowels are processed superficially. The highest rate in the CV transposition (and not the VV transposition) indicates that at the intermediate L2 proficiency, these L1 Arabic L2 English learners might be starting to process words in a linear manner, where consonants and vowels are beginning to be processed equally, at least in longer words. These findings signal that vowel blindness phenomenon might only be a partial explanation for L2 word processing difficulties found in L1 Arabic L2 English learners. The L2 processing at this L2 proficiency level is more complex than transferring the L1 Arabic processing technique of consonant extrapolation, and requires further investigation. These results also require taking visuo-perceptual factors into consideration which are of great importance in the word recognition research. In this

[97] For the link between the word recognition and spelling, see Abbott, Berninger, & Fayol, 2010.

study these factors included a differential allocation of attention in L1 Arabic L2 English learners compared to L1 English readers. Some of the errors found in this study also imply right-to-left processing in these intermediate L1 Arabic L2 English learners which occurs due to L1 transfer (Hamada, 2017; Randall & Meara, 1988; 2.4.1). This will be further discussed in 6.1.2.

It is of importance that compared to testing letter deletions and substitutions, the results pertaining to CV transpositions indicate difficulties not only in vowel or consonant letters in isolation but also in word segmentation, i.e., parsing lexical items into [98]syllables. It is noteworthy that the highest variability in individual responses was recorded in the CV transposition condition. This means that within the intermediate group there are noticeable differences in the processing syllables. Although the L2 proficiency was not found to be significant, participants at the higher end of intermediate L2 proficiency performed better in this condition, which suggests that the processing of syllables tends to improve with L2 proficiency and more exposure to L2 print.

The item error analysis in this task revealed that the highest error frequency was detected in 3-syllable items. This is significant as 10-letter words with fewer syllables are likely to consist of a more complex CV structure containing multiple consonant as well as vowel clusters. These were expected to pose difficulties for L1 Arabic L2 English learners as L1 Arabic syllabic structure has a regular CV structure while the consonant clusters are considerably more limited compared to English (2.2.1). Furthermore, difficulties processing L2 syllabic structure in L1 Arabic L2 Arabic learners can already be deduced from the naturalistic observations in the L2 English classroom; the learners frequently demonstrate difficulties dividing lexical items into smaller segments (Bowen, 2011).

Apart from the CV transposition error rate, more errors were recorded in the VV than CC manipulations in this study. This converges with the findings in *L1* English letter transposition research where CC transpositions were found to have larger priming effects in contrast to VV transpositions which produce more inconsistent results, both

[98] *Syllables* consist of a vowel unit in isolation or combined with one or more optional units, i.e., usually consonants (Matthews, 2007).

in L1 and L2 English readers (2.1.2.3). The results obtained in this study are therefore in line with a large body of research that consonants are universally more prominent than vowels (New et al., 2008; Share, 2008; Shimron, 1993). This is specifically harnessed by Berent & Perfetti's consonant/vowel reading model (1995), which posits consonants and vowels work at different levels and require different processing mechanisms (2.1.1.3).

In this vein, the CC transposition errors are also worth mentioning. Although the participants overall demonstrated sensitivity to CC transpositions, the item error analysis showed that almost half of the CC transposition errors (**conlcusion*) still featured in the 22 most frequent errors by item (see Table 11 in 5.1.2.2). This suggests that there are more complex mechanisms at play in how intermediate L1 Arabic L2 English learners process sequences of consonant and vowel letters in English rather than what vowel blindness suggests (for visuo-perceptual processing factors in L2 word recognition, see 6.1.2).

Turning to response times, this variable did not reach statistical significance in the Different Condition (Type of Transposition). Despite that, certain trends could be observed. Due to L1 Arabic word processing preferences where consonants are typically focused on, the L1 Arabic L2 English learners were expected to respond fastest in CC transpositions. Instead, a reverse trend was found. The L1 Arabic L2 English learners were marginally the fastest in detecting VV transpositions. Similarly, Hayes-Harb (2006) reported unexpected results from their [99]between-group analysis showing faster response times for the vowel deletion condition than consonant deletion condition (for more detail, see 2.4.1).

Interestingly, the VV transposition in this study was the only condition where participants of lower-intermediate L2 proficiency outperformed the participants of higher-intermediate L2 proficiency. This contributes to the inconsistent findings regarding the processing speed of vowels in L2 learners, and therefore requires further investigation. Furthermore, these findings demonstrate that consonants are not necessarily processed faster than vowels, which points towards linear processing also in *lower*-level intermediate L1 Arabic L2 English L2 learners. For regular grapheme-

[99] L1 Arabic, L1 Non-Arabic and L1 English

phoneme correspondences in the VV transposition condition, which may have had facilitative effects on these results, see 5.1.2.2.

Position of Transposition

Regarding the Position of Transposition, the intermediate L1 Arabic L2 English learners demonstrated the highest error rate in mid-word transposition condition. The item error analysis also confirmed that the intermediate L1 Arabic L2 English learners were the most successful at detecting letter transpositions in word-initial and to a lesser extent in word-final positions, while they were the least successful processing transpositions in the mid-word positions. This confirms the initial eye fixation at the leftmost word boundary, which is in line with the well-documented superior processing at word boundaries found in L1 English readers (Bruner & O'Dowd, 1958; Hammond & Green, 1982). These results also converge with the results reported in Ryan and Meara (1991) who also found the vowel deletions to be processed the slowest in the mid-word position (position 6) in their Arabic learner group.

The results obtained from the item error analysis demonstrated that the error rate increased with the position of transposition which indicates left-to-right word processing in this group of L2 learners. A similar pattern was also reported in Ryan & Meara (1991) who also found deletions in word-initial positions (2 and 4) to be detected significantly faster in all the [100]groups, including in their Arabic learner group. Therefore, the results obtained from analysing letter positions signal similar processing patterns in L1 Arabic L2 English learners reported in Ryan and Meara (1991) and in this study, regardless of different letter manipulations employed in the two.

Naturalistic observations from the L2 English classroom also support left-to-right processing in lower-frequency and likely unfamiliar longer words, not only in Non-Arabic but also in L1 Arabic L2 English learners. When asked to read these, L1 Arabic L2 English learners tend to accurately process the beginning of a word. This frequently activates the highest-frequency word with the same initial letter string/syllable and therefore results in word confusion (e.g., the word item *president* is activated instead

[100] Non-Arabic L2 English group and L1 English control group

of the target item *precedent*). Similar findings were also obtained in the Auditory-Visual Letter Word Matching Task and will further be discussed in 6.1.2. For processing initial letter sequences and syllables, see Taft (1979); for more detail in processing word-initial positions in L1 Arabic L2 English learners, see 6.1.2.

The error analysis by participant revealed that the individual variability in performance in error rate was the highest in mid-word positions (*SD*=4.92). Although the L2 proficiency was not found to be significant in this task, the individual variability in error rate in mid-word positions was especially evident in *lower*-intermediate L2 learners. This demonstrates that the processing in L2 learners varies significantly more in how accurately they detect the transpositions in mid-word positions compared to higher-intermediate L2 learners. This could be explained by more variability in the exposure to L2 print found in lower-intermediate L2 learners. For mid-word positions yielding poorer performance than external word positions in L1 English readers, see 2.1.2.3.

Although the response times were also not found to be significant in the Position of Transposition, the mid-position transposition also yielded marginally the slowest responses compared to the word-initial and word-final transpositions. This does not reflect accuracy/speed trade-off as it was expected. The slowest processing in mid-word positions again suggests the processing advantage of external letter positions. More importantly, these results do not indicate the mid-word fixation (consonant extrapolation) in these L2 learners as these letter positions would have otherwise yielded the lowest error rate. Therefore, similarly to the Type of Transposition results, the Position of Transposition results also demonstrate left-to-right processing and the use of the phonological route (for poorer processing in word-final positions, see Stein, 2010). The findings indicate that intermediate L1 Arabic L2 English learners are starting to process words in L2 English in a linear manner. These findings are of great importance as they diverge from the phenomenon of vowel blindness which postulates non-linear processing involving consonant extrapolation.

In contrast, the item error analysis also revealed that the processing of the word-initial positions revealed a different processing trend in these L2 learners compared to the processing of mid-word positions. A relatively high error rate in word-initial positions (**cnostantly, *porcession*) especially with the items containing the CC transposition (*a<u>sb</u>olutely; *i<u>pm</u>ossible; *di<u>ts</u>ribute)* might nevertheless suggest mid-word fixation. This might have occurred as some L1 Arabic L2 English learners might have attempted employing the L1 processing technique of extrapolating the consonant root (see 4.1.3 for similar findings in shorter stimuli).

These findings indicate the attempt to use the orthographic route (Martin, 2011; Taylor, 2008) in the processing of some of these 10-letter words. Longer words, even if higher frequency were expected to trigger the use of the phonological route in L1 Arabic L2 English learners. Arabic words are overall shorter than words in English and these L2 learners were found to typically over-rely on this processing route when reading words in L2 English (e.g., Alhazmi et al., 2019). Fluent L1 English readers recognise even longer words of higher frequency by taking a 'snapshot' of the whole word, i.e., of consonants and vowel letters. These findings signal that the orthographic route was employed in these L1 Arabic L2 English learners but was not utilised efficiently as vowels were not processed accurately.

For the explanation of these results including visuo-perceptual factors, see 6.1.2.

5.2 Chapter Summary

This chapter presented the Letter Transposition Task which tested the effects of letter transposition on L2 word recognition in L1 Arabic L2 English learners. First, the rationale for the experimental task and its evaluation were provided. Subsequently, the materials and testing procedure were presented (including the stimuli and design constraints) before outlining the hypotheses and analytical procedures employed. Next, the results and a detailed item error analysis in the Different Transposition Condition were presented prior to discussing the impact of letter transposition on L2 word recognition and vowel blindness in L1 Arabic L2 English learners.

The following chapter will summarise and discuss the results from both experiments conducted in this study.

Chapter 6: General Discussion

This chapter will synthesise the most important findings obtained from both experimental tasks in this study and discuss them in the context of the vowel blindness phenomenon. First of all, the main findings regarding vowel processing will be presented, followed by the effects of L2 proficiency and individual variability in the performance of the tested L1 Arabic L2 English learners. Subsequently, word length effects found in this study will be elaborated on prior to providing alternative explanations to the concept of vowel blindness based on the comparison with young L1 readers.

6.1 Main Findings Regarding Vowel Processing of L1 Arabic L2 English Learners

The intermediate L1 Arabic L2 English learners did not perform at ceiling in either of the experimental tasks conducted in this study which demonstrates that difficulties with the processing of vowels are still present in these L2 learners. For instance, certain orthographic patterns had not been found to be consolidated yet. The findings demonstrated inaccurate processing of the word-final letter <e> as well as difficulties differentiating between the [101]/ɪ/ and /e/ phonemes and mapping them onto <i> and <e> graphemes. Secondly, short vowels still attracted more errors than long vowels in these L2 learners.

However, the findings in this study also demonstrated that at the intermediate L2 proficiency level, vowels are starting to be processed more accurately as well as faster. For example, lower error rate and faster response times were found in the VV transposition condition than in the CV transposition condition. Furthermore, rather than having difficulties distinguishing between short and long vowels, more difficulties were recorded differentiating between diphthongs and long vowels. Notably, in order

[101] These phonemes are allophonic in Arabic and are therefore frequently confused by L1 Arabic L2 English learners when processing words in L2 English.

to increase the reliability of these findings, L1 English readers and/or L2 readers from other, Non-Arabic L1 backgrounds ought to be tested as well (7.3).

6.1.1 L2 Proficiency and Variability in Individual Performance

Within the context of vowel blindness, other factors, such as word length, letter position, L2 proficiency, syllabic structure, ought to be taken into consideration as well. These provide a further insight into the complex workings of how L1 Arabic L2 English learners process words in L2 English. This helps in understanding their idiosyncratic L2 reading difficulties.

In terms of L2 proficiency level, the Auditory-Visual Word Matching Task demonstrated a significant difference between the higher- and lower-intermediate L2 learners regarding error rate. The former were more likely to have had more exposure to L2 print and acquired a larger L2 vocabulary size which facilitated their L2 word recognition. Although the differences between these two groups were not found to be significant in the Letter Transposition Task, there was a trend of higher-intermediate L2 learners outperforming the lower-intermediate L2 learners. Therefore, the L2 proficiency findings in this study also demonstrate more accurate vowel processing in higher than lower-intermediate L1 Arabic L2 English learners as well as indicate better knowledge of frequent vowel/consonant orthographic patterns in higher-intermediate L2 learners.

The significant difference between the higher- and lower-intermediate L2 learners found in the Auditory-Visual Word Matching Task could be attributed to the fact that this task was specifically designed for L1 Arabic L2 English learners. Therefore, it succeeded in tapping into specific processing difficulties found in these L2 learners, i.e., within a single (intermediate) L2 proficiency level. In this vein, if elementary and advanced L2 learners had been tested, the differences in the processing between these L2 proficiency groups would be expected to be even more pronounced (see 7.5 for the *Recommendations for Future Research*).

Regarding the variability in *individual* performance, the Letter Transposition Task demonstrated large differences in performance comparing the tested participants while the Auditory-Visual Word Matching Task did not. This might be explained by the difference in the two task types employed. The Letter Transposition Task could be construed as a more of a cognitive rather than a linguistic task, therefore some participants might be more successful at it than others, regardless of their L2 proficiency level (5.1.1.2). Conversely, the Auditory-Visual Word-Matching Task was designed for L1 Arabic L2 English learners and focused on specific errors which are typically found in this L2 learner group.

On the other hand, response time in the Letter Transposition Task did not provide a wide variability in individual responses. This ties in with the cross-linguistic research where L1 Arabic L2 English learners were found to be significantly less accurate than other L2 learners but not necessarily significantly slower (e.g., Ryan & Meara, 1991). Interestingly, L1 Arabic L2 learners were found to overuse the phonological route in L2 English (e.g., Masrai, 2021), which results in slower processing compared to the use of the orthographic route. Fast L2 word recognition found in L1 Arabic L2 English learners (when words are processed correctly), might mean that the phonological route was employed. However, instead of processing the whole word, the word-initial letter sequences were processed only while the remainder of the word was predicted. This could have lowered the response times in these L2 learners (for *errors* employing the phonological route by using the word-initial positions only, see the next section).

6.1.2 Word Length and the Processing Routes Employed

Turning to word length, this word property was found to have a significant effect on how intermediate L1 Arabic L2 English learners process words in English when measured in terms of the number of syllables. More errors were found in shorter, monosyllabic words than in longer, polysyllabic words. This was explained by the fact that shorter, monosyllabic words are more difficult to discriminate between as they frequently demonstrate only one vowel letter as a distinguishing feature (e.g., *bit/bat/but*). Although longer words contain more letters to process, they also contain more distinguishing features (letters they differ in/not share), which could explain a better performance in longer, polysyllabic words.

The word length effects are also closely connected to the processing routes employed (1.2). One of the most important findings in this study was that longer words in both experimental tasks were found to be processed employing the phonological route which involves letter-by-letter, left-to-right processing. This was supported by the participant and item error analyses. This type of processing is of great importance as it suggests that L1 Arabic L2 English learners of intermediate L2 proficiency are starting to process both, consonants and vowels in a similar manner. This diverges from the vowel blindness phenomenon which postulates that vowels are processed superficially compared to consonants.

Errors which occurred in *longer* words can be explained by the fact that initial-letter positions were processed accurately while the remainder of the word might have been predicted. The beginning of the word informed the identification and a retrieval of a familiar word (most likely of high frequency) which starts with the same/similar letter/sound sequence and exists in the mental lexicon. For example, the target word [102]*precedent* <*pres*-d-n-t> will likely activate the word *president* <*prez*-d-n-t> which is higher-frequency. When taking visuo-perceptual factors in word recognition into account, this type of processing is referred to in the literature as [103]*parafoveal* processing (see below).

During the initial fixation, readers can preview the remainder of the word and/or the initial letters of the following word with the parafoveal view. Adopting the technique of processing the word-initial letter sequences is possible in English as the initial letters can help constrain word identities (Farid & Grainger, 1996). In other words, word-initial positions in English are more informative as these include 'unique linguistic information' which distinguishes one word from other, orthographically similar words (Broerse & Zwaan, 1966)**.** Developing this processing technique in Arabic is less likely to occur. Arabic words are shorter and consonants are distributed around the word, i.e.,

[102] In English letter <c> frequently maps onto the phoneme /s/ (*precedent*). Although letter <s> in *president* is pronounced as /z/, the orthographic form prevails over the phonological form. This results in processing both beginnings of the words as /pres---/ which activates a higher-frequency word (*president* over *precedent*).

[103] The foveal region (fixation) extends from 0° to 1° of the visual angle; here letters are best identified. Parafoveal region extends from 1° to 5° of the visual angle on either side of the fixation. In this region we can preview letters but cannot identify them as well as in the fovea region (Schotter, Angele, & Rayner, 2012).

they are not necessarily adjacent (2.2.3). As the lexical space in Arabic is denser, the parafoveal preview of the initial letters might not benefit word recognition in Arabic (AlJassmi, Warrington, McGowan, White, & Paterson, 2022).

Turning to the number of consonants, these were also employed as a measurement of word length to test whether the consonants were processed in more detail than vowels. These results were not found to be significant, which once again diverges from the concept of vowel blindness (consonant root extrapolation) in intermediate L1 Arabic L2 English learners. As explained earlier, these findings also suggest these L2 learners are starting to process letters overall sequentially (linear or letter-by-letter processing) in both, shorter and longer words.

Another important finding which is not in line with the concept of vowel blindness is the highest error rate found in the CV transposition (rather than VV transposition condition) in the Letter Transposition task. This has important implications for the processing in intermediate L1 Arabic L2 English learners as it points towards difficulties in processing *syllables*. This was also supported by the item error analysis where the highest error rate was recorded in long (10-letter) words consisting of 3 syllables. These words tend to consist of a larger number of [104]consonant and vowel clusters (e.g., CC/CCC/CCCC; VVV), which differs from the regular CVCV structure typically found in L1 Arabic. This poses processing difficulties in these L2 learners as they typically try to break down the consonant clusters to attain the regular CVCV structure (e.g., **sipring* for *spring*). The highest error rate in the CV transposition position also diverges from the concept of vowel blindness as it demonstrates difficulties with processing letter sequences rather than letters in isolation which is postulated by vowel blindness.

In spite of the findings above pointing away from the consonant extrapolation and vowel blindness in intermediate L1 Arabic L2 English learners, there is some evidence that the processing technique of mid-word fixation might have been employed, especially in *shorter* words.

[104] Conversely, for good performance in consonant clusters in intermediate L1 Arabic L2 English learners, see Saigh and Schmitt (2012).

Difficulties processing shorter words could be explained by the fact that there was an attempt of accessing these words via the orthographic route. This is otherwise an efficient way of accessing high-frequency (sight) words. It involves a 'snapshot' of a whole word by processing consonants and vowels sequentially and is employed by fluent L1 English readers/proficient L2 English readers. However, as L1 Arabic L2 English learners processed these shorter, monosyllabic words inaccurately, this indicates the inaccurate use of the orthographic route in English due to L1 transfer. This would involve the L1 Arabic technique of consonant extrapolation where vowels were processed superficially. This example of non-linear processing is postulated by the phenomenon of vowel blindness, which suggests that it is still present in how intermediate L1 Arabic L2 English learners process words in L2 English.

This study also found some evidence of L1 Arabic L2 English learners accessing *longer* words (not only shorter words) through the orthographic route, however, this evidence is limited. The mid-word fixation in longer words most likely occurred as high error rate was found in word-initial CC transpositions (**cnonstantly*). This indicates that the word-initial position was not processed accurately which points against left-to-right processing.

These errors might also indicate that these intermediate L1 Arabic L2 English learners processed some longer words in the right-to-left direction, which occurs due to transferring L1 processing techniques to L2 English. In contrast to English, Arabic is read from right to left; therefore, the initial fixation when reading Arabic words tends to fall [105]right to the centre of the word while the best performance in English occurs when the fixation falls centre-left. Therefore, the location where the fixation occurs in a word is mirror-reversed in the two scripts (Deutsch & Rayner, 1999; Nazir, 2000). This is also supported by errors found in non-adjacent C-C transpositions where L1 Arabic L2 English learners were expected to perform at ceiling (**colour* was confused with *coral*; **pristine* with *percent*). These types of error are [106]not commonly found in

[105] Notably, unlike in left-to-right scripts (e.g., English), in Arabic, the position where the optimal fixation occurs was found to be dependent on the morphology of the word employed (for more detail, see Farid & Grainger, 1996). Therefore, L1 Arabic word processing transfer effects on L2 word processing require further investigation.

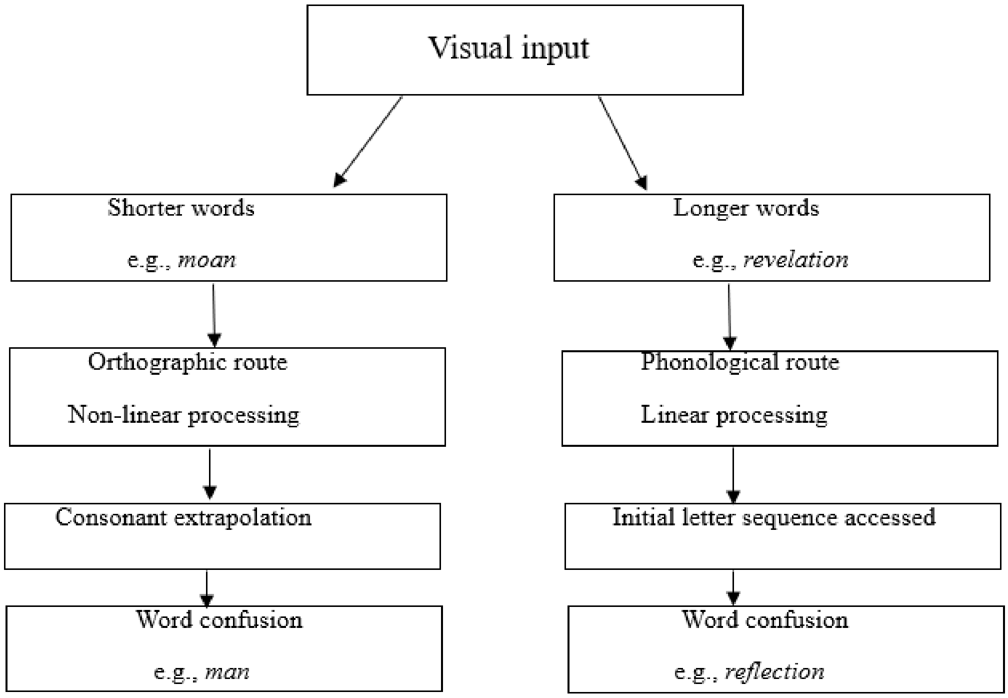
[106] It is noteworthy that the error rate found in this condition was low.

these L2 learners because in L1 Arabic, recognising a consonant *sequence* is vital in successful word recognition (2.2.3).

Taking these exceptions aside, it can be concluded that intermediate L1 Arabic L2 English learners predominantly access longer words in English via the phonological route and shorter words through the orthographic route. This might occur as words in Arabic are generally shorter than words in English (2.2.3). Therefore, processing *longer* words in English is expected to cause more difficulties for L1 Arabic L2 English learners in general, especially via the 'snapshot' orthographic route employed in skilled L1 readers. This could also explain why L1 Arabic L2 English learners in this study were also found to use the phonological route more than the orthographic route when processing L2 words. This also ties in with their widely-reported superior phonological processing skills (e.g., Alhazmi et al., 2019).

When taking all the findings obtained in this study into consideration, a pattern resulting in word confusion errors emerges with regard to the L2 processing in intermediate L1 Arabic L2 English learners, which is based on word length. Errors with shorter and longer words signal that neither of the processing routes were utilised efficiently when processing words in English. These errors involve failing to take a snapshot of both consonants and vowels in shorter words and not processing the word fully in longer words (see Figure 12).

Figure 12: L2 Word Processing in L1 Arabic L2 English Learners by Word Length Resulting in Word Confusion



6.1.3 Comparisons with L1 Young Readers

There are also alternative explanations for the errors found in shorter, monosyllabic words as well as in some instances in longer words which are not related to the consonant extrapolation and the phenomenon of vowel blindness. The errors recorded in the intermediate L1 Arabic L2 English learners in this study are reminiscent of the reading patterns observed in young L1 English readers (see Ehri 1995; 2005 for the *Reading development framework*).

The reading patterns in the L2 learners in this study were found to resemble the *partial alphabetic reading stage* in L1 English children where the connections between graphemes and phonemes are not consolidated yet. Both of these groups typically focus on the most visually salient features, which are most commonly consonant letters or letters at word boundaries (Randall & Meara, 1988). This occurs as they are not able to segment words into all its phonemes yet. Due to a large variation in grapheme-phoneme mapping in English, both groups tend to find vowels difficult to discriminate between, which frequently results in word confusion. Similarly, in terms of spelling, young L1 readers and L1 Arabic L2 English learners are both prone to inventing partial spellings of words by only writing the most salient sounds (predominantly consonants) and omitting letters in mid-word positions (predominantly vowels) which suggests that orthographic representations in the mental lexicon are not fully consolidated yet. This could be illustrated by the findings from the error item analysis in this study where errors with the orthographic patterns, such as the final silent letter <e> have not been consolidated yet (see 4.1.2.1 for *Vowel Modification*s).

This reading stage also indicates that the reading skills in L1 Arabic L2 English learners could improve through a larger exposure to L2 print which also increases the L2 vocabulary size, i.e., the number of word forms in mental lexicon. This would subsequently lead to the *full-alphabetic phase* where readers have acquired the sufficient knowledge of the ortho-phonemic system which can subsequently be used to utilise the connections between graphemes and phonemes. This knowledge further facilitates decoding unfamiliar words and storing fully-analysed sight words in the mental lexicon (Ehri, 1995; 2005). The learners of higher-intermediate L2 proficiency in this study demonstrated processing high-frequency orthographic sequences including vowels with higher accuracy than lower-intermediate learners. This illustrates that more exposure to L2 print ultimately leads to the final reading phase of becoming a fluent reader.

Overall, this study has demonstrated complex workings of how L2 words are recognised in intermediate L1 Arabic L2 English learners with specific relation to vowels. To properly analyse their L2 processing errors - frequently resulting in word confusion - various factors ought to be taken into consideration (e.g., word length, letter position, processing route, syllable structure), rather than solely focusing on the processing of vowels. This study recorded limited evidence supporting vowel blindness in intermediate L1 Arabic L2 English learners. This phenomenon was found to still be present but not prevalent in intermediate L1 Arabic L2 English learners, and cannot fully explain the reading difficulties found in these L2 learners. For the summary of various factors pointing against the prominence of vowel blindness in intermediate L1 Arabic L2 English learners, see 2.5.

6.2 Chapter Summary

This chapter synthesised the most important findings obtained from both experimental tasks in this study and discussed them in the context of the vowel blindness phenomenon. First of all, the main findings regarding vowel processing were presented, followed by the effects of L2 proficiency and individual variability in performance. Subsequently, the word length effects as well as the processing routes employed were discussed. Finally, alternative explanations to the concept of vowel blindness based on comparisons with young L1 readers were provided.

Chapter 7: Conclusion

7.1 General Summary

This study explored L2 word processing and L2 word recognition in adult intermediate L1 Arabic L2 English learners with a specific focus on vowel blindness typically found in this L2 learner group. Two experimental tasks were administered to investigate whether this phenomenon still persists at the intermediate L2 proficiency level. This study also aimed to investigate whether other factors, such a word length, letter position or the choice of a processing route have a significant effect on how these L2 learners process words. The study was conducted with the view to gaining an insight into why these L2 learners face specific difficulties in reading at word level (e.g., word confusion), the reasons for which were predicted to go beyond the well-documented phenomenon of vowel blindness.

The introductory chapter situated the current research within the framework of L1 English literacy. The notion of vowel blindness in L1 Arabic L2 English learners was introduced alongside some of the principal studies investigating this area, which served as the basis for this study. Subsequently, a number of methodological limitations in the existing literature were outlined and various gaps were identified. It was posited that the role of vowel blindness in intermediate L1 Arabic L2 English learners might not be sufficient in explaining difficulties these L2 learners demonstrate in L2 English word processing.

Chapter 2 reviewed previous literature relevant to the current study. First, word recognition in L1 English was introduced prior to outlining word recognition in L1 Arabic. Subsequently, *L2* English word recognition was introduced which highlighted the key research on the L2 word processing in L1 Arabic L2 English learners. Chapter 3 presented the overview of the current research by introducing the participants, their reading habits and the methodology employed in this study. Chapter 4 and 5 introduced the 2 experimental tasks. For each of the experiments, the rationale was outlined before presenting the methodology, results obtained and discussing the results.

The Auditory-Visual Word Matching Task tested the impact of vowel blindness on L2 word recognition in intermediate L1 Arabic L2 English learners by exploring word length effects in shorter, monosyllabic words and longer, polysyllabic words. The second, Letter Transposition Task tested vowel blindness via letter transposition effects in longer, polysyllabic 10-letter words. Chapter 6 provided an in-depth discussion of the findings obtained in both experiments, while this chapter provides the conclusion of the thesis.

In the subsequent section of this chapter, the limitations of the study will be delineated. The contribution of this study to the wider L2 reading research will be discussed and some practical implications of the results obtained in this study will be presented. Lastly, ideas for the future research will be elaborated on. This section is followed by the literature consulted (References) and Appendices.

7.2 Main Conclusions

Vowel blindness is an L2 processing phenomenon typically found in L1 Arabic L2 English learners of lower L2 proficiency, and it is expected to become less pertinent with L2 proficiency and more exposure to L2 print. Due to L1 transfer, this phenomenon posits non-linear word processing where consonants are processed in detail while vowels tend to be processed superficially via consonant extrapolation. This leads to retrieving an erroneous word form from the mental lexicon and results in errors, such as word confusion. Conversely, a fluent L1 English/L2 English reader will process consonants as well as vowels in a linear manner.

According to the principles of word recognition posited in the Dual Route Reading Models, words are processed through the orthographic and/or phonological routes. To access high-frequency sight words, the faster, orthographic route will be employed while unfamiliar and lower-frequency words will be processed through the phonological route (1.2).

In connection to the processing routes outlined above, this study revealed that word length has an effect on how intermediate L1 Arabic L2 English leaners process L2 words. The findings demonstrate that these L2 learners alternate between using [107]both routes when processing words in English. Word length was also found to inform the preferential processing route employed – shorter, monosyllabic words were overall found to attract the use of the orthographic route while longer words were found to elicit the use of the phonological route. When errors resulting in word confusion occurred in the tested L1 Arabic L2 English learners, these suggest that neither of the processing routes were utilised efficiently (Figure 12).

The findings in this study confirmed that difficulties in the L2 processing in intermediate L1 Arabic L2 English learners are only partially connected to the phenomenon of vowel blindness. These results contribute to the growing evidence which points against the prominence of this phenomenon, especially in the L2 processing in intermediate and higher L2-proficiency L1 Arabic L2 English learners (Allmark, 2022).

The highest error rate in this study was recorded in the CV transposition condition and not the VV transposition condition. Therefore, L1 Arabic L2 English learners were primarily found to have difficulties with syllables and letter sequences (CV), rather than letters in isolation, which is postulated by vowel blindness. This has important implications for pedagogical practices and for further research, which will be elaborated on in the subsequent sections (see 7.4.1)

Overall, the error analyses in this study demonstrated left-to-right reading direction in the processing in intermediate L1 Arabic L2 learners. This suggests that at this L2 proficiency level, there is a shift from non-linear processing to linear processing, which means that consonants and vowels are being processed sequentially. In this regard it can be concluded that the intermediate L1 Arabic L2 English learners in this study used the phonological route more than the orthographic route when processing L2 words. These results are in line with the vast body of literature on L2 word recognition in L1 Arabic L2 English learners (1.3.1).

The L2 word recognition performance in intermediate L1 Arabic L2 English learners in this study is reminiscent of the *partial alphabetic reading stage* found in young L1

[107] For alternating between the orthographic and phonological processing routes, see Goswami (2010).

English readers (Ehri, 1995; 2005). This intermediate reading stage also features inaccurate vowel processing, which is a vital step in becoming a fluent reader. This is of great importance as it suggests that intermediate L1 Arabic L2 learners can transition from the partial alphabetic to *full alphabetic stage* where they become fluent readers. This can be achieved through more exposure to L2 print, which expands the L2 vocabulary size (orthographic knowledge), as well as through guided print input. This facilitates the recognition of frequent orthographic patterns including syllables, which are essential for successful sublexical processing. These combined factors contribute to successful word recognition.

It can be concluded that vowel blindness is still present but not pertinent in L2 word processing in intermediate L1 Arabic L2 learners and cannot fully explain the reading difficulties found in these L2 learners. Understanding their L2 processing difficulties requires going beyond vowel blindness and investigating other areas, such as the processing of consonant/vowel letters in different word positions and the processing of syllables, as well as exploring the effects of various word properties (e.g., word length).

7.3 Limitations

This study is subject to limitations predominantly due to the research design adopted which was restricted to L1 Arabic L2 English learners and therefore limited the interpretation of the results. Other limitations included certain methodological choices, such as the stimuli employed and the garnered participant pool. All of these will be elaborated on in more detail below.

Regarding the research design in this study, L1 Arabic L2 English learners were the only learner group tested, which allowed delving deeper into their L2 word processing. However, this research design also reduced the scope and validity of the research by limiting the interpretation of its results, i.e., not allowing direct comparisons with other L2 proficiency levels (elementary/advanced), other intermediate L2 learner groups (Non-Arabic L2 learners) or the control group (L1 English readers). Therefore, it is not clear whether the findings occurred only in L1 Arabic L2 learners or whether these were also applicable to other L2 learner groups and/or L1 English readers (see *Item Error Analyses* in 4.1.2.1 and 5.1.2.2).

Within the context of this study, adopting between-subjects design over the one-group research design would have been beneficial in investigating the extent of the superior processing of consonants over vowels with regard to *response times* which has frequently yielded non-conclusive results in [108]L2 word recognition research. In the same vein, item error analyses in both experiments in this study would have benefited from comparing the results with L1 readers/ L2 learners. The one-group research design in this study only allowed drawing conclusions based on L1 transfer and previous one-group research conducted on L1 Arabic L2 English learners.

Turning to the stimuli employed, this study aimed to control various variables when designing the stimuli for both experimental tasks presented. These restrictions resulted in a varying number of stimuli across different categories/conditions (see *Stimuli Constraints* in 5.1.1.2). For instance, the number of items in the CV transposition condition was higher than in the VV and CC transposition conditions. This might have also contributed to the highest error rate found in the CV transposition condition. Therefore, some caution needs to be exercised when interpreting these results (for an unequal number of stimuli in consonant/vowel conditions in L2 word recognition research, see Martin, 2017).

In relation to the stimuli, piloting word items employed in the Auditory-Visual Word Matching Task also needs mentioning. The piloting in this task was conducted on L2 Non-Arabic learners as initially the task was intended to be administered on Non-Arabic L2 English learners as well. The participants in the pilot should normally match the participants' profile in the main study as closely as possible. Therefore, the pilot should have been administered on[109]L1 Arabic L2 English learners, even though this might have potentially resulted in a small pilot sample. This would have been more informative of the suitability of the task specifically designed for L1 Arabic L2 English

[108] See Alhazmi et al., 2019; Hayes-Harb, 2006. For the critique of the one-group reading research in L1 Arabic L2 English learners, see Allmark (2022).

[109] In the Letter Transposition Task, the stimuli were piloted on L1 Arabic L2 English learners.

learners who typically demonstrate more L2 reading difficulties and differential processing patterns to other L2 learner groups.

In terms of the L2 proficiency in English, The L1 Arabic L2 English participants in this study were recruited based on their overall IELTS scores. These include the reading and writing component scores, pertinent for this study investigating L2 word processing, alongside speaking and listening components, which are of lesser importance for this study. As speaking and listening are areas L1 Arabic L2 English learners typically demonstrate superior performance in, the total IELTS score might have been inflated, i.e., not representative of the participants' reading and spelling/writing skills. Recruiting participants solely based on their reading and writing scores would have yielded a more well-defined participant group. At the same time, the results from the baseline Vocabulary Size X-Lex Test confirmed that the L2 vocabulary size in the L1 Arabic L2 English participants in this study broadly fell within the intermediate L2 proficiency range, which extends to their reading and writing skills as well (for more detail, see 3.3.1.1)

Lastly, the participant group in this study was considered to be more homogenous than in some other studies testing L1 Arabic L2 English learners (e.g., compared to the L2 proficiency range in Alsadoon & Heift, 2015, or compared to the sample size in Ryan & Meara, 1991). However, there are certain shortcomings regarding these areas in this study that ought to be mentioned.

For instance, although all the participants in this study were assessed as broadly intermediate, they still varied considerably in terms of their L2 proficiency (IELTS:3.0-6.0;CEFR:A2-B2). A more homogenous group in terms of L2 proficiency might have yielded smaller individual variability in performance and therefore reveal stronger processing effects, i.e., stronger presence of vowel blindness in lower L2 proficiency learners and the absence of it in higher L2 proficiency learners. In order to counterbalance for a potential lack of group homogeneity, the participants were divided into a higher- and a lower-L2 proficiency groups, which demonstrated the transition from non-linear to linear processing in L1 Arabic L2 English learners within the intermediate language learning stage.

Due to time constraints, a larger sample size could not be recruited. A limited participant pool (N=26) is of specific importance for the item error analyses where descriptive statistical methods were employed to analyse the data (see 4.1.1.3 and 5.1.2.2). A smaller sample size means the findings obtained through item error analysis in this study might not extend to all the L1 Arabic L2 English learners and the results should be approached with caution. For descriptive statistical analysis, see 3.4.1.

7.4 Contribution and Implications of this Study

Several main implications have arisen from the current study. The findings have contributed to the understanding of L2 literacy in L1 Arabic L2 English in terms of the processing at L2 word level.

Although L1 Arabic L2 English learners overall represent a relatively large proportion of L2 learners, L2 word processing in this L2 group has received considerably less attention compared to other L2 learner groups with L1 Non-Roman-Alphabetic orthographies (e.g., L1 Chinese). In contrast to the cross-linguistic studies, this study focused solely on L2 word processing in L1 Arabic L2 English learners. This enabled delving deeper into the specific reading difficulties in this L2 group (also see 7.3. for *Limitations*).

This study aimed to further investigate L2 reading difficulties by limiting them to *intermediate* L1 Arabic L2 English learners. Focusing on this L2 proficiency level was of great significance. This study has demonstrated that at this level, the L2 word processing in these L2 learners tends to shift from predominantly focusing on consonant letters in isolation driven by the vowel blindness phenomenon (non-linear processing technique of extrapolating the consonant root) to linear processing where letters are processed sequentially in alphabetic scripts.

In this way, vowel blindness might only be partially responsible for L2 word recognition difficulties typically found in intermediate and higher-level L1 Arabic L2 English learners, which is one of the most important implications of this study. Therefore, this study challenged the role of vowel blindness as the main source of L2 reading difficulties found in *intermediate* L1 Arabic L2 English learners and contributed to the research literature that tries to go beyond this processing phenomenon, by revealing other sources for their L2 reading difficulties. These amongst others cover difficulties with word segmentation, i.e., processing of syllables and letter sequences rather than letters in isolation. Secondly, this study also included the impact of word length and letter position on L2 processing which can have significant effects on the processing route employed. Until now, fine-grained sublexical processing has prompted relatively little investigation in these L2 learners. Thirdly, results from the item error analysis in this study also pointed towards investigating visuo-perceptual factors in L2 word recognition in these L2 learners, which include reading direction. This will provide an important insight into understanding specific reading patterns typically found in L1 Arabic L2 English learners.

Overall, the findings presented here also raise wider, universal implications in how readers learn to recognise words. The participants in this study demonstrated L2 processing difficulties which may be interpreted as arising from the progressive nature of mandatory reading stages involved in becoming an effective L1 and L2 reader.

Based on the findings in this study and rooted in the principles of word recognition in the Dual- Route and Connectionist Reading Models (2.1.1), the present study has also contributed towards developing a non-computational reading model (Figure 12) by identifying the need to provide an account of the effects of word length. This revealed the complex mechanisms underpinning the specific L2 reading difficulties found in intermediate L1 Arabic L2 English learners, and opened new avenues of research into the phenomenon of vowel blindness as well as the wider area of L2 word recognition.

This study has confirmed that the task selection and the task demand have specific implications for these L2 learners due to the specificity of L1 Arabic word processing techniques and their transfer onto L2 English (Martin, 2015). A significant difference in the processing between higher- and lower-intermediate L1 Arabic L2 English learners was only found in the Auditory-Visual Word Matching Task specifically designed for L1 Arabic L2 English learners in this study. This methodological contribution demonstrates that the stimuli specifically designed for these L2 learners can tap into the fine-grained processing areas in these L2 learners more successfully compared to the stimuli designed for all L2 English learners.

7.4.1 Practical Outcomes

The findings obtained in this study also have important implications for teaching L2 English. Due to the previous research detailing the vowel blindness phenomenon in L1 Arabic L2 English learners, the reading instruction specialised for these L2 learners is currently predominantly focused on highlighting vowels in isolation. However, the results of the current study point towards the need to teach English orthographic patterns, i.e., common letter sequences (linear processing), rather than over-focusing on letters in isolation. This suggests a pedagogical approach employing the explicit teaching of phonics could be beneficial for these L2 learners. For example, the use of rhyme (see Taylor, 2008), which is commonly employed in teaching literacy to L1 English children, would also be beneficial for L1 Arabic L2 English learners. Furthermore, special attention might also be given to explicitly teaching common consonant cluster patterns (e.g., <str> in word-initial positions), as the findings presented here indicate this is still a specific area of processing difficulty found in intermediate L1 Arabic L2 English learners.

Secondly, the findings in this study highlight the importance of developing an appreciation of syllabic structure in English which underpins the gradual move from non-linear towards linear processing in intermediate L1 Arabic L2 learners. In the L2 English classroom, more emphasis could be placed on segmenting words into syllables, not only in their phonological form but also in their orthographic form. This would help learners develop L2 word recognition processing accuracy in their reading, especially when encountering new words. Training on syllabic awareness would also reduce difficulties with consonant clusters (see above). These include epenthesis or vowel deletion (*forest* for *frost*) and elision or vowel addition (*frost* for *forest*), which are errors commonly found in L1 Arabic L2 English learners (4.1.2.1; 5.1.2.2).

To practise segmentation, longer, polysyllabic words could be strategically employed as these tend to be the most challenging to divide into syllables. Focusing on longer words in L1 Arabic L2 English learners is also crucial as these items might represent new vocabulary these learners would not typically encounter in everyday conversations. Longer words are overall more likely to be of lower-frequency (Miller, Newman, & Friedman, 1958), and they are usually found in print in English. As L1

Arabic L2 English learners are frequently reported to have poor L2 reading habits (e.g., see 3.3.1), they are less likely to encounter polysyllabic words in English.

In contrast to orthographic pattern and syllable processing outlined above in longer words, improving accuracy in shorter, monosyllabic words requires highlighting vowels in isolation. Practising minimal pairs (*bit/bet*), where vowel modifications are crucial to disambiguate the word could be of great help to L1 Arabic L2 English learners.

7.5 Recommendations for Future Research

Various aspects of the current study would benefit from further exploration. These concern the replication of the experimental tasks with the emphasis of employing methodological refinements to the research and task design as well as to the stimuli employed. This would provide invaluable insight into how L1 Arabic L2 English learners process words in L2 English with the view of understanding how to tackle the specific L2 reading difficulties these learners typically demonstrate.

One of the main areas to focus on when testing L1 Arabic L2 English learners is the task demand and task selection/design. L1 Arabic L2 English learners typically demonstrate specific L2 word processing difficulties to other L2 groups. Thus, tasks specifically designed for this L2 learner group were found to most successfully tap into their processing difficulties (4.1.3).

Informed by the limitations, future research on L2 word processing in these learners would also greatly benefit from focusing more on L2 proficiency level and therefore employing a between-subjects research design. Effects of vowel blindness are expected to vary in impact depending on the L2 proficiency of the L1 Arabic L2 English learners (elementary/intermediate/advanced). Comparing these learner groups would provide an insight into the L2 word processing changes that occur parallel to acquiring L2 proficiency. In order to test the participants' L2 proficiency, IELTS reading/writing scores rather than overall test scores should ideally be used as the former would be more representative of the learners' L2 word processing skills. Moreover, future research would benefit from including L1 English readers and other L2 learner groups in the research design. This would help determine whether errors in L1 Arabic L2 English learners are specific to them or could be extended to L1 and/or L2 readers.

This study focused solely on intermediate L1 Arabic L2 English learners and therefore yielded important implications for further research – to focus more on linear processing rather than vowel blindness, especially in intermediate and higher-level L1 Arabic L2 English learners. Testing the processing of syllables instead of letters in isolation would further explore the shift from non-linear to linear processing in these learners. For instance, it would be beneficial to measure error rate and response times in transposed syllables (e.g., *chocolate*-**cholacote*; see Perea, Duñabeitia, & Carreiras, 2008) as these word manipulations do not only test the processing of adjacent letters (see Letter Transposition Task in this study) but also the ability to segment letter combinations as a vital factor in successful L2 processing.

Although linear processing requires more attention in future research, vowel blindness (non-linear processing) and therefore letter processing still need to be explored in more depth. For instance, it would be beneficial to further investigate the unexpectedly high error rate in the CC transposition (**ipmossible)* found in this study. Stimuli could be manipulated by consonant/vowel letter substitution (**canclusion*) or letter deletion (**cnclusion*); the conditions could be compared in terms of error rate and response times to verify whether the errors occurred due to inaccurate processing of consonant/vowel *letters* or *vowels* per se. To reduce the task demand, the manipulations could be incorporated on the stressed syllables and/or on the suffixes. As the present findings demonstrate a great deal of complexity in L2 word processing in intermediate L1 Arabic L2 English learners, the processing of consonants ought to be explored alongside vowels in these L2 learners.

With regard to the CC transposition errors in word-initial positions found in this study, these were attributed to the potential right-to-left processing in L1 Arabic L2 English learners, however this requires further investigation. So far, the reading direction research has mainly been conducted on [110]L1 English and L1 Arabic but not in L2. In this vein, visuo-perceptual factors in visual word recognition (e.g., allocation of

[110] For an overview in L1 English/L1 Hebrew, see Nazir, 2000; for an overview in L1 Arabic, see AlJassmi et al., 2022.

attention; parafoveal processing) should be taken into consideration as these are vital components in investigating reading direction.

Lastly, within the context of vowel blindness, letter position within a word would be worth pursuing in more depth to investigate why the worst performance was recorded in mid-word positions and whether the same trend was found in L1 English readers and/or other L2 learners. In relation to that, the effect of word length would benefit from further exploration as well. This word property could be investigated more systematically than in this study by employing short and long words of uniform length and varying the vowel letters in different word positions.

7.6 Chapter Summary

This chapter summarised the content of this thesis by chapter before outlining its main conclusions. Subsequently, the limitations of this study were delineated and the contribution of this study to a wider area of L2 literacy was discussed. This included the practical outcomes which derived from the conclusions of this study. Finally, the recommendations for the future research were provided. In the following section, the literature consulted for this study will be listed (References), followed by the Appendices.

References

Abbott, R. D., Berninger, V. W., & Fayol, M. (2010). Longitudinal relationships of levels of language in writing and between writing and reading in grades 1 to 7. *Journal of Educational Psychology, 102(2),* 281–298.

Abu-Rabia, S. (1998). Reading Arabic texts: Effects of text type, reader type and vowelisation. *Reading and Writing, 10(2),* 105-119.

Abu-Rabia, S. (2001). The role of vowels in reading semitic scripts: Data from Arabic and Hebrew. *Reading and Writing, 14(1),* 39-59.

Abu-Rabia, S. (2002). Reading in a root-based-morphology language: The case of Arabic. *Journal of Research in Reading, 25(3),* 299-309.

Abu-Rabia, S., & Siegel, L. S. (2002). Reading, syntactic, orthographic, and working memory skills of bilingual Arabic-English speaking Canadian children. *Journal of Psycholinguistic Research, 31(6),* 661-678.

Abu-Rabia, S., & Awwad, J. (2004), Morphological structures in visual word recognition: The case of Arabic. *Journal of Research in Reading, 27(3),* 321-336.

Abu-Rabia, S., & Sammour, R. (2013). Spelling errors' analysis of regular and dyslexic bilingual Arabic-English students. *Open Journal of Modern Linguistics, 3(1),* 58-68.

Abu-Rabia, S. (2019). The Role of Short Vowels in Reading Arabic: A Critical Literature Review. *Journal of Psycholinguistic Research, 48(4),* 785- 795.

Acha, J., & Perea, M. (2008). The effect of neighborhood frequency in reading: Evidence with transposed-letter neighbours. *Cognition, 108(1),* 290-300.

Adams, M. J. (1990). *Beginning to read: Thinking and learning about print.* Cambridge, MA: MIT Press.

Aitchison, J. (2012). *Words in the mind: An introduction to the mental lexicon*. Chichester, UK: Wiley Blackwell.

Akamatsu, N. (1999). The effects of first language orthographic features on word recognition processing in English as a second language. *Reading and Writing, 11(4),* 381–403.

Al-Ani, S. (1970). *Arabic Phonology*. An acoustical and physiological investigation. The Hague, the Netherlands: Mouton.

Alasmi, M. (2016). *The fourth grade English as a second language curriculum as perceived by teachers and supervisors in Saudi Arabia*. [Doctoral dissertation, University of Indiana, USA]. ProQuest and Theses Global.

Alderson, J. C. (1984). A reading problem or a language problem? In J. C. Alderson & A. H. Urquhart (Eds.), *Reading in a Foreign Language* (pp. 1-27). New York, NY: Longman.

Al-Hazemi, H. (1993). *Low level EFL vocabulary tests for Arabic speakers*. [Unpublished doctoral dissertation, University of Wales, Swansea].

Alhazmi, K., & Milton, J. (2015). Phonological vocabulary size, orthographic vocabulary size, and EFL reading ability among native Arabic speakers. *Journal of Applied Linguistics*, *30*, 26-43.

Alhazmi, K., Milton, J., & Johnston, S. (2019). Examining ‘vowel blindness’ among native Arabic speakers reading English words from the perspective of eye-tracking. *System*, *80*, 235-245.

AlJassmi, M. A., Warrington, K. L., McGowan, V. A., White, S. J., & Paterson, K. B. (2022). Effects of word predictability on eye movements during Arabic reading. *Attention, Perception, & Psychophysics, 84*(1), 10–24.

Allmark, N. (2022). An Evaluation of the Conceptual Validity of Vowel Blindness as an Explanation for Differences in Arabic Readers' L2 Word Recognition. In R. Al-Mahrooqi & C.J. Denman (Eds.), *Individual and Contextual Factors in the English Language Classroom* (pp. 115–137). *English Language Education*, *24.*

Al-Mahrooqi, R. & Denman, C. (2016). Establishing a reading culture in Arabic and English in Oman. *Arab World English Journal, 7(1),* 5-17.

Alsadoon, R., & Heift, T. (2015). Textual Input Enhancement for vowel blindness: A study with Arabic ESL learners. *The Modern Language Journal, 99(1)*, 57-79.

Alsaif, A., & Milton, J. (2012). Vocabulary input from school textbooks as a potential contributor to the small vocabulary uptake gained by EFL learners in Saudi Arabia. *The Language Learning Journal, 40(1)*, 21-33.

Al-Sulaimani, A. (1990). *Reading Difficulties in Arab Learners of English*. [Unpublished doctoral dissertation, University of Wales, Swansea].

Alzahrani, D. S. M. (2014). The acquisition of tense/lax distinction by Arabic speakers learning English as a second language. [Master's dissertation, Southern Illinois University, Carbondale, USA]. ProQuest and Theses Global.

Andrews, S. (1996). Lexical retrieval and selection processes: Effects of transposed-letter confusability. *Journal of Memory and Language, 35(6),* 775–800.

Azzam, R. (1989). Orthography and reading of the Arabic language. In P. Aaron & M. Joshi (Eds.), *Reading and Writing Disorders in Different Orthographic Systems*. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Baddeley, A. D., Thomson, N., & Buchanan, M. (1975). Word length and the structure of short-term memory. *Journal of Verbal Learning & Verbal Behavior, 14*(6), 575–589.

Berent, I., & Perfetti, C. (1995). A Rose is a REEZ: the two-cycles model of phonology assembly in reading English. *Psychological Review, 102(1)*, 146-184.

Beyersmann, E., Grainger, J., & Taft, M. (2020). Evidence for embedded word length effects in complex nonwords. *Language, Cognition and Neuroscience, 35(2),* 235–245.

Birch, B. M. (2014). *English L2 Reading: Getting to the Bottom* (3rd ed.). New York, NY: Routledge.

Boudelaa, S., & Marslen-Wilson, W. (2001). Morphological units in the Arabic mental lexicon. *Cognition, 81(1),* 65-92.

Bowen, H. (2011). Spelling it out! Accounting for spelling difficulties for Arab learners of English. Zayed University, Dubai. Retrieved from marifa.hct.ac.ae

Broerse, A. C., & Zwaan, E. J. (1966). The information value of initial letters in the identification of words. *Journal of Verbal Learning & Verbal Behavior, 5*(5), 441–446.

Brown, T. L., & Haynes, M. (1985). Literacy background and reading development in a second language. In T. H. Carr (Ed.), *The Development of Reading Skills* (pp. 19-34). San Francisco, CA: Jossey-Bass.

Bruyer, R., & Brysbaert, M. (2011). Combining speed and accuracy in cognitive psychology: Is the inverse efficiency score (IES) a better dependent variable than the mean reaction time (RT) and the percentage of errors (PE)? *Psychologica Belgica, 51(1),* 5–13.

Brysbaert, M., Lagrou, E., & Stevens, M. (2017). Visual word recognition in a second language: A test of the lexical entrenchment hypothesis with lexical decision times. *Bilingualism: Language and Cognition, 20(3),* 530–548.

Brysbaert, M., Mandera, P., & Keuleers E. (2018). The word frequency effect in word processing: An updated review. *Current Directions in Psychological Science, 27(1),* 45-50.

Buchwald, A., & Rapp, B. (2006). Consonants and vowels in orthographic representations. *Cognitive Neuropsychology, 23(2),* 308–337.

Burt, J. S., & Tate, H. (2002). Does a reading lexicon provide orthographic representations for spelling? *Journal of Memory and Language, 46(3),* 518–543.

Campbell, G. (1997). *Handbook of scripts and alphabets*. London, UK: Routledge.

Caplan, D. (1987). *Neurolinguistics and linguistic aphasiology*. Cambridge Studies in Speech Science and Communication. Cambridge, UK: Cambridge University Press.

Caramazza, A., & Miceli, G. (1990). The structure of graphemic representations. *Cognition, 37(3),* 243-97.

Caramazza, A., Chialant, D., Capasso, R., & Miceli, G. (2000). Separable processing of consonants and vowels. *Nature, 403(6768),* 428-30.

Carreiras, M., & Price, C. (2008). Brain activation for consonants and vowels. *Cerebral Cortex, 18(7),* 1727-1735.

Castles A., Rastle K., & Nation, K. (2018). Ending the reading wars: Reading acquisition from novice to expert. *Psychological Science in the Public Interest, 19(1),* 5-51.

Chambers, S, M. (1979). Letter and order information in lexical access. Journal of *Verbal Learning & Verbal Behaviour, 18*(2), 225-241.

Coderre, E. L., & Van Heuven, W. J. B. (2014). The effect of script similarity on executive control in bilinguals. *Frontiers in Psychology, 5,* Article 1070.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108(1),* 204-256.

Coltheart, M. (2005). Modelling reading: the dual-route approach. In M. J. Snowling & C. Hulme (Eds.), Blackwell handbooks of developmental psychology. The *science of reading: A handbook* (pp. 6–23). Oxford, UK: Blackwell Publishing.

Connine, C. M., Mullennix, J., Shernoff, E., & Yelen, J. (1990). Word familiarity and frequency in visual and auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16(6),* 1084-1096.

Conrad, M., Grainger, J., & Jacobs, A. M. (2007). Phonology as the source of syllable frequency effects in visual word recognition: Evidence from French. *Memory & Cognition, 35(5),* 974–983.

Cook, V. J. & Bassetti, B. (2005). An introduction to researching second language writing systems. In V. J. Cook & B. Bassetti (Eds.), *Second language writing systems* (pp. 1-67). Clevedon, UK: Multilingual Matters.

Deacon, S., Pasquarella, A., Marinus, E., Tims, T., & Castles, A. (2019). Orthographic Processing and children’s word reading. *Applied Linguistics, 40*(2), 509-534.

De Groot, A. M. B. (2011). Language and cognition in bilinguals and multilinguals: An introduction. New York-Hove, NY: Psychology Press.

Deutsch, A., & Rayner, K. (1999). Initial fixation location effects in reading Hebrew words. *Language and Cognitive Processes, 14(4),* 393–421.

Ehri, L. C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading, 18(2),* 116-125.

Ehri, L. C. (2005). Development of sight word reading: phases and findings. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 135–154). Oxford, UK: Blackwell Publishing.

Ehri, L. C. (2014). Orthographic mapping in the acquisition of sight word reading, spelling memory, and vocabulary learning. *Scientific Studies of Reading, 18(1),* 5-21.

Elbeheri, G., & Everatt, J. (2007). Literacy ability and phonological processing skills amongst dyslexic and non-dyslexic speakers of Arabic. *Reading* and *Writing, 20(3),* 273-294.

Farid, M., & Grainger, J. (1996). How initial fixation position influences visual word recognition: A comparison of French and Arabic. *Brain and Language, 53*(3), 351-368.

Fender, M. (2003). English word recognition and word integration skills of native Arabic and Japanese-speaking learners of English as a second language. *Applied Psycholinguistics, 24(2),* 289-315.

Fender, M. (2008). Spelling knowledge and reading development: Insight from Arab ESL learners. *Reading in a Foreign Language, 20(1),* 19-42.

Forster, K. I., & Chambers, S. M. (1973). Lexical access and naming time. *Journal of Verbal Learning & Verbal Behaviour, 12(6),* 627-635.

Frankish, C., & Turner, E. (2007). SIHGT and SUNOD: The role of orthography and phonology in the perception of transposed letter anagrams. *Journal of Memory and Language, 56(2),* 189–211.

Frost, R. (2005). Orthographic systems and skilled word recognition processes in reading. In M. J. Snowling & C. Hulme (Eds.), *Blackwell handbooks of developmental psychology*. *The science of reading: A handbook* (pp. 272–295). Oxford, UK: Blackwell Publishing.

Funder Hansen, G. (2014). Word Recognition in Arabic: Approaching a Language-Specific Reading Model. In E. Saiegh-Haddad & R. Joshi (Eds.), *Handbook of Arabic Literacy*. *Literacy Studies*, *9* (pp. 55-76). Dordrecht, the Netherlands: Springer.

Goswami, U. (2010). A psycholinguistic grain size view of reading acquisition across languages. In N. Brunswick, S. McDougall & P. de Mornal Davies (Eds.), *Reading and dyslexia in different orthographies*. New York, NY: Psychology Press.

Grainger, J. (2008). Cracking the orthographic code: An introduction. *Language and Cognitive Processes, 23(1),* 1-35.

Grainger, J., Lété, B., Bertand, D., Dufau, S., & Ziegler, J. C. (2012). Evidence for multiple routes in learning to read. *Cognition, 123*(2), 280–292.

Grainger, J., & Ziegler, J. C. (2011). A dual-route approach to orthographic processing. *Frontiers in Psychology, 2, Article 54*.

Green, D., & Meara, P. (1987). The effects of script on visual search. *Second Language*

Research, 3(2), 102-113.

Guerrera, C., & Forster, K. (2008). Masked form priming with extreme transposition. *Language and Cognitive Processes, 23(1),* 117–142.

Guitard, D., Saint-Aubin, J., Tehan, G., & Tolan A. (2018). Does neighbourhood size really cause the word length effect? *Memory & Cognition, 46(2),* 244-260.

Haggan, M. (1991). Spelling errors in native Arabic-speaking English majors: A comparison between remedial students and fourth year students. *System, 19(1-2),* 45-61.

Hammond, E. J., & Green, D. W. (1982). Detecting targets in letter and non-letter arrays. *Canadian Journal of Psychology, 36(1),* 67–82.

Hamada, M., & Koda, K. (2008). Influence of first language orthographic experience on second language decoding and word learning. *Language Learning, 58(1),* 1-31.

Hamada, M. (2017). L2 word recognition: Influence of L1 orthography on multi-syllabic word recognition. *Journal of Psycholinguistic Research, 46(5),* 1101–1118.

Hayes-Harb, R. (2006). Native speakers of Arabic and ESL texts: Evidence for the transfer of written word identification processes. *TESOL Quarterly, 40(2),* 321-339.

Henderson, L. (1982). Orthography and word recognition in reading. New York, NY: Academic Press.

Houghton, G., & Zorzi, M. (2003). Normal and impaired spelling in a connectionist dual-route architecture. Cognitive Neuropsychology, *20(2),* 115-162.

Humphreys, G. W., Evett, L. J., & Quinlan, P. T. (1990). Orthographic processing in visual word identification. *Cognitive Psychology, 22(4),* 517–560.

Ibrahim, M. H. (1978). Patterns in Spelling Errors. *ELT Journal, 32(3)*, 207-212.

Ibrahim, R., Eviatar, Z., & Aharon-Peretz, J. (2007). Metalinguistic awareness and reading performance: A cross language comparison. *Journal of Psycholinguistic Research*, *36*(*4*), 297–317.

Jalbert, A., Neath, I., & Surprenant, A. M. (2011). Does length or neighbourhood size cause the word length effect? *Memory & Cognition*, *39(7),* 1198-210.

Jiang, N. (2011). *Conducting reaction time research in second language studies*. New York, NY: Routledge.

Jiang, N., & Wu, X. (2022). Orthographic Priming in Second-Language Visual Word Recognition. *Language Learning, 72(1)*.

Katz, L., & Frost, R. (1992). The reading process is different for different orthographies: The orthographic depth hypothesis. In R. Frost & L. Katz (Eds.), *Orthography*, *phonology, morphology, and meaning* (pp. 67-84). Amsterdam, the Netherlands: Elsevier North Holland Press.

Keller, R. D. (2020). Word-Study for Arabic Speakers to Read English. [Master's dissertation, Arizona State University, USA]. ProQuest and Theses Global.

Khan, M. F. (2013). Embedded vowels: Remedying the problems arising out of embedded vowels in the English writings of Arab learners. *RELC Journal, 44(2),* 233-251.

Kharma, N. N., & Hajjaj, A. H. (1997). *Errors in English among Arabic speakers: Analysis and remedies*. Beirut, Lebanon: Librairie du Liban.

Kinoshita S. (2006). Additive and interactive effects of word frequency and masked repetition in the lexical decision task. *Psychonomic Bulletin & Review, 13(4),* 668-73.

Kleiman, G. M., (1975). Speech recoding in reading. *Journal of Verbal Learning and Verbal Behavior, 14(4),* 323-339.

Koda, K. (1988). Cognitive process in second language reading: Transfer of L1 reading skills and strategies. *Second Language Research, 4(2),* 133-156.

Koda, K. (1990). Effects of L1 orthographic structures on L2 phonological recording strategies. *Studies in Second Language Acquisition, 12(2),* 393-410.

Koda, K. (1996). L2 word recognition research: A critical review. *The Modern Language Journal, 80(4),* 450-460.

Koda, K. (2016). Development of word recognition in a second language. In X. Chen, V. Dronjic & R. Helms-Park (Eds.), *Reading in a second language: Cognitive and psycholinguistic issues* (pp. 70-98). New York, NY: Routledge.

Koriat, A. (1985). Lateralization effects in reading pointed and unpointed Hebrew. *British Journal of Psychology, 76(2),* 161-173.

Kramer, B. & McLean, S. (2019). L2 reading rate and word length: The necessity of character-based measurement. *Reading in a Foreign Language, 31(2),* 201-225.

Lazaraton, A. (2005). Quantitative research methods. In E. Hinkel (Ed.), *Handbook of research in Second language teaching and learning* (pp. 209-224). Mahwah, NJ: Lawrence Erlbaum Associates.

Lee, H., Rayner, K., & Pollatsek, A. (2002). The processing of consonants and vowels in reading: Evidence from the fast priming paradigm. *Psychonomic Bulletin & Review, 9(4),* 766–772.

Lupker, S. J., Perea, M., & Davis, C. J. (2008). Transposed-letter effects: Consonants, vowels and letter frequency. *Language and Cognitive Processes, 23(1),* 93–116.

Martens, V. E., & De Jong, P.F. (2006). The effect of word length on lexical decision in dyslexic and normal reading children. *Brain & Language, 98(2),* 140-149.

Martin, K. I. (2011). *Reading in English: A comparison of native Arabic and native English speakers*. [Master's dissertation, University of Pittsburgh, USA]. Retrieved from D-Scholarship@Pitt.

Martin, K.I., (2015). L1 impacts on L2 component reading skills, word skills and overall reading achievement. [Doctoral dissertation, University of Pittsburgh, USA]. Retrieved from D-Scholarship@Pitt.

Martin, K. I. (2017). The impact of L1 writing system on ESL knowledge of vowel and consonant spellings. *Reading and Writing, 30(2),* 279-298.

Maroun, L., Ibrahim, R., & Eviatar, Z. (2019). Visual and orthographic processing in Arabic word recognition among dyslexic and typical readers. *Writing Systems Research, 11(2),* 142-158.

Mason, M. (1978). From print to sound in mature readers as a function of reader ability and two forms of orthographic regularity. *Memory & Cognition* 6, 568–581

Masrai, A., & Milton, J. (2015). Word difficulty and learning among native Arabic learners of EFL. *English Language Teaching, 8(6),* 1-10.

Masrai, A. (2021). Phonological and orthographic vocabulary knowledge and processing speed of L2 written text: the case of native Arabic EFL learners. *Cognitive Processing 22,* 37–46.

McCarthy, M. (2006). What is an advanced level vocabulary? Teachers of English to speakers of other languages, Inc. (TESOL). Retrieved from http://www.tesol.org/docs/default-source/new-resource-library/symposium-on vocabulary-4.pdf?sfvrsn=0

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review, 88(5)*, 375–407.

McDowell, H. J. (2011). The relationship between phonological awareness and alphabetic literacy, with reference to L1 Chinese users of L2 English. [Unpublished doctoral dissertation, Birkbeck College, University of London].

Meara, P. & Milton, J. (2003). *X-Lex: Swansea Vocabulary Levels Test*. Swansea: Lognostics.

Meara, P. (2005). *X_Lex: A Test of Vocabulary Breadth*. Lognostics. Retrieved from http://www.lognostics.co.uk/

Miller, G.A., E.B. Newman, E.B., & Friedman, E.A. (1958). Length-frequency statistics for written English. *Information and Control*, *1(4)*, 370-389.

Milton, J., & Hopkins, N. (2006). Comparing phonological and orthographic vocabulary size: Do vocabulary tests underestimate the knowledge of some learners. *The Canadian Modern Language Review, 63(1)*, 127-147.

Mor, B. & Prior, A. (2019). Individual differences in L2 frequency effects in different script bilinguals. *International Journal of Bilingualism 24(4).*

Muljani, D., Koda, K., & Moates, D. R. (1998). The development of word recognition in a second language. *Applied Psycholinguistics, 19(1),* 99–11.

Nassaji, H. (2003). Higher-level and lower-level text processing skills in advanced ESL reading comprehension. *Modern Language Journal, 87(2),* 261–276.

Nazir, T. A. (2000). Traces of print along the visual pathway. In A. Kennedy, R. Radach, D. Heller, & J. Pynte (Eds.), *Reading as a perceptual process* (pp. 3–22). Oxford, UK: North-Holland/Elsevier Science Publishers.

Neath, I., & Nairne, J. S. (1995). Word-length effects in immediate memory: Overwriting trace decay theory. *Psychonomic Bulletin & Review, 2*(4), 429–441.

New, B., Ferrand, L., Pallier, C., & Brysbaert, M. (2006). Reexamining the word length effect in visual word recognition: New evidence from the English Lexicon Project. *Psychonomic Bulletin & Review, 13(1),* 45–52.

New, B., Araújo, V., & Nazzi, T. (2008). Differential processing of consonants and vowels in lexical access through reading. *Psychological Science, 19(12),* 1223-1227.

Norris, D. (2013). Models of visual word recognition. *Trends in Cognitive Sciences, 17(3),* 517-524.

Perea, M., & Rosa, E. (2000). Repetition and form priming interact with neighbourhood density at a brief stimulus-onset asynchrony. *Psychonomic Bulletin and Review, 7(4),* 668–677.

Perea, M., & Lupker, S. J. (2003a). Transposed-letter confusability effects in masked form priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 97–120). New York, NY: Psychology Press.

Perea, M., & Lupker, S. J. (2003b). Does jugde activate COURT? Transposed-letter similarity effects in masked associative priming. *Memory & Cognition, 31(6),* 829–841.

Perea, M., & Carreiras, M. (2008). Do orthotactics and phonology constrain the transposed-letter effect? *Language and Cognitive Processes, 23(1),* 69-92.

Perea, M., Duñabeitia, J. A., & Carreiras, M. (2008). Transposed-letter priming effects for close versus distant transpositions. *Experimental Psychology, 55(6),* 384–393.

Perea, M., Mallouh, R.A., & Carreiras, M. (2010). The search for an input-coding scheme: Transposed-letter priming in Arabic. *Psychonomic Bulletin & Review, 17(3),* 375–380.

Perry, C. (2013). Graphemic parsing and the basic orthographic syllable structure. *Language and Cognitive Processes, 28(3),* 355–376.

Randall, M., & Meara, P. (1988). How Arabs Read Roman Letters. *Reading in a Foreign Language, 4(2),* 133-45.

Randall, M. (2009). Word recognition, psycholinguistics and teaching second language reading. In D. Anderson & M. McGuire (Eds.), *Cultivating Real Readers; Emerging theory and practice for adult Arab learners* (pp. 13-25). Abu Dhabi, UAE: HCT Press.

Rastle, K. (2016). Visual word recognition. In G. Hickok & S. Small (Eds.), Neurobiology of Language (pp. 255-264). Cambridge, MA: Academic Press.

Ryan, A., & Meara, P. (1991). The case of invisible vowels: Arabic speakers reading English words. *Reading in a Foreign Language, 12(7),* 531-539.

Ryan, A. (1993). Vowel blindness in Arabic learners of English. [Unpublished doctoral dissertation, University of Wales, Swansea].

Ryan, A. (1997). Learning the orthographical form of L2 vocabulary: A receptive and productive process. In N. Schmitt & M. McCarthy (Eds.), *Vocabulary: Description, acquisition and pedagogy* (pp. 181-198). Cambridge, UK: Cambridge University Press.

Ryding, K.C. (2005). *A Reference Grammar of Modern Standard Arabic*. New York, NY: Cambridge University Press.

Saiegh-Haddad, E. (2018). MAWRID: A Model of Arabic Word Reading in Development. *Journal of Learning Disabilities, 51(5),* 454-4762.

Saigh, K., & Schmitt, N. (2012). Difficulties with vocabulary word form: The case of Arabic ESL learners. *System, 40(1),* 24–36.

Schotter, E. R., Angele, B., & Rayner, K. (2012). Parafoveal processing in reading. *Attention, Perception, & Psychophysics, 74*(1), 5–35.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. Psychological Review, *96(4),* 523-68.

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition, 55(2),* 151-218.

Share, D. L. (2008). On the Anglocentrism of current reading research and practice: The perils of overreliance on an “outlier orthography”. *Psychological Bulletin, 134(4),* 584-615.

Shillaw, J. (1996). The application of Rasch modelling to Yes/No vocabulary tests. *Vocabulary Acquisition Research Group,* University of Wales Swansea, UK. Retrieved from http://www.swan.ac.uk/cals/calsres/vlibrary/js96a.htm

Shimron, J. (1993). The role of vowels in reading: A review of studies of English and Hebrew. *Psychological Bulletin, 114(1),* 52–67.

Shimron, J., & Sivan, T. (1994). Reading proficiency and orthography: Evidence from Hebrew and English. *Language Learning, 44(1),* 5-27.

Solso, R. L., Barbuto, P. F. & Juel, C. L. (1979). Bigram and trigram frequencies and versatilities in the English language. *Behavior Research Methods & Instrumentation, 11(5),* 475–484.

Stæhr, L. S. (2008). Vocabulary size and the skills of listening, reading and writing. *The Language Learning Journal, 36(2),* 139-152.

Stanovich, K. E., & West, R. F. (1989). Exposure to Print and Orthographic Processing. *Reading Research Quarterly, 24*(4), 402–433.

Stein, R. E. (2010). Sensitivity to Consonantal Context in Reading English Vowels: The Case of Arabic Learners. [Doctoral dissertation, University of Memphis, USA].

Taibah, N., & Haynes, C. (2011). Contributions of phonological processing skills to reading skills in Arabic speaking children. *Reading and Writing, 24(9),* 1019-1042.

Taft, M. (1979). Lexical access-via an orthographic code: The basic orthographic syllabic structure (BOSS). *Journal of Verbal Learning and Verbal Behaviour, 18(1),* 21-39.

Taylor, M. (2008). Orthographic and phonological awareness among L1 Arabic ESL Learners. [A quasi-experimental Study, University of Phoenix, USA]. ProQuest and Theses Global.

Thompson-Panos K., & Thomas-Ružić M. (1983). The Least You Should Know About Arabic: Implications for the ESL Writing Instructor. *Tesol Quarterly, 17(4),* 609-623.

Treiman, R., Kessler, B., & Bick, S. (2003). Influence of consonantal context on the pronunciation of vowels: A comparison of human readers and computational models. *Cognition, 88(1),* 49–78.

Treiman, R., & Kessler, B. (2006). Spelling as statistical learning: Using consonantal context to spell vowels. *Journal of Educational Psychology, 98(3),* 642-652.

Van Heuven, W. J., Dijkstra, T., & Grainger, J. (1998). Orthographic neighbourhood effects in bilingual word recognition. *Journal of Memory and Language, 39,* 458-483.

Velan, H., & Frost, R. (2007). Cambridge university versus Hebrew university: The impact of letter transposition on reading English and Hebrew. *Psychonomic Bulletin & Review, 14(5),* 913-918.

Velan, H., & Frost, R. (2009). Letter-transposition effects are not universal: The impact of transposing letters in Hebrew. *Journal of Memory and Language, 61(3),* 285-302.

Venezky, R. (1970). *The Structure of English Orthography*. The Hague, Netherlands: Moulton.

Wade-Woolley, L. (1999). First language influences on second language word reading: All roads lead to Rome. *Language Learning, 49(3),* 447-471.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101*(2), 192–212.

Wang, H., Castles, A., & Nickels, L. (2012). Word regularity affects orthographic learning. *Quarterly Journal of Experimental Psychology, 65(5),* 856-864.

Yamashita, J. (2013). Effects of extensive reading on reading attitudes in a foreign language. *Reading in a Foreign Language*, *25(2)*, 248-263.

Ziegler, J., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, *131(1)*, 3-29.

Appendices

APPENDIX A: L2 English Proficiency Scales and Description

IELTS	CEFR	LSE	Description	Vocabulary size (words)
9.0	C2	Advanced	A learner can understand and produce excellent English without any mistakes	4,500-5,000
8.0	C1	Advanced	A learner can speak very well A learner can understand almost everything they read A learner can write clear, complex English with few mistakes A learner can understand almost everything they hear	3,750-4,500
7.0	B2	Pre-advanced	A learner speak well but they still make mistakes A learner can read independently without a lot of problems A learner can write mostly clear, complex English with some mistakes A learner can understand almost everything in everyday situations	
6.0	B2	Upper Intermediate	People understand me the learner but they still make a lot of mistakes A learner can read independently but they need to re-read sometimes A learner’s writing is generally well organised and they can use a range of linkers A learner can understand well but there are still words they’re not sure of in everyday situations	3,250-3,750
5.0	B1	Intermediate	A learner can speak clearly but they have problems with difficult grammar and vocabulary A learner can understand the topic but detail is sometimes harder A learner can write clearly and simply with basic linkers A learner can understand clear speech on everyday topics	2,750-3,250
4.0	B1	Low Intermediate	A learner can make simple sentences but they need more vocabulary A learner can read simple texts when I understand the subject but they need to re-read sometimes. A learner can write short simple texts on familiar topics using a few basic linkers. Understands straightforward factual information about every day topics, provided speech has basic structure	2,500-2,750
3.0	A2	Pre-intermediate	A learner can make people understand them but with some problems. A learner can read short texts on familiar topics A learner can write short simple texts on familiar topics using a few very basic linkers. A learner can understand speech that is simple and clear	1,500-2,500
2.0	A1	Elementary	A learner can say a few things in English. A learner can read very short, simple texts but need to re-read a lot A learner can write a short paragraph about themselves A learner can understand slow simple speech with pauses so that they can think	<1,500

APPENDIX B: Stimulus items by Task

Auditory-Visual Word Matching Task (Chapter 4)

You're going to see 30 rows of words. In every line, you're going to see four words, a), b), c) and d). You're going to hear one word from each row twice. Circle the word that you hear (a), b), c) or d)). There will be some words which will be new for you but you don't have to worry about those.

e.g. a) sing b) sang c) sung d) song

1.	bun	ban	open	bone
2.	upon	pane	pawn	bean
3.	man	many	mane	men
4.	moan	mean	money	mine
5.	kite	acute	coat	caught
6.	cute	cut	actor	cot
7.	hell	hill	holly	hole
8.	hall	heel	hello	hale
9.	bit	about	bite	bat
10.	bought	boat	apart	bode
11.	steer	star	satire	sort
12.	stair	stir	sitar	cord
13.	stirrup	sport	strop	strap
14.	spell	slip	supple	spill
15.	spoil	sloppy	slob	slap
16.	colon	clone	clean	canal
17.	clear	coral	curl	cruel
18.	frost	foster	first	forest
19.	part	party	potter	port
20.	list	lest	lotus	lustre
21.	better	bitter	beret	battery

22.	revolution	revelation	reflection	irrelevant
23.	parade	appeared	parody	patter
24.	century	contrary	country	certainty
25.	colour	crawl	creole	coral
26.	surreal	surly	cereal	solar
27.	colon	cologne	kneel	kennel
28.	spirit	support	separate	serpent
29.	supple	supply	sloppy	spill
30.	present	precedent	percent	peasant

Letter Transposition Task (Chapter 5)

You're going to see 2 words, one after the other. There will be approximately a 1-second difference between them. If you think the two words are the same press 1, if you think they're different, press 3. Every time to load a new pair of words, you press 2.

1 Same Condition

disappoint~disappoint understood~understood settlement~settlement appearance~appearance discussion~discussion punishment~punishment particular~particular possession~possession friendship~friendship attractive~attractive assistance~assistance democratic~democratic constitute~constitute illustrate~illustrate excitement~excitement conscience~conscience suggestion~suggestion individual~individual concerning~concerning philosophy~philosophy admiration~admiration impossible~impossible opposition~opposition production~production mechanical~mechanical appreciate~appreciate lieutenant~lieutenant revolution~revolution collection~collection contribute~contribute importance~importance successful~successful foundation~foundation expression~expression scientific~scientific reputation~reputatation photograph~photograph connection~connection remarkable~remarkable profession~profession expedition~expedition commercial~commercial employment~employment commission~commission sufficient~sufficient

2 Different Condition

difficulty~difficutly honourable~honuorable delightful~delihgtful difference~differnece convenient~cnovenient themselves~themsleves industrial~indusrtial mysterious~msyterious university~unviersity impossible~ipmossible apparently~apparnetly procession~porcession afterwards~aftrewards protection~protetcion generation~genreation instrument~insturment reasonable~reaosnable conclusion~conlcusion distribute~ditsribute throughout~throughuot surprising~sruprising literature~litreature especially~esepcially experience~expereince constantly~cnostantly government~govermnent accomplish~accompilsh favourable~favuorable resolution~resloution everywhere~everywehre automobile~automoblie enthusiasm~enthusaism impression~imperssion throughly~thorouhgly frequently~freqeuntly altogether~altogetehr conference~confernece experiment~expermient tremendous~tremednous invitation~inivtation completely~completley management~mangaement absolutely~asbolutely atmosphere~atmoshpere parliament~parlaiment

APPENDIX C: Auditory-Visual Word Matching Task; Word Categories by Group (Chapter 4)

WORD CATEGORIES

GROUP I	C sequence Groups C-C	Target word	Modified V [87](foil)	Final silent <e> (foil)	2-syllable (foil)
	b/p – n	bun (S)	ban (S)	bone	open
		bean (L)	pawn (L)	pane	upon
	m – n	man (S)	men (S)	mane	many
		moan (L)	mean (L)	mine	money
	c – t	cot (S)	cut (S)	cute	actor
		caught (L)	coat (L)	kite	acute
	h – l	hell (S)	hill (S)	hole	holly
		heel (L)	hall (L)	hale	hello
	b/p – t	bit (S)	bat (S)	bite	about
		boat (L)	bought (L)	bode	apart

[88]GROUP II monosyllabic	C-C-C+	Target word	Modified V	2-syllable	C transposition
	s-t-r	star (L)	steer (L)	satire	sort
		stair (L)	stir (L)	sitar	assert
	s-t-r-p	strap (S)	strop (S)	stirrup	sport
	s-p-l	spill (S)	spell (S)	supple	slip
	s-l-p/b	slap (S)	slob (S)	sloppy	spoil
	c-l-n	clean (L)	clown (L)	colon	canal
	c-r-l	cruel (L)	curl (L)	carol	clear
	f-r-s-t	frost (S)	**first (L)	forest	foster
	p-r-t	port (L)	part (L)	party	potter
	l-s-t	list (S)	lest (S)	lust(r)e	lotus

GROUP III polysyllabic	C-C-C +	Target word	Modified V	Modified V	C transposition
	b-t-r	better	bitter	battery	ba(r)ter
	r-v/f-l-t-n	revolution	revelation	reflection	irrelevant
	p-r-d/t	appeared*	parade	parody	patter
	c-n-t-r	century	contrary	country	certainty
	c-r-l	coral	crawl	creole	colour
	s/c-r-l	cereal	surreal	surly	solar
	c/k-l-n	colony	clan	clone	kennel
	s-p-r-t	spirit	support	separate	serpent
	t-r-n	terrain	train	turn	tenor
	p-r-c/s-n-t	percent	present	precedent	pristine

APPENDIX D: Informed Consent Form

Informed consent form – Study project (PhD dissertation in Applied linguistics)

Title: How Arabic students read words in English

Researcher: Emina Tuzovic

University: Birkbeck College, University of London

Participant statement:

1. The researcher (Emina) has fully explained to me what the study project is about and I understand what my part in it is.
2. I understand that if at any time I do not wish to participate in this study project, I can tell the researcher and I will be removed from the study project.
3. I understand that the information I provide will be submitted as part of the research thesis.
4. I understand that the personal information (e.g., names and my proficiency level in English) will be strictly confidential.
5. I agree to participate in this study project.

Signature:

Date: