Summer 2024

Processing Visual Form Information during L1 and L2 Lexical Access

Xinwen Zhang
University of Texas at Arlington

PROCESSING VISUAL FORM INFORMATION DURING L1 AND L2 LEXICAL ACCESS

by

XINWEN ZHANG

DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy at
The University of Texas at Arlington
August, 2024

Arlington, Texas

Supervising Committee:

Jeffrey Witzel, Supervising Professor
Naoko Witzel, Supervising Professor
Xiaomei Qiao

ACKNOWLEDGEMENTS

Words cannot express my gratitude to my committee, without whom I could not have undertaken this journey. I would like to express my deepest appreciation to my supervisor Dr. Jeffrey Witzel for his invaluable patience and expertise. He generously provided guidance and constructive feedback through each stage of the process. I am also thankful to Dr. Naoko Witzel for her substantial criticism on the theory-motivated research question. She also kindly allocated monetary support to participant payments from her grant -- College of Liberal Arts Endowment Grant for Faculty Research -- awarded by the University of Texas at Arlington. I am also deeply indebted to Dr. Xiaomei Qiao for inspiring my interest in psycholinguistics. She has been continuously spreading positive energy and encouraging me to think about questions creatively, critically, and comprehensively.

Many thanks to the professors at the Department of Linguistics and TESOL and other departments at UTA. Special thanks to Dr. Ivy Hauser who aroused my enthusiasm in phonetics and phonology and inspired me to deeply think about the connection between spoken word recognition and visual word recognition. I would like to extend my sincere thanks to Dr. Laurel Stvan who encouragingly supported me and Dr. Joseph Sabbagh who provided me with an excellent model of being a better linguist. I would also like to acknowledge Dr. Amy Hodges for her guidance in academic writing.

Thanks should also go to my colleagues at the department and my lab mates for their insightful feedback when I was developing my argumentations. I am also grateful to the participants for their time and dedication. I would be remiss in not mentioning the support from the College of Liberal Arts through the Dean’s Doctoral Assistantship and from the Office of Graduate Studies through the Summer Dissertation Fellowship.

DEDICATION

This endeavor would not have been possible without moral support and encouragement from my family. My father and mother have been continuously providing both mental and financial support unconditionally. My sisters have been generously sharing their working experience and life experience with me so that I am prepared to overcome obstacles and to relieve stress. My little niece and my little nephew are always thinking I am the best. I adopt from them a lifestyle that offers peace of mind and gratitude. I loved them more than words can say. Therefore, this dissertation is

For my family.

ABSTRACT

Processing Visual Form Information during L1 and L2 Lexical Access

Xinwen Zhang, Ph.D.

The University of Texas at Arlington, 2024

Supervising Professor: Dr. Jeffrey Witzel, Dr. Naoko Witzel

This study investigates visual word recognition in the first language (L1) and second language (L2). Several studies in this area have reported L1/L2 processing differences at the lexical form level; however, the nature of these differences remains a matter of theoretical debate. The present study examines the extent to which these differences might relate to disparities in orthographic processing in the L1 and L2. Specifically, it uses masked identity priming to investigate whether skilled L2 readers differ from skilled L1 readers in terms of the efficiency with which they access abstract lexical representations during the early stages of visual word recognition. Previous studies have reported that skilled L1 readers show comparable masked identity priming effects for prime-target pairs that are visually similar (e.g., *cook-COOK*) and visually dissimilar (e.g., *edge-EDGE*). These form-independent identity priming effects have been interpreted to indicate that skilled L1 readers are largely unaffected by visual similarities/dissimilarities between uppercase and lowercase word forms during the early stages of visual word recognition. That is, skilled L1 readers appear to efficiently abstract away from low-level orthographic form characteristics when accessing lexical representations. This study investigates whether skilled L2 readers access abstract lexical representations from visual forms

as efficiently as skilled L1 readers. The results largely replicated form-independent masked identity priming effect for skilled L1 readers (*N*=64). Moreover, although L2 readers exhibited a slightly larger priming effect for visually similar prime-target pairs, the overall pattern of results for this group was comparable to that of L1 readers. In addition, when L2 readers were divided into same-script bilinguals and different-script bilinguals based on their L1/L2 script properties, different-script bilinguals (*N*=54) exhibited comparable form-independent masked identity priming effects to that of L1 readers, whereas there was a larger difference in the priming effects under the similar and dissimilar conditions for the same-script bilinguals (*N*=16) than for both the skilled L1 readers and the different-script bilinguals. Taken together, these results indicate that although there might be slight difference between skilled L1 and L2 readers that seemed to be driven by same-script bilinguals, there appears to be no fundamental difference between skilled L1 and L2 readers in terms of the efficiency with which they use visual information -- and letter shapes in particular -- to access abstract lexical representations during the early stages of visual word recognition, especially when L2 readers are highly proficient and when they are processing low-level orthographic form information for relatively high-frequency words. Furthermore, this comparable processing efficiency for low-level orthographic characteristics suggests that observed L1/L2 lexical form processing disparities are likely not primarily attributable to persistent differences at this early (pre-lexical) stage of visual word recognition.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

LIST OF ABBREVIATIONS

AoA	age of acquisition
ERP	event-related potential
L1	first language
L2	second language
LME	linear mixed effects
ms	milliseconds
RT	reaction time
SOA	stimulus-onset asynchrony

Chapter 1 Introduction

1.1 Introduction

In the literature on bilingualism, one important question is whether second language (L2) learners are able to process their L2 in a native-like way. One way to approach this question is to examine the influence of low-level form characteristics (e.g., letter shapes, sizes, fonts, cases, etc.) on first language (L1) and L2 visual word recognition. Most current models of bilingual lexical processing assume that L2 visual word recognition relies on abstract lexical representations. These representations are assumed to be largely invariant in that each word has a single abstract representation that can be activated by the specific instances of that word, even though those instances might differ in terms of certain low-level form characteristics. For example, *word* and *WORD* are assumed to be represented by the same lexical representation in the mental lexicon, even though these instances differ in terms of the shapes of their component lowercase/uppercase letters. At the same time, *word* and *letter* are assumed to be represented by distinct lexical representations. With these issues in mind, it is important to consider how readers make contact with abstract lexical representations corresponding to the visual input and whether this process is as efficient in the L2 as in the L1. The present study examines these questions by investigating the processing of printed words that are visually similar/dissimilar in their lowercase and uppercase forms in skilled L1 and L2 readers using a masked priming paradigm. In this way, this study examines whether skilled L2 readers differ from skilled L1 readers in terms of the efficiency with which they abstract away from low-level form characteristics when accessing lexical representations during visual word recognition.

1.2 Literature Review and Research Question

1.2.1 The Importance of Examining Orthographic Processing Differences during L1 and L2 Lexical Access

The questions addressed in this study are important for theory development in bilingual visual word recognition in light of several studies that have reported L1/L2 processing differences at the form level. In particular, masked priming studies examining the processing of form-related words at early stages of visual word recognition have revealed striking differences between L1 and L2 readers (e.g., Bijeljac-babic et al., 1997; Jiang, 2021a; Nakayama & Lupker, 2018; Qiao & Forster, 2013; 2017). In the masked priming paradigm, the participant responds to a stimulus, which is called a target. This target is preceded by another stimulus that is presented very briefly (e.g., 50 milliseconds, hence ms), which is called a prime. Although the prime is not consciously registered in such a short period of time, responses to targets have been found to be influenced when the prime and target are related to each other. One of these effects is the masked word form priming effect. In studies examining this effect, a word target (e.g., *PITY*) is typically preceded either by a one-letter-different word prime (e.g., *city-PITY*) or by a totally unrelated word prime (e.g., *door-PITY*). Studies investigating this effect in L1 and L2 comprehenders have found that form-related word primes affect the processing of the following target compared with unrelated primes (e.g., Bijeljac-babic et al., 1997; Jiang, 2021a; Nakayama & Lupker, 2018; Qiao & Forster, 2013; 2017). However, these studies have revealed differences in the direction of this effect -- either inhibitory or facilitatory -- in the L1 and L2. An inhibitory masked word form priming effect is indicated by *longer* reaction times (RTs) to the target when it is preceded by a form-related word prime. In contrast, a facilitatory masked word form priming effect is indicated by *shorter* RTs to the target when it is preceded by a form-related word prime. The masked word form priming effects reported in these studies were consistently either inhibitory or null for native speakers (Bijeljac-babic et al., 1997; Jiang, 2021a; Nakayama & Lupker, 2018; Qiao & Forster, 2013) and early balanced bilinguals (Bijeljac-babic et al., 1997), while the effects were facilitatory for late bilinguals (Jiang, 2021a; Nakayama & Lupker, 2018; Qiao & Forster, 2017; but see null priming effect for newly learned words in Kida et al., 2022).

Although these processing patterns at the form level for L1 readers and L2 readers are strikingly different, no consensus on how to explain these differences has been reached. For example, Nakayama and Lupker (2018) accounted for this discrepancy in masked word form priming effects between L1 and L2 readers in terms of L2 readers' slow processing of the prime. The evidence supporting this explanation is that when the stimulus-onset asynchrony (i.e, the amount of time between the start of the prime and the start of the target, hence SOA) was increased to 175ms, facilitatory form priming was eliminated. That is, when the SOA was long enough, L2 readers showed a similar masked word form priming effect to that of L1 readers. On the other hand, the episodic L2 hypothesis (Jiang & Forster, 2001; Witzel & Forster, 2012) posits that words in bilinguals' two languages are represented in separate memory systems. Specifically, L1 words are represented in the lexical memory system, while L2 words are represented in the episodic memory system. As a result, it is not surprising that there are different processing patterns at the form level for L1 and L2 readers.

The present study investigates another possible account for L1/L2 processing differences at the form level. Specifically, it examines whether these differences relate to disparities between L1 and L2 readers in terms of the efficiency with which they access abstract lexical representations from visual input at the early stages of visual words recognition.

1.2.2 Orthographic Processing Efficiency as Reflected in a Developing Trajectory of Abstract

Lexical Representations

Although it is clear that there are differences in L1 and L2 processing at the level of lexical form, the nature of these differences remains a matter of theoretical debate. One possibility is that these differences relate to L1/L2 disparities at earlier stages of processing -- and at the orthographic processing stage, in particular. In the present study, this idea is pursued by investigating whether skilled L1 and L2 readers differ in their ability to abstract away from the low-level visual form characteristics of a word when accessing its associated lexical representation. This approach is motivated primarily by the idea that the familiarity of a word is shaped by readers' exposure. As exposure increases, the familiarity of a word and its specific orthographic forms increases, and thus it becomes easier to recognize the word. At the same time, the lexical representation of the word becomes progressively more abstract. However, the form information encoded in this representation might depend on the variants of the word in the input. This developing trajectory of abstract lexical representations -- illustrated in Figure 1 -- has been supported by studies comparing less skilled L1 readers with skilled L1 readers (see below; also see similar discussion with evidence on words with specific forms in Kinoshita et al., 2021). As shown in this figure, if a word is largely, if not completely, encountered under a certain orthographic form, as exemplified by the word *DNA* in Panel A, the reader will develop an abstract representation for this word, but this representation will also likely be associated with this specific form. That is, since a word like *DNA* is usually only encountered in uppercase, this form characteristic will likely be encoded in its lexical representation. The lowercase variant of this word *dna* will thus not readily activate its lexical representation -- and may even be treated as a nonword. The more typical case is a word that is encountered in under many different orthographic forms, exemplified by the common word *edge* in Panel B. Once the reader has been exposed to these forms to a sufficient extent (i.e., reaching some threshold), they develop a representation that can be readily accessed by any of its variants in the input (e.g., by *edge*, *Edge*, or *EDGE*). Note, however, that until such representations are developed, the extent to which a lexical representation is activated by its variants in the input might be modulated by low-level visual similarity among these orthographic forms. For example, a word like *cook* (shown in Panel C) might be easily activated by any of its variants (e.g., by *cook*, *Cook*, *COOK*) in light of the strong visual similarity among these variants.

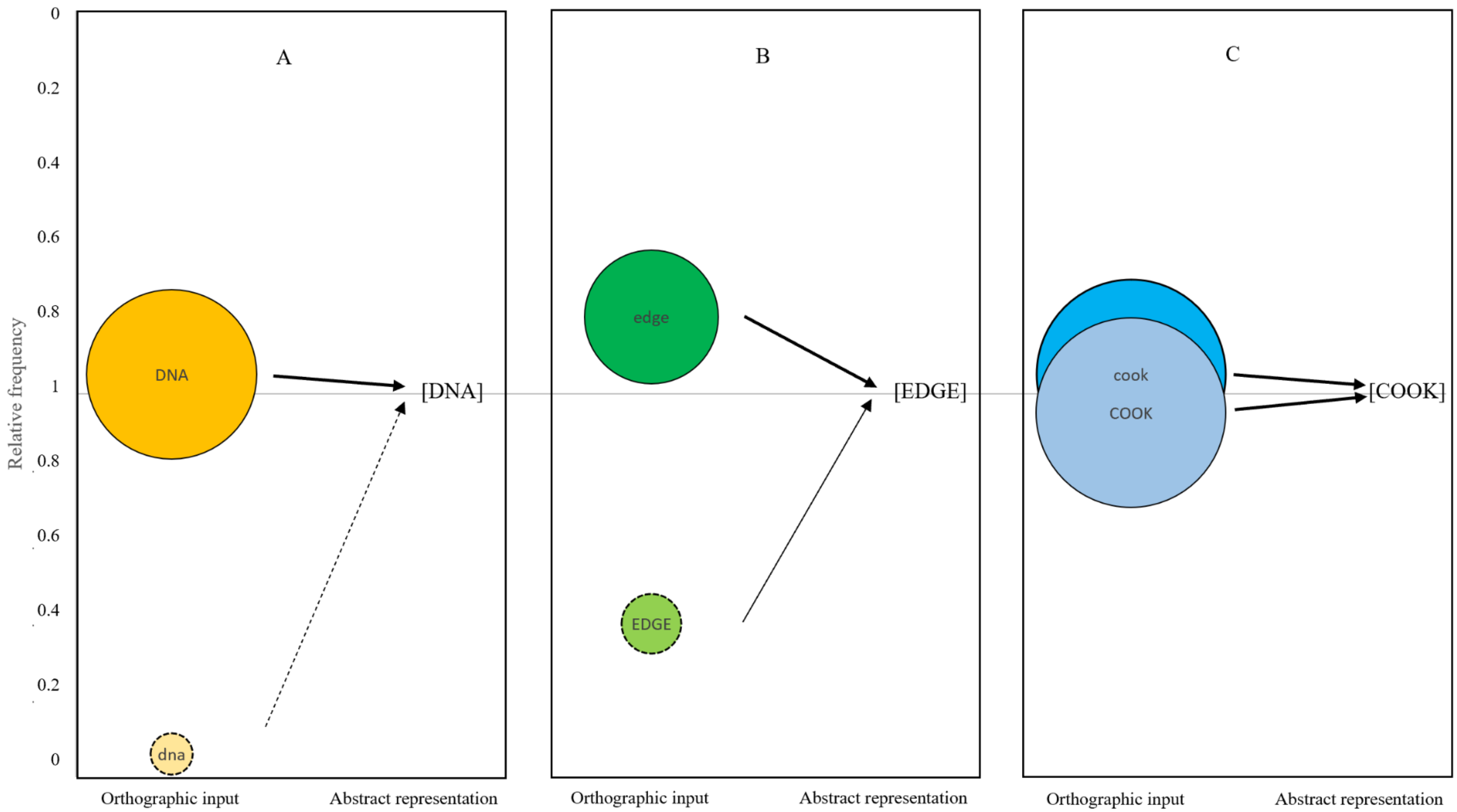

Figure 1. Examples representing a developing trajectory of abstract lexical representations with increasing exposure.

With this model in mind, the present study examines whether L2 readers differ from L1 readers in terms of the efficiency with which they access abstract lexical representations from visual input at early stages of visual word recognition. This investigation will focus on common words -- or words that are encountered in various forms in the input. Specifically, this study will use a priming paradigm to investigate whether low-level visual form similarity between the prime and the target modulates priming effects. If, as suggested above, efficient processing of such words involves abstracting away from low-level form characteristics of the visual stimulus to access a "form-invariant" lexical representation -- i.e., a representation that does not encode specific low-level form characteristics related to things like lowercase/uppercase -- there should be little influence of these characteristics on these priming effects. The sections below discuss the empirical motivation for this approach, the priming manipulation of particular interest, and the specific predictions with respect to this manipulation.

1.2.3 Evidence in Support of L2 Readers' Sensitivity to Low-Level Form Characteristics

There is some evidence suggesting that L2 readers might be particularly attuned to low-level form characteristics related to uppercase/lowercase, as indicated by case effects in visual word recognition tasks. For example, Jiang (2021b) measured participants' RTs to English stimuli with a lexical decision task, where participants were asked to decide whether a letter string was an English word or not, regardless of the case it appeared in (i.e., lowercase vs. uppercase). This study tested both native speakers of English and L2 learners of English. One group of L2 learners was from a Romance L1 background, while the other group was made up of L1 Chinese speakers of L2 English. That is, the study included both same-script (Romance-English) and different-script (Chinese-English) bilingual groups. Jiang (2021b) reported that

Chinese-English bilinguals took significantly longer to make a decision when a target word was displayed in uppercase than in lowercase, thus showing a case effect. In addition, this case effect was not modulated by the frequencies of the target words (the effect size for high-frequency words: 123ms; for low-frequency words: 115ms). However, this case effect was not observed for either the English native speakers or the Romance-L1 bilinguals. This study therefore indicates that L2 learners experience difficulty when reading words in their less-familiar, uppercase forms, especially when these learners come from an L1 with a very different script.

1.2.4 Masked Priming Paradigm as a Convention in Lexical Processing

The present study examines the extent to which case familiarity effects of this type influence the earliest stages of L2 visual word recognition using a masked priming paradigm. Although this paradigm was introduced briefly above, in light of the fact that this study will focus primarily on masked priming results, it is useful to discuss this method in more detail before proceeding. The masked priming paradigm was developed by Forster and Davis (1984). Since then, it has been used as a conventional method to investigate early stages of lexical processing. In this paradigm, a single trial is usually presented as a sequence of three successive frames including a string of symbols (e.g., #####) and two separate letter strings. The initial string of symbols functions as a forward mask. The first letter string functions as a prime, while the second letter string functions as a target. The prime is presented briefly (e.g., about 50ms), while the target is presented for a longer time (e.g., 500ms or more). In addition, to avoid any fusion effect -- i.e., the perception that the prime and the target constitute a single stimulus -- the prime is usually presented in lowercase, while the target is presented in uppercase. The relationship between the prime and the target varies depending on the research questions or the specific masked priming effects being measured (e.g., identity priming effects, form priming effects, semantic priming effects, etc.). In this paradigm, participants are usually unaware of the prime because it is presented for such a short period of time and because the uppercase target acts as a backward mask. The lack of awareness of the prime is particularly useful because it prevents participants from developing decision-making strategies that are irrelevant to the effects being tested. Although participants do not consciously register the prime, it is nevertheless processed automatically. This is evidenced by the fact that these primes can influence the processing of the target at different linguistic (processing) levels (e.g., at the form level, meaning level, etc.).

What is most relevant to the current study is the well-documented masked identity priming effect. In studies examining this effect, the prime and the target bear the same identity, but they are presented in a way such that they are visually distinct from each other -- by, for instance, being presented in different cases (e.g., *pity-PITY*). The response to the word target (in uppercase) is faster when this word is preceded by an identical prime (in lowercase, e.g., *pity-PITY*) than when it is preceded by an orthographically, phonologically, and semantically unrelated word (e.g., *door-PITY*). Importantly for the present study, masked identity priming effects have been frequently reported for L1 readers (e.g., Forster & Davis, 1984; Forster et al., 2003) as well as for L2 readers (e.g., Aparicio & Lavaur, 2016; de Groot & Nas, 1991; Dimitropoulou et al., 2011a, b; Dubey et al., 2018; Finkbeiner et al., 2004; Foote et al., 2020; Gollan et al., 1997; Heyer & Clahsen, 2015; Hoshino et al., 2010; Jiang, 1999; Midgley et al., 2009; Nakayama & Lupker, 2018; Nakayama et al., 2013; Silva & Clahsen, 2008; Smith et al., 2019; Xia & Andrews, 2015). Although these effects have been used to explore various aspects of L1 lexical processing, in L2 studies, this manipulation is usually included to verify that masked L2 primes can be processed sufficiently well by L2 participants. The present study, however, focuses on these masked identity priming effects as a way to uncover the degree to which the automatic processing in L2 is similar to that in L1. More specifically, the current study uses the masked identity priming effects as a diagnostic to investigate whether L2 readers differ from L1 readers in terms of the efficiency with which they deal with low-level form characteristics of the input at the earliest stages of visual word recognition.

1.2.5 Orthographic Processing Efficiency in Skilled L1 Readers and Less Skilled L1 Readers

One finding that has been taken to indicate the efficiency with which skilled L1 readers access abstract lexical representations during visual word recognition comes from studies showing form-independent masked identity priming effects. For example, Bowers et al. (1998, Experiment 1) investigated whether the masked identity priming effect is affected by the visual similarity of words in their uppercase and lowercase forms. The target words in this study were divided into two categories: similar words and dissimilar words. Similar words are composed of letters that are visually similar in their lowercase and uppercase (e.g., *cook-COOK*, in which *c/C*, *o/O*, and *k/K* are similar in lowercase and uppercase, respectively), whereas dissimilar words are composed of letters that are visually dissimilar in their lowercase and uppercase (e.g., *edge-EDGE*, in which *e/E*, *d/D*, and *g/G* are dissimilar in lowercase and uppercase, respectively). The study reported masked identity priming effects for both similar words (with an effect size of 22ms) and dissimilar words (with an effect size of 25ms). More importantly, although there was a numerical difference between the priming effects for these word types (i.e., -3ms), these effects were not significantly different under the similar and dissimilar conditions, showing a form-independent masked identity priming effect. This effect has been interpreted to indicate that skilled L1 readers are largely unaffected by visual similarities/dissimilarities between uppercase and lowercase word forms during the early stages of visual word recognition. Rather, skilled L1 readers appear to efficiently abstract away from such low-level form characteristics when accessing lexical representations.

Interestingly, a different pattern of results has been found for developing L1 readers. Indeed, studies investigating these readers have shown that the magnitude of the masked identity priming effect differs substantially depending on the visual similarity of words in their uppercase and lowercase forms (e.g., Gutiérrez-Sigut et al., 2019; Perea et al., 2015). For example, Perea et al. (2015) compared responses to Spanish words among three groups of native speakers -- third-grade children, fifth-grade children, and young (college-age) adults -- using visual similarity manipulations comparable to those in Bowers et al. (1998). The key finding of this study was that while it replicated the form-independent masked identity priming effects for the skilled L1 readers -- i.e., for the young adults and the fifth-grade children -- it showed form-dependent masked identity priming effects for the developing readers -- i.e., for the third-grade children. Specifically, the young adult group showed masked identity priming effects under both the similar condition (with an effect size of 49ms) and the dissimilar condition (with the effect size of 43ms), and the difference in the magnitude of the priming effects was a nonsignificant 6ms advantage of the similar condition over the dissimilar condition. Similarly, the fifth-grade children showed masked identity priming effects under both the similar condition (with an effect size of 85ms) and the dissimilar condition (with an effect size of 77ms) as well, and the difference in the magnitude of the priming effects was a nonsignificant 8ms advantage of the similar condition over the dissimilar condition. In contrast to both of these groups, the third-grade children showed different magnitudes of masked identity priming under these two conditions. Specifically, this group showed a priming effect under the similar condition (with an effect size of 47ms), but no indication of a priming effect under the dissimilar condition (with an effect size of 0ms), resulting in a significant 47ms advantage of the similar condition over the dissimilar condition. These results have been interpreted to indicate that less skilled L1 readers may not have fast, automatic access to abstract lexical representations (Perea et al., 2015). That is, less skilled L1 readers may not be able to abstract away from (largely irrelevant) low-level visual form information as efficiently as skilled L1 readers during lexical access. Instead, they appear to rely on the low-level details of orthographic forms at the early stages of lexical processing. In this way, these findings indicating differential processing efficiency for low-level form characteristics between skilled and less skilled L1 readers have been taken to reflect a developing trajectory of lexical representations that becomes more abstract with increasing reading experience/exposure (e.g., Kinoshita et al., 2021; Perea et al., 2015; see above).

1.2.6 Orthographic Processing Efficiency in Skilled L2 Readers and Research Question

A relevant question then -- and the question that is investigated in the present study -- is whether highly proficient L2 readers also differ from skilled L1 readers in terms of the efficiency with which they access abstract lexical representations at early stages of visual word recognition. As in the studies detailed above, this will be examined using a masked identity priming paradigm in which the low-level visual similarity of the prime and target is manipulated. Also as in these studies, the extent to which these effects relate to this visual similarity will be taken as a diagnostic of orthographic processing efficiency, with form-dependent effects indicating less efficient processing at this level. Of course, this research question is of general empirical interest in that it will shed light on a potential L1/L2 processing difference that persists even into higher levels of L2 proficiency. Moreover, as suggested above, to the extent that there are major differences between skilled L1 and L2 readers in terms of orthographic processing efficiency, such differences might also help to explain other L1/L2 processing disparities that have been observed at the level of lexical form.

1.3 Cross-case Similarity: Similar vs. Dissimilar Words

Since the visual similarity of a word between its uppercase and lowercase forms is manipulated to investigate the research question of interest, it is important to clarify how cross-case similarity is operationalized in this study. In order to define the cross-case similarity of a word in its uppercase and lowercase forms, the similarity of cross-case letters is considered first. In English, each letter can be written in both uppercase and lowercase. Some letters have similar forms in the two cases, like *C/c* and *O/o*, while others do not, like *A/a* and *B/b*. Relevant to the current study, Boles and Clifford (1989) systematically investigated the cross-case similarity of each letter in English (e.g., *A/a*; see the second column in Appendix A for their results). The possible similarity rating of each letter in its uppercase and lowercase forms in this study ranged from 0 to 500. On this continuum, lower values (towards the end of 0) indicated lower similarity of a letter in its uppercase and lowercase forms, whereas higher values (towards the end of 500) indicated higher similarity. For example, the similarity rating of the letter *A/a* was 237 -- a comparatively low similarity rating -- thus indicating the two specific instances of this letter are less similar to each other. In contrast, the similarity rating of the letter *O/o* was 434 -- a comparatively high similarity rating -- thus indicating the two specific instances of this letter are more similar to each other.

The cross-case similarity ratings in Boles and Clifford (1989) largely match with the criteria set to separate similar letters from dissimilar letters in many studies investigating abstract letter/word identity (e.g., Bowers & Turner, 2005; Bowers et al., 1998; Jacobs & Grainger, 1991; Kinoshita & Kaplan, 2008; Kinoshita & Norris, 2009; Kinoshita et al., 2021; Madec et al. 2016; Norris & Kinoshita, 2008; Perea et al., 2014; Schubert et al., 2018; Ziegler et al., 2000; See Appendix A for more details of the corresponding judgments on the similarity of each letter in these studies). Specifically, across these studies, any letter with a similarity rating lower than 300 was consistently regarded as a cross-case dissimilar letter, while any letter with a similarity rating higher than 400 was consistently regarded as a cross-case similar letter. For letters with a similarity rating higher than 300 and lower than 400, the similarity judgments on these letters varied across studies.

Following the consistent judgments on the similarity of a letter in its uppercase and lowercase forms, the present study only includes unambiguously cross-case similar letters as similar letters and unambiguously cross-case dissimilar letters as dissimilar letters. Specifically, in the current study, the cross-case similar letters include *C/c*, *K/k*, *O/o*, *P/p*, *S/s*, *U/u*, *V/v*, *W/w*, *X/x*, and *Z/z*, while the cross-case dissimilar letters include *A/a*, *B/b*, *D/d*, *E/e*, *G/g*, *Q/q*, and *R/r*. All other letters, including *F/f*, *H/h*, *I/i*, *J/j*, *M/m*, *N/n*, *T/t*, and *Y/y*, are regarded as cross-case neutral letters. In addition, the letter *L/l* was used as a neutral letter in primes only under unrelated conditions, conditions that do not affect the effect sizes of the priming of interest. The restriction was put in place for two reasons. First, this letter was treated as a similar and dissimilar letter in Bowers et al. (1998), although this letter has a comparatively low similarity rating (i.e., 255) in Boles and Clifford (1989). Second, to avoid any confusion, several studies have avoided using this letter in their critical stimuli (e.g., Jacobs & Grainger, 1991; Madec et al., 2016; Norris & Kinoshita, 2008; Schubert et al., 2018; Ziegler et al., 2000).

With respect to the similarity manipulation in the present study, similar words were composed of at least N-1 cross-case similar letters and maximally one cross-case neutral letter, where N stands for the length of the word. Similarly, dissimilar words were composed of at least N-1 cross-case dissimilar letters and maximally one cross-case neutral letter. In addition, the degree of similarity of the stimuli (i.e., the number of similar words and dissimilar words considering word length) was balanced in the experimental lists (see more detailed information on section 2.1.2).

1.4 The Present Study and Predictions

This study uses masked identity priming effects as a diagnostic and manipulates the visual similarity of the prime and target to investigate whether skilled L2 readers differ from skilled L1 readers in terms of the efficiency with which they abstract away from low-level form characteristics when accessing lexical representations at early stages of visual word recognition. More specifically, a lexical decision task with masked priming was conducted, in which the relatedness of the prime-target pairs (related vs. unrelated), the visual similarity of related pairs (similar words vs. dissimilar words), and reader group (skilled L1 readers vs. skilled L2 readers) were manipulated. The predictions are as follows. For skilled L1 readers, masked identity priming effects are predicted to be observed under both similar and dissimilar conditions, with comparable effect sizes under both conditions. As in previous studies, this form-independent masked identity priming effect will be taken to indicate that skilled L1 readers efficiently abstract away from low-level form characteristics when accessing lexical representations (e.g., Bowers et al., 1998; Perea et al., 2015). If skilled L2 reading is characterized by comparable processing efficiency, the L2 group should reveal similar form-independent identity priming effects. However, if skilled L2 reading is characterized by persistent inefficiencies at this level of processing, the L2 group should show much larger priming effects under the similar condition than under the dissimilar condition. That is, this group should show a pattern of form-dependent identity priming effects similar to that which has been shown for developing L1 readers (Perea et al., 2015).

1.5 Chapter Outline

Following Chapter 1, Chapter 2 reports on the experiment sketched above. Chapter 3 then details several post-hoc analyses that were conducted to examine individual differences that might modulate the effects of interest. Finally, Chapter 4 summarizes the main findings of the experiment, discusses the implications of this study for theory development in bilingual visual word recognition, and offers directions for future research.

Chapter 2 Experiment

This study uses masked identity priming effects as a diagnostic to investigate whether skilled L2 readers differ from skilled L1 readers in terms of the efficiency with which they abstract away from low-level form characteristics when accessing lexical representations during the early stages of visual word recognition. Specifically, a lexical decision task with masked priming was conducted, in which the relatedness of the prime-target pairs (related vs. unrelated), the visual similarity of related pairs (similar words vs. dissimilar words), and reader group (skilled L1 readers vs. skilled L2 readers) were manipulated. For skilled L1 readers, comparable masked identity priming effects are predicted under similar and dissimilar conditions. This form-independent masked identity priming effect will be taken to indicate that skilled L1 readers efficiently abstract away from low-level form characteristics when accessing lexical representations. If skilled L2 reading is characterized by persistent inefficiencies of orthographic processing at the level of lexical form, the L2 group should show a form-dependent masked identity priming effect -- i.e., much larger priming effects under the similar condition than under the dissimilar condition. This differential orthographic processing efficiency should be indicated by a three-way interaction among the three factors. However, if skilled L2 reading is characterized by comparable processing efficiency with L1 reading, the L2 group should reveal a similar form-independent priming effect. This comparable orthographic processing efficiency will be indicated by a lack of a three-way interaction.

2.1 Methods

2.1.1 Participants

One hundred and thirty-four (134) students who were registered in degree-granting programs at the University of Texas at Arlington participated in this experiment. Sixty-four (64) were native speakers of English who started learning English at or before the age of five and who reported English as their dominant language. Seventy (70) were L2 learners of English from various L1 backgrounds (Arabic: 3; Azeri: 3; Bengali: 3; Gujarati: 4; Hindi: 5; Korean: 4; Mandarin: 8; Marathi: 3; Nepali: 1; Odia: 1; Persian: 6; Sinhala: 1; Spanish: 8; Swedish: 1; Tamil: 1; Telugu: 11; Vietnamese: 5; Yoruba: 2). These L2 readers of English either reported English as their less dominant language or started learning English after the age of five. English proficiency was assessed with two measurements -- self-rated proficiency and LexTALE scores (Lexical Test for Advanced Learners of English; Lemhöfer & Broersma, 2012). In addition to the two measurements, standardized test (i.e., TOEFL or IELTS) scores were collected from L2 readers. The language background information of the participants (after all exclusions had been made, as detailed below) is summarized in Table 1. This placed the L2 learners of English as advanced learners. Native speakers of English participated in the experiment for course credit, while the L2 learners of English participated in the experiment for a small monetary award.

Table 1. The language background information of both the skilled L1 and L2 readers of English.

Language Group	L1 (*N*=64)	L2 (*N*=70)
Age of acquisition (AoA) for English: mean	1.16	8.17
AoA for English: range	0-5	1-16
Self-rated proficiency (English): mean	9.72	7.93
Self-rated proficiency (English): range	8-10	4-10
Self-rated proficiency (L1 other than English): mean	n/a	9.84
Self-rated proficiency (L1 other than English): range	n/a	8-10
LexTALE scores: mean	84.14	75.95
LexTALE scores: range	58.75-98.75	46.25-100
TOEFL: mean	n/a	97.08 (*N*=26)
TOEFL: range	n/a	74-116
IELTS: mean	n/a	7.04 (*N*=24)
IELTS: range	n/a	6.5-8

Note. self-rated proficiency is on a rating scale from 0 to 10; *N* represents the number of participants under that category; n/a represents not applicable.

2.1.2 Materials and Design

The design of the experiment largely followed that of Bowers et al. (1998). However, improving on that study, the current experiment involved a larger number of items and tighter restrictions on the selection criteria for the stimuli. Specifically, the word targets were 100 English words (see the full set of stimuli used in the experiment in Appendix B). Eighty-four (84) were composed of four letters, while 16 were composed of five letters. These words were further divided into similar words and dissimilar words based on the similarity of a word in its uppercase and lowercase forms, following the criteria introduced above (see Chapter 1). Half of them were defined as similar words, while the other half were dissimilar words. Similar words with four letters (e.g., *cook/COOK* and *know/KNOW*) were composed of at least three cross-case similar letters (i.e., *C/c*, *K/k*, *O/o*, *P/p*, *S/s*, *U/u*, *V/v*, *W/w*, *X/x*, and *Z/z*) and maximally one cross-case neutral letter (i.e., *F/f*, *H/h*, *I/i*, *J/j*, *M/m*, *N/n*, *T/t*, *Y/y*). Similar words with five letters (e.g., *knock/KNOCK*) were composed of four cross-case similar letters and one neutral letter. Following the same selection criteria, dissimilar words with four letters (e.g., *bear/BEAR* and *hear/HEAR*) were composed of at least three cross-case dissimilar letters (i.e., *A/a*, *B/b*, *D/d*, *E/e*, *G/g*, *Q/q*, *R/r*) and maximally one neutral letter. Dissimilar words with five letters (e.g., *grand/GRAND*) were composed of four cross-case dissimilar letters and one neutral letter. Altogether, the word targets were composed of 42 four-letter similar words, eight five-letter similar words, 42 four-letter dissimilar words, and eight five-letter dissimilar words. In this way, the degree of similarity between similar and dissimilar words (i.e., the number of similar words and dissimilar words regarding word length) was also controlled.

The word targets were high-frequency words with mean log frequency being 3.20, ranging from 1.18 to 5.47 based on the SUBTLEX-US database (Brysbaert & New, 2009; similar words: mean log frequency = 3.18, ranging from 1.32 to 5.47; dissimilar words: mean log frequency = 3.23, ranging from 1.18 to 4.44). Each word target was preceded by one of the two types of primes: (1) related (e.g., *cook-COOK*, *bear-BEAR*), or (2) unrelated (e.g., *fill-COOK*, *wind-BEAR*). The word primes in the unrelated condition were selected such that the primes and the targets matched in word length (four- or five-letter long) and log frequency, with mean log frequency of these primes being 3.20, ranging from 1.20 to 5.50 (similar/unrelated condition: mean log frequency = 3.18, ranging from 1.32 to 5.50; dissimilar/unrelated condition: mean log frequency = 3.23, ranging from 1.20 to 4.48), but no prime-target pairs contained the same letter in the same relative position.

In addition, 100 nonword targets, which adhered to both orthographic and phonological constraints in English, were selected from the ARC nonword database (Rastle et al., 2002). These nonword targets had similar characteristics as the word targets with respect to length and the degree of similarity between those identified as similar and dissimilar. Examples of these nonwords are *zoop*, *poom*, *swoof*, *breb*, *geaf*, and *fadge*. Related and unrelated primes were also created for the nonword targets. Unrelated primes adhered to orthographic and phonological constraints in English, and the primes and the targets matched in word length (four or five letters long), but no prime-target pairs contained the same letter in the same relative position. In addition to the 100 word targets, 100 nonword targets, and the corresponding primes, there were four word prime-target pairs and four nonword prime-target pairs used for practice, selected according to the criteria described above.

The word and nonword stimuli were divided into two counterbalanced lists (with the words in each list matched on mean frequency and degree of word similarity). That is, if a target was preceded by a related prime in one list, it would be preceded by an unrelated prime in the other list, and vice versa. Each target appeared once in a list, and across the two lists, so that it was paired with both prime types. Participants were assigned to one of the two lists randomly.

2.1.3 Procedures

This experiment was conducted online using a web-deployable version of DMDX (Forster & Forster, 2003). Each trial started with a forward mask (#####) presented for 500ms, which was replaced by a prime presented for 50ms. The prime was then immediately replaced by a target, which was presented for 500ms. Primes and targets were presented in 12-point Courier New font. The primes were in lowercase, while the targets were in uppercase. Participants were asked to decide whether a letter string was a real English word as quickly and accurately as possible by pressing either the left Ctrl key (for nonwords) or the right Ctrl key (for words). The participants were given feedback on the speed and accuracy after each of their responses. The next trial began automatically after a 500ms intertrial interval. RT and accuracy for each decision were collected by the computer automatically. The experiment began with eight practice trials.

The experimental trials were then presented in five blocks of 40 items, in a different random order for each participant. Participants were encouraged to take a short break after each block.

Before doing the lexical decision task, participants answered a short language background questionnaire that included questions on their language background and took the LexTALE test (Lemhöfer & Broersma, 2012). Altogether, it took approximately 30 minutes to complete the questionnaire, the LexTALE test, and the lexical decision task.

2.2 Results (Confirmatory Analyses)

The data analyses were conducted on RT data and error data. Participants with overall error rates over 25% were removed from the analyses. This criterion excluded data sets from three skilled L1 readers of English, and one more dataset was excluded because the participant reported vision problems. These participants were replaced by another four skilled L1 readers of English who met the inclusion criterion. This criterion also excluded data sets from eight skilled L2 readers of English, and one more dataset was excluded because there were too many display errors, which indicated that the collected data from this participant were unreliable. These participants were replaced by another nine skilled L2 readers of English who met the inclusion criterion. An analysis of the error rates confirmed that the L2 readers were highly proficient in English. Indeed, there was no reliable difference ($t = 0.26$, $p = .796$) in the error rates between L1 readers (mean:11.07%; range: 2.50% - 22.50%) and L2 readers (mean: 11.31%; range: 2.00% - 25.00%). Note that the language background information for participants reported in section 2.1.1 was based on the information from participants whose data were included in the data analyses. The analyses of the RT data only included correct responses. RTs shorter than 300ms and longer than 2000ms were removed as outliers. RTs that were more than three standard deviations above or below the participant's mean were set equal to the value three standard deviations above or below their mean. The RTs for correct responses were analyzed by using linear mixed effects (LME) models using the lme4 package (Bates et al., 2015) in R (version 4.4.0; R Development Core Team, 2024).

In these models, the relatedness of the prime-target pairs (related vs. unrelated), the visual similarity of related pairs (similar words vs. dissimilar words), and reader group (skilled L1 readers vs. skilled L2 readers) were sum-coded fixed effects. The initial model included relatedness, similarity, reader group, and the interactions among these factors as fixed effects, and by-subject and by-item intercepts and slopes for relatedness, similarity, reader group, and their interaction terms as random effects. The maximal random effects structure (Barr et al., 2013) was used whenever possible: DV ~ similarity * relatedness * group + (1 + similarity * relatedness | subj) + (1 + relatedness * group | item), where DV stands for the dependent variable. In the cases in which the maximal model failed to converge, the random-effect structure was simplified by removing the by-subject or by-item random slope for the interaction. The *p*-values for these models were estimated using the Satterthwaite approximation implemented in the lmerTest package (Kuznetsova et al., 2017).

The raw RTs were log-transformed prior to analyses in order to meet the Gaussian distributional assumptions of the statistical models. Estimated marginal means and standard errors for the log-transformed RTs were calculated based on the mixed-effects model reported using the emmeans package (Lenth, 2019). This package was also used to conduct relevant pairwise comparisons. For these pairwise comparisons, the *p*-values again were based on the Satterthwaite approximation. Error data were analyzed using a mixed-effects logistic model (Jaeger, 2008) with the same fixed effects and with by-subject and by-item intercepts and slopes as random effects.

2.2.1 Word Targets

Table 2 shows the descriptive statistics related to readers' RTs to word targets, and Table 3 shows the output from the model examining the effects of relatedness, similarity, and reader group on these RTs. As shown in the tables, the main effect of similarity was not significant (β = 0.01, *SE* = 0.01, *t* = 1.06, *p* = .290), indicating that the participants had similar RTs to words under the similar condition and the dissimilar condition. However, the main effect of relatedness was significant (β = 0.03, *SE* = 0.00, *t* = 16.45, *p* < .001). Participants' RTs to word targets under the related condition were shorter than those under the unrelated condition, indicating a general masked identity priming effect for word targets. Indeed, for both reader groups, there were reliable masked identity priming effects under both the similar condition (skilled L1 readers: β = -0.08, *SE* = 0.01, *t* = -10.62, *p* < .001; skilled L2 readers: β = -0.08, *SE* = 0.01, *t* = -9.52, *p* < .001) and the dissimilar condition (skilled L1 readers: β = -0.06, *SE* = 0.01, *t* = -8.25, *p* < .001; skilled L2 readers: β = -0.05, *SE* = 0.01, *t* = -6.43, *p* < .001). There was also a significant main effect of group (β = 0.07, *SE* = 0.01, *t* = 4.83, *p* < .001), reflecting the fact that the skilled L1 readers had shorter RTs than the skilled L2 readers for word targets.

In addition, the two-way interaction between similarity and relatedness was also significant (β = -0.01, *SE* = 0.00, *t* = -2.89, *p* = .005), indicating that the magnitude of masked identity priming effects was generally larger under the similar condition than under the dissimilar condition. There were no other significant two-way interactions (all *p*'s > .05). Moreover, there was no three-way interaction among relatedness, similarity, and reader group (β = -0.00, *SE* = 0.00, *t* = -0.47, *p* = .637), indicating that the interaction of form similarity with relatedness was not significantly different for the two groups of readers. The lack of the three-way interaction demonstrates that skilled L2 readers appear to abstract away from low-level form characteristics when accessing lexical representations at the early stages of visual word recognition with a similar efficiency to that of skilled L1 readers. That is, there does not appear to be a fundamental difference between skilled L1 and L2 readers in terms of orthographic processing efficiency.

Table 2. Estimated marginal means for log-transformed RTs, standard errors (in parentheses), and mean RTs (in ms; in squared parentheses) to word targets.

Group	Similarity	Relatedness		Priming effect (in ms)	Form-dependent priming effect (in ms)
		Related	Unrelated		
L1					
	similar	6.23 (0.02) [508]	6.31 (0.02) [550]	42***	10
	dissimilar	6.25 (0.02) [518]	6.31 (0.02) [550]	32***	
L2					
	similar	6.36 (0.02) [578]	6.44 (0.02) [626]	48***	18
	dissimilar	6.39 (0.02) [596]	6.44 (0.02) [626]	30***	

Note. similar: stimuli composed of at least N-1 cross-case similar letters under similar conditions, with N indicating the length of a word; dissimilar: stimuli composed of at least N-1 cross-case dissimilar letters under dissimilar conditions; ***, $p < .001$.

Table 3. Output of the statistical analysis on the log-transformed RTs to word targets.

	β	*SE*	*t*	*p*
Intercept	6.34	0.01	422.94	<.001
similarity	0.01	0.01	1.06	0.290
relatedness	**0.03**	**0.00**	**16.45**	**<.001**
group	**0.07**	**0.01**	**4.83**	**<.001**
similarity*relatedness	**-0.01**	**0.00**	**-2.89**	**0.005**
similarity*group	0.00	0.00	0.69	0.493
relatedness*group	-0.00	0.00	-0.89	0.374
similarity*relatedness*group	-0.00	0.00	-0.47	0.637

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * group + (1 + similarity * relatedness | subj) + (1 + relatedness * group | item))

To better understand the nature of the skilled L1 and L2 readers' performance, analyses were also conducted for the skilled L1 readers and the skilled L2 readers, separately. Table 4 shows the output from the model examining the effects of relatedness and similarity on RTs for the L1 readers. As shown in the table, the main effect of similarity was not significant (β = 0.01, *SE* = 0.01, *t* = 0.83, *p* = .411), indicating that the skilled L1 readers had similar RTs to words under similar and dissimilar conditions. However, the main effect of relatedness was significant (β = 0.04, *SE* = 0.00, *t* = 12.65, *p* < .001). This reflects the fact that the skilled L1 readers' RTs to word targets under the related condition were shorter than those under the unrelated condition, indicating a general masked identity priming effect. However, the two-way interaction between similarity and relatedness was not significant (β = -0.00, *SE* = 0.00, *t* = -1.90, *p* = .061), indicating that the magnitude of masked identity priming effects was not reliably different under the similar condition and the dissimilar condition. That is, the skilled L1 readers did not show a reliable influence of form similarity on the masked identity priming effect. This demonstrates that skilled L1 readers are largely unaffected by visual dissimilarities between uppercase and lowercase word forms during the early stages of visual word recognition, and that they efficiently abstract away from such low-level form characteristics when accessing lexical representations.

Table 4. Output of the statistical analysis on the log-transformed RTs to word targets from the skilled L1 readers.

	β	*SE*	*t*	*p*
Intercept	6.27	0.02	320.92	<.001
similarity	0.01	0.01	0.83	0.411
relatedness	**0.04**	**0.00**	**12.65**	**<.001**
similarity*relatedness	-0.00	0.00	-1.90	0.061

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness + (1 + similarity * relatedness | subj) + (1 + relatedness | item))

Table 5 shows the output from the model examining the effects of relatedness and similarity on RTs for the L2 readers. As shown in the table, the main effect of similarity was not significant (*β* = 0.01, *SE* = 0.01, *t* = 1.23, *p* = .222), indicating that the skilled L2 readers had similar RTs to words under similar and dissimilar conditions. However, the main effect of relatedness was significant (*β* = 0.03, *SE* = 0.00, *t* = 11.25, *p* < .001). This reflects the fact that the skilled L2 readers' RTs to the word targets under the related condition were shorter than those under the unrelated condition, indicating a general masked identity priming effect. In addition, the two-way interaction between relatedness and similarity was also significant (*β* = -0.01, *SE* = 0.00, *t* = -2.43, *p* = .017), indicating that the magnitude of the masked identity priming effects was larger under the similar condition than under the dissimilar condition. That is, unlike the skilled L1 readers, the skilled L2 readers showed a masked identity priming effect that was reliably modulated by low-level form similarity between the prime and target. This indicates that for skilled L2 readers, these low-level form characteristics influence access to abstract lexical representations at the early stages of visual word recognition.

Table 5. Output of the statistical analysis on the log-transformed RTs to word targets from the skilled L2 readers.

	β	*SE*	*t*	*p*
Intercept	6.40	0.02	307.14	<.001
similarity	0.01	0.01	1.23	0.222
relatedness	**0.03**	**0.00**	**11.25**	**<.001**
similarity*relatedness	**-0.01**	**0.00**	**-2.43**	**0.017**

Note: The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness + (1 + similarity * relatedness | subj) + (1 + relatedness | item))

Table 6 shows the descriptive statistics related to readers' error rates to word targets, and Table 7 shows the output from the model examining the effects of relatedness, similarity, and reader group on these error rates. As shown in the tables, the main effect of similarity was not significant (*β* = -0.06, *SE* = 0.10, *z* = -0.60, *p* = .550), indicating that the participants made a similar number of errors to words under similar and dissimilar conditions. However, there was a significant main effect of relatedness (β = 0.18, *SE* = 0.04, z = 4.23, $p < .001$), indicating that the participants made fewer errors to word targets under the related condition (error rate = 9.30%) than under the unrelated condition (error rate = 11.17%). Indeed, the skilled L1 readers made fewer errors under the similar/related condition than under the similar/unrelated condition (similar condition: β = -0.53, *SE* = 0.16, z = 3.43, $p < .001$; dissimilar condition: β = -0.11, *SE* = 0.15, z = -0.76, p = .448), but the skilled L2 readers made fewer errors under both the similar/related condition and the dissimilar/related condition compared with their unrelated counterparts (similar condition: β = -0.42, *SE* = 0.15, z = -2.90, p = .004; dissimilar condition: β = -0.37, *SE* = 0.15, z = -2.51, p = .012). The main effect of reader group was not significant (β = -0.00, *SE* = 0.07, z = 0.00, p = 1.000). This reflects the fact that the skilled L2 readers (10.86%) made a similar number of errors to word targets as the skilled L1 readers (9.61%), re-confirming L2 readers' high proficiency in L2 English. The two-way interactions and three-way interaction were not significant (all *p*'s > .05). The comparable proficiency between L1 and L2 readers reflected through the error rate analyses on word targets indicates that any difference in orthographic processing efficiency at lexical level between the two groups should not be attributable to L2 readers' inadequate proficiency in English.

Table 6. Descriptive data of the mean error rates (in percentage) on raw data to word targets.

Group	Similarity	Relatedness		Priming effect
		Related	Unrelated	
L1	similar	8.69	11.38	2.69***
	dissimilar	9.13	9.25	0.12
L2	similar	10.63	12.97	2.34**
	dissimilar	8.74	11.09	2.35*

Note. similar: stimuli composed of at least N-1 cross-case similar letters under similar conditions, with N indicating the length of a word; dissimilar: stimuli composed of at least N-1 cross-case dissimilar letters under dissimilar conditions; ***, $p < .001$; **, $p < .01$; *, $p < .05$.

Table 7. Output of the statistical analysis on the error data to word targets.

	β	*SE*	*z*	*p*
Intercept	-2.68	0.11	-23.45	<.001
similarity	-0.06	0.10	-0.60	0.550
relatedness	**0.18**	**0.04**	**4.23**	**<.001**
group	-0.00	0.07	0.00	1.000
similarity*relatedness	-0.06	0.04	-1.55	0.120
similarity*group	-0.04	0.04	-0.84	0.401
relatedness*group	0.02	0.04	0.50	0.615
similarity*relatedness*group	0.05	0.03	1.41	0.158

Note. The statistical model for the error data was coded as follows: glmer (error ~ similarity * relatedness * group + (1 + similarity * relatedness | subj) + (1 + relatedness * group | item))

2.2.2 Nonword Targets

In a lexical decision task with masked priming, a fundamental dissociation in identity priming effects between word targets and nonword targets is frequently reported (e.g., see Forster, 1998 for a review). Specifically, identity priming effects for word targets are consistently large, whereas identity priming effects for nonword targets are small or negligible. This has been taken to indicate that masked priming effects are lexical in nature. To examine whether a similar dissociation between word and nonword targets is also observed when the similarity of nonwords between their uppercase and lowercase forms is manipulated, responses to nonword targets were also analyzed.

Table 8 shows the descriptive statistics related to readers' RTs to nonword targets, and Table 9 shows the output from the model examining the effects of relatedness, similarity, and reader group on these RTs. As shown in the tables, the main effect of similarity was significant ($\beta = 0.04$, $SE = 0.01$, $t = 6.65$, $p < .001$), indicating that the participants had shorter RTs to nonwords under the similar condition than under the dissimilar condition. The main effect of relatedness was also significant ($\beta = 0.01$, $SE = 0.00$, $t = 4.77$, $p < .001$). This reflects the fact that the participants' RTs to the nonword targets under the related condition were shorter than those under the unrelated condition, indicating a general masked identity priming effect for nonword targets. Indeed, for both reader groups, there were small but reliable masked identity priming effects for nonword targets under both the similar condition (skilled L1 readers: β = -0.02, *SE* = 0.01, *t* = -2.33, *p* = .022; skilled L2 readers: β = -0.03, *SE* = 0.01, *t* = -3.39, *p* < .001) and the dissimilar condition (skilled L1 readers: β = -0.02, *SE* = 0.01, *t* = -2.30, *p* = .024; skilled L2 readers: β = -0.02, *SE* = 0.01, *t* = -2.29, *p* = .024). There was also a significant main effect of reader group (β = 0.07, *SE* = 0.02, *t* = 427, *p* < .001), indicating that the skilled L1 readers had shorter RTs than the skilled L2 readers for nonword targets.

In addition, the two-way interaction between similarity and group was also significant (β = 0.01, *SE* = 0.00, *t* = 3.31, *p* = .001), indicating the difference of RTs to nonwords between similar and dissimilar conditions was larger for the skilled L2 readers (68ms) than for the skilled L1 readers (36ms). There were no other significant two-way interactions or a three-way interaction (all *p*'s > .05). Compared with the robust masked identity priming effects observed in analyses on readers' RTs to word targets, the small priming effects to nonword targets indicates the fundamental dissociation in identity priming effects between word and nonword targets. In addition, the effect of similarity that was not observed on RTs to word targets was observed on RTs to nonword targets, indicating that low-level form characteristics might affect orthographic processing efficiency in words and nonwords differently.

Table 8. Estimated marginal means for log-transformed RTs, standard errors (in parentheses), and mean RTs (in ms; in squared parentheses) to nonword targets.

Group	Similarity	Relatedness		Priming effect (in ms)	Form-dependent priming effect (in ms)
		Related	Unrelated		
L1					
	similar	6.35 (0.02) [572]	6.37 (0.02) [584]	12*	0
	dissimilar	6.41 (0.03) [608]	6.43 (0.03) [620]	12*	
L2					
	similar	6.46 (0.02) [639]	6.49 (0.02) [659]	20***	12
	dissimilar	6.57 (0.02) [713]	6.58 (0.02) [721]	8*	

Note. similar: stimuli composed of at least N-1 cross-case similar letters under similar conditions, with N indicating the length of a word; dissimilar: stimuli composed of at least N-1 cross-case dissimilar letters under dissimilar conditions. ***, $p < .001$; *, $p < .05$.

Table 9. Output of the statistical analysis on the lexical decision times to nonword targets.

	β	*SE*	*z*	*p*
Intercept	6.46	0.02	400.33	<.001
similarity	**0.04**	**0.01**	**6.65**	**<.001**
relatedness	**0.01**	**0.00**	**4.77**	**<.001**
group	**0.07**	**0.02**	**4.27**	**<.001**
similarity*relatedness	-0.00	0.00	-0.30	0.762
similarity*group	**0.01**	**0.00**	**3.31**	**0.001**
relatedness*group	0.00	0.00	0.33	0.743
similarity*relatedness*group	-0.00	0.00	-0.52	0.606

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * group + (1 + similarity * relatedness | subj) + (1 + relatedness * group | item))

Table 10 shows the descriptive data of the readers' error rates to nonword targets, and Table 11 shows the output from the model examining the effects of relatedness, similarity, and reader group on these error rates. As shown in the tables, there was a significant main effect of similarity (β = 0.18, SE = 0.08, z = 2.29, p = .022), indicating that the participants made more errors to nonword targets under the dissimilar condition (error rate = 15.43%) than under the similar condition (error rate = 11.34%). The main effect of relatedness was not significant (β = 0.00, SE = 0.04, z = 0.05, p = .963), indicating that the participants made a similar number of errors under the related condition (13.51%) and the unrelated condition (13.26%). Indeed, both the skilled L1 and L2 readers made similar numbers of errors for related and unrelated prime-target pairs under the similar condition (skilled L1 readers: β = 0.14, *SE* = 0.16, *z* = 0.87, *p* = .386; skilled L2 readers: β = -0.08, *SE* = 0.14, *z* = -0.61, *p* = .540) and the dissimilar condition (skilled L1 readers: β = -0.17, *SE* = 0.15, *z* = -1.09, *p* = .278; skilled L2 readers: β = 0.10, *SE* = 0.12, *z* = 0.80, *p* = .425). The main effect of the reader group was also not significant (β = 0.01, *SE* = 0.07, *z* = 0.20, *p* = .840). This reflects the fact that the skilled L2 readers made a similar number of errors to nonword targets as the skilled L1 readers, re-confirming L2 readers' high proficiency in their L2 English. There were no other significant main effects, two-way interactions, or a three-way interaction (all *p*'s > .05). The comparable proficiency between L1 and L2 readers reflected in the error rate analyses for nonword targets indicates that any difference in processing low-level form characteristics of nonwords/words between the two groups should not be attributable to L2 readers' inadequate proficiency in English.

Table 10. Descriptive data of the mean error rates (in percentage) on raw data to nonword targets.

Group	Similarity	Relatedness		Priming effect
		Related	Unrelated	
L1	similar	12.94	10.94	-2.00
	dissimilar	14.13	15.94	1.81
L2	similar	10.69	10.80	0.11
	dissimilar	16.29	15.37	-0.92

Note. similar: stimuli composed of at least N-1 cross-case similar letters under similar conditions, with N indicating the length of a word; dissimilar: stimuli composed of at least N-1 cross-case dissimilar letters under dissimilar conditions.

Table 11. Output of the statistical analysis on error data to nonword targets.

	β	*SE*	*z*	*p*
Intercept	-2.25	0.10	-22.31	<.001
similarity	**0.18**	**0.08**	**2.29**	**0.022**
relatedness	0.00	0.04	0.05	0.963
group	0.01	0.07	0.20	0.840
similarity*relatedness	0.02	0.04	0.41	0.684
similarity*group	0.05	0.03	1.53	0.127
relatedness*group	-0.00	0.03	-0.13	0.894
similarity*relatedness*group	-0.06	0.03	-1.84	0.066

Note. The statistical model for error data was coded as follows: glmer (error ~ similarity * relatedness * group + (1 + similarity * relatedness | subj) + (1 + relatedness * group | item))

2.3 Brief Summary

This experiment used the masked identity priming effects as a diagnostic and manipulated the visual similarity of the prime and target to investigate whether skilled L2 readers differ from skilled L1 readers in terms of the efficiency with which they abstract away from low-level form characteristics when accessing lexical representations during the early stages of visual word recognition. The main findings are as follows. First, in the RT analyses, robust masked identity priming effects were found for word targets in both the L1 and L2 groups. This finding replicates well-documented masked identity priming effects in previous literature (e.g., for L1 readers: Forster & Davis, 1984; Forster et al., 2003; for L2 readers: Aparicio & Lavaur, 2016; de Groot & Nas, 1991; Dimitropoulou et al., 2011a, b; Dubey et al., 2018; Finkbeiner et al., 2004; Foote et al., 2020; Gollan et al., 1997; Heyer & Clahsen, 2015; Hoshino et al., 2010; Jiang, 1999; Midgley et al., 2009; Nakayama & Lupker, 2018; Nakayama et al., 2013; Silva & Clahsen, 2008; Smith et al., 2019; Xia & Andrews, 2015). Second, for the skilled L1 readers, the results largely replicated form-independent masked identity priming effect, which was indicated by the lack of the two-way interaction between relatedness and similarity for this group. Specifically, for the skilled L1 readers, the magnitude of masked identity priming effects was not reliably different (i.e., 10ms) under the similar condition (i.e., 42ms) and the dissimilar condition (i.e., 32ms). This finding adds supportive evidence to the conclusion that skilled L1 readers are largely unaffected by visual similarities/dissimilarities between uppercase and lowercase word forms during the early stages of visual word recognition. Rather, they appear to efficiently abstract away from low-level form characteristics when accessing lexical representations.

The skilled L2 readers, however, showed a masked identity priming effect that seemed to be modulated by low-level form similarities/dissimilarities between the prime and target -- at least to some extent. Specifically, the L2 readers exhibited a slightly larger priming effect (i.e., 18ms) for visually similar prime-target pairs (i.e., 48ms) than for visually dissimilar prime-target pairs (i.e., 30ms) -- which was indicated by the two-way interaction between relatedness and similarity for this group. Compared with the form-independent masked identity priming effect observed for the L1 readers, this form-dependent masked identity priming effect for the skilled L2 readers suggests a difference between skilled L1 and L2 readers in terms of orthographic processing efficiency at the early stages of visual word recognition.

It is important to note, however, that this differential processing efficiency for low-level form characteristics between skilled L1 and L2 readers is not as large as that between skilled and less skilled L1 readers (as introduced in section 1.2.5), where less skilled L1 readers showed a robust masked identity priming effect under the similar condition (i.e., 47ms) but no indication of a priming effect under the dissimilar condition (i.e., 0ms). And indeed, in the present study, the three-way interaction of relatedness, similarity, and group was not statistically reliable, as would be expected if there were an especially large difference between these groups with respect to the influence of prime-target visual similarity on masked identity priming effects. Taken together, these findings thus suggest a quantitative, but not qualitative difference between L1 and

L2 readers in terms of the efficiency with which they process low-level form characteristics. That is, while there appears to be a slight difference between skilled L1 and L2 readers in terms of the efficiency with which they use visual information to access abstract lexical representations, these groups do not differ fundamentally from each other in this processing domain. It therefore seems that if L2 readers achieve a sufficient level of proficiency in the L2, they appear to be able to process low-level form characteristics -- and letter shapes in particular -- at a level of efficiency that approximates that of L1 readers. The high proficiency of L2 readers in L2 English in the current study was indicated by the fact that the error rates to word targets, nonword targets, and the overall error rates to all stimuli were similar for the L1 and L2 groups, and that the L2 participants had relatively high scores in standardized tests of English proficiency (TOEFL mean = 97.08; IELTS mean = 7.04). We will return to discussing the similarities/differences between L1 and L2 readers in terms of orthographic processing efficiency in more detail in the General discussion.

In addition to these findings related to the core research questions, several results are worthy of note. First, replicating previous findings, there was a fundamental dissociation in identity priming effects between word targets and nonword targets, which was indicated by a larger identity priming effect for word targets and a small identity priming effect for nonword targets. Moreover, the pattern that similar nonwords were processed faster and more accurately than dissimilar nonwords in general was not observed with word targets. This indicates a differential processing pattern for low-level form characteristics between words and nonwords. Although a full explanation on the underpinnings of masked identity priming with nonwords is beyond the scope of the current study, it, nevertheless, provides empirical evidence that visual form information is processed differently between words and nonwords.

Chapter 3 Post-hoc Analyses (Exploratory Analyses)

In the previous chapter, confirmatory analyses were conducted to investigate the main research questions of interest. This chapter details several post-hoc analyses that were conducted to examine individual differences that might modulate the priming effects reported for above -- and for the L2 group in particular. The first analysis explores whether/how the consistency of the scripts in a bilingual's two languages might influence identity priming effects for similar and dissimilar prime-target pairs. Other analyses then examine how factors such as L2 vocabulary knowledge, L2 proficiency, and L2 age of acquisition (AoA) might influence these effects. All of these analyses focus on the data for word targets -- the data of primary interest in most masked priming studies.

3.1 L1/L2 Script Properties

The analyses reported in this section were conducted to explore whether individual differences in orthographic processing efficiency systematically vary depending on the consistency of the scripts in a bilingual's two languages. This factor is potentially important in light of several studies that have reported L1/L2 processing differences at the form level when L1/L2 script is taken into consideration. For example, Jiang (2021b) reported a case effect for Chinese-English bilinguals -- i.e., different-script bilinguals -- while such an effect was absent for English native speakers and Romance-L1 bilinguals -- i.e., same-script bilinguals (see more details in section 1.2.3). In addition, the discrepancy in the directions of the masked word form priming effects in the L1 and L2 (see more details in section 1.2.1) also appears to be related to L1/L2 script properties. Specifically, inhibitory masked word form priming effects have been reported for French-English bilinguals (e.g., Bijeljac-babic et al., 1997) -- i.e., same-script bilinguals -- while facilitatory masked word form priming effects have been reported for Japanese-English bilinguals (e.g., Nakayama & Lupker, 2018) and Chinese-English bilinguals (e.g., Jiang, 2021a; Qiao & Forster, 2017) -- i.e., different-script bilinguals. In light of this difference, it is possible that the consistency of the scripts in a bilingual's two languages affects their performance on form-related words. Therefore, it is reasonable to explore whether skilled L2 readers differ from skilled L1 readers in terms of the efficiency with which they abstract away from low-level form characteristics during the early stages of visual word recognition when the L1/L2 scripts of L2 readers are taken into consideration.

The participants were divided into three groups: L1 readers, same-script bilinguals, and different-script bilinguals. Same-script bilinguals were from L1s with Latin-based scripts (e.g., Spanish, Vietnamese, Swedish, and Yoruba), while different-script bilinguals were from L1s based on different (alphabetic or logographic) writing systems (e.g., Arabic, Azeri, Bengali, Gujarati, Hindi, Korean, Mandarin, Marathi, Nepali, Odia, Persian, Sinhala, Tamil, Telugu). As a result, 16 L2 readers were categorized as same-script bilinguals, and 54 were categorized as different-script bilinguals. The language background information for these two groups is summarized in Table 12. There were no significant differences between the two L2 groups in terms of English AoA, self-rated L2 English proficiency, self-rated L1 proficiency, or LexTALE scores (all $p > .05$).

Table 12. The language background information for the same-script and different-script bilinguals.

Language Group	Same-script bilinguals (*N*=16)	different-script bilinguals (*N*=54)
AoA for English: mean	7.81	8.28
AoA for English: range	1-15	1-16
self-rated proficiency (English): mean	8	7.91
self-rated proficiency (English): range	6-9	4-10
self-rated proficiency (L1 other than English): mean	9.81	9.84
self-rated proficiency (L1 other than English): range	8-10	8-10
LexTALE scores: mean	79.22	74.98
LexTALE scores: range	65-93.75	46.25-100
TOEFL: mean	103 (*N*=1)	96.84 (*N*=25)
TOEFL: range	103-103	74-116
IELTS: mean	7 (*N*=1)	7.04 (*N*=23)
IELTS: range	7-7	6.5-8

Note. self-rated proficiency is on a rating scale from 0 to 10. *N* represents the number of participants under that category.

Similar to the confirmatory analysis in section 2.2, a linear mixed effects model was used to examine the effects of the relatedness of the prime-target pairs (related vs. unrelated), the visual similarity of related pairs (similar words vs. dissimilar words), script (L1 readers vs. same-script bilinguals vs. different-script bilinguals), and their interactions on log-transformed RTs, while a linear mixed-effects logistic model was used to examine the effects of the same predictors on the error data. In these models, relatedness and similarity were sum-coded fixed effects (as in section 2.2), while script was a treatment-coded fixed effect (with the L1 group as the reference level). The maximal random effects structure was used in these models, as illustrated here: DV ~ similarity * relatedness * script + (1 + similarity * relatedness | subj) + (1 + relatedness * script | item), where DV stands for the dependent variable. The dependent variables were specified in the model reported below -- either log-transformed RTs or error responses. The analyses focus on the role of script -- of L1/L2 script properties in particular -- in modulating the influence of prime-target similarity on masked identity priming effects.

Table 13 shows the descriptive statistics related to readers' RTs to word targets, and Table 14 shows the output from the model examining the effects of relatedness, similarity, and script on these RTs. In this model, the L1 group is the reference level, represented by the intercept, and all estimates are relative to this baseline. Turning first to the interaction between relatedness and script, averaging across prime-target similarity, the overall priming effect did not differ between the same-script bilinguals and the L1 readers (β = -0.00, *SE* = 0.01, *t* = -0.70, *p* = .486) or between the different-script bilinguals and the L1 readers (β = -0.00, *SE* = 0.00, *t* = -0.75, *p* = .455). However, a reliable three-way interaction among relatedness, similarity, and script showed that the influence of prime-target similarity on the masked identity priming effect was different for the same-script bilinguals and the L1 readers (β = -0.02, *SE* = 0.01, *t* = -2.45, *p* = .016). Specifically, there was a larger difference in the priming effects under the similar and dissimilar conditions for the same-script group (64 ms vs. 12 ms) than for the L1 group (42 ms vs. 32 ms). However, a difference along these lines was not observed for the different-script bilinguals relative to the L1 readers (β = 0.00, *SE* = 0.00, *t* = 0.70, *p* = .487). Specifically, there were comparable priming effects under the similar and dissimilar conditions for the different-script group (42ms vs. 43ms) and for the L1 group.

A subsequent paired comparison of just the bilingual groups also showed that the influence of prime-target similarity on the identity priming effect was larger for the same-script bilinguals than for the different-script bilinguals (β = 0.01, *SE* = 0.00, *t* = 2.66, *p* = .009). Indeed, the same-script bilinguals showed the masked identity priming effect under the similar condition (β = -0.11, *SE* = 0.02, *t* = -5.53, $p < .001$) but not under the dissimilar condition (β = -0.02, *SE* = 0.02, *t* = -1.06, *p* = .293), whereas the different-script bilinguals showed the priming effects under both conditions (similar condition: β = -0.07, *SE* = 0.01, *t* = -8.27, $p < .001$; dissimilar condition: β = -0.06, *SE* = 0.01, *t* = -7.48, *p* < .001). This pattern of results indicates that different-script bilinguals are able to abstract away from low-level form characteristics as efficiently as L1 readers, whereas same-script bilinguals seem to be less efficient in processing low-level form characteristics than both L1 readers and different-script bilinguals. Note that this somewhat counterintuitive conclusion should be interpreted with caution, considering the limited number of same-script bilinguals in the experiment. This caveat notwithstanding, it is clear that the slightly larger influence of prime-target similarity on identity priming for the L2 readers that was found in confirmatory analyses was not driven by the different-script bilinguals.

Table 13. Estimated marginal means for log-transformed RTs, standard errors (in parentheses), and mean RTs (in ms; in squared parentheses) to word targets in terms of script group.

Group	Similarity	Relatedness		Priming effect (in ms)	Form-dependent priming effect (in ms)
		Related	Unrelated		
L1 readers					
	similar	6.23 (0.02) [508]	6.31 (0.02) [550]	42***	10
	dissimilar	6.25 (0.02) [518]	6.31 (0.02) [550]	32***	
same-script bilinguals	similar	6.31 (0.04) [550]	6.42 (0.04) [614]	64***	52
	dissimilar	6.37 (0.04) [584]	6.39 (0.04) [596]	12	
different-script bilinguals	similar	6.37 (0.02) [584]	6.44 (0.02) [626]	42***	-1
	dissimilar	6.39 (0.03) [596]	6.46 (0.02) [639]	43***	

Note. similar: stimuli composed of at least N-1 cross-case similar letters under similar conditions, with N indicating the length of a word; dissimilar: stimuli composed of at least N-1 cross-case dissimilar letters under dissimilar conditions. ***, *p* < .001.

Table 14. Output of the statistical analysis on the log-transformed RTs to word targets in terms of script group.

	β	*SE*	*t*	*p*
Intercept	6.27	0.02	305.83	<.001
similarity	0.01	0.01	0.82	0.412
relatedness	**0.04**	**0.00**	**12.95**	**<.001**
scriptB_samescript	**0.10**	**0.04**	**2.20**	**0.029**
scriptC_differentscript	**0.14**	**0.03**	**4.88**	**<.001**
similarity*relatedness	-0.01	0.00	-1.86	0.064
similarity* scriptB_samescript	-0.00	0.01	-0.01	0.994
similarity* scriptC_differentscript	0.00	0.01	0.86	0.391
relatedness* scriptB_samescript	-0.00	0.01	-0.70	0.486
relatedness* scriptC_differentscript	-0.00	0.00	-0.75	0.455
similarity*relatedness* scriptB_samescript	**-0.02**	**0.01**	**-2.45**	**0.016**
similarity*relatedness* scriptC_differentscript	0.00	0.00	0.70	0.487

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * script + (1 + similarity * relatedness | subj) + (1 + relatedness * script | item))

Table 15 shows the descriptive statistics related to readers' error rates to word targets, and Table 16 shows the output from the model examining the effects of relatedness, similarity, and script on these error rates. In this model, the L1 group is the reference level, represented by the intercept, and all estimates are relative to this baseline. First, the non-significant effects of script indicates that there was no difference in error rates to word targets between the same-script bilinguals and the L1 readers (β = -0.44, *SE* = 0.24, *z* = -1.85, *p* = .064) or between the different-script bilinguals and the L1 readers (β = 0.07, *SE* = 0.15, *z* = 0.48, *p* = .633). Indeed, there were comparable error rates between the same-script bilinguals (8.06%) and the L1 group (9.61%), and between the different-script bilinguals (11.69%) and the L1 group. Examining the interaction between relatedness and script, averaging across prime-target similarity, the overall priming effect did not differ between the same-script bilinguals and the L1 readers (β = -0.17, *SE* = 0.15, *z* = -1.18, *p* = .237) or between the different-script bilinguals and the L1 readers (β = 0.08, *SE* = 0.08, *z* = 0.99, *p* = .323). Moreover, non-significant three-way interactions of relatedness, similarity, and script indicated that the influence of prime-target similarity on the masked identity priming effect was comparable for the same-script bilinguals and the L1 readers (β = 0.01, *SE* = 0.12, *z* = 0.05, *p* = .961) as well as for the different-script bilinguals and the L1 readers (β = 0.12, *SE* = 0.07, *z* = 1.69, *p* = .092).

A subsequent paired comparison of just the bilingual groups showed that the influence of prime-target similarity on the identity priming effect was not significantly different for the same-script and different-script bilinguals (β = 0.06, *SE* = 0.06, *z* = 0.96, *p* = .336). However, it is perhaps important to note that the same-script bilinguals did not show a masked identity priming effect in error rates to word targets under the similar condition (β = -0.18, *SE* = 0.36, *z* = -0.48, *p* = .629) or the dissimilar condition (β = 0.23, *SE* = 0.37, *z* = 0.62, *p* = .535), whereas the different-script bilinguals showed priming effects under both conditions (similar condition: β = -0.46, *SE* = 0.16, *z* = -2.80, *p* = .005; dissimilar condition: β = -0.50, *SE* = 0.17, *z* = -3.00, *p* = .003). Nevertheless, the non-significant main effects of script, two-way interactions between relatedness and script, and three-way interactions show that in terms of accuracy, the three groups performed comparatively well and did not differ reliably from each other in terms of the influence of prime-target similarity on error-related identity priming effects. The comparable proficiency among the three groups also indicates that any differences in orthographic processing efficiency shown above should not be attributable to a specific group’s inadequate proficiency in English.

Table 15. Descriptive data of the mean error rates (in percentage) on raw data to word targets in terms of script group.

Group	Similarity	Relatedness		Priming effect	Form-dependent priming effect
		Related	Unrelated		
L1 readers					
	similar	8.69	11.38	2.69***	2.57
	dissimilar	9.13	9.25	0.12	
same-script bilinguals	similar	7.25	8.75	1.50	1.25
	dissimilar	8.00	8.25	0.25	
different-script bilinguals	similar	11.63	14.22	2.59**	-0.38
	dissimilar	8.96	11.93	2.97**	

Note. similar: stimuli composed of at least N-1 cross-case similar letters under similar conditions, with N indicating the length of a word; dissimilar: stimuli composed of at least N-1 cross-case dissimilar letters under dissimilar conditions. ***, $p < .001$. **, $p < .01$.

Table 16. Output of the statistical analysis on error data to word targets in terms of script group.

	β	*SE*	*z*	*p*
Intercept	-2.68	0.13	-20.94	<.001
similarity	-0.03	0.10	-0.27	0.788
relatedness	**0.16**	**0.06**	**2.81**	**0.005**
scriptB_samescript	-0.44	0.24	-1.85	0.064
scriptC_differentscript	0.07	0.15	0.48	0.633
similarity*relatedness	**-0.11**	**0.05**	**-2.09**	**0.036**
similarity* scriptB_samescript	0.01	0.14	0.11	0.915
similarity* scriptC_differentscript	-0.10	0.10	-1.02	0.306
relatedness* scriptB_samescript	-0.17	0.15	-1.18	0.237
relatedness*scriptC_differentscript	0.08	0.08	0.99	0.323
similarity*relatedness* scriptB_samescript	0.01	0.12	0.05	0.961
similarity*relatedness* scriptC_differentscript	0.12	0.07	1.69	0.092

Note. The statistical model for error data was coded as follows: glmer (error ~ similarity * relatedness * script + (1 + similarity * relatedness | subj) + (1 + relatedness * script | item))

3.2 L2 Vocabulary Knowledge

L2 vocabulary knowledge is another factor that could affect orthographic processing efficiency during the early stages of visual word recognition. In light of the differential processing efficiency for low-level form characteristics between skilled L1 readers -- a reader group potentially with a large vocabulary size -- and less skilled L1 readers -- a reader group potentially with a small vocabulary size -- it is possible that L2 vocabulary knowledge affects L2 readers' processing patterns for similar and dissimilar prime-target pairs. As introduced by Lemhöfer & Broersma (2012), LexTALE scores were taken as a measure of participants' vocabulary knowledge. A linear mixed effects model was used to explore the effects of relatedness, similarity, LexTALE scores, and their interactions on log-transformed RTs for the L2 participants. Prior to data analysis, the LexTALE scores were scaled, and the other two predictors were sum-coded. The three predictors were coded as fixed effects as in section 2.2, and the models included the maximal random effects structure: logRT ~ similarity * relatedness * LexTale_scaled + (1 + similarity * relatedness | subj) + (1 + relatedness * LexTale_scaled | item), where logRT stands for the log-transformed RT. In the cases in which the maximal model failed to converge, the random-effect structure was simplified by removing the by-subject or by-item random slope for the interaction. The analysis focuses on the role of vocabulary knowledge with respect to form-dependent masked identity priming effects, given the somewhat larger effects of this type reported for the skilled L2 readers in the confirmatory analysis (see section 2.2.1).

Table 17 shows the output from the model examining the effects of relatedness, similarity, and LexTALE scores on these RTs, and Figure 2 shows log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) LexTALE scores. The three-way interaction among relatedness, similarity, and LexTALE scores was not significant (β = -0.00, SE = 0.00, t = -0.51, p = .609), indicating that the influence of prime-target similarity on the masked identity priming effect was relatively stable across L2 readers with different levels of vocabulary knowledge. This pattern of results suggests that skilled L2 readers' orthographic processing efficiency is not affected substantially by differences in vocabulary knowledge (as measured by the LexTALE), at least in learners at this generally high level of L2 proficiency.

Table 17. Output of the statistical analysis on log-transformed RTs to word targets in terms of LexTALE scores.

	β	*SE*	*t*	*p*
Intercept	6.40	0.02	331.09	<.001
similarity	0.01	0.01	1.24	0.220
relatedness	**0.03**	**0.00**	**11.20**	**<.001**
LexTale_scale	**-0.07**	**0.02**	**-3.74**	**<.001**
similarity*relatedness	**-0.01**	**0.00**	**-2.40**	**0.018**
similarity* LexTale_scale	-0.00	0.00	-1.74	0.087
relatedness* LexTale_scale	0.00	0.00	0.34	0.733
similarity*relatedness* LexTale_scale	-0.00	0.00	-0.51	0.609

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * LexTale_scale + (1 + similarity + relatedness | subj) + (1 + relatedness * LexTale_scale |item))

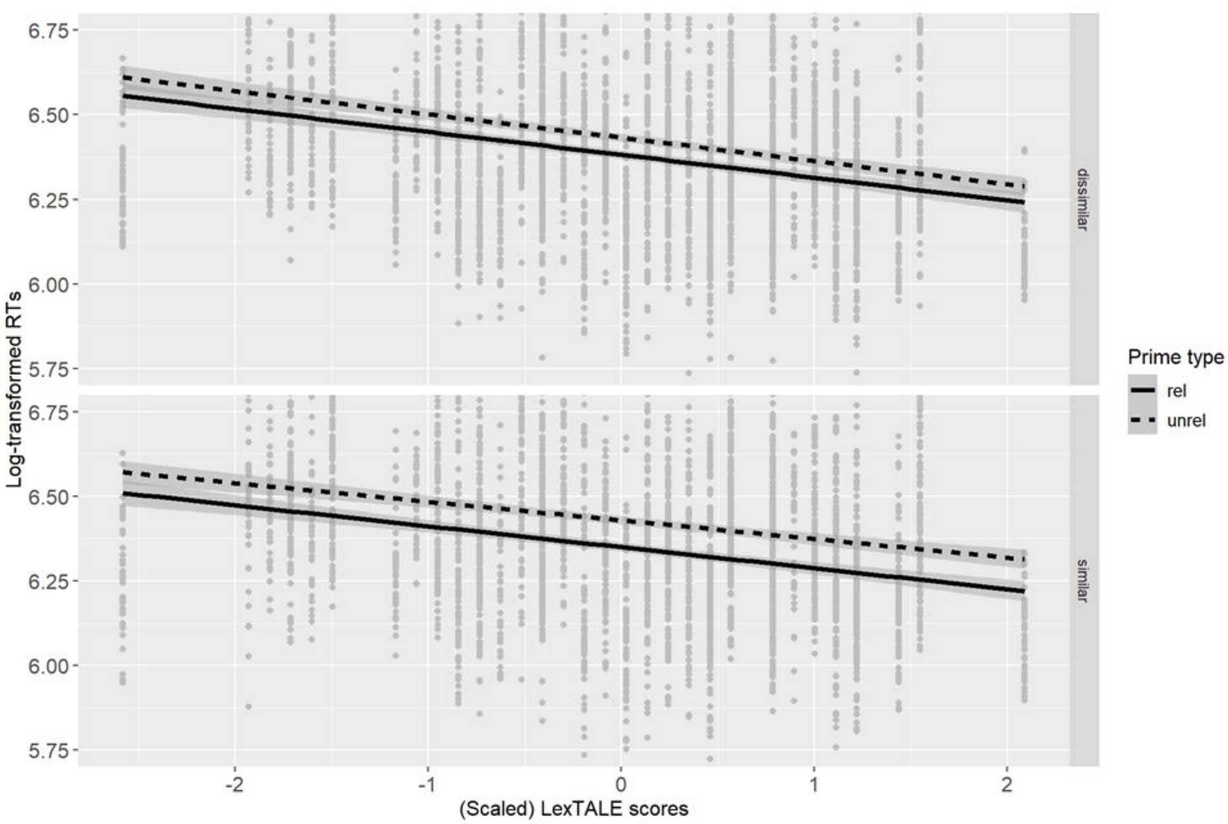

Figure 2: Log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) LexTALE scores.

3.3 L2 Proficiency

In light of the fact that there appear to be clear differences in processing efficiency for low-level form characteristics between skilled and less skilled L1 readers (e.g., Perea et al., 2015), L2 proficiency might influence identity priming effects for similar and dissimilar prime-target pairs among L2 readers. The analyses reported in this section were conducted to explore whether individual differences in orthographic processing efficiency systematically vary depending on L2 proficiency. Specifically, these analyses investigate the effects of relatedness, similarity, L2 proficiency, and their interactions on log-transformed RTs for the L2 participants. These analyses took into consideration three different proficiency measures -- (i) self-rated English overall proficiency, (ii) self-rated English reading proficiency, and (iii) self-rated English writing proficiency. The last two measures are of particular interest because they tap into L2 English literacy skills.

Table 18 shows the output from the model examining the effects of relatedness, similarity, and self-rated English overall proficiency on these RTs, and Figure 3 shows log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) self-rated English overall proficiency. The three-way interaction among relatedness, similarity, and self-rated English overall proficiency was not significant ($\beta = 0.00$, $SE = 0.00$, $t = 0.41$, $p = .685$), indicating that the influence of prime-target similarity on the masked identity priming effect was relatively stable across L2 readers with different levels of self-reported English overall proficiency. A similar pattern of results was also observed when self-rated English reading proficiency -- as shown in Table 19 and Figure 4 -- and self-rated English writing proficiency -- as shown in Table 20 and Figure 5 -- were entered into the models, respectively. This pattern of results suggests that skilled L2 readers' orthographic processing efficiency is not affected substantially by differences in L2 proficiency, at least in learners at this general high level of L2 proficiency and with the three measures being tested.

Table 18. Output of the statistical analysis on log-transformed RTs to word targets in terms of self-rated English overall proficiency.

	β	*SE*	*t*	*p*
Intercept	6.40	0.02	320.50	<.001
Similarity	0.01	0.01	1.22	0.225
Relatedness	**0.03**	**0.00**	**11.21**	**<.001**
English_Prof_scale	**-0.05**	**0.02**	**-2.88**	**0.005**
Similarity*relatedness	**-0.01**	**0.00**	**-2.39**	**0.019**
Similarity* English_Prof_scale	-0.00	0.00	-1.39	0.172
Relatedness* English_Prof_scale	0.00	0.00	1.23	0.220
Similarity*relatedness* English_Prof_scale	0.00	0.00	0.41	0.685

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * English_Prof_scale + (1 + similarity * relatedness | subj) + (1 + relatedness * English_Prof_scale | item))

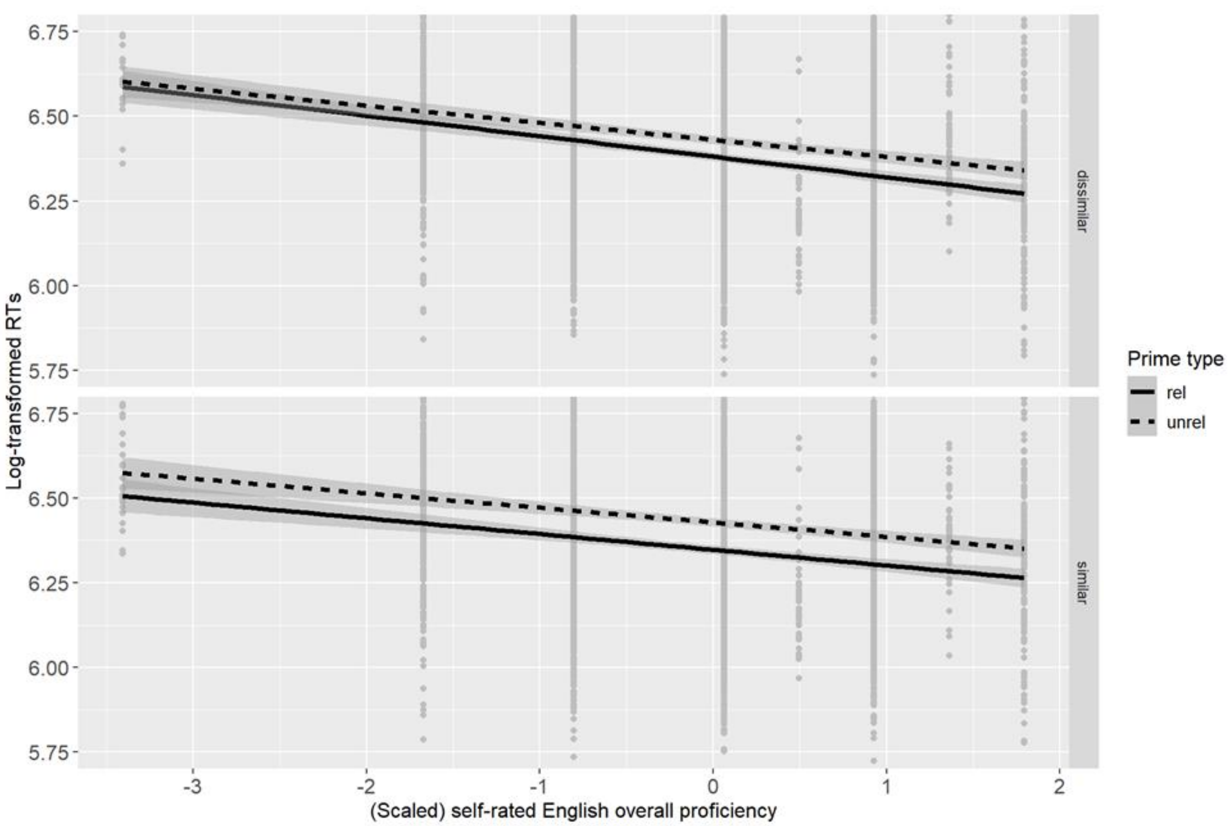

Figure 3: Log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) self-rated English overall proficiency.

Table 19. Output of the statistical analysis on log-transformed RTs to word targets in terms of self-rated English reading proficiency.

	β	*SE*	*t*	*p*
Intercept	6.40	0.02	320.80	<.001
Similarity	0.01	0.01	1.22	0.226
Relatedness	**0.03**	**0.00**	**11.21**	**<.001**
English_RP_scale	**-0.05**	**0.02**	**-2.90**	**0.005**
Similarity*relatedness	**-0.01**	**0.00**	**-2.39**	**0.019**
Similarity* English_RP_scale	-0.00	0.00	-1.04	0.301
Relatedness* English_RP_scale	0.00	0.00	1.11	0.267
Similarity*relatedness* English_RP_scale	0.00	0.00	0.34	0.732

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * English_RP_scale + (1 + similarity * relatedness | subj) + (1 + relatedness * English_RP_scale | item))

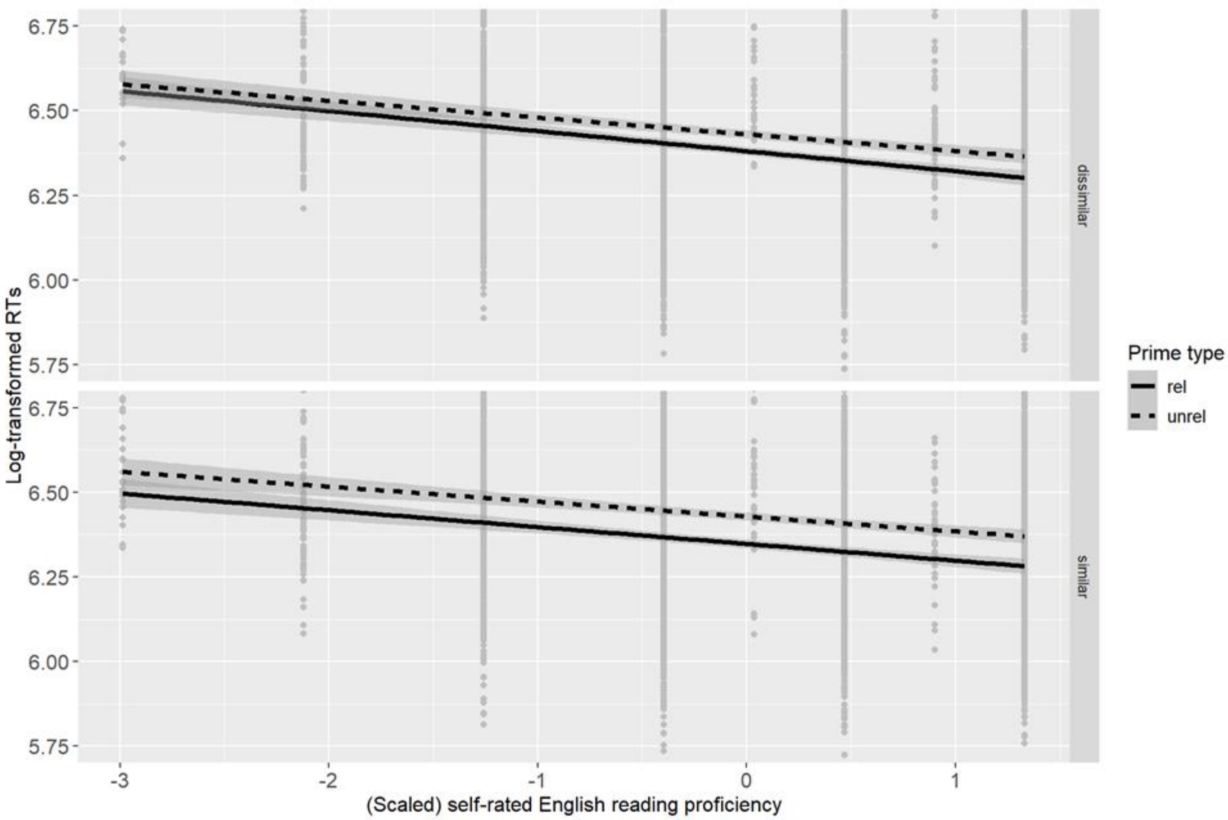

Figure 4: Log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) self-rated English reading proficiency.

Table 20. Output of the statistical analysis on log-transformed RTs to word targets in terms of self-rated English writing proficiency.

	β	*SE*	*t*	*p*
Intercept	6.40	0.02	313.09	<.001
Similarity	0.01	0.01	1.21	0.230
Relatedness	**0.03**	**0.00**	**10.96**	**<.001**
English_WP_scale	**-0.04**	**0.02**	**-2.09**	**0.041**
Similarity*relatedness	**-0.01**	**0.00**	**-2.35**	**0.021**
Similarity* English_WP_scale	-0.00	0.00	-0.42	0.679
Relatedness* English_WP_scale	0.00	0.00	0.46	0.650
Similarity*relatedness* English_WP_scale	0.00	0.00	1.37	0.172

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * English_WP_scale + (1 + similarity * relatedness | subj) + (1 + relatedness * English_WP_scale | item))

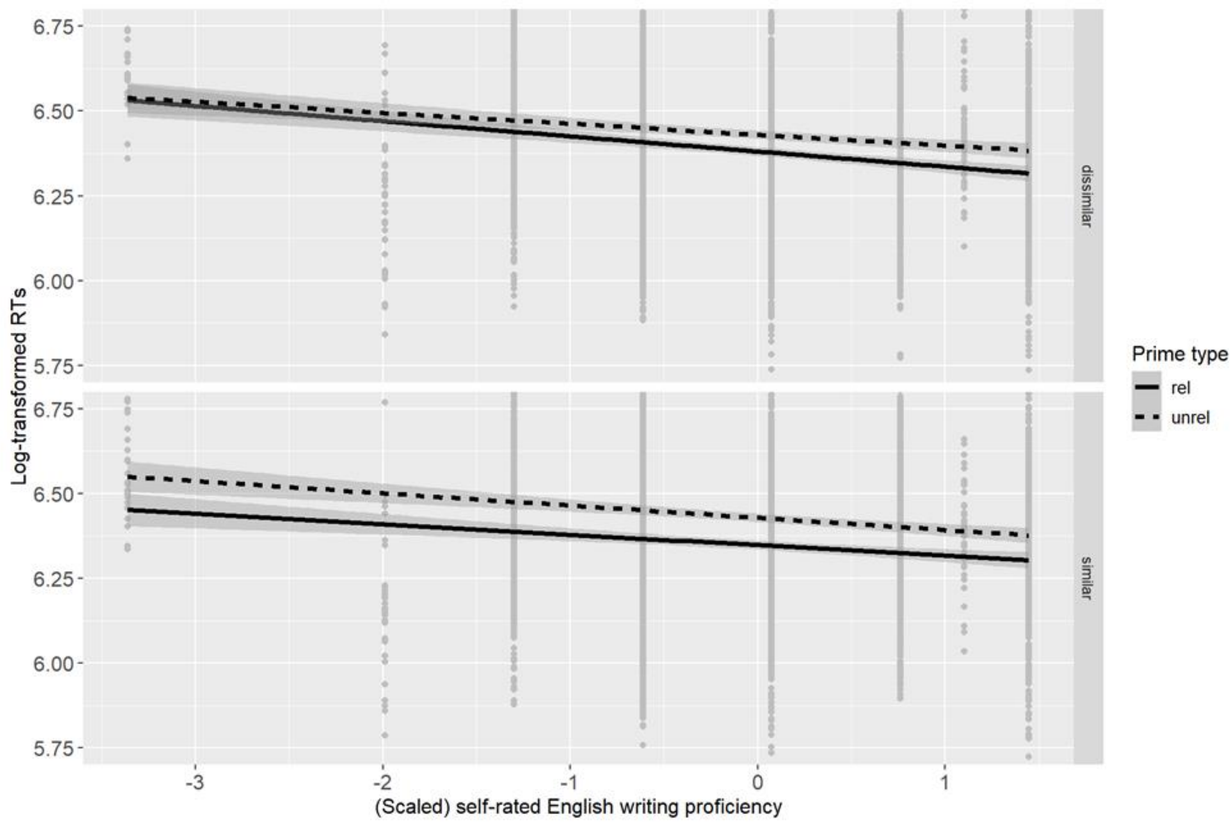

Figure 5: Log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) self-rated English writing proficiency.

3.4 L2 AoA for L2 English

The discrepancy in the directions of masked word form priming effects in the L1 and L2 (see more details in section 1.2.1) appears to be related in part to L2 AoA. Specifically, inhibitory masked word form priming effects have been reported for early balanced bilinguals (e.g., Bijeljac-babic et al., 1997) -- who were exposed to both languages from early childhood and continued to use them daily at work and/or at home -- while facilitatory masked word form priming effects have been reported for late bilinguals (e.g., Nakayama & Lupker, 2018) -- for whom the average L2 AoA was at 10.5 years old (standard derivation: 3.2). In light of this difference, it is possible that L2 AoA affects their performance on form-related words. The analysis reported in this section therefore focuses on the influence of this factor on identity priming effects for similar and dissimilar prime-target pairs for L2 readers. Specifically, they examine the effects of relatedness, similarity, L2 AoA, and their interactions on log-transformed RTs for the L2 participants.

Table 21 shows the output from the model examining the effects of relatedness, similarity, and L2 AoA on these RTs, and Figure 6 shows log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) L2 AoA. The three-way interaction among relatedness, similarity, and AoA was not significant (β = 0.00, *SE* = 0.00, *t* = 0.59, *p* = .555), indicating that the influence of prime-target similarity on the masked identity priming effect was relatively stable across the L2 readers with different levels of L2 AoA. That is, this pattern of results suggests that skilled L2 readers' orthographic processing efficiency is not affected substantially by differences in L2 AoA. One reason for this might relate to the generally early AoAs for the participants in this study. Indeed, the average L2 AoA for the L2 readers in this experiment was at about eight years old, ranging from one to 16 years old, with 49 of them (70%) having started learning L2 English at or before the age of 10.

Table 21. Output of the statistical analysis on log-transformed RTs to word targets in terms of AoA for English.

	β	*SE*	*t*	*p*
Intercept	6.40	0.02	344.39	<.001
Similarity	0.01	0.01	1.21	0.228
Relatedness	**0.03**	**0.00**	**11.39**	**<.001**
AoA_scale	**0.08**	**0.02**	**4.71**	**<.001**
Similarity*relatedness	**-0.01**	**0.00**	**-2.46**	**0.016**
Similarity* AoA_scale	0.00	0.00	0.67	0.507
Relatedness* AoA_scale	-0.00	0.00	-1.49	0.138
Similarity*relatedness* AoA_scale	0.00	0.00	0.59	0.555

Note. The statistical model for RTs was coded as follows: lmer (logRT ~ similarity * relatedness * English_AoA_scale + (1 + similarity * relatedness | subj) + (1 + relatedness * English_AoA_scale | item))

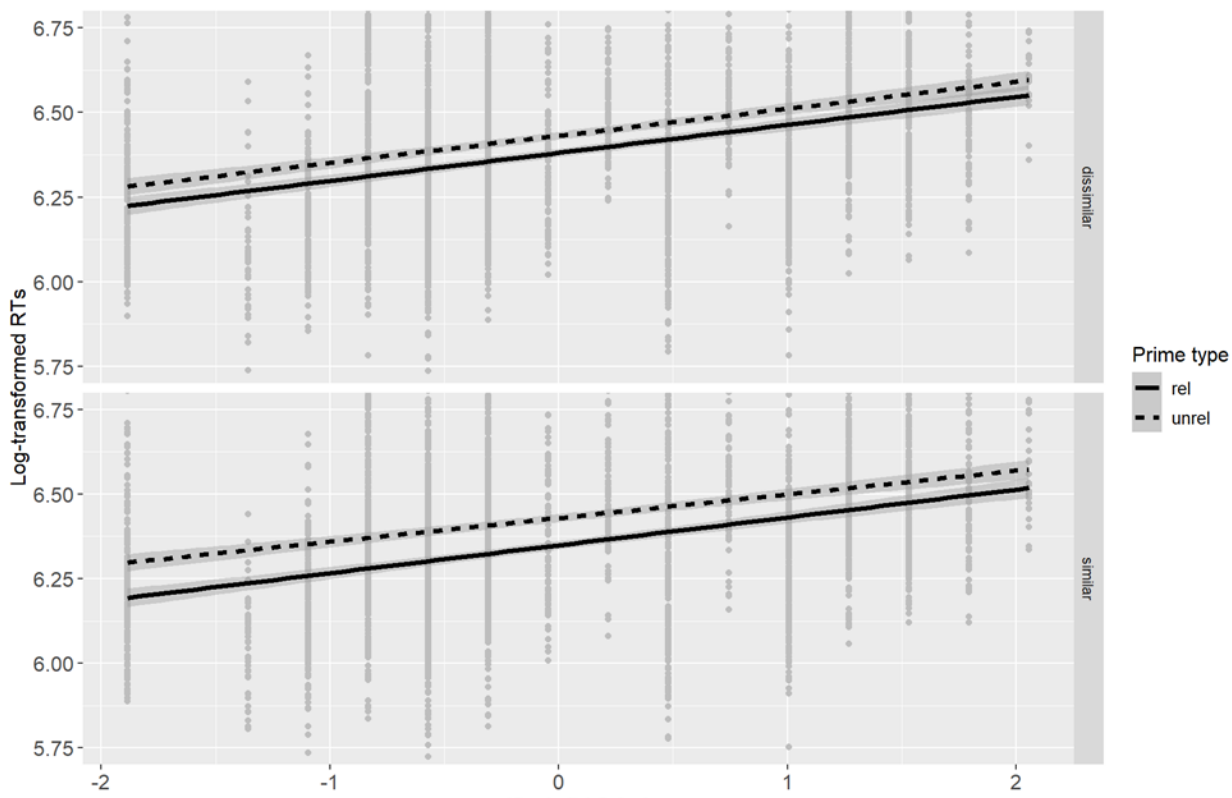

Figure 6: Log-transformed RTs for related and unrelated prime-target pairs under similar and dissimilar conditions as a function of (scaled) L2 AoA.

3.5 Other Factors

Additional post-hoc analyses were conducted to investigate whether orthographic processing efficiency systematically varies depending on other individual difference factors, including standardized English test scores, self-reported language dominance, the length of natural exposure to L2 English, and the length of L2 learning. Standardized English test scores provide objective measures of L2 proficiency, in contrast to the subjective measures of proficiency reported in section 3.3. In the current study, 26 L2 participants reported their TOEFL scores and 24 participants reported their IELTS scores. However, in a model that included these scores as a predictor, only the main effect of relatedness was significant. The lack of the main effect of this variable indicates that participants' RTs did not vary depending on their standardized English test scores, and the lack of a three-way interaction indicates that any effect of prime-target similarity on the identity priming was not modulated by this variable. That is, for the L2 readers in this study, standardized English test scores did not appear to be related to lexical processing speed in general or to differences in identity priming for similar and dissimilar prime-target pairs. This was also the case even after these scores were converted to the same scale and combined (where N=47, since three participants reported scores for both tests and only the higher scores were included). Therefore, data analyses including this variable are not reported in detail.

Self-reported language dominance was another factor that was considered. This is a subjective measure of language dominance, thus potentially reflecting subjective L2 proficiency. Among the L2 readers, seven of them reported that they were equally proficient in their L1 and L2, although all of them started to learn English after the age of five. In the data analysis conducted so far, these participants were regarded as L2 readers because they started learning English relatively late in life. However, excluding these participants from the data analysis did not change the pattern of results reported in the confirmatory analyses in section 2.2.1.

Therefore, data analyses taking this variable into consideration are not reported in detail.

The length of natural exposure to L2 was another factor that could affect L2 readers' performance. The idea is that as the length of natural exposure to L2 increases, there are more opportunities for an L2 learner to be immersed in that language, and thus they will potentially encounter different variants of words in L2, resulting in efficient orthographic processing in L2. In the current study, 57 L2 participants reported the length of living in an English-speaking country/countries. Among these participants, more than half of them reported the lengths of such natural exposure were less than 2 years. In addition, in a model that included the length of natural exposure to L2 as a predictor, only the main effect of relatedness was significant. The lack of the main effect of this variable indicates that participants' RTs did not vary depending on their length of natural exposure to L2, and the lack of a three-way interaction indicates that any effect of prime-target similarity on the identity priming was not modulated by this variable. That is, for the L2 readers in this study, length of natural exposure to L2 did not appear to be related to lexical processing speed in general or to differences in identity priming for similar and dissimilar prime-target pairs. Therefore, data analyses including this variable are not reported in detail.

Finally, length of L2 learning was considered as another potentially interesting individual difference variable. The length of L2 learning was calculated by subtracting the participant's L2 AoA from their age at the time of testing. The idea is that as the length of L2 learning increases, it becomes more likely that a participant will be more familiar with the language, thus increasing their orthographic processing efficiency in that language. Among the L2 participants, 51 participants (73%) reported that they have learnt English for at least 15 years. In addition, in a model that included length of L2 learning as a predictor, only the main effect of relatedness and the two-way interaction between relatedness and similarity were significant. This indicates that

L2 readers showed a masked identity priming effect that was reliably modulated by low-level form similarity between the prime and target. However, the lack of the main effect of length of L2 learning indicates that participants' RTs did not vary depending on their length of L2 learning, and the lack of a three-way interaction indicates that any effect of prime-target similarity on the identity priming was not modulated by this variable. That is, for the L2 readers in this study, length of L2 learning did not appear to be related to lexical processing speed in general or to differences in identity priming for similar and dissimilar prime-target pairs. Therefore, data analyses including this factor are not reported in detail.

3.6 Brief Summary

Post-hoc analyses were conducted to examine individual differences that might modulate orthographic processing efficiency for the L2 group. These analyses on RT data to word targets revealed that the consistency of the scripts in a bilingual's two languages appears to modulate whether skilled L2 readers process low-level form characteristics -- and letter shapes in particular -- as efficiently as skilled L1 readers when accessing abstract lexical representations during the early stages of visual word recognition. Specifically, different-script bilinguals exhibited comparable form-independent masked identity priming effect (i.e., -1ms) to that of L1 readers (i.e., 10ms) -- which was indicated by the lack of a three-way interaction among the three factors of interest for these two groups -- whereas there was a larger difference in the priming effects under the similar and dissimilar conditions for the same-script bilinguals (i.e., 52ms) than for the skilled L1 readers -- which was indicated by the three-way interaction among the factors of interest for these two groups. In addition, there was also a larger difference in the priming effects under the similar and dissimilar conditions for the same-script bilinguals than for the different-script bilinguals -- which was again indicated by the three-way interaction among the factors of interest for these two groups. Indeed, different-script bilinguals exhibited robust identity priming effects under both the similar condition (i.e., 42ms) and the dissimilar condition (i.e., 43ms), whereas same-script bilinguals exhibited a robust masked identity priming effect for visually similar prime-target pairs (i.e., 64ms), but only a nonsignificant trend toward a priming effect for visually dissimilar prime-target pairs (i.e., 12ms). This pattern of results indicates that like skilled L1 readers, different-script bilinguals seem to be largely unaffected by visual similarities/dissimilarities between uppercase and lowercase word forms during the early stages of visual word recognition, whereas same-script bilinguals seem to be affected by such visual similarities/dissimilarities to a larger degree than both skilled L1 readers and different-script bilinguals. In addition, it also seems to indicate that the slight difference between L1 and L2 readers in terms of the influence of prime-target similarity on the identity priming that was found in confirmatory analyses was not driven by the different-script bilinguals.

This pattern of results, however, seems to be counterintuitive in that it is inconsistent with the findings from the studies in which inconsistent L1/L2 script properties produce negative effects on the lexical processing at form level (e.g., Jiang, 2021b). It seems to demonstrate that different-script bilinguals appear to be able to abstract away from low-level form characteristics -- and letter shapes in particular -- at a level of efficiency that largely does not differ from that of L1 readers, whereas same-script bilinguals appear to be less efficient in processing these characteristics compared to both L1 readers and different-script bilinguals. This pattern should be regarded with caution, however, in light of the relatively small number of same-script bilinguals (*N*=16) in this study.

It is important to note that the different processing patterns between same-script bilinguals and L1 readers (and the similar processing patterns between different-script bilinguals and L1 readers) does not appear to be attributable to a specific group's inadequate proficiency in English. Indeed, the three groups performed comparatively well in terms of accuracy and did not differ reliably from each other in terms of the influence of prime-target similarity on error-related identity priming effects -- which was indicated by the non-significant main effects of script, two-way interactions between relatedness and script, and three-way interactions among relatedness, similarity, and script. We will return to this issue in more detail in the General Discussion.

Other factors were also included in the post-hoc analyses. They included L2 vocabulary knowledge, subjective and objective L2 proficiency, L2 AoA, self-reported language dominance, the length of natural exposure to L2 English, and the length of L2 learning. However, under the design of the current study, and with only skilled L2 readers being tested, these factors either did not modulate the individual differences in orthographic processing efficiency in L2 or they did not appear to be related to lexical processing speed in general or to differences in identity priming for similar and dissimilar prime-target pairs for the L2 readers in this study. Future studies may investigate the effects of these factors with respect to orthographic processing efficiency in L2 with more careful manipulations.

Chapter 4 General Discussion

This study investigated whether skilled L2 readers differ from skilled L1 readers in terms of the efficiency with which they abstract away from low-level form characteristics when accessing lexical representations during the early stages of visual word recognition. First, in the RT analyses, robust masked identity priming effects were found for word targets in both groups, with shorter RTs under the related condition than under the unrelated condition. These results are in line with previous studies examining this effect (for L1 readers: Forster & Davis, 1984; Forster et al., 2003; for L2 readers: Aparicio & Lavaur, 2016; de Groot & Nas, 1991; Dimitropoulou et al., 2011a, b; Dubey et al., 2018; Finkbeiner et al., 2004; Foote et al., 2020; Gollan et al., 1997; Heyer & Clahsen, 2015; Hoshino et al., 2010; Jiang, 1999; Midgley et al., 2009; Nakayama & Lupker, 2018; Nakayama et al., 2013; Silva & Clahsen, 2008; Smith et al., 2019; Xia & Andrews, 2015). Second, for skilled L1 readers, the results largely replicated form-independent masked identity priming effect (i.e., 10ms) -- with comparable masked identity priming effects for visually similar (i.e., 42ms) and dissimilar (i.e., 32ms) prime-target pairs. That is, skilled L1 readers did not show a reliable influence of prime-target similarity on this masked identity priming effect. This adds supportive evidence to the conclusion that skilled L1 readers are largely unaffected by visual (dis)similarities between uppercase and lowercase word forms during the early stages of visual word recognition. Rather, they appear to efficiently abstract away from low-level form characteristics when accessing lexical representations.

The skilled L2 readers, however, exhibited the influence of prime-target similarity on the masked identity priming effects -- at least to some extent. Specifically, for the skilled L2 readers, there was a slightly larger priming effect (i.e., 18ms) for visually similar prime-target pairs than for visually dissimilar prime-target pairs (48ms vs. 30ms). Compared with the form-independent masked identity priming effect observed for the L1 readers, this form-dependent masked identity priming effect for the skilled L2 readers suggests a difference between skilled L1 and L2 readers in terms of the degree of the influence of prime-target similarity on the masked identity priming effect. That is, there seems to be a difference between skilled L1 and L2 readers in terms of the efficiency with which they access abstract lexical representation at the early stages of visual word recognition.

It is important to note, however, that this differential processing of low-level form characteristics between skilled L1 and L2 readers is not as large as that between skilled and less skilled L1 readers (as introduced in section 1.2.5), where less skilled L1 readers showed a robust masked identity priming effects under the similar condition (i.e., 47ms) but no indication of a priming effect under the dissimilar condition (i.e., 0ms). Indeed, in the present study, the three-way interaction of relatedness, similarity, and group was not statistically reliable, as would be expected if there were an especially large difference between skilled L1 and L2 readers with respect to the influence of prime-target visual similarity on masked identity priming effects. Taken together, these findings thus suggest a quantitative, but not qualitative difference between L1 and L2 readers in terms of the efficiency with which they process low-level form characteristics. That is, while there appears to be a slight difference between skilled L1 and L2 readers in terms of the efficiency with which they use visual information to access abstract lexical representations, these groups do not differ fundamentally from each other in this processing domain. It therefore seems that if L2 readers achieve a sufficient level of proficiency in the L2, they appear to be able to process low-level form characteristics -- and for letter shapes in particular -- at a level of efficiency that approximates that of L1 readers.

In addition to these findings from the confirmatory analyses, post-hoc analyses on RT data to word targets revealed an influence of L1/L2 script properties on the masked identity priming. Specifically, different-script bilinguals exhibited comparable form-independent masked identity priming effect (i.e., -1ms) to that of L1 readers (i.e., 10ms), whereas there was a larger difference in the priming effects under the similar and dissimilar conditions for the same-script bilinguals (i.e., 52ms) than for both the L1 readers and the different-script bilinguals. Indeed, different-script bilinguals exhibited robust masked identity priming effects under both the similar condition (i.e., 42ms) and the dissimilar condition (i.e., 43ms), whereas same-script bilinguals exhibited a robust masked identity priming effect for visually similar prime-target pairs (i.e., 64ms), but only a nonsignificant trend toward a priming effect for visually dissimilar prime-target pairs (i.e., 12ms). This pattern of results indicates that different-script bilinguals seem to be unaffected by visual similarities/dissimilarities between uppercase and lowercase word forms during the early stages of visual word recognition to a degree that is similar to that of L1 readers, whereas same-script bilinguals seem to be affected by such visual similarities/dissimilarities to a larger degree than both L1 readers and different-script bilinguals. It is also important to note that the different processing patterns between same-script bilinguals and L1 readers (and the similar processing patterns between different-script bilinguals and L1 readers) does not appear to be attributable to a specific group's inadequate proficiency in English.

This surprising pattern of results is somewhat counterintuitive, in that it appears to run contrary to the findings from the studies in which consistent L1/L2 script properties tends to produce positive effects on the lexical processing at the form level (e.g., Jiang, 2021b). The different processing patterns between same-script bilinguals and L1 readers suggests that same-script bilinguals appear to be less efficient when abstracting away from low-level form characteristics than L1 readers. This pattern should be regarded with caution, however, in light of the relatively small number of same-script bilinguals (*N*=16) in this study. Having said that, when considering a possible reason for why same-script bilinguals exhibited a larger priming effect for visually similar prime-target pairs than for visually dissimilar prime-target pairs (64ms vs. 12ms), it is interesting to note that these bilinguals were unusually fast under the similar/related condition (i.e., 550ms) -- much faster than under any of the other conditions (similar/unrelated condition: 614ms; dissimilar/related condition: 584ms; dissimilar/unrelated condition: 596ms). By contrast, these similar prime-target pairs did not give different-script bilinguals as much help. One possibility is that different-script bilinguals might not have enough exposure to an L2 script, and therefore they might not benefit as much from the visual similarities between lowercase and uppercase word forms as bilinguals who are very familiar with the script and are more sensitive to the lowercase/uppercase word form differences.

In sum, this study was conducted to examine a potential L1/L2 processing difference that might persist even into higher levels of L2 proficiency -- and that might help to explain other processing differences between L1 and L2 readers at the form level. However, the pattern of results demonstrates that although there might be a slight difference between skilled L1 and L2 readers, these two groups do not differ fundamentally from each other in terms of the efficiency with which they access abstract lexical representations from visual input at the early stages of visual word recognition, especially when L2 readers are highly proficient and when they are processing low-level orthographic form information for relatively high-frequency words. Furthermore, this comparable processing efficiency for low-level orthographic characteristics suggests that observed L1/L2 lexical form processing disparities are likely not primarily attributable to persistent differences at this early stage of visual word recognition.

A relevant question then is whether the differences of orthographic processing efficiency between skilled L1 and L2 readers has been underestimated in this study. One possibility is that the influence of prime-target similarity on the masked identity priming effect is underestimated with RT data. As suggested by Gomaz et al. (2021), “Performance in a lexical decision task is a convolution of several components like motor processes (executing the keypress), core processes (lexical, semantic), strategic considerations (emphasis on speed vs. accuracy), and encoding processes (mapping the retinotopic input onto abstract representations of letters/words)” (p.1544). One may argue that these somewhat noisy RTs might wash out subtle influences of low-level form characteristics on lexical processing. This possibility has been supported by studies examining the effect of cases in visual word recognition in L1. Specifically, Jiang (2021b) reported that English native speakers took comparable time to make a decision when a target word was displayed in uppercase and in lowercase, thus without showing a case effect (high-frequency words: 18ms; low-frequency words: 10ms). However, Vergara-Martinez et al. (2020) recorded event-related potentials (ERPs) and reported a lowercase advantage -- that is, words elicited larger N/P150 and N250 amplitudes when presented in lowercase than when presented in uppercase. In addition, a lowercase advantage was also found in response speed (high-frequency word: 12ms; low-frequency words: 13ms). Therefore, ERP measures are apparently more sensitive to low-level form characteristics (i.e., letter cases). However, a more sensitive measure does not necessarily mean a better measure, especially when we are comparing the performance between two groups instead of comparing the performance of one group under different conditions. Therefore, although orthographic processing efficiency for L1 readers might be underestimated in this study, orthographic processing efficiency for highly proficient L2 readers appears to be largely similar to that of L1 readers.

Finally, although the present study indicates that observed L1/L2 lexical form processing disparities are not primarily attributable to persistent differences in orthographic processing efficiency at the early stage of visual word recognition, it is important to note that only one aspect of processing at this level was examined. Therefore, the question of what causes observed L1/L2 lexical form processing disparities should be investigated with regard to other aspects of orthographic processing in future research. For example, the flexibility of the letter-position encoding between the L1 and L2 reading is of particular interest. Specifically, adult native speakers are consistently reported to show a transposed-letter effect in masked priming, where the response to a target word is faster when it is preceded by a prime with transposed letters (e.g., *jugde-JUDGE*) than when it is preceded by a prime with substituted letters (e.g., *jupte-JUDGE*; Duñabeitia et al., 2009; Ktori et al. 2014; Perea & Carreiras, 2006; Perea & Lupker, 2004; Perea & Pérez, 2009; Schoonbaert & Grainger, 2004; Vergara-Martinez et al. 2013). This transposed-letter effect has been taken to indicate a flexible orthographic coding in L1. However, studies on how flexibly/precisely L2 readers encode letter position in a word has not been investigated extensively. There is some evidence showing that flexible orthographic processing increases with print exposure (e.g., Meade et al., 2022). Therefore, it will be interesting and worthwhile to investigate whether L2 readers achieve a similar degree of flexible letter-position coding to that of L1 readers. For example, if skilled L2 reading is characterized by persistently precise letter-position coding, L2 readers should show a smaller transposed-letter effect than L1 readers. However, if skilled L2 reading is characterized by comparably flexible letter-position coding as L1 reading, L2 readers should reveal a similar transposed-letter effect to that of L1 readers. Studies along these lines will contribute to a more complete understanding of L2 orthographic processing. Indeed, as argued in this dissertation, this understanding is especially important in that it might help to shed light on observed L1/L2 differences at other (higher) levels of language processing.

Appendices

Appendix A. Similarity rating and examples of similarity judgments in previous studies.

letter	similarity rating in Boles and Clifford (1989)	Kinoshita & Kaplan (2008)	Kinoshita & Norris (2009)	Norris & Kinoshita (2008)	Schubert et al. (2018)	Perea et al. (2014)	Perea et al. (2015)	Bowers et al. (1998)	Bowers & Turner (2005)	Ziegler et al. (2000)	Jacobs & Grainger (1991)	Madec et al. (2016)
G/g	221											
Q/q	225											
R/r	233											
A/a	237											
D/d	242											
L/l	255							ambiguous				
E/e	259											
B/b	263											
N/n	304							ambiguous				
T/t	309							ambiguous	ambiguous			
Y/y	309											
I/i	313											
H/h	321											
M/m	334											
F/f	359											
J/j	379											
U/u	409											
W/w	409											
C/c	413											
P/p	413											
S/s	417											
X/x	417											
V/v	429											
K/k	434											
O/o	434											
Z/z	442											

Notes: The cells highlighted in green indicate that the corresponding letters are treated as dissimilar letters; the cells highlighted in yellow indicate that the corresponding letters are treated as similar letters; the cells highlighted in blue indicate that the corresponding letters are treated as neutral letters; the color coding in the first column indicates the similarity judgment for each letter in this study, with L/l being used as a neutral letter in primes only under unrelated conditions.

Appendix B. Stimuli used in the current study.

Similar condition			Dissimilar condition		
Target	Related prime	Unrelated prime	Target	Related prime	Unrelated prime
		Words			
STUCK	stuck	dying	GREEN	green	awful
FOCUS	focus	enter	RANGE	range	photo
COUCH	couch	nerve	ANGER	anger	fifth
SPOON	spoon	depth	RIDER	rider	sunny
KNOW	know	have	HEAR	hear	kind
SHOW	show	care	HEAD	head	most
SUCH	such	door	HARD	hard	open
PICK	pick	send	FREE	free	book
KISS	kiss	drop	DATE	date	pull
KICK	kick	fell	BEAT	beat	sign
UPON	upon	west	AREA	area	soul
COST	cost	burn	TREE	tree	foot
COPY	copy	hall	DARE	dare	lock
HOOK	hook	view	BIRD	bird	cake
POST	post	harm	GATE	gate	swim
SOUP	soup	yard	TEAR	tear	wood
SKIP	skip	deny	DATA	data	golf
SONS	sons	lack	EDGE	edge	pity
PUMP	pump	task	BEEF	beef	salt
POPS	pops	lend	BEND	bend	host
COWS	cows	grip	DEBT	debt	corn
VOWS	vows	hike	DEER	deer	rank
MOCK	mock	peel	MERE	mere	soil
ZOOM	zoom	sigh	FADE	fade	doom
MOPS	mops	emit	NERD	nerd	pies
KNOCK	knock	laugh	GRAND	grand	south
SHOCK	shock	plant	DRAMA	drama	purse
PUPPY	puppy	sheet	BRAND	brand	theme
SHOOK	shook	cycle	REFER	refer	fatal
STOP	stop	feel	BABY	baby	mind
TOOK	took	live	IDEA	idea	wife
SOON	soon	true	YEAR	year	lost
SICK	sick	full	DIED	died	hang
COPS	cops	bank	RIDE	ride	fast
PUSH	push	film	NEAR	near	trip
SPOT	spot	wine	FEAR	fear	suit

(*Appendix continued*)

Appendix B (*continued*)

Similar condition			Dissimilar condition		
Target	Related prime	Unrelated prime	Target	Related prime	Unrelated prime
SHOP	shop	cell	BEAR	bear	wind
COOK	cook	fill	BAND	band	rose
SUCK	suck	vote	FEED	feed	wash
SNOW	snow	bath	GANG	gang	tour
PUTS	puts	fail	DRAG	drag	hunt
OWNS	owns	seek	RATE	rate	duck
CHOP	chop	exam	RARE	rare	bowl
TOSS	toss	link	EARN	earn	pour
CUTS	cuts	lazy	DEAF	deaf	flip
SOCK	sock	hint	DEED	deed	tips
CUPS	cups	bake	BARE	bare	drum
SUNK	sunk	yoga	BEAN	bean	myth
POTS	pots	flea	HERB	herb	quiz
SWUM	swum	oxen	BEET	beet	inns
Nonwords					
SWOOF	swoof	kulch	GRART	grart	psolk
ZOUCH	zouch	spage	FRERB	frerb	swull
SOIPS	soips	zeard	FADGE	fadge	scorp
WHUSS	whuss	pague	GRERF	grerf	voach
SPOC	spoc	nars	DREA	drea	irch
WUSK	wusk	heef	DARB	darb	twim
SKUP	skup	fref	DREE	dree	nuit
ZOUS	zous	jarm	BREG	breg	yunt
SWOX	swox	farn	GRER	grer	taub
SPOF	spof	nern	DREF	dref	tisk
POCH	poch	nart	BRAM	bram	tive
VUSH	vush	nelp	BERM	berm	hipt
SPUM	spum	tene	RARN	rarn	tybe
SKUN	skun	talm	DRET	dret	thab
POWN	pown	yalt	BRIB	brib	thox
WOOT	woot	memp	GAND	gand	jile
SUST	sust	yand	RAME	rame	firp
SWUT	swut	jeme	DRIG	drig	thel
SKIC	skic	yath	ANGE	ange	tilk
WUMP	wump	tain	FARB	farb	tife
SWIX	swix	flup	JEAD	jead	nink
SNOC	snoc	teft	FARD	fard	yime

(*Appendix continued*)

Appendix B (*continued*)

Similar condition			Dissimilar condition		
Target	Related prime	Unrelated prime	Target	Related prime	Unrelated prime
SMOP	smop	frit	MEBE	mebe	fing
SMUV	smuv	hett	FAGE	fage	tinx
YOOK	yook	flig	TREG	treg	minn
SKOWN	skown	pubed	TRARB	trarb	woule
SCISC	scisc	porce	TARED	tared	splog
SHOSS	shoss	purnt	NARGE	narge	kound
KNOOP	knoop	scaze	BRARM	brarm	zoche
SOOK	sook	ferv	BREB	breb	huth
ZOOP	zoop	yars	GRED	gred	fuin
SCUS	scus	jarf	DAGE	dage	froy
SPUV	spuv	fran	DERG	derg	yazz
KOOF	koof	nach	GEAF	geaf	triv
SWOF	swof	malc	BERF	berf	fiss
SOSH	sosh	telk	GREM	grem	tish
POOM	poom	jank	DRAN	dran	mibe
VOON	voon	melf	REET	reet	fipe
SOUN	soun	nelm	GERT	gert	fich
PUCT	puct	hamp	GAMB	gamb	thek
VOST	vost	famb	BAFE	bafe	nist
ZOUT	zout	nafe	RETE	rete	jids
SPOY	spoy	tate	ANED	aned	mirt
KOMP	komp	teff	JEBB	jebb	miln
KUNS	kuns	naft	NERB	nerb	yilt
SPIZ	spiz	mant	YEED	yeed	fims
SISK	sisk	flon	NABE	nabe	ints
ZISP	zisp	flav	JEDE	jede	nift
NUCK	nuck	flet	FRAD	frad	thit
NOOP	noop	flin	FERG	ferg	yint

References

Aparicio, X., Lavaur, JM. (2016). Masked translation priming effects in visual word recognition by trilinguals. *Journal of Psycholinguistic Research, 45*, 1369-1388. https://doi.org/10.1007/s10936-015-9409-8

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*(3), 255-278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software, 67*(1), 1-48. https://doi.org/10.18637/jss.v067.i01

Bijeljac-babic, R., Biardeau, A., & Grainger, J. (1997). Masked orthographic priming in bilingual word recognition. *Memory & Cognition, 25*, 447-457. https://doi.org/10.3758/BF03201121

Boles, D. B., & Clifford, J. E. (1989). An upper- and lowercase alphabetic similarity matrix, with derived generation similarity values. *Behavior Research Methods, Instruments, & Computers, 21*, 579-586. http://dx.doi.org/10.3758/BF03210580.

Bowers, J. S., & Turner, E. L. (2005). Masked priming is abstract in the left and right visual fields. *Brain and Language, 95*(3), 414-422. https://doi.org/10.1016/j.bandl.2005.03.004.

Bowers, J. S., Vigliocco, G., & Haan, R. (1998). Orthographic, phonological, and articulatory contributions to masked letter and word priming. *Journal of Experimental Psychology. Human Perception and Performance, 24*, 1705-1719. https://doi.org/10.1037/0096-1523.24.6.1705.

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*, 977-990. https://doi.org/10.3758/BRM.41.4.977

de Groot, A. M. B., & Nas, G. L. J. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language, 30*(1), 90-123. https://doi.org/10.1016/0749-596X(91)90012-9

Dimitropoulou, M., Duñabeitia, J. A., & Carreiras, M. (2011a). Masked translation priming effects with low proficient bilinguals. *Memory & Cognition*, *39*, 260-275. https://doi.org/10.3758/s13421-010-0004-9

Dimitropoulou, M., Duñabeitia, J. A., & Carreiras, M. (2011b). Two words, one meaning: Evidence of automatic co-activation of translation equivalents. *Frontiers in Psychology*, *2*, 1-20. https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2011.00188

Dubey, N., Witzel, N., & Witzel, J. (2018). Script differences and masked translation priming: Evidence from Hindi-English bilinguals. *Quarterly Journal of Experimental Psychology*, *71*(11), 2421-2438. https://doi.org/10.1177/1747021817743241

Duñabeitia, J. A., Molinaro, N., Laka, I., Estévez, A., & Carreiras, M. (2009). N250 effects for letter transpositions depend on lexicality: 'casual' or 'causal'?. *NeuroReport*, *20*(4), 381-387. DOI: 10.1097/WNR.0b013e3283249b1c

Finkbeiner, M., Forster, K., Nicol, J., & Nakamura, K. (2004). The role of polysemy in masked semantic and translation priming. *Journal of Memory and Language, 51*(1), 1-22. https://doi.org/10.1016/j.jml.2004.01.004

Foote, R., Qasem, M. & Trentman, E. (2020). Morphological Decomposition in L2 Arabic: A

Masked Priming Study. *Journal of Psycholinguistic Research, 49*, 291-317. https://doi.org/10.1007/s10936-020-09688-6

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*(4), 680-698. https://doi.org/10.1037/0278-7393.10.4.680

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments and Computers, 35*, 116-124. https://doi.org/10.3758/BF03195503

Forster, K. I., Mohan, K., & Hector, J. (2003). The mechanics of masked priming. In S. Kinoshita & S. Lupker (Eds.), *Masked priming: State of the art* (pp. 3-37). New York: Psychology Press.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(5), 1122-1139. https://doi.org/10.1037/0278-7393.23.5.1122

Gomez, P., Marcet, A., & Perea, M. (2021). Are better young readers more likely to confuse their mother with their mohter? *Quarterly Journal of Experimental Psychology*, *74*(9), 1542-1552. https://doi.org/10.1177/17470218211012960

Gutiérrez-Sigut, E., Vergara-Martínez, M., & Perea, M. (2019). Deaf readers benefit from lexical feedback during orthographic processing. *Scientific Reports*, *9*(1), 12313-12321. https://doi.org/10.1038/s41598-019-48702-3.

Heyer, V., & Clahsen, H. (2015). Late bilinguals see a scan in scanner AND in scandal: Dissecting formal overlap from morphological priming in the processing of derived words. *Bilingualism: Language and Cognition, 18*(3), 543-550. https://doi.org/10.1017/S1366728914000662

Hoshino, N., Midgley, K. J., Holcomb, P. J., & Grainger, J. (2010). An ERP investigation of masked cross-script translation priming. *Brain research*, *1344*, 159-172. https://doi.org/10.1016/j.brainres.2010.05.005

Jacobs, A.M., & Grainger, J. (1991). Automatic letter priming in an alphabetic decision task. *Perception & Psychophysics, 49*, 43-52. https://doi.org/10.3758/BF03211615

Jacobs, A. M., Grainger, J. & Ferrand, L. (1995). The incremental priming technique: A method for determining within-condition priming effects. *Perception & Psychophysics*, *57*, 1101-1110. https://doi.org/10.3758/BF03208367

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, *59*, 434-446. http://dx.doi.org/10.1016/j.jml.2007.11.007

Jiang, N. (1999). Testing processing explanations for the asymmetry in masked cross-language priming. *Bilingualism: Language and Cognition, 2*(1), 59-75. doi:10.1017/S1366728999000152

Jiang, N. (2021a). Orthographic friends and lexical strangers in the L2 lexicon. *Journal of Second Language Studies*, *4*(2), 224-244. https://doi.org/10.1075/jsls.21012.jia

Jiang, N. (2021b). Examining L1 influence in L2 word recognition: A case for case. *Journal of Second Language Studies*, *4*(1), 1-18. https://doi.org/10.1075/jsls.19039.jia

Jiang, N., & Forster, K. I. (2001). Cross-language priming asymmetries in lexical decision and episodic recognition. *Journal of memory and language, 44*(1), 32-51. https://doi.org/10.1006/jmla.2000.2737

Kida, S., Barcroft, J. & Sommers, M. (2022). Word learning and lexicalization in a second language: Evidence from the Prime lexicality effect in masked form priming. *Memory & Cognition*, *50,* 1414-1431 (2022). https://doi.org/10.3758/s13421-022-01274-6

Kinoshita, S., & Kaplan, L. (2008). Priming of abstract letter identities in the letter match task. *Quarterly Journal of Experimental Psychology*, *61*, 1873-1885. https://doi.org/10.1080/17470210701781114.

Kinoshita, S., & Norris, D. (2009). Transposed-letter priming of prelexical orthographic representations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(1), 1-18. https://doi-org.ezproxy.uta.edu/10.1037/a0014277

Kinoshita, S., Whiting, D., & Norris, D. (2021). What masked priming effects with abbreviations can tell us about abstract letter identities. *Journal of Memory and Language*, *117*, 104209. https://doi.org/10.1016/j.jml.2020.104209

Ktori, M., Kingma, B., Hannagan, T., Holcomb, P. J., & Grainger, J. (2014). On the time-course of adjacent and non-adjacent transposed-letter priming. *Journal of Cognitive Psychology, 26*(5), 491-505. https://doi.org/10.1080/20445911.2014.922092

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software, 82*(13), 1-26. https://doi.org/10.18637/jss.v082.i13

Lemhöfer, K., & Broersma, M. (2012). Introducing LexTALE: A quick and valid Lexical Test for Advanced Learners of English. *Behavior Research Methods*, *44*, 325-343. https://doi.org/10.3758/s13428-011-0146-0

Lenth, R. (2019). *Emmeans: Estimated marginal means, aka least-squares means*. Retrieved from https://CRAN.R-project.org/package=emmeans

Madec, S., Le Goff, K., Riès, S. K., Legou, T., Rousselet, G., Courrieu, P., ... & Rey, A. (2016). The time course of visual influences in letter recognition. *Cognitive, Affective, & Behavioral Neuroscience, 16*, 406-414. https://doi.org/10.3758/s13415-015-0400-5

Meade, G., Grainger, J., & Holcomb, P. J. (2022). Language dominance modulates transposed-letter N400 priming effects in bilinguals. *Journal of Cognition, 5*(1), 1-13. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8740640/

Midgley, K. J., Holcomb, P. J., & Grainger, J. (2009). Masked repetition and translation priming in second language learners: A window on the time-course of form and meaning activation using ERPs. *Psychophysiology, 46*, 551-565. https://doi.org/10.1111/j.1469-8986.2009.00784.x

Nakayama, M., & Lupker, S. J. (2018). Is there lexical competition in the recognition of L2 words for different-script bilinguals? An examination using masked priming with Japanese-English bilinguals. *Journal of Experimental Psychology: Human Perception and Performance, 44*(8), 1168-1185. https://doi.org/10.1037/xhp0000525

Nakayama, M., Sears, C.R., Hino, Y., & Lupker, S.J. (2013). Masked translation priming with Japanese-English bilinguals: Interactions between cognate status, target frequency, and L2 proficiency. *Journal of Cognitive Psychology, 25*, 949-981. https://doi.org/10.1080/20445911.2013.839560

Norris, D., & Kinoshita, S. (2008). Perception as evidence accumulation and Bayesian inference: Insights from masked priming. *Journal of Experimental Psychology: General, 137*, 434-455. https://doi.org/10.1037/a0012799

Perea, M., & Carreiras, M. (2006). Do transposed-letter effects occur across lexeme boundaries?. *Psychonomic Bulletin & Review, 13*, 418-422. https://doi.org/10.3758/BF03193863

Perea, M., Jiménez, M., & Gómez, P. (2014). A challenging dissociation in masked identity priming with the lexical decision task. *Acta Psychologica*, *148*, 130-135. https://doi.org/10.1016/j.actpsy.2014.01.014

Perea, M., Jiménez, M., & Gómez, P. (2015). Do young readers have fast access to abstract lexical representations? Evidence from masked priming. *Journal of experimental child psychology*, *129*, 140-147. https://doi.org/10.1016/j.jecp.2014.09.005

Perea, M., & Lupker, S. J. (2004). Can *CANISO* activate *CASINO*? Transposed-letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language*, *51*(2), 231-246. https://doi.org/10.1016/j.jml.2004.05.005

Perea, M., & Pérez, E. (2009). Beyond alphabetic orthographies: The role of form and phonology in transposition effects in Katakana. *Language and Cognitive Processes*, *24*(1), 67-88. https://doi.org/10.1080/01690960802053924

Qiao, X., & Forster, K. I. (2013). Novel word lexicalization and the prime lexicality effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(4), 1064-1074. https://doi.org/10.1037/a0030528

Qiao, X., & Forster, K. I. (2017). Is the L2 lexical different from the L1 lexicon? Evidence from novel word lexicalization. *Cognition*, *158*, 147-152. https://doi.org/10.1016/j.cognition.2016.10.026

Rastle, K., Harrington, J., & Coltheart, M. (2002). 358,534 nonwords: The ARC Nonword Database. *Quarterly Journal of Experimental Psychology Section A*, *55*(4), 1339-1362. https://doi.org/10.1080/02724980244000099

Schoonbaert, S., & Grainger, J. (2004). Letter position coding in printed word perception: Effects of repeated and transposed letters. *Language and Cognitive Processes*, *19*(3), 333-367. https://doi.org/10.1080/01690960344000198

Schubert, T., Gawthrop, R., & Kinoshita, S. (2018). Evidence for cross-script abstract identities in learners of Japanese kana. *Memory & Cognition, 46*, 1010-1021. https://doi.org/10.3758/s13421-018-0818-4

Silva, R., & Clahsen, H. (2008). Morphologically complex words in L1 and L2 processing: Evidence from masked priming experiments in English. *Bilingualism: Language and cognition, 11*(2), 245-260. https://doi.org/10.1017/S1366728908003404

Smith, Y., Walters, J., & Prior, A. (2019). Target accessibility contributes to asymmetric priming in translation and cross-language semantic priming in unbalanced bilinguals. *Bilingualism: Language and Cognition, 22*(1), 157-176. doi:10.1017/S1366728917000645

Team, R. D. C. (2024). R Programming. R Development Core Team. https://www.r-project.org/

Vergara-Martínez, M., Gómez, P., Jiménez, M., Perea, M. (2015). Lexical enhancement during prime-target integration: ERP evidence from matched-case identity priming. *Cognitive, Affective, & Behavioral Neuroscience, 15*, 492-504. https://doi.org/10.3758/s13415-014-0330-7

Vergara-Martínez, M., Perea, M., Gómez, P., & Swaab, T. Y. (2013). ERP correlates of letter identity and letter position are modulated by lexical frequency. *Brain and Language, 125*(1), 11-27. https://doi.org/10.1016/j.bandl.2012.12.009

Vergara-Martínez, M., Perea, M., & Leone-Fernandez, B. (2020). The time course of the lowercase advantage in visual word recognition: An ERP investigation. *Neuropsychologia, 146*, 107556. https://doi.org/10.1016/j.neuropsychologia.2020.107556

Witzel, N. O., & Forster, K. I. (2012). How L2 words are stored: The episodic L2 hypothesis.

Journal of Experimental Psychology: Learning, Memory, and Cognition, 38(6), 1608-1621. https://doi.org/10.1037/a0028072

Xia, V., & Andrews, S. (2015). Masked translation priming asymmetry in Chinese-English bilinguals: Making sense of the Sense Model. *The Quarterly Journal of Experimental Psychology, 68*(2), 294-325. http://dx.doi.org/10.1080/17470218.2014.944195

Ziegler, J. C., Ferrand, L., Jacobs, A. M., Rey, A., & Grainger, J. (2000). Visual and Phonological Codes in Letter and Word Recognition: Evidence from Incremental Priming. *The Quarterly Journal of Experimental Psychology Section A, 53*(3), 671-692. https://doi.org/10.1080/713755906