SECOND LANGUAGE PROCESSING OF
ENGLISH PAST TENSE MORPHOLOGY

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DECLARATION OF ORIGINALITY

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ABSTRACT

Second Language Processing of English Past Tense Morphology

In the present study, highly proficient second language (L2) speakers' processing of English past tense morphology was investigated in order to understand whether their processing routes (i.e., decomposition, storage or a dual-route) were comparable with native (L1) speakers of English. To this end, two instruments were developed. In the masked priming task, the reaction times (RT) for regular and irregular verbs were measured. The prime-target pairs were presented in three prime conditions: i) Identity (save-SAVE; build-BUILD), (ii) Test (saved-SAVE; built-BUILD), and (iii) Unrelated (carry-SAVE; share-BUILD). In the sentence reading task, the same regular and irregular verbs used in the masked priming task were inserted in sentences and the participants' fixation durations for each verb type were compared. The study also sought to explore whether working memory (WM) has any relationship with L2 morphological processing. In addition to these, two WM measures, Automated Reading Span (ARSPAN) and Automated Operation Span (AOSPAN) tasks were adopted in order to discern whether WM correlates with the RTs in the masked priming task and fixation durations in the eye tracking task. The L2 speakers also received a Turkish version of the ARSPAN so that any confounding effects of language on WM performance could be ruled out.

The findings of the masked priming task showed that L2 speakers had slower RTs than native speakers. In addition, the regular verbs were responded to slower than

irregular verbs in both groups. Further analyses revealed a partial priming pattern across the conditions for regular verbs ($identity_{RT} < test_{RT} < unrelated_{RT}$), which is interpreted as reduced decomposition and full priming pattern for the irregular verbs ($identity_{RT} = test_{RT} < unrelated_{RT}$), which is interpreted as decomposition, in both groups. In the eye tracking task, major significant differences were not found between the participant groups and verb types in terms of early (first-fixation duration, gaze duration) and late (second fixation duration, total fixation duration) processing measures. Regular and irregular verbs yielded significantly different fixation durations only in the native speaker group with regard to gaze duration, with slower durations for regular verbs. The correlation analyses did not point to any relationship between WM and masked priming and eye tracking results in either group. The extreme-groups analysis, whereby high and low WM subgroups in each participant group were compared, also did not result in significant between-group differences in terms of morphological processing.

Comparable processing patterns in native and nonnative groups obtained in the present study oppose to earlier views that L2 learners are less sensitive to the morphological structure of the target language compared to native speakers. It seems that high proficiency L2 English speakers can employ the decomposition route in accessing inflected forms in the L2 similar to native speakers. Thus, our findings suggest that real-time processing of morphologically complex words can ultimately be native-like for adult L2 learners. Despite the lack of qualitative differences in processing, quantitative differences were found in the form of slower RTs in the L2 English group. These differences could not be accounted for by differences in WM.

ÖZET

İngilizce Geçmiş Zaman Biçimbirimlerini İkinci Dilde İşlemleme

Bu çalışmada ileri seviye ikinci dil (D2) konuşanlarının İngilizce geçmiş zaman biçimbirimlerini işlemlemesi araştırılmıştır. D2 konuşanlarının işlemleme yöntemlerinin (ayrıştırma, bütünsel listeleme, ikili sistem) anadil (D1) konuşanlarıyla örtüşüp örtüşmediğini anlamak amacıyla iki deney geliştirilmiştir. Maskelenmiş çağrıştırma testi aracılığıyla düzenli ve düzensiz eylemlere verilen tepki süreleri (TS) ölçülmüştür. Çağrıştırıcı-hedef çiftleri üç farklı durumda sunulmuştur: i) Özdeş (koru-KORU; kur-KUR), (ii) Biçimbirimsel İlişkili (korudu-KORU; kurdu-KUR) ve (iii) Anlam, ortografi ve biçimbirim açısından İlişkisiz (taşı-KORU; paylaş-KUR). Göz hareketlerini izleme düzeneğiyle eş zamanlı tümce okuma testinde ise, çağrıştırma testinde kullanılan eylemler tümce içerisine yerleştirilerek düzenli ve düzensiz eylemlere odaklanma süreleri karşılaştırılmıştır. Çalışmada ayrıca işler bellek (İB) ve D2 biçimbirimlerinin işlemlemesi arasında bir ilişki olup olmadığı incelenmiştir. Bunlara ek olarak, İB ile çağrıştırma testi ve göz hareketlerini izleme testi sonuçları arasında bir ilişki olup olmadığını anlamak amacıyla katılımcılara Okuma Süresi Testi (OST) ve İşlem Süresi Testi (İST) verilmiştir. İkinci dilin İB üzerindeki olası etkilerini ortadan kaldırmak amacıyla D2 konuşanlarına OST'nin Türkçe sürümü de uygulanmıştır.

Çağrıştırma testinin bulguları D2 konuşanlarının D1 konuşanlarına göre daha yavaş TS'leri olduğunu ortaya koymuştur. Ayrıca düzenli eylemlere, düzensiz eylemlere

göre daha yavaş tepki verilmiştir. Çağrıştırıcı çeşitleri esas alınarak yapılan ek analizler düzenli eylemler için kısmi ayrıştırma olarak yorumlanan, kısmi çağrıştırma örüntüsüne (özdeş durum$_{TS}$ < deney durumu$_{TS}$ < ilişkisiz durum$_{TS}$), düzensiz eylemler içinse ayrıştırma olarak yorumlanan tam çağrıştırma örüntüsüne (özdeş durum$_{TS}$ = deney durumu$_{TS}$ < ilişkisiz durum$_{TS}$) işaret etmiştir. Göz hareketlerini inceleme testi ise iki katılımcı grup arasında erken (ilk odaklanma süresi, sabit bakış süresi) ve geç işlemleme (ikinci odaklanma süresi, toplam okuma süresi) ölçütleri açısından eylem türüne göre önemli farklılıklarla sonuçlanmamıştır. Sadece D1 konuşanları grubunda düzenli ve düzensiz eylemlerin sabit bakış süreleri arasında, düzensiz eylemler lehine önemli bir fark bulunmuştur. Yapılan korelasyon analizleri İB ve çağrıştırma testi ve göz hareketlerini inceleme testleri arasında önemli bir ilişki göstermemiştir. Yüksek ve düşük İB gruplarının biçimbirim işlemleme testleri sonuçlarının karşılaştırıldığı uç gruplar analizinde de önemli gruplar arası farklar çıkmamıştır.

Bu çalışmada, D1 ve D2 konuşan grupları arasında benzer işlemleme örüntülerinin bulunması D2 konuşanlarının hedef dilin biçimbirim yapılarına daha az hassasiyet gösterdiği savıyla örtüşmemektedir. D1 konuşanlarıyla benzer şekilde ileri düzey D2 İngilizce konuşanlarının da çekimli yapılara erişirken ayrıştırma yolunu kullanabildikleri söylenebilir. Çalışma sonuçları karmaşık biçimbirimli sözcüklerin gerçek zamanlı işlemlemesinin anadil konuşanlarına benzer şekilde gerçekleştiğini önermektedir. Test sonuçlarında iki katılımcı grup arasında işlemleme açısından nitel farklar bulunmamasına rağmen nicel farklar bulunmuştur. Bu farklılıklar İB farklılıkları ile açıklanamamaktadır.

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LIST OF ABBREVIATIONS

AOI	Area of Interest
AOSPAN	Automated Operation Span
ARSPAN	Automated Reading Span
L1	First Language
L2	Second Language
LTM	Long Term Memory
SLA	Second Language Acquisition
RST	Reading Span Task
RT	Reaction/Response Time
SOA	Stimulus Onset Asynchrony
STM	Short Term Memory
WM	Working Memory
WMC	Working Memory Capacity

CHAPTER 1

INTRODUCTION

1.1 Background

In the field of second language (L2) acquisition, the comprehension and particularly the production of inflectional morphology has been characterized by a large degree of variability in late L2 learners, who start learning an L2 after a critical period (Lardiere, 2009; McCarthy, 2008).

From the perspective of the mental representation and processing of morphologically complex forms, similar problems have been reported in late L2 learners of different languages (Clahsen, Felser, Neubauer, Sato, & Silva, 2010; Silva & Clahsen, 2008). The question has been investigated with regard to specific processing routes that speakers of a language follow when processing morphologically complex words. The concept of morphological regularity has been central in this debate since it lends itself well to comparing the two main processing patterns for morphologically complex words: storage versus decomposition.

In the context of representation/processing of regular versus irregular morphology, some researchers argue for native-non-native differences: native speakers of a language are assumed to have the implicit competence to do combinatorial processing (i.e., they are able to do decompose affixed words into their stem and affix) whenever they need to process regularly inflected words. For words with irregular morphology, on the other hand, whole-word storage is relevant. Unlike native speakers, non-native speakers are believed to be inherently less sensitive to the internal structure of morphologically complex words (e.g., Neubauer & Clahsen, 2009; Silva & Clahsen, 2008). This suggests that L2 learners fail to do implicit morphological computations and resort to lexical storage not only for irregular words but also for regularly inflected words, as suggested by Ullman (2004). Moreover, unlike native speakers, L2 learners are observed to be less sensitive to morphological cues (e.g., verbal morphology), and instead rely on semantic and lexical cues (e.g., time adverbials) in sentence interpretation (Leeser, 2007; Sagarra, 2007). It has been suggested that increased use of the declarative memory due to maturational changes in adulthood underlies this overreliance on lexical cues in L2 learning (Ullman, 2005). The position that advocates native/non-native differences in language processing is generally known as the Shallow Processing Account (Clahsen & Felser, 2006). In the early versions of the Shallow Processing Account, a possibility of native-like attainment in L2 processing is dismissed altogether. Even highly advanced L2 learners are expected to demonstrate nonnative processing patterns. Moreover, it is assumed that insensitivity to L2 morphology is observed regardless of the morphological richness of L2 learners' first language (L1). Under this view, positive (i.e., facilitative) L1 transfer on L2 processing is not likely to occur due to a general computational incapability on the part of late L2 learners (Silva & Clahsen, 2008). Although more recent versions of this account leave a room for the possibility of near native-like processing at very proficient stages (Clahsen et al., 2010), studies based on this theory do not document similar processing results for native and non-native speakers (Bosch & Clahsen, 2015; Clahsen, Balkhair, Schutter, & Cunnings, 2013).

Another group of researchers assume that L2 learners essentially use similar mechanisms as native speakers in morphological processing. Some accounts argue that L2 learners will have a tendency to decompose complex words after a very initial ‘chunk learning phase’. The assumption here is that given the small lexicon in the L2, L2 learners cannot rely on storage for processing unknown words (Gor, 2015; Gor & Jackson, 2013). Another possibility is that they may be less automatized at the recomposition of morphemes and the stem into the inflected word after the decomposition stage, coinciding with reintegration of morphosyntactic information (Gor, 2015).

Other views focus on the concept of regularity and propose more unitary accounts for processing regular and irregular forms. Specifically, regularity is perceived to be a graded concept whereby all complex items are decomposed into their stem and affix to varying degrees on the basis of their regularity (Feldman et al., 2010). The degree of decomposition might be greater for regular verbs than that for irregular verbs. L2 learners are expected to gradually improve their decompositional processing skills with increased proficiency. While these decompositional accounts differ in their explanations of the specific mechanisms involved in processing complex words, they converge on the premise that any processing differences to be observed between native and non-native speakers will be quantitative but not qualitative in nature (Feldman, Kostic, Basnight-Brown, Durdevic., & Pastizzo, 2010; Gor & Cook, 2010). Furthermore, there is room for L1 transfer in L2 morphological processing (Basnight-Brown, Chen, Kostić, & Feldman, 2007). Although L2 speakers are generally slower than native speakers in terms of processing speed in language experiments (Gor, 2015), morphological richness in their L1 might make a difference in their processing pattern.

More specifically, L2 learners with a morphologically rich L1 might be more sensitive to morphological markers in the L2 than those with a morphologically-limited L1, (Basnight-Brown et al., 2007).

Quantitative differences such as slower processing, poor decoding ability and limited cognitive resources have also been implicated in cognitive accounts of language processing. In such accounts, it has been emphasized that L2 learning is prone to individual differences in cognitive skills, which might lead to variable outcomes. L2 learners' failure to make online morphosyntactic computations may be linked to their limited cognitive resources (McDonald, 2006). Among these cognitive resources, working memory capacity (WMC), the capacity to store information temporarily while processing another material, is thought to be a strong predictor of success in L2 acquisition (Juffs & Harrington, 2011; Linck et al., 2014; Wen & Skehan, 2011). For example, morphosyntactic problems are expected to diminish as L2 learners' working memory capacity (WMC) in the L2 increases as a function of increased L2 proficiency (Coughlin & Tremblay, 2013; Leeser, 2007; Linck, Osthus, Koeth, & Bunting, 2014).

Since the construct of working memory (WM) basically involves an ability to store/access information under online processing demands, it is usually implicated in language learning aptitude in general and vocabulary learning as well as sentence processing in particular (Juffs & Harrington, 2011). Nevertheless, the role of WM in morphological processing has not been explored to the same extent. This is surprising considering that morphological processing is one of the most difficult areas for adult L2 learners.

To date, few studies have associated morphological processing routes with WMC. However, studies on L1 processing point to a relationship between WM and accurate/rapid processing of morphologically complex words in both children and adults (Nemeth et al., 2010; Service & Maury, 2015; Service & Tujulin, 2002). It has been revealed that recall of morphologically complex words, particularly inflected words, is generally poorer than that of morphologically simplex words of the same length (Cohen-Mimran et al., 2013; Nemeth et al., 2011; Service & Tujulin, 2001). This is indicative of a higher processing load triggered by morphological complexity of words on WM and brings to mind the question of whether individuals with higher WMC process morphologically complex words in their L1 more efficiently (in terms of accuracy and speed) than those with low WMC. The same question can be applied to L2 acquisition in the sense that WMC may have an impact on the access of complex words in the L2 as well. After all, L2 word recognition is believed to be less automatic than that of L1, particularly in the initial L2 state (Abutalebi & Green, 2007; see also Juffs & Harrington, 2011 for a review). Furthermore, unlike in L1 acquisition, there is much individual variation in ultimate success in adult L2 acquisition. It is possible that differences in WMC play a more determining role in L2 processing than L1 processing. The underlying assumption in this thesis is that decomposition defined as an online implicit linguistic computation induces a higher WM load than full listing does. In other words, the speed and accuracy of morphemic (de)composition may rely on WMC more than whole-word storage does. Thus, the question of whether a particular way (decomposition or full listing) of processing L2 morphology occurs in relation to higher or lower WMC needs to be answered within this context.

1.2 The current study

Within this background this study aims to contribute to L2 mental lexicon research by comparing native and non-native speakers' online processing of regular and irregular verbal inflection as measured by masked priming and eye-tracking tasks in L2 English. Processing inflectional morphology is examined in relation to the role of WMC. More specifically, the aim is to investigate the extent to which L2 learners' morphological processing patterns (i.e., decomposition or full listing) can be linked to high or low WMC as measured by both the Reading Span Task and Operation Span Task. Unlike many previous studies, the present investigation looks at online morphological processing of inflected words both in word and sentence context. In other words, masked priming and eye-tracking paradigms are used to examine L2 learners' processing patterns in complex words presented in isolation and in sentences, respectively.

1.3 Overview of the dissertation

This introduction is followed by a detailed discussion of L2 acquisition of morphological forms (Chapter 2). Subsequent to this, there will be a comprehensive review of current accounts of processing L2 morphology (Chapter 3). The ensuing chapter will introduce the construct of WM in relation to L2 learning and morphological processing (Chapter 4). The design of the two experiments aiming to identify the potential relationship between morphological processing and WMC will be presented in the methodology section (Chapter 5). The results of the experiments and the interpretation and the discussion of the data will be presented in Chapter 6 and Chapter

7, respectively. Potential implications of the present study for L2 learning and recommendations for future morphological processing research are presented in the final chapter (Chapter 8).

1.4 Definition of key terms

Decomposition: Processing/representation of morphologically complex words by extracting the morphemic unit(s) (Taft & Forster, 1975).

Eye tracking: Monitoring the movements of the eye by measuring the point of gaze.

Full-listing (Storage, Direct Access): Processing/representation of morphologically complex words as a whole (Butterworth, 1983).

Lexical decision task: A procedure in which a participant decides whether a presented stimulus is a real word or not in a given language.

Masked priming: A paradigm developed by Forster and Davis (1984) is the presentation of a hidden prime in between a forward mask and the target word. Since the prime is invisible to the seer, it is assumed to tap into unconscious, implicit processes.

Mental lexicon: An imaginary mental dictionary comprising semantic, phonological, morphological and orthographic representations of words.

Root (stem-cluster, base, lemma) frequency: Frequency of the root and all variants of that root.

Word (surface, whole-word) frequency: Total frequency of a word's full form in a corpus.

Working memory: Mental workspace where information is stored or manipulated temporarily, while another task is carried out concurrently (Baddeley & Hitch, 1974).

Working memory capacity: An individual's capacity to withhold information for a short time, while carrying out another task.

CHAPTER 2

ACQUISITION OF MORPHOLOGY IN THE L2

L2 morphology is one of the most difficult areas to master, particularly in late L2 learning. Inflectional morphemes are especially notorious for being prone to variability and persistent errors in production even at advanced levels of proficiency. Therefore, it will be relevant to look at previous studies on L2 acquisition of inflectional morphology before delving into the literature on processing inflections in the L2. For the sake of clarity, the section below first presents an overview of past tense formation in English, as it will be the focus of the present investigation.

2.1 A note on past tense morphology in English

Although English has a rich derivational system, it is generally recognized as an inflectionally limited language. As in other languages, inflectional morphemes do not form a new lexical entry, nor do they change the grammatical class of the words they are attached to, yet they are considered to take part in the realization of morphosyntactic features as opposed to derivational morphology which is related to lexis (Marslen-Wilson, 2007). There are eight bound inflectional morphemes, two of which are attached to nouns (plural –s and possessive –s) while two are attached to adjectives (comparative –er and superlative –est). There are also four verbal inflectional morphemes: third-person singular present tense marker –s, past tense marker –ed, past participle –ed/-en, and the progressive –ing.

The past tense suffix –ed has productive features. While some of the inflected past forms are produced by adding –ed to the bare verb (e.g., walk-ed, start-ed), some are formed by changing certain sounds in the bare form (e.g., give-gave, keep-kept, buy-bought, spill-spilt). Except for 180-200 irregular verbs, all of the past forms are formed in the former style (See Table 1). The –ed suffix has three allophones depending on the final phoneme: /t/, /d/ and /əd/. /t/ is used in verbs ending with a voiceless sound (e.g., push, laugh), /d/ is used in verbs ending with a voiced sound (e.g., save, judge, grin), and /əd/ occurs in verbs ending with alveolar stops /t/ and /d/ (e.g., fret, skid) (Greenbaum, 1996).

Table 1. Past Tense Formation in English

Regular Verbs	Irregular Verbs
1. Addition of –ed: *start-started* 2. Doubling: *rob-robbed* 3. Change of y to ie: *cry-cried*	1. No change: *sit-sit, put-put* 2. Change of internal vowel only: *run-ran* 3. Change of whole word: *go-went* 4. Change of <y> to <aid> : *pay-paid* 5. Addition of <t> : *spoil-spoilt* 6. Change of vowel + final <t> or <d>: *feel-felt*, *buy-bought*, *tell-told* 7. Change of vowel + final consonant deletion + final <t> : *bring-brought*

Note: This categorization was adapted from Bybee and Slobin (1982, pp. 104-105)

Although they constitute the minority in past forms, the frequency of use of irregular past forms is quite high (Kucera & Francis, 1967). It is hard to make a classification of irregular verbs, but it is easily noticeable that some are formed by vowel changes (e.g., sing-sang, fall-fell, speak-spoke) while some others are constructed by consonant changes or addition of –t (e.g., make-made) (Bybee & Slobin, 1982).

The rule-based formulation of the regular past forms and semi-regular and irregular formation of the remaining past forms makes them ideal candidates for testing computational versus storage-based accounts of verb formation, as will be discussed in the following sections.

2.2 Variability in L2 inflectional morphology

Starting with the morpheme order studies in the 1970s, L2 acquisition (SLA) research has focused on the acquisition of L2 morphology and various problems associated with it. Access to Universal Grammar (UG), impaired syntactic representations, possible L1 influence, and cognitive factors were considered among the reasons underlying fluctuating L2 performance (Clahsen, 1998; McDonald, 2006). Frequency, morphophonological salience, semantic complexity, morphological regularity, and syntactic complexity of the linguistic structures have been investigated in relation to this difficulty (Goldschneider & DeKeyser, 2005).

The earliest morpheme order studies established that L2 learners, regardless of their length of exposure to English, type of exposure, age and first language (L1) background, tend to have similar difficulty acquiring L2 morphemes. In the speech samples elicited from L2 learners, the least problematic of the eleven target English morphemes were listed as the –ing, plural –s, contractible copula *be* and articles, while the most problematic ones were listed as third person singular –s, possessive –s, long plural (–es) and the regular past tense inflection (–ed) (Dulay & Burt, 1973, 1974).

Despite some of the weaknesses in measurement of acquisition based on group rather than individual performance and on the number of suppliance (irrespective of whether or not the morpheme used is target-like), these studies eventually led researchers to establish a connection between the acquisition of morphemes and their underlying syntactic structure. To illustrate, the earlier acquisition of copula *be* in contrast to auxiliary *be* was accounted for by its syntactic properties. The proposal that auxiliary *be* has more complex selectional requirements (i.e., Verb Phrase (VP) with a V–ing) than copula *be* (i.e., nearly everything except a VP) was one of such attempts (Hawkins, 2001).

Different accounts have been proposed with regard to the later acquisition of tense markers. One such account linked this phenomenon to syntactic movement. While both copula and auxiliary *be* rise to the Inflection (I) position to pick up their bound morphemes, in tense marking, the affix is lowered to the VP to take the third person singular –s affix[1], which might be a more complex operation (Hawkins, 2001). Similarly, Ionin & Wexler (2002) argue that at early stages, affixal morphology is associated with suppletive *be* raising and therefore the inflection affixes are omitted.

As for the relatively earlier acquisition of irregular past forms compared to regular forms, Zobl (1998) found that in oral and written production of L2 learners from various L1 backgrounds, the frequency of the use of irregular forms outnumbered that of regular forms, mirroring the L1 statistics. Similarly, self-corrections of irregular forms outnumbered that of regular forms, pointing to increased awareness of the form. However, error rates were higher in the production of irregular forms, which was interpreted to reflect the non-computable nature of the structure. However, the small

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[1] English is not considered to be a verb-raising language except for, auxiliary *be* forms (Pollock, 1989).

sample size and the heterogeneity of the L2 group threaten the generalizability of the results.

In the past 25 years of SLA research, the explanation of morphological problems in relation to syntax has been carried out in two main approaches. The earliest studies have supported the impaired representations view (Clahsen, 1988; Eubank, 1993/94; Meisel, 1997). On the other hand, based on the premises of UG theories, some generativist accounts have argued that the syntactic representation of relevant functional categories (i.e., I, VP) accessible through UG are available to L2 learners at the initial stage.

2.2.1 Impaired representation approaches

The impaired representation theories in general associate L2 learners' morphological problems with their syntactic representations. One of the notable theories in this line is the Minimal Trees Hypothesis (Vainikka & Young-Scholten, 1994). The advocates of the theory assert that initially only lexical categories (i.e., Noun, Adjective, Verb which denote lexical morphemes) of the L1 are available to L2 learners in such a way that the initial lexical projections resemble minimal syntactic trees (e.g., VP). At this initial stage, the underlying L2 representations are claimed to be temporarily impaired due to the absence of functional categories. Functional categories emerge in succession during later stages of development as the L2 morphemes are acquired on the basis of positive evidence, without any L1 influence. However, slight differences in the L2 acquisition patterns of learners from typologically different L1s have challenged this argument (Haznedar & Schwartz, 1997; Lardiere 1998). Moreover, the proposal that the complementizer phrase (CP) will not emerge until VP and inflection phrase (IP) emerge was later questioned after evidence to the contrary was obtained from L2 learners' early productions (Gavruseva & Lardiere, 1996). It was also illustrated that IP is evident in the initial state of child L2 acquisition in English (Haznedar, 2001).

Similar to the Minimal Trees Hypothesis, in Valueless Features Hypothesis, Eubank (1993/94) argues that all of the categories are transferred from the L1 to the L2, yet their feature values, such as strength of I are not, which makes them valueless. In syntax, the strength of I is associated with verb-raising (e.g., French) (Pollock, 1989) while weakness implies the lack of verb raising, as in English. The optional verb raising and lack of inflection in early L2 French learners' production is explained by the neutralization of the feature strength value in the L2. These feature values are expected to be acquired gradually during the course of L2 development. Like the Minimal Trees Hypothesis, this proposal holds that the initial state of L2 representations is impaired since the feature values are lacking.

A portion of SLA approaches are not that optimistic about the ultimate attainment of L2 learners and assume permanent impairment of L2 grammars. The proponents of the local impairment view allege that the feature values will never be acquired (Beck, 1998). Based on the Principles and Parameters approach, it has been argued that parameters related to the feature strength are inaccessible (Hawkins & Chan, 1997; Tsimpli, 1997). The Representational Deficit Hypothesis also posits that the L1 parameters that are incompatible with the L2 cannot be reset. Thus, L2 learners are expected to experience difficulty comprehending and producing these morphosyntactic structures (Hawkins & Chan, 1997). On the other hand, some researchers support the global impairment view and describe L2 grammars as wild grammars, not constrained by UG (Meisel, 1997). This view is based on evidence for the use of non-finite forms in finite contexts, which is caused by incomplete acquisition of inflectional morphology. Clahsen (1988) also holds that adult L2 acquisition is devoid of UG access, but, general learning mechanisms are used in place of UG. As will be discussed in the following section, the proponents of this deficient L2 competence view have, in subsequent years, maintained that L2 learners differ from native speakers in online morphological computations (Neubauer & Clahsen, 2009; Silva & Clahsen, 2008), arguing for deficiency both in abstract linguistic representation and processing components of adult L2 acquisition.

2.2.2 Intact representation approaches

Within the UG framework, impaired representational accounts have been challenged by more recent SLA approaches that suggest that morphological problems do not imply a lack of functional categories at an abstract level (Haznedar & Schwartz, 1997; Lardiere, 2000; White, 2003). The proponents of this view postulate that L2 grammars are UG-constrained. For example, the Missing Surface Inflection Hypothesis maintains that all lexical and functional categories are available to learners at the initial stage (Haznedar, 2001; Prévost & White, 2000). In this view, L2 learners' morphological errors are not necessarily viewed as an indication of lack of access to abstract categories and features. The frequent and accurate use of suppletive forms like auxiliary and copula *be* 'is', 'was' in L2 production are considered to be an instantiation of tense and feature checking mechanisms (Ionin & Wexler, 2002). Likewise, the presence of overt subjects indicates that subjects are raised to Specifier IP position to check their features

(Haznedar, 2001). Contrary to the global impairment view, there is consistency in the use of finite forms. In other words, finite forms are not used in place of non-finite forms while non-finite forms can be used as default forms instead of finite forms (Haznedar & Schwartz, 1997; Prévost & White, 2000). When present, inflected forms are usually accurate and the observed errors are usually in the form of omission rather than substitution, which support the systematicity in L2 learners' productions (Haznedar, 2001).

What about the persistence of optional form use even after prolonged exposure to L2 and high L2 proficiency? Lardiere (1998) addressed this issue, which is generally referred to as fossilization, in a longitudinal study of an end-state L1 Chinese L2 English learner. Despite a high rate of omission of agreement and tense markers, this learner's knowledge of verb movement was intact and she never raised thematic verbs. This syntax-morphology asymmetry cannot be completely accounted for on the basis of the lack of inflectional morphology in Chinese, since other L2 studies have shown that end-state learners whose L1 has rich morphology, such as Turkish, may also omit L2 inflectional markers at the ultimate attainment level. For instance, longitudinal data from an L1 Turkish-L2 English speaker showed evidence for variable use of the past tense and third person agreement inflections despite a high level of accuracy in syntactic representations, such as case assignment and the use of overt subjects (White, 2003).

All of this evidence suggests that despite problems in surface morphology, syntactic representations are intact in the L2. Morphological variability does not indicate syntactic deficits. In other words, it is not the lack of abstract functional categories or resetting of parameters, rather the mapping of surface morphological features to abstract forms that causes L2 learning difficulties (Lardiere, 2000). Prévost and White (2000) explain this mapping problem within Distributed Morphology (Halle & Marantz, 1993). In this theory, inflected forms are inserted to their terminal syntactic nodes if their features correspond to the features of that node, such as person and number agreement. It is argued that L2 learners have the features of the terminal nodes but lack their feature specifications, which lead them to produce underspecified forms such as nonfinite forms as default forms in place of finite forms. Furthermore, it is suggested that L2 learners' optional use of nonfinite forms in production might be explained by retrieval and communication pressure (Prévost & White, 2000).

Lardiere (2009) subsequently altered her account and proposed the Feature Re-assembly Hypothesis inspired by the Minimalist Program (Chomsky, 1995), in which language acquisition encompasses feature selection and feature assembly into functional categories and lexical items. Variations in these processes lead to parametric differences between languages. Lardiere (2009) asserts that existing L1 features are reassembled into new functional categories in the L2 if they have different morpho-lexical expressions. It is the configuration of these features, which is problematic in L2 acquisition. For instance, while definiteness and number are expressed in a single feature in Chinese, the same features are expressed separately in English, which complicates their reassembly in L2 acquisition.

An alternative view, The Prosodic Transfer Hypothesis, links variability in morphological production to transfer of L1 prosodic representations (Goad & White, 2006). According to this view, in English in which regular past tense markers are attached to the prosodic word (PWd) while irregular inflection is PWd-internal, which might cause difficulties in the overt realization of past-tense regular inflection.

Based on all of the accounts mentioned earlier, Slabakova (2009) put forward an alternative view: The Bottleneck Hypothesis. In this line of reasoning, inflectional morphology– mostly due to its interface with syntax– is considered to be the bottleneck of L2 acquisition. The inflectional properties of languages are unique, whereas syntactic and semantic properties are universal. Thus, this approach asserts that the acquisition of L2 syntax and semantics is fairly unproblematic, unlike inflectional morphology.

The majority of SLA hypotheses have emerged on the basis of production data. Data merely based on production may be misleading in terms of assessing L2 learners' competence. For this reason, L2 learners' online comprehension (i.e., online access to morphologically complex forms) needs to be examined as well. Recent evidence from comprehension studies suggests that problems with inflectional morphology are not restricted to production. It has been demonstrated that L2 learners of English are insensitive to violations of number agreement in a self-pace reading task (Jiang, 2004). In an L2 Spanish study, McCarthy (2008) also demonstrated that L1 English learners of Spanish have difficulty in comprehension and production of number and gender morphology. This result challenges the Missing Surface Inflection Hypothesis. Nevertheless, McCarthy's finding that learners' errors are usually in the morphological domain supports the syntax-morphology dissociation. Still, some recent studies report that L2 learners show sensitivity to morphological violations, but they may be delayed in detecting these violations as measured by online processing tasks. It is suggested that L2 learners may have some computational difficulties (Coughlin & Tremblay, 2013; Hopp, 2010). In the meanwhile, the debate on the computational and representational accounts still continues and studies adopting psycholinguistic and neurolinguistic methods have been attempting to resolve the ongoing controversy.

CHAPTER 3

PSYCHOLINGUISTIC INVESTIGATIONS OF THE MENTAL LEXICON

The question of how words are accessed and represented in the mental lexicon has been one of the most extensively studied psycholinguistic issues in the past thirty decades. This line of research has focused on two main processing routes in relation to decomposition. While single-route models assume either full-listing or decomposition, dual-route models have incorporated these two routes and postulated that either of them will be adopted depending on various characteristics of a given word. The main assumptions and proposals of each model are presented below after a brief section introducing the basic methodology used in mental lexicon research.

3.1 Basic methods used to investigate the mental lexicon

3.1.1 Simple lexical decision paradigm

Lexical Decision Task (LDT) is commonly utilized for measuring reaction times (RTs) in morphological processing studies. In this paradigm, individuals are presented with single words/nonwords visually or auditorily and are asked to press a “yes” or “no” button to indicate whether the presented stimulus is a real word in a certain language. Comparison of RTs to words which are categorized based on various characteristics (e.g., semantic, morphological properties, etc.) reveals information on how these features influence their processing speed. This allows researchers to test their hypotheses on the mental representation and/or access to words based on related theoretical background. To illustrate, the faster RTs for high frequency words compared to low frequency words may indicate easier access their mental representations. In addition, semantic characteristics of words may influence their processing time (Chumbley & Balota, 1984). The error rates across different word categories are also computed and analyzed in order to check whether specific categories yield more errors. In addition, participants with an error rate of 15-20% are removed from analysis.

3.1.2 The priming paradigm

In word recognition research, lexical decision tasks are usually carried out within the framework of the priming paradigm. In priming experiments, a prime, which is related to a target word, is presented before the target overtly or covertly in order to facilitate the speed of its access/recognition (see Marslen-Wilson, 2007 for a review of the priming paradigm). If the presentation of a related prime results in faster RTs to the target word in comparison with an unrelated prime, it could be argued that a priming effect has emerged. More specifically, this priming effect reveals that the relationship between a prime and a target has a role in their processing. In addition to manipulating the relationship between a prime and a target, the time between the start of the prime and the target, which is called the stimulus-onset asynchrony (SOA) can also be manipulated.

In linguistic processing research, it has generally been demonstrated that presentation of semantically related prime words prior to target word stems (e.g., nurse -

DOCTOR[2]) yields full priming as reflected by shorter response time in lexical decision tasks compared with an unrelated prime (orange - DOCTOR), which serves as the control condition. Another control condition is the identity condition, where the prime and target are identical (doctor - DOCTOR) and the highest level of priming is expected (Coughlin & Tremblay, 2015; Silva and Clahsen, 2008).

There are also cross-modal priming experiments where an auditory prime is immediately followed by a visual prime or vice versa. This paradigm eliminates the possible confounding effects of orthographical similarity between the prime and the target and modality in lexical decision (Sonnenstuhl, Eisenbeiss & Clahsen, 1999). In this way, possible effects of episodic memory and strategy use are also reduced.

Another type of priming is masked priming, in which the prime is presented very briefly, for about 40-50 milliseconds (ms), following a series of hash marks such that the experimentee cannot even notice and remember the prime (Forster & Davis, 1984). The rationale for keeping the display time so short is to tap implicit processing and the early stages of processing.

3.2 Processing L1 morphology at the word level

Traditionally, most research into the mental lexicon has involved recognition/access of words presented in isolation. Accordingly, morphological processing theories were mainly derived from empirical evidence from the single word context. Therefore, I will first evaluate morphological processing models based on the isolated word context, and then move on to the sentence context.

[2] The target word is in capital letters in order to minimize visual similarity.

Models of the mental lexicon developed on the basis of single word recognition are mainly categorized as single route and dual route models in line with their predictions as to whether morphological parser uses both full-listing and decomposition or only one of them in lexical processing. The section below details the basic premises of these two models as they relate to the main topic of investigation in this thesis.

3.2.1 Single route models

Single Route Models, in general, do not make a distinction between the processing of lexicon and grammar, as they assume that a single mechanism is at work in processing both domains. Therefore, they do not favor distinct cognitive systems for processing different aspects of language.

The earliest single-route model is the Obligatory Decomposition Model proposed by Taft and Forster (1975). In this model, it is assumed that morphologically complex words such as ‘walked’ are decomposed into their constituent morphemes (e.g., walk-ed) and the stem’s entry (e.g., walk) is accessed in the lexicon via this linguistic computation. The pre-lexical affix stripping process is followed by access to the full lexical form (e.g., walked) from a hypothetical master file containing the stem’s morphological variants as whole words (e.g., walks, walking, etc.). As for storage, the root morpheme and the affixes will have individual entries and other morphological variants of ‘walk’ (e.g., walked, walking, walks) will not have separate representations. This maintains economy in terms of storage capacity in the lexicon.

Initial evidence for the affix-stripping hypothesis was obtained from lexical decision data whereby RTs to reject pseudowords composed of real morphemes (e.g., dejuvenate) were found to be slower than that for pseudowords with nonexistent morphemes (e.g., depertoire) (Taft & Forster, 1975). Further evidence demonstrated that affixed words with higher base (i.e., stem-cluster or lemma frequency) frequency[3] are recognized earlier than those with lower base frequency. For example, although 'seeming' and 'mending' have the same whole-word frequency[4] (i.e., surface frequency), 'seem' has a higher base frequency, which results in faster recognition of 'seeming' (Taft, 1979). A higher combined frequency of morphological variants that share the same base (e.g., seem) facilitates the recognition of 'seeming', which implies a decomposition process in accessing multimorphemic words.

In the more recent version of the Obligatory Decomposition Model (Taft, 1994, 2004), the lemma level has been incorporated. In this revised model, there are morphemic representations both at the form (i.e., orthography-phonology) and lemma level (an intermediary level between the form and the function (semantic-syntactic) levels). The morphemes are activated when the form code is activated and this activation hierarchically extends to the lemma and function levels. In morphologically transparent and complex words (e.g., mend-ing, seem-ing), decomposition takes place at the early stages of processing. Their transparent form constituents are sufficient for reaching the functional information level where the semantic/syntactic features of the stem and the related affix are combined.

[3] Combined frequency of all variants of a stem (e.g., walk, walks, walked, walking).
[4] The frequency of the inflected word form.

With regard to the morphologically complex words whose constituents are less transparent (i.e., functional information about the word cannot be predicted from the constituents), there might be a lemma form for the whole word. Taft (2004) illustrates this through the word 'feathery', whose opaque meaning (i.e., light) cannot be extracted from the stem and the suffix constituents. It is hypothesized that the form representations of the constituent morphemes, 'feather' and 'y', activate the whole-word lemma representation to pinpoint the semantic level information. Thus, form-level representation is not necessary for the whole-word since it is accessed via the lemma representation. Given the lack of whole-word form representations for affixed words, obligatory decomposition is suggested for all affixed words.

The Obligatory Decomposition Model has been challenged in several studies. The earliest of these is the documentation of storage effects for inflected words with a frequency of over six per million (Alegre & Gordon, 1999). Prado & Ullman (2009) have also reported frequency effects in the processing of English regular verb forms. Cautioning that such storage effects may be relevant to languages like English, which have poor inflectional morphology, Hankamer (1989) suggests that decomposition seems to be a more viable way of processing morphologically rich languages like Turkish, since storing all morphological variants might tax memory. However, more recent evidence tapping into early stages of processing has also demonstrated storage effects for highly frequent morphologically complex words in Finnish (Soveri, Lehtonen, & Laine, 2007) and in Turkish (Gürel, 1999).

There are other single route models which assume full-listing *only* in the representation/processing of morphologically complex words in the mental lexicon. Full-listing or direct access assumption is in complete contrast with the decompositional route. It proposes separate storage or separate lexical entry for each morphological variant of a morphologically complex word (Butterworth, 1983). For example, in this model, the stem 'walk' and all of its inflected forms, such as 'walked', 'walks' are separate lexical entries in the mental dictionary. Therefore, the morphological properties of words are not expected to make any difference in their processing. In the same vein, words with high whole-word (surface) frequency are assumed to be processed faster than those with low whole-word frequency. This model is assumed to be less costly in terms of morphological computation. Nevertheless, it requires a large mental storage space. Hence, the Full-Listing approach has been criticized on the grounds that a very large storage space would be required for agglutinative languages, which have a highly decomposable structure consisting of many affixes (Hankamer, 1989).

Some connectionist accounts of lexical access have similarities with the full-listing model in that all words, whether morphologically simple or complex, are stored in the mental lexicon and the morphological structure of the word does not influence its processing. The computation of words relies not on rules, but on associative networks of orthographic, phonological and semantic connections formed through repeated exposure to words. Learning words takes place by modifying the weight of these connections. Verb regularity and affix category are not supposed to influence processing since a single way of morphological processing is recognized.

One of the most well-known connectionist accounts of word recognition is the Interactive Activation Model (McClelland & Rumelhart, 1981). In this model, there are three levels of representation: feature, letter and word levels, connected by facilitatory or inhibitory lines. At the feature level, the letter features (e.g., round) are recognized and letters possessing this feature (e.g., O, P, C) are activated while the other letters (e.g., A, L, V) are inhibited. These letter representations then activate word-level representations and inhibit competing representations. To exemplify, upon being presented with the word “WORK”, the letters ‘W’, ‘O’, ‘R’, ‘K’ are excited and other letters are inhibited. Similarly, words beginning with “WO”, “WOR” are activated and those beginning without ‘W’ are inhibited, and finally “WORK” is recognized. The interactive nature of the model allows for simultaneous operations within and among multiple levels. The more frequently these levels are activated, the more easily the word will be processed. That is, words with high frequency are expected to be processed more easily.

Another connectionist line of research has generated the Parallel Distributed Processing (PDP) model (Rumelhart & McClelland, 1986; Seidenberg & McCllelland, 1989). The “parallel” aspect of the model emphasizes the simultaneous activation of different levels of information while the “distributedness” aspect points to the distributed semantic, orthographic, and phonological connections among word units. As such, it is formulated that the distributed networks are related to specific types of information. The connections between information units have differing weights and learning is basically the gradual adjustment of the input-output units’ weights through training.

As a domain-general learning-oriented model, the PDP premises can be extended to all types of learning, but the model focuses on lexical learning. Rumelhart and McClelland (1986) accounted for the differences in learning regular and irregular past verb formation by the differences in their distributional properties instead of diverse processing routes. This model was critiqued since it could not generalize verb formation in nearly a third of the regular verbs. Interestingly, however, formation of irregular forms did not yield the same amount of errors, which is questionable since the basic proposition of the model argues for a single processing type for all kinds of words. Proponents of the model argue that the presence of behavioral or representational differences between regular and irregular verbs does not necessarily point to separate cognitive mechanisms (McClelland & Patterson, 2002).

3.2.2 Dual route models

The dual-system models incorporate both full-listing and parsing routes and assume that either will be utilized depending on such factors as regularity, frequency, affix type, neighborhood size, etc. of words. The earliest of these models is the Augmented Addressed Morphology Model (AAM). According to the model, both the full form and the morphemic constituents are activated when a word is accessed (Chialant & Caramazza, 1995). However, the full form is activated earlier in the case of familiar words while unfamiliar words or low frequency regular words are decomposed into their constituents.

Another dual-route model is the Morphological Race Model, according to which a number of factors run in parallel and compete in order to determine the morphological processing type (Frauenfelder & Schreuder, 1992). To illustrate, transparency and frequency interact in the processing of words: words with high transparency (e.g., government) tend to be decomposed while words with low transparency (e.g., department) tend to be full-listed (Marslen-Wilson, Tyler, Waksler, & Oldeet, 1994). Other factors that might interact in the competition of processing include orthographic and phonological neighborhood density (Luce & Pisoni, 1998), family size (Schreuder & Baayen, 1997), affixal homonymy and word length (Niswander, 2003). The model does not consider categorical differences such as regularity and affix type as potential factors causing differences in morphological processing (Baayen, Dijkstra, & Schreuder, 1997).

In terms of inflectional morphology, dual-route models have generally focused on the past tense forms and the regularity factor as an explanation for the argument of differential processing routes. The earliest of these accounts is the Words and Rules Model (Pinker, 1999). In this model, as in traditional linguistic theories, the language system comprises lexicon and grammar. The lexicon incorporates stored words as well as fixed expressions and affixes. On the other hand, grammar comprises combinatorial operations for forming words, phrases and sentences. The rules for combining the lexicon's elements can be found in the morphology domain. To illustrate, in the processing of inflected words, if the form has a stored representation, the link between lexicon and grammar is blocked and the word is accessed via the lexicon only, which is usually the case with irregular forms. Since there is no general rule for processing irregular verbs, these verbs are learned by memorization through repeated exposure to the form. In the case of regular forms, the verb and the affix –ed are attached through links between the lexicon and grammar (Pinker & Ullman, 2002). Due to this computation, regular forms are expected to be retrieved slower than irregular forms. In the early, and strong version of the model, it was suggested that regular verb forms are always decomposed (Prasada et al., 1990). Later, the weak version of the model was formulated, stating that frequent regular forms can also be stored because the storage route wins over the decomposition route in highly frequent words (Prasada & Pinker, 1993).

The Declarative/Procedural Model expands the Words and Rules Model by incorporating the declarative-procedural memory distinction proposed by Paradis

(1994) and explaining the processing of regular and irregular words on the basis of their connection to mental lexicon and mental grammar respectively (Ullman, 2001). The model assumes that the processing of irregular words is subserved by the Declarative Memory (DM) which stores facts, arbitrary information and mental lexicon. On the other hand, the processing of regular words is subserved by the Procedural Memory (PM), which is related to the learning and processing of motor skills, sequential information and mental grammar (Table 2). There is even a neuroanatomical reflection of this distinction: the brain areas related to the processing of irregular words predominantly involve medial temporal lobe regions and hippocampus, subserving the declarative memory (Ullman, 2004). On the other hand, the processing of regular words principally involves the inferior frontal gyrus (Broca's area), basal ganglia and parietal lobe and cerebellar structures, subserving the procedural memory (Ullman, 2004).

Table 2. Overview of The Declarative/Procedural Model

	Declarative Memory	Procedural Memory
Type of knowledge	facts (semantic), events (episodic), words (lexical)	motor and cognitive skills (esp. sequences), rules, grammar
Related brain regions	temporo-parietal cortex	frontal cortex, basal ganglia

(Based on Pinker & Ullman, 2002; Ullman, 2004).

DM and PM are assumed to complement and compensate for each other during the different stages of language acquisition (Ullman, 2004, 2005). DM may be utilized more in the initial stages since it enhances faster learning of basic vocabulary and grammatical forms in chunk, while PM facilitates gradual acquisition of grammatical rules. In the transition from childhood to adulthood, PM gradually becomes less effective and DM is utilized more in learning new knowledge, resembling a see-saw effect[5] (Paradis, 1994; Ullman, 2005). It is also presumed that individual differences may influence the dominance of one type of memory over the other (Ullman, 2004; Ullman, 2005).

Neurocognitive evidence from brain damaged patients and neurodegenerative disorders mainly support the Declarative/Procedural (DP) Model's assumption of double dissociation of declarative and procedural memory. For example, in Alzheimer's disease, which damages the medial and neocortical temporal lobe associated with stored knowledge, patients have difficulty in producing irregular words but have less difficulty in producing regular words and suffixation (Ullman et al., 1997). Parkinson's disease patients, on the other hand, have been found to perform better in terms of producing irregular words than regular words (Marslen-Wilson & Tyler, 1997; Ullman et al., 1997). This may result from degeneration of basal ganglia structures and deterioration of motor skills which are associated with the procedural memory.

Studies on other clinical populations also have implications for the regular-irregular dichotomy. In an immediate auditory priming study on non-fluent English speaking aphasics, dissociations were found between the processing of regular and irregular verbs (Marslen-Wilson & Tyler, 1997). The patients showed priming for irregular forms but only partial priming for regular forms. This was explained by impairment in the left inferior frontal region of the brain, an area which is associated with the processing of inflection (Tyler et al., 2004). Based on these studies, Marslen-

[5] Improvement of skills in one area leads to worse functioning in another area, and vice versa.

Wilson & Tyler (2007) have formulated a neurocognitive model of inflection processing, The Core Decompositional Network Model, in which the fronto-temporal neural system assists processing of the regularly inflected forms on the basis of morphophonological rules and semantics. Since regular forms have a morphophonologically overt affix, they will undergo decomposition, while irregular forms which lack this structure will be stored.

3.2.3 Empirical evidence on L1 processing of past tense morphology in English

Studies on inflectional processing focus on the differences between the processing of regular and irregular inflection in English. The reason why this particular inflection type is selected is that past regular forms are morphophonologically overt and thus their detachable internal structure is transparent enough for revealing decompositional processing, while irregular forms have a more idiosyncratic and opaque structure associated with full-listing although the two are identical in terms of semantic and syntactic function. Moreover, 1000 of the most common verbs in English have regular past morphemes (Pinker, 1999). The related literature on the regular-irregular verb distinction in processing is substantial in terms of the variety of methods employed, and populations. This diversity is also evident in the varying results.

3.2.3.1 Empirical evidence for the dual-route model

The earliest studies reporting evidence for the dual-system are primarily based on production data (Beck, 1997; Stanners et al., 1979). One of the most well-known production studies is Prasada, Pinker and Synder's study (1990), where they presented participants with the bare verb form and asked them to produce the past form. The regular verbs matched for base (cluster) frequency and differing in whole-word frequency, yielded similar production times. This was taken as evidence that regular verbs are not represented as whole forms in the mental lexicon. In the irregular verbs, the frequency manipulation yielded faster RTs for higher frequency verbs, which can be interpreted as the presence of whole-word representations for irregular forms. In another production study involving children, real, pseudo-regular and irregular English verbs were found to be overgeneralized, whereas irregularization of regular verbs was not evident (van der Lely & Ullman, 2001). In addition, frequency effects were found for irregular but not regular verbs, which supports full-listing for irregular and decomposition for regular verb processing.

In a cross-modal priming study, Marslen-Wilson et al. (1993) found full priming effects for regular English verbs; facilitation, but no significant priming for suffixed semi-regular verbs (e.g., feel-felt) and interference effects for irregular verbs with vowel change (e.g., sing-sang). In other words, responses to the stem after the presentation of the irregular past form were actually slower when compared with unrelated primes, which might reflect competition between the two forms.

Although most dual-system studies have associated decomposition with regular verbs, Alegre and Gordon (1999) warn that this association might be misleading, since their findings point to stored representations of even regular forms with a frequency of at least six per million in English. The researchers argue that this is still in line with dual-route accounts, according to which decomposition and storage routes compete with each other when processing morphologically complex words, and word frequency controls which route will be the winner. Lately, it has been reiterated that despite the strong association of irregular verbs with storage, regular verbs might also be stored or decomposed on the basis of numerous variables. Some of the variables that might trigger storage for regular verbs are gender of the participants and imageability of the words. It has been demonstrated that female children (Babcock et al., 2012; Dye et al., 2013) and adults (Prado & Ullman, 2009) have a tendency to store regular forms possibly due to their enhanced declarative memory. Another observed difference is that male children and adults tend to store highly imageable irregular but not regular verbs (Dye et al., 2013; Prado & Ullman, 2009).

More recent electrophysiological and neuroanatomical studies have also found evidence for regular-irregular dissociations in favor of distinct cognitive mechanisms for morphological processing in English. The earliest studies report reduced N400 effects for regular but not irregular verbs (Münte et al., 1999). In the Event Related Potentials (ERP) literature, N400 effects are associated with lexical processing and interpreted as a response to unexpected words. Reduced N400 to primed regular words indicates reactivation of words encountered earlier, that is, priming. The lack of a similar effect in irregular verbs implies lack of access to the root form in irregular forms.

Subsequent neuroimaging studies have also found dissociations between regular and irregular verb processing. However, some of these relate this dissociation to the phonological form of the regular forms, which initiate automatic segmentation of the stem rather than presence of distinct mechanisms (Marslen-Wilson & Tyler, 2007). To illustrate, in a functional magnetic resonance imaging (fMRI) study, English-speaking participants were presented with spoken regular (same: walked-walked, different: talked-talk) and irregular (same: caught-caught, different: taught-teach) stem-verb pairs and asked to judge whether they are the same or not (Tyler et al., 2005). The results revealed that irregular pairs activated only areas related to memory, whereas the regular pairs also activated the left inferior frontal regions, which are related to verb processing, and thus decomposition.

Data from other languages of different typologies have found additional evidence for dual-route processing. In a cross-modal priming experiment in German, full-priming (priming equivalent to priming in the identity condition) was observed for regular past participles (e.g., gekauft–KAUFE), while priming effects were highly reduced in the case of irregular verbs (e.g., gelaufen–LAUFE) despite orthographic and phonological overlap between the prime and the target (Sonnenstuhl, Eisenbeiss, & Clahsen, 1999). These results echo the priming effects found for only regular forms in English (Münte et al., 1999) and in Spanish (Rodríguez−Fornells, Münte & Clahsen, 2002).

3.2.3.2 Empirical evidence against the dual-route model

The direct dissociation of regular-irregular verb formation has not been supported by all researchers. Classical behavioral studies along with contemporary neuroimaging technologies have supported or refuted assumptions about morphological processing as will be discussed below. The majority of these studies have employed masked priming due to its detection of early processes in visual word recognition.

The proponents of the unitary processing accounts, Kielar, Joanisse and Hare (2008) criticize dual-route models for evaluating morphological processing through a categorical approach based on regularity. They point to the fact that regularity is a graded concept. Through masked and cross-modal priming experiments with different

SOAs (0 and 500 ms) between the prime and the target, they illustrate that priming is also evident in semi-regular (e.g., kept-KEEP) as well as regular verbs while documenting the least amount of priming in vowel change irregular verbs (e.g., sang-SING). In previous work, the opposite trend was observed and priming was observed in vowel change verbs (Pastizzo & Feldman, 2002). This priming was interpreted to be morphological in nature because it was not affected from modality change induced by auditory priming. Moreover, it was not semantic in nature because semantic priming was only found in the vowel-change irregulars and not in semantically related pairs. Phonological overlap did not explain the priming effect either, since pseudo-irregular past forms did not yield any priming. Thus, it was concluded that morphological priming is the interaction between orthographic, phonological and semantic overlap between the verb root and stem. The degree of priming is higher in regular and semi-regular verbs, as there is more overlap between the root and the stem. This does not mean that regular and irregular verbs are processed through a different mechanism; the processor functions similarly, but the degree of priming changes, depending on the probabilistic phonological, orthographic and semantic factors. Moreover, the type of priming changes depending on the SOA between the prime and the target; shorter SOAs yield more formal (i.e., orthographic) priming effects, while longer SOAs yield more semantic priming.

The graded priming effects for irregular verbs have been supported in ensuing studies. In a large-scale analysis of RTs for regular and irregular verbs, Lignos and Gorman (2012) were able to show decomposition effects for all regular verbs regardless of frequency. This contradicted Alegre and Gordon’s (1999) prediction of the frequency “six per million” as the threshold for storage effects for regular verbs. For the irregular verbs, class similarity (e.g., end rime in caught, fought) was found to be a predictor of processing time; however, a single mechanism (i.e., decomposition) is suggested for processing both morphologically complex word types.

While supporting a single-route account, in contrast to similarity-based, probabilistic single-route accounts, Stockall and Marantz (2006) argue for an obligatory decomposition model for both regular and irregular verbs prior to lexical access of the root and recombination of stem and affix, with some phonological readjustment of the stem when necessary. In a series of priming experiments with Magnetoencephalography (MEG), they found an M350 effect associated with morphological priming for both regular and irregular prime-target pairs. In a further masked priming study with MEG, the M170 effect, indicative of decomposition, was found for irregular verbs (Fruchter et al., 2013). Similarly, Justus et al. (2009) found reduced N400 effects, interpreted as morphological priming effects for both regular and irregular past forms in an ERP experiment. They also interpret surface frequency effects in the computation of regular verbs as frequent employment of re-composition of stem and affix rather than storage, in contrast to what is widely held in the literature. In the same way, such effects are regarded to be indicators of stored representations, rather than storage mechanisms.

Another recent study has proposed an alternative view based on a series of masked priming experiments (Crepaldi et al., 2010). In this study, the results of orthographic manipulations revealed no facilitation for orthographically related English prime-target pairs (e.g., bell-BALL) in contrast to significant facilitation for irregular prime-target pairs (spoke-SPEAK). It was argued that although irregular verbs are not decomposed into their stem and affix, they access their base form's lemma representation, an intermediate level between morpho-orthographic and semantic representations. Therefore, both regularly and irregularly inflected words are assumed to activate their lemmas prior to morphological processing, but the degree of priming is expected to be higher in the case of regulars since they also have orthographic overlap with the base form at a second level. The findings were replicated in a further ERP study (Rastle, Lavric, Elchlepp, & Crepaldi, 2015).

Data from other languages also present evidence for a single route for processing morphology. Meunier and Marslen-Wilson (2004) have found equal rate of priming for regular and irregular verbs in French. Smolka, Zwitserlood and Rösler (2007) have reported similar priming effects for regular and irregular verbs in German.

Recent neurological disorder studies on morphologically richer languages like German, have also gathered counter-evidence for the dissociation of regular and irregular forms. In their study with Broca's aphasics, Wernicke's aphasics, Parkinson's disease patients and healthy groups, Penke and Wimmer (2012) have observed consistent difficulty in producing infrequent irregular verbs regardless of neurological disorder. Furthermore, Joanisse and Seidenberg (1999) have proposed that selective deficits in regular and irregular verbs should not be taken as evidence for dissociation in processing. In their revised connectionist model, the phonological and semantic subsystems serve a common system, whereby regular verbs are related to the phonological subsystem and irregular verbs are related to semantic subsystem. However, this model has been criticized for ignoring the morphological aspects of regular and irregular verb processing.

3.3 Processing L2 morphology at the word level

As in other fields of L2 processing, studies on morphological processing in the L2 have attempted to compare and contrast native and non-native processing. In this respect, psycholinguistic accounts complement current L2 acquisition research investigating whether it is the underlying representations or processing difficulties that pose difficulty for L2 learners. Two approaches have been proposed to explain the issue: non-decompositional and decompositional. While non-decompositional accounts suggest a shift from storage to decomposition, which is only possible at very proficient L2 stages, the decompositional accounts suggest an earlier utilization of decomposition due to lower probability of stored representations at early stages.

3.3.1 Non-decompositional accounts

The DP Model and the Shallow Structure Hypothesis are the two main proponents of the non-decompositional accounts. From a neurocognitive point of view, L2 learners' overreliance on lexical cues rather than morphological cues is linked to overreliance on declarative memory for all types of learning in adult L2 learning (Ullman, 2004). The Shallow Structure Hypothesis asserts that late L2 learners have reduced morphological sensitivity, which is responsible for their difficulty in decomposition while processing complex words. Slower processing speed, inefficient decoding strategies and individual differences in cognitive factors such as working memory capacity are other factors thought to be affecting morphological processing, which will be discussed in the following chapter (McDonald, 2006).

3.3.1.1 The declarative procedural model and L2 processing

As noted earlier, this model attempts to explain language acquisition on the basis of neurocognitive evidence. It is argued that in L1 and early L2 acquisition, the PM is exploited in the processing of syntax and regular morphology which require rule-based computational operations, while the DM is relied on for the processing of lexical items and irregular morphology, which depends on memorization and storage skills (Ullman, 2001, 2005).

In late L2 learning, maturational differences arising due to changes in hormones and neurotransmitters are expected to result in gradual attenuation of PM after adolescence, hence, overreliance on the DM in processing and learning of all kinds of information (Paradis, 1994, 2004, 2009; Ullman, 2005). This overreliance on the DM will result in considerable difficulties in learning grammatical and morphological aspects of L2, yet relatively fewer problems with the lexical aspects at least in the initial stages of L2 learning (Ullman, 2005). With enough exposure to the target language, reliance on the DM will gradually decrease, with the PM being depended on more in the processing of morphosyntax and thus L2 processing is expected to be more nativelike. Therefore, dissociation between the processing of stored and computed representations are expected to be more pronounced at proficient stages. However, the level of this proficiency is not specified by the researchers.

The shifts between DM and PM in cognitive functioning imply several differences both within and across individuals in terms of language learning (Ullman, 2005). Young L2 learners are supposed to use the PM more efficiently, which might explain their relative success in ultimate attainment of morphosyntax. On the other hand, it could be argued that late L2 learners will be more advantageous at the initial stages of language learning, due to their faster memorization of lexical and grammatical items.

3.3.1.2 Shallow structure hypothesis

The Shallow Structure Hypothesis (SSH) was constructed on the basis of complex sentence processing studies, but it also has implications for inflection processing. Similar to the DP Model, SSH suggests that L2 learners mainly rely on lexical and semantic information and ignore morphological information and thus their morpho-syntactic processing is shallow when compared with the full parsing of native speakers (Clahsen & Felser, 2006). Clahsen, Hadler and Weyerts (2004) argue that cognitive resource limitations and slower processing speed can be ruled out as an explanation for this shallow parsing in late L2 learners since young children, who have limited cognitive resources, were found to process morphological forms like adult native speakers.

For native speakers, SSH proposes a strong dissociation between the processing of regular and irregular forms, suggesting storage for irregular forms and decomposition for regular forms. This morphological dissociation may be experienced in late L2 learning at varying degrees, at least in highly proficient stages, but with low probability (Clahsen & Felser, 2006; Clahsen et al., 2010). Similarly, late L2 learners are not expected to perform like native-speakers in sentence processing. L1 influence cannot account for this persistent difficulty, as L2 learners from various L1 backgrounds tend to experience similar difficulties in processing complex structures such as relative clause attachment (Dussias, 2003), agreement dependencies (Coughlin & Tremblay, 2013; Keating, 2009) and long distance wh-dependencies (Çele, 2010).

3.3.2 Decompositional accounts

According to decompositional accounts, L2 learners quickly become adept at decomposing morphologically complex words in the initial stages of learning, gradually shifting to storage of high frequency inflected forms (Gor, 2014). This view is even more viable for morphologically rich languages, which are supposed to be processed mainly by decomposition while the storage route may also be used depending on the inflectional paradigm, input frequency, L2 proficiency and L1 background (Gor, 2014, 2015). The main rationale for this view, namely Rules and Probabilities Model, is that in morphologically rich languages, storage of all morphological variants of a stem is not expected, given that L2 learners have a narrow lexicon and insufficient exposure to all word forms. The view also supports initial decompositional learning of morphologically limited languages like English. Under this view, early level L2 learners are expected to decompose inflected forms; however, their focus might be on form-meaning mapping after the decomposition stage and they might be slower in terms of recombination of the root and affix at the morpho-syntactic integration stage. The lack of automatization in decomposition might also disrupt decomposition.

Another similar decompositional approach is that L2 learners will move from storage to decomposition of complex forms with increased proficiency regardless of the complex form's frequency (Basnight-Brown et al., 2007; Feldman et al., 2010). Moreover, regularity should be viewed as a graded concept; decomposition effects are expected to be higher in magnitude in regular forms in comparison with irregular forms due to higher form overlap. This does not overrule the observation that irregular forms are decomposable and a unitary mode of morphological processing is possible for both L1 and L2 speakers.

3.3.3 Empirical evidence on L2 processing of past tense morphology

Following morphological processing research in L1, L2 studies have investigated whether nativelike processing of morphology is possible in the target language. Involvement of dual-route processing in the L2 has been questioned in many studies on the basis of evidence suggesting that L2 learners process not only irregular but also regular inflection within whole-word representations (Babcock et al. 2008, 2012; Brovetto, 2002; Clahsen et al., 2010). As in the L1 processing literature, L2 morphological processing studies have yielded results challenging the dissociation of regular-irregular inflection processing (Basnight-Brown et al., 2007; Feldman et al., 2010). Given that the L1 processing literature has generated inconsistent results related to this distinction, the question of nativelikeness is even more controversial in the L2 literature.

3.3.3.1 Studies supporting nonnativelike processing of L2 past tense morphology

Most of the evidence for the presence of the dual-route in morphological processing comes from masked priming studies carried out by means of various psycholinguistic and neurolinguistic methods by Clahsen and collaborators. In terms of L2 English, learners from various L1 backgrounds have been studied. In one of the earliest studies, the processing of regular verbs by advanced L1 Chinese and L1 German speaking learners and native speakers of English was investigated (Silva & Clahsen, 2008). In the first experiment, the masked priming task with a stimulus onset asynchrony (SOA) of 60 ms, native speakers showed similar amount of priming in both test and identity conditions, which indicated full priming of regular forms. However, priming effects were restricted to the identity condition in non-native speakers, which indicated lack of morphological priming. The 30 ms SOA masked priming study repeated the earlier findings. As a result, it was inferred that L2 learners do not tend to decompose regular inflections. What is more, it was highlighted that this reduced sensitivity to morphological forms showed itself regardless of L2 learners' high proficiency level and L1 background. Another surprising finding was that L2 learners with a morphologically rich L1 background also demonstrated difficulty in processing morphology, even in the case of learning morphologically poor L2s. Clahsen et al.'s (2013) application of the same test to L1 Arabic learners of English replicated these findings. However, the absence of irregular verbs in the experiment is a weakness of the study since it has been demonstrated that irregulars can be primed, too (Crepaldi et al., 2010).

In a replication of Silva and Clahsen's (2008) study, Rehak and Juffs (2011) found priming effects for regular past forms in L1 Spanish learners of English, but surprisingly not in native speakers of English. As for the L1 Chinese learners of English, only repetition priming effects were observed; that is, the response rates for the identical condition (e.g., boil–BOIL) was faster than for the unrelated condition (e.g., meet–BOIL). This might stem from the fact that the L1 English group actually responded faster in the test condition than in the identity condition.

Proponents of the Declarative/Procedural Model also support differential processing of morphology by L2 speakers; however, they also suggest that a proficiency-based shift towards native norms is possible. Their results, however, point to a lack of nativelike patterns among L2 speakers. The reliance on production tasks might lie behind these results. For instance, in a speeded production task, Brovetto (2002) found that high-frequency regular and irregular verbs were produced faster than low frequency verbs in the L2 group, whereas L1 speakers showed frequency effects only in irregular forms. The results confirm other production studies where frequency effects are observed for only irregular forms by L1 speakers as opposed to L2 speakers from various L1 backgrounds, who show equal priming for regular and irregular forms (Babcock et al., 2008; Babcock et al. 2012; Birdsong & Flege, 2001). Babcock et al. (2012) additionally have pointed out that later arrival age may boost storage effects for L2 speakers.

Pliatsikas & Marinis (2013) found converging evidence for the dissociation between native and nonnative processing of morphology, but the nature of the difference was slightly different from what was found in the previous studies. In the study, priming effects were found for both regular and irregular forms in the L1 English group. In the L2 English group, priming effects were confined to irregular forms. As for the regulars, in contrast to priming facilitation, an inhibitory effect was found. That is, responses to the regular targets were actually slower after the morphological prime. The researchers linked this effect to the higher cognitive load triggered by the regular inflection.

A portion of studies on morphologically richer L2s appear to confirm the dual-route approach. In a masked priming study on advanced L1 Polish learners of German, priming of regular past inflection was not reported for L2 learners, yet full priming of the regular past forms was observed among native speakers of German (Neubauer & Clahsen, 2009). However, irregular forms received partial priming in both native and non-native speakers of German. These findings support the dual-route hypothesis although it should be noted that German irregular past forms are also realized by the addition of a suffix, which hints that L2 learners may also decompose the irregular past forms in German. In a production task, Bowden, Gelfand, Sanz and Ullman (2010) found frequency effects for both regular and irregular verbs in intermediate to advanced level English learners of L2 Spanish, while no frequency effects for regular verbs in the L1 Spanish group.

One factor, which is considered to underlie the L1-L2 processing differences, is the overall processing speed. It has generally been accepted that L2 learners are slower and less automatic in response experiments (McDonald, 2006). However, Neubauer and Clahsen (2009) challenged this premise by matching native and non-native speakers on response speed and comparing their processing patterns, which continued to differ. In another study with advanced L1 Arabic learners of English, Clahsen et al. (2013) administered the masked priming task with and without a delay in order to understand whether providing more time to L2 learners would change their processing routes for English past forms. The results were similar in both conditions: morphological priming for regulars was not found in the L2 group as opposed to the L1 group, leaving out the possibility that speed differences created the L1-L2 processing difference. In addition, Clahsen and Felser (2006) argue that if processing speed were to explain differences in morphological processing, children would show different processing patterns than adult native speakers due to their limited WMC.

Still another factor which might result in differences in L2 morphological processing is the learning environment. Formal learning environments which emphasize memorization of visual materials might trigger storage of the target forms, whereas immersion contexts might trigger decomposition by exposing the L2 learners to auditory stimuli (Kırkıcı, 2005; Portin et al., 2008).

Table 3 presents an overview of the studies supporting differential processing of L2 morphology by non-native speakers. Although there is a substantial amount of evidence in favor of non-nativelike processing, there is a lack of a consensus for the employment of single or dual-route systems for morphological processing. These studies have generally replicated the methodologies utilized by dual-mechanism model supporters in L1 studies (Brovetto, 2002, Clahsen et al., 2010).

Table 3. Summary of Key Studies Supporting Nonnativelike Processing of Regular and Irregular Inflection

	Participants	Form	Method	Key Findings
Babcock et al. (2008)	L1 English L1 Chinese-L2 English (intermediate-advanced) L1 Spanish-L2 English (intermediate-advanced)	English Past tense	Speeded Production	Native speakers-Large frequency effects in processing irregular forms Non-native speakers-Equal frequency effects for both regulars and irregulars
Silva & Clahsen (2008)	L1 English L1 Chinese-L2 English (advanced) L1 German-L2 English (advanced)	English Past tense	Masked Priming (SOA:60 ms, 30 ms)	Native speakers- Priming for regular forms Non-native speakers-No priming for regular forms -Greater reliance on memorization in inflected forms (no irregular condition)
Neubauer & Clahsen (2009)	L1 German L1 Polish L2 German (advanced)	German Past tense	Masked Priming (SOA: 60 ms)	Native speakers -Full-stem priming for regular forms, but partial priming for irregular forms Non-native speakers-No priming for regular forms, but partial priming for irregular forms
Pliatsikas & Marinis (2013)	L1 English L1 Greek-L2 English (advanced)	English Past tense	Masked Priming (SOA:50 ms)	Native speakers-Priming for both regular and irregular forms Non-native speakers -No priming for regular forms, priming for irregular forms -Inhibition for regular forms

3.3.3.2 Studies supporting nativelike processing of L2 past tense morphology

This line of research reports that although L2 learners may be slower and less automatic than native speakers, their morphological processing routes appear to be similar. In other words, any changes between the two groups are expected to be quantitative rather than qualitative. Nevertheless, similar to the studies which support non-nativelike processing of L2 morphology, studies which argue for nativelike L2 processing diverge in terms of the nature of the mechanisms adopted by L2 learners in morphological processing.

The earliest studies in this track focused on production data. In one of these behavioral studies, Beck (1997) measured the response times of L2 English speakers producing past tense forms. In the first experiments, she found an unexpected anti-frequency effect for regular verbs in the L1 and L2 groups; that is, response times to the more frequent items were actually slower than that of less frequent items. In the case of irregular verbs, frequency effects were found in the L1 group but not in the L2 group. Upon adding fillers in the experimental design, differences were found between L1 and L2 groups. This time, neither the L1 nor the L2 group's response times were influenced by the frequency of the regular verbs while frequency effects emerged in the production of irregular verbs only in the L1 group. While supporting the dual-mechanism account, the results indicated that L2 speakers processed morphology in the same way as that of native speakers.

Although some studies on L2 learners from various L1 backgrounds do not provide evidence for differential processing patterns among non-native speakers (Babcock et al., 2012; Silva & Clahsen, 2008), some have reported L1 influence on L2 morphological processing (Basnight-Brown et al., 2007). In a cross-modal priming task, Basnight-Brown et al. (2007) presented L1 English, L1 Serbian and L1 Chinese groups with four groups of English past forms: irregular verbs with stem change (e.g., bought–BUY), irregular nested stems (e.g., drawn–DRAW), and regular past tense forms varying in low and high resonance (semantic richness) defined as the number of other words associated with the verb (e.g., guided-GUIDE – low resonance; pushed-PUSH – high resonance). The L1 English group showed facilitation effects in all verb groups, pointing to a unitary route of morphological processing. This may have been revealed by the match in the semantic aspects of regular and irregular verbs, which may have been ignored in previous dual-account studies. In the L1 Serbian group, this facilitation effect was observed only for regular verbs and irregular nested verbs. On the other hand, no facilitation was observed in the processing of nested and stem change irregular verbs in the L1 Chinese group, supporting the influence of L1 on L2 morphological processing. The L1 Serbian's group's facilitated processing of nested irregular verbs can be explained by their analytical approach to processing, whereas the L1 Chinese group's lack of facilitation for irregular verbs can be explained by their tendency for storage. An unexpected finding of this study is both L2 groups' tendency to decompose regular verbs, supporting a reversed version of dual-mechanism account for non-native processing of morphology. This supports the view that non-native speakers can employ decomposition, at least in the case of regulars. However, Clahsen et al. (2010) warn that these counter-results may be confined to cross-modal priming, which taps into later phases of processing associated with semantic effects as opposed to masked priming, which taps into earlier stages associated with morphological effects.

In a more recent study, Feldman et al. (2010) experimented with L1 Serbian learners and native speakers of English through both cross-modal and masked priming tasks. The researchers set up a test design comprising three conditions: Morphological (e.g., billed–BILL), Orthographical (e.g., billion–BILL) and Unrelated (e.g., careful–BILL) and three types of verbs: regular verbs, irregular verbs with similar length of present and past forms (e.g., fell–FALL) and irregular verbs whose present and past forms differ in length (e.g., caught–CATCH). In the masked priming task, native speakers processed all verbs in the morphological condition faster. A similar processing facilitation was observed in L2 learners; the processing of morphological condition pairs was faster compared to the other conditions. Analogous results were obtained in the cross-modal priming experiment in that facilitation was observed for all verb types in the morphological condition and an inhibitory effect was noticed in the orthographical condition in the L1 group. As for the L2 learners, the morphological facilitation effect was repeated, but the magnitude of priming for regular pairs was more pronounced, which is in contradiction with the dual-route accounts. The overall findings contradicted both dual-route and non-nativelike processing accounts. In addition, it was argued that all forms are accessed through a unitary processing mechanism, but formal features such as orthography seems to influence non-native speakers more than native speakers.

Feldman et al.'s (2010) findings support a proficiency-based shift in processing routes. The low proficiency group in the study showed priming effects only for irregular forms at varying lengths unlike the high proficiency group who showed facilitation for regular and irregular forms with fixed length preserved forms, too. This could be interpreted as a proficiency-based shift from storage to decomposition. Kırkıcı's (2005) visual priming study with L1 Turkish-L2 English speakers also documented that storage is more dominant in the processing of both regular and irregular forms at the initial stages of L2 learning. Frequency effects, indicating lack of morphological decomposition, were documented in the processing of both regulars and irregulars in the low, but not the high proficiency group. Although the processing of regular forms took more time than that of irregulars in the latter group, frequency effects were absent in both verb types. The unexpected lack of frequency effects in irregulars in the high proficiency group was explained by the memorization of irregular form lists in formal learning settings. The difference in the two L2 groups' processing routes suggested that with increasing proficiency, decomposition is exploited more in the case of regular verbs and the storage route is confined to the processing of irregular verbs. However, the L1 English group in this study did not show any frequency effects in regular and irregular verbs, which supports nativelike processing in the high-proficiency group and challenges the dual-mechanism system. The researchers account for the unexpected lack of frequency effects in irregular verbs by the small sample size in the L1 English group.

Production studies have also gathered evidence in favor of native-like processing of L2 morphology. To illustrate, Kırkıcı (2010) tested the dual-mechanism hypothesis through presenting Turkish speaking learners of English with novel regular and irregular verbs. The learners' production of two types of inflected verbs was found to follow different mechanisms: decomposition for regulars and full-listing for irregulars, although the learners made more irregularization errors than native controls. Furthermore, a proficiency-based change in processing routes was not evident. Recall that in a previous study on L1 Turkish learners' comprehension of L2 English past tense morphology (Kırkıcı, 2005), evidence to the contrary was found. Whether proficiency-based shifts to native-like processing are confined to comprehension is a matter of question, but there is proof that immersion may trigger nativelike processing. In a production study by Babcock et al. (2012) it was found that both regular and irregular forms tend to be stored by L2 learners of English to a lower degree as length of residence increases.

In order to check the generalizability of findings from L2 English to other languages, languages with different morphological features have also been investigated. In Russian, which exhibits gradient regularity in inflection where there are more than two declension types, frequency effects were reported for both regular and irregular verbs in Russian in both L1 and L2 groups (Gor, 2007; Gor & Cook, 2010). A hybrid theory combining decomposition and input-frequency based probabilistic mechanism has been put forward to accommodate the results and to formulate a theory for processing morphologically rich languages. The theory suggests that composition does not depend on a single rule, but on rules differentiating between default and non-default conjugation patterns (subregular) in the formation of regular verbs. In addition to this, associative patterns also apply to complex word formation (Gor & Cook, 2010). Native speakers, who have received both extensive input and instruction, can employ either storage or decomposition, while L2 learners tend to employ mainly decomposition due to lack of L2 input and smaller L2 mental lexicon. Furthermore, they focus on root access and neglect recomposition after affix-stripping. Proficiency-based changes towards nativelike processing are explained by the proceduralization of knowledge theory (DeKeyser, 2007).

Evidence of from L1 English-L2 Turkish learners converges with the rules and probabilities for morphologically rich languages. Gürel and Uygun (2013) have found that both L1 and highly proficient L2 speakers of Turkish use the storage route to process complex morphology in order to avoid additional computational costs, whereas lower proficiency L2 learners might resort to conscious decomposition since they have not proceduralized full-listing of complex words. This study promotes the idea of proficiency-dependent gradual approximation to native-like processing patterns. However, unlike the chunk storage then decomposition view (e.g., Gor, 2015; Gor & Jackson, 2013), this study involving an unmasked lexical decision paradigm argues that conscious decomposition of morphology is a marker of low-level L2 proficiency. L2 learners, like native speakers of a morphologically-rich language tend to store multimorphemic words as chunks to avoid decomposition for the sake of computational efficiency.

An overview of the key studies providing evidence for nativelike processing of L2 morphology can be found in Table 4. The majority of the studies have used the masked priming paradigm and its variants in order to trace morphological priming effects and shown that nativelike patterns of L2 processing is possible at least at higher levels of proficiency. The differences within and across studies supporting nativelike or nonnativelike processing of L2 morphology may be related to the variety of the methods employed (i.e., masked priming, cross-modal priming, production, etc.) and the variability among items and participants (Veríssimo, 2015).

Table 4. Summary of Key Studies Supporting Nativelike Processing of Regular and Irregular Inflection

	Participants	Form	Method	Key Findings
Basnight-Brown et al. (2007)	L1 English L1 Serbian- L2 English (upper-intermediate) L1 Chinese-L2 English (upper-intermediate)	English Past tense	Cross-modal Masked priming (SOA:50 ms)	-Facilitation for regular forms in all groups. -Facilitation for nested irregular forms in both in L1 English and Serbian groups. -Facilitation for stem-change irregular forms only in L1 English group. -Possible L1 influence in L2 morphological processing.
Feldman et al. (2010)	L1 English L1 Serbian-L2 English (upper-intermediate)	English Past tense	Masked priming Cross-modal priming (SOA:50 ms)	-At low proficiency levels, L2 speakers may diverge from L1 speakers, BUT at high proficiency levels they process morphology similar to L1 speakers. -Priming effects for both regular and irregular forms.
Kırkıcı (2010)	L1 English L1 Turkish-L2 English (advanced)	English Past tense	Production	-Non-native speakers followed the dual-route processing in production of regular and irregular past forms similar to L1 speakers.
Gor & Jackson (2013)	L1 Russian L1 English-L2 Russian (advanced)	Russian Verb Conjugations	Cross-modal priming	-Both L1 and L2 speakers decompose morphologically complex words. -L2 learners beyond low proficiency decompose inflected words like native speakers.
Coughlin & Tremblay (2015)	L1 French L1 English-L2 French (advanced)	French -er Verb conjugation	Masked Priming Word Naming (SOA:50 ms)	-Both L1 and L2 speakers decompose morphologically complex words. -Mid-high proficiency L2 learners decompose inflected words like native speakers.

3.3.4 Summary

On the basis of the previous studies on L2 morphological processing, it is hard to reach a conclusion regarding the possibility of achieving nativelikeness in the pattern of processing for inflections. Employment of various methodologies (e.g., masked and/or cross-modal priming, ERP, fMRI) which differ in terms of sensitivity of measurement, use of visual or auditory stimuli, focus on comprehension or production, the use of varying frequency counts may underlie these conflicting results. Nativelike and non-nativelike processing accounts converge on the idea that there may be a gradual proficiency-based shift to nativelike morphological processing. However, there is no agreement on the nature of this shift; while the proponents of the Declarative/Procedural Model suggest a shift from storage to decomposition, the proponents of the Rules and Probabilities Model advocate a shift from decomposition to storage. It is of significance to note that the Declarative/Procedural Model is based on evidence from morphologically impoverished languages, while the latter model is based on evidence from morphologically richer languages. Another notable trend is that the majority of the studies have analyzed morphological processing in the single word context. It is crucial to analyze morphological processing in the sentence context in order to arrive at more reliable conclusions. The following section provides an overview of the studies exploring morphological processing in words within a sentence context.

3.4 Processing L1 morphology in the sentence context

As noted earlier, the majority of the morphological processing literature has focused on processing words in isolation. Recently, efforts have been directed to understanding whether the results obtained in these studies can be generalized to the sentence context, which presents a more natural environment for visual processing of words. Some researchers do not deem possible the presence of two different processes for identifying words in isolation and in context, due to redundancy of two mechanisms for a relatively automatic process (Rayner et al., 2012). However, it might be the case that the lexical decision task oriented single-word processing research is biased by the decision-making component of the methodology or other factors specific to the word context. As Bertram (2011) maintains, it is necessary to employ a variety of methods in order to tap into different stages of processing and reach a clear understanding of morphological processing routes. In the following sections, morphological studies carried out on the sentential context will be elucidated with a specific focus on English verbal morphology.

3.4.1 Sentence context L1 morphological processing studies

Randall and Marslen-Wilson's (1998) study on the processing of English verbal morphology can be considered to be one of the earliest studies involving sentence context. In this study, regular and irregular verbs of high and low frequency were embedded in the same sentence context and native English speakers were asked to read the sentences in a self-paced reading test. The results revealed that regardless of frequency, regular verbs were read more slowly than irregular verbs.

More recently, Luke and Christianson (2011) compared the stem (root) and whole-word frequency effects in past tense inflected English verbs through a lexical decision task and self-paced reading task. In the isolated word context, solely stem frequency effects were found, pointing to decomposition. However, when presented in sentences, the same inflected words yielded whole-word frequency effects, implying storage-based processing. This study highlighted the importance of task effects in measurement of morphological processing routes in accessing multimorphemic words.

Apart from these, ERP studies investigating morphological processing in the sentence context have become more common. One of the most well-known of these is Allen, Badecker and Osterhout's (2003) study on English past markers. As in self-paced reading studies, regular and irregular inflected verbs differing in frequency were embedded in grammatically correct and violated sentences. The sentences involving regular inflection yielded P600 effects, associated with grammatical processing in the literature, regardless of frequency. P600 effects, which were also observed in the case of irregular verb sentences, interacted with frequency; stronger P600 effects were produced in higher frequency irregular items. Moreover, the P600 effects emerged later in regular form violations when compared to that of high frequency irregular forms, highlighting the relatively complex and taxing decomposition process in the regular forms once more. These discrepancies reinforced the dual-mechanism assumption in verbal inflection processing in English.

In a subsequent ERP study, Newman et al. (2007) created grammatically violated sentences by presenting past regular and irregular verbs in their infinitive form, thus omitting the past markers (e.g., *Yesterday, I whip an egg.). Regular and irregular verbs were also presented in sentences with word category violations (e.g.,*Yesterday I drank Lisa's brandy the fire.) and in a third group of sentences with semantic violations (e.g., *Yesterday Daniel sipped his sarcasm for hours). The word category violations yielded LAN effects for the regular verbs. The semantic violations yielded N400 effects. The lack of LAN effects in the irregular verbs was interpreted as evidence for the dual-mechanism accounts of morphological processing.

In general, the sentence context processing studies have produced diverging results for explaining morphological processing mechanisms, but especially the ERP studies have sustained the dual-mechanism accounts.

3.4.2 Eye movement studies in L1 morphological processing

The eye tracking paradigm is commonly adopted in sentence processing research. Recently, it has also been adopted in morphological processing research, especially with regard to compound processing (Bertram, 2011; Pollatsek & Hyönä, 2006). Kuperman et al. (2013) posit that eye fixations might be better indicators of lexical processing when compared with lexical decision tasks, considering the fact that LDTs boost strategic thinking and decision making. Self-paced reading may compensate for this weakness; however, it yields only the total reading time values and does not provide a natural reading environment. The strength of the eye tracking paradigm is its ability to differentiate between early (unconscious) and late (more conscious) phases of processing under normal reading conditions.

In eye tracking literature, the eye's rapid movements from one point to another are called 'saccades' (20-40 ms, 8 letters on average) and the times when the eye focuses on a specific point or area are called 'fixations' (200-250 ms on average for adults) (Rayner et al., 2012). In adult readers, nearly 85 percent of the saccades are forward saccades while the rest are 'regressions', associated with comprehension difficulty (Rayner, Pollatsek, & Shotter, 2012). A rigorous body of research has arrived at certain converging assumptions with regard to eye movements in reading:

1. The average fixation duration on a word by adult readers is 200-250 ms (Rayner & Pollatsek, 2006).
2. Short words (e.g., function words) have a higher chance of being skipped or receiving shorter fixation durations due to parafoveal preview advantage[6]. Longer words (eight letters and longer) as well as content words have a lower skipping probability (Rayner et al., 2012).
3. It is assumed that longer complex words tend to be processed via decomposition, while shorter words tend to be full-listed (Bertram & Hyöna, 2003).
4. High frequency words tend to be skipped more and fixated for a shorter time (Rayner & Duffy, 1986).
5. Words at the end of a sentence receive higher fixation duration due to sentence wrap-up effect, indicating the integration of syntactic information (Just & Carpenter, 1980). Similarly, words at the beginning of a sentence are prone to high skipping rates or start-up effects (Rayner et al., 2012). Therefore, these two areas are not ideal for measuring processing while reading.
6. Words that can be predicted based on context have a higher skipping rate and receive relatively shorter fixations (Rayner, Pollatsek, & Shotter, 2012).
7. Morphologically complex words receive longer fixation durations than length-matched monomorphemic words (Hyöna, Vainio, & Laine, 2002).
8. Other factors that might influence reading times for words include word familiarity, phonological neighborhood, age of acquisition, and lexical ambiguity (see Rayner & Pollatsek, 2006 for a review).

[6] When a reader looks at the word n, some or all parts of the following word, n+1 is also previewed, creating a processing advantage for this word (Rayner & Pollatsek, 2006).

The most commonly adopted reading time measures in morphological processing inquiries are first fixation duration and gaze duration, since they tap into early phases of processing (see Table 5). Late processing measures are also analyzed in order to understand the stages of word recognition.

Table 5. Interpretation of Reading Time Variables in Morphological Processing

Early processing measures	
First-fixation duration	Duration of the first (or single) fixation time on the target region. If the region received a single fixation, it is also called the single fixation duration.
Gaze duration	The summed duration of all fixations on the target region before moving to either direction (if the region is a single word, gaze duration is the first pass time)
Skipping rates	The probability of passing the target region without fixating it.
Late processing measures	
Second-fixation duration	The time spent rereading the region after leaving it.
Spill-over duration	The duration of the fixation on the spill-over region (one or two words following the target word)
Total reading time	The sum of all fixation durations on the region including fixations following regressions (gaze duration + second pass duration)

(Based on Niswander-Klement & Pollatsek, 2006)

In one of the earliest eye movement studies on the processing of English inflections, Lima (1987) documented longer fixation durations for pseudo-prefixed words (e.g., rescue) in comparison to prefixed words (e.g., revive). The interpretation of this finding was that the root of the real prefixed word “vive” can be accessed more easily than that of the pseudo-prefixed word. This was taken as further evidence for affix stripping accounts. Similarly, Niswander, Pollatsek and Rayner (2000) reported root frequency effects on the fixation durations of derived words (e.g., government). They also compared the reading times for regularly inflected past verbs differing in whole-word and stem-frequency. Stem-frequency effects, indicative of decomposition were not reported for regularly inflected verbs. The lack of decomposition effects for regulars was accounted for by the fact that the noun equivalent of the target verbs had higher frequency than the verb forms. Another possible explanation for storage effects in inflected words is that the length of the target verbs (i.e., 6 characters) might not be long enough to induce decomposition. Still another explanation may be the relative length of the suffix (-ed) to the root: if the suffix is relatively short, the root can easily be accessed, without yielding extra processing cost (Pollatsek & Hyöna, 2006).

In a further eye tracking study, Niswander (2003) investigated the processing of the past inflection suffix (-ed) in English. This time, all of the target verbs were selected to be verb-dominant in terms of frequency. Effects of whole-word frequency were found in both early and late reading time measures, pointing to direct access to inflected forms, as in the previous study. Small root frequency effects were also obtained in second-pass reading times, which was interpreted as the presence of a dual-route processing route dominated by direct-access. A dual frequency effect (both root and whole-word frequency effect) trend was also found in the fixation durations of English prefixed words in a later study (Niswander-Klement & Pollatsek, 2006).

The regular-irregular processing discussion was revisited by Cunnings and Clahsen (2008) in an eye movement study, this time with the focus on nominal morphology. In a series of experiments, it was understood that the constraint that regular verbs (e.g., *rats eater) are not acceptable inside compounds in contrast to irregulars (e.g., mice eater) was also valid for nominal morphemes (*fleasless vs. liceless). Derived words containing regulars were found to receive more total viewing times than that of irregulars, which accentuates an underlying morphological processing difference.

In a more recent eye-tracking study, suffixed English words (ending in –er/or, -ist, -ing) with varying stem and whole-word frequency were embedded in sentences. An analysis of fixation-durations on the target words revealed that high stem-frequency suffixed words induce a competition between full-form and decompositional processing in skilled readers (Kuperman & van Dyke, 2011). Poor readers, on the other hand are less influenced by such a competition as they have not developed highly automatized full-form representations.

The eye-tracking paradigm has also proved to be a valid tool for scrutinizing into processing of complex forms in morphologically rich languages like Finnish. Hyöna, (2002) have highlighted the role of context in processing by comparing RTs for inflected nouns by means of a lexical decision task and two sentence reading tasks. The lexical decision task yielded longer reaction times to inflected words than frequency and length-matched monomorphemic words. In the sentence context, this processing effort was not observed in the fixation durations and RTs. The researchers speculated that this may be a processing facilitation triggered by the syntactic and/or semantic context. The processing effort seen in lexical decision tasks may indicate efforts of syntactic/semantic integration.

The results of a recent eye movement study confirm the facilitating effect of the syntactic properties of sentence context in the processing of English inflections (Luke & Christianson, 2015). In this study, transposed letter effects (transposing two letters in a word, e.g. judge-*jugde) caused more disruption in fixation durations when the inflected verbs were transposed. This strongly embraces the assumption that speakers make powerful predictions about what to expect in a sentence based on the syntactic context and provides further support for the facilitating role of sentence context in morphological processing.

3.5 Processing L2 morphology in the sentence context

As in the L1 processing literature, studies investigating L2 morphological processing in the sentence context are limited although there has been a noticeable interest in this area in the recent years.

3.5.1 Sentence context L2 morphological processing studies

In the domain of L2 English, Pliatsikas & Marinis (2012) have compared morphological processing in the word and sentence context. They presented L1 English and highly proficient L1 Greek-L2 English participants with sentences containing regular, irregular, regularized (e.g., feel-*feeled) and irregularized (e.g., reach-*raught) forms. The reaction times for the target verbs as measured by means of a self-paced reading test revealed a processing cost for the regular forms. Similarly, a processing cost was reported for the irregularized forms comparative to the regularized forms in both groups. Nevertheless, a subsequent masked priming study on past forms in English revealed non-nativelike morphological processing patterns, highlighting the discrepancy between sentence and isolated word context investigations (Pliatsikas & Marinis, 2013). In contrast to the processing cost for regular verbs in the sentence context for the L2 group, a priming effect was not found in the masked priming experiment.

In another moving window self-paced reading study, Dronjic (2013) compared reading times for the English past tense, plural and present tense singular inflection by L1 English, Korean, and Chinese speakers. Grammatical and ungrammatical (with morpheme omission) sentences with or without memory load were presented to participants, requiring the reader to make a mathematical calculation concurrent with sentence reading in order to report the result after finishing reading. Surprisingly, sensitivity to violations of inflectional morphology was evident in the L2 English groups, but not in the L1 English group. However, with regard to derivations, L1 English speakers displayed early sensitivity to violations of derived forms and did not slow down after the morpheme violations contrary to the L2 English groups. Moreover, the L1 Korean group performed more nativelike than the L1 Chinese group, which was interpreted as a possible L1 influence effect.

The violation paradigm is also a commonly employed tool in ERP research. Hahne, Müller and Clahsen (2006) utilized this paradigm in order to examine how L1 Russian L2 German learners responded when they were presented with regular and irregular verbs embedded into the final position of sentences. Some of the past forms were overregularized while some were irregularized. The irregularized regular verbs yielded late anterior negativity (LAN), which is interpreted as response to morphological violations while regularized irregulars yielded N400 effects, indicative of lexical violations. Therefore, it could be argued that L2 learners processed the violations in the same way as native speakers, and differentiated between the two verb types. However, the LAN effects were more powerful in the L1 group, pointing to subtle differences between native and non-native morphological processing.

As can be understood from the limited research, studies pointing to nonnativelike processing of L2 morphology are fewer when the sentence context is utilized and supplemented with more advanced instruments. The dearth of sentence-context studies necessitates carrying out more research in different L1-L2 pairs through manipulations of the sentence context in comprehension and production.

3.5.2 Eye movement studies in L2 morphological processing

Eye movement studies on the processing of inflections in an L2 are even more limited within the scope of sentence context studies; therefore, the most relevant of the available studies will be discussed here.

In an eye-movement study with L2 learners of English, involving nominal inflection, Clahsen, Balkhair, Schutter and Cunnings (2013) replicated their previous study on processing regular (e.g., pigsless) and irregularly (e.g., oxenless) inflected plural nouns inside derived words (Cunnings & Clahsen, 2008), this time including an L2 English group. The L1 English group showed longer fixation durations to the regular plurals in comparison with the irregulars due to sensitivity to the violation of the morphological constraint. Such a discrepancy was not observed in the L2 group, comprising advanced L1 Dutch learners. The L2 group showed sensitivity to morphological constraints for the regulars only in a grammaticality judgment task. This was taken as evidence that L2 learners are not only slower but also less sensitive in terms of morphological processing.

With a focus on the role of attention in L2 learning, another eye movement study investigated the processing of regular and irregular past inflection in L2 German. The findings revealed that beginner L2 learners fixate more on irregular verbs, which contain stem changes in comparison with regular verbs, which lack stem-change (Godfroid, 2013). This can be interpreted as evidence for sensitivity to morphological markers, at least in L2 German.

The previous literature suggests that eye movement monitoring has proven to be a promising ground on which L2 morphological processing assumptions can be tested. A relatively more naturalistic reading environment it provides during testing and the ease of distinguishing between early and late processing has the potential to contribute to existing research.

3.6 Overview of L2 morphological processing research

Studies on L2 inflectional processing have generally investigated whether nativelike processing is viable for L2 speakers. The regular-irregular distinction has been commonly used as a ground for testing this assumption. L1 morphological processing research has generally reported priming effects and decomposition for regular verbs (Lignos & Gorman, 2012; Silva & Clahsen, 2008; Ullman, 2004) with a few exceptions (Alegre & Gordon, 1999; Prado & Ullman, 2009), but the results related to irregular verbs are more divergent (Crepaldi et al., 2010; Rastle, et al., 2015; Stockall & Marantz, 2006). The same divergence is also observed in L2 processing. While some studies point to nonnativelike patterns in the processing of inflection (Babcock et al., 2012; Silva & Clahsen, 2008), more recent studies have gathered evidence in favor of nativelike patterns (Basnight-Brown et al., 2007; Feldman et al., 2010). The variety of the methods employed (i.e., masked priming, cross-modal priming, production, etc.) and the variability among items and participants may underlie this diversity (Veríssimo, 2015). In addition, the majority of the literature is based on word processing in the single word context and the limited amount of studies carried out in the sentence context yield results that contrast with word context studies (Niswander, Pollatsek, & Rayner, 2000; Pliatsikas & Marinis, 2012). Therefore, more studies in the sentence context are needed to be carried out by means of more sensitive measurement techniques like eye tracking in order to generalize findings obtained in the isolated word context.

CHAPTER 4

THE ROLE OF WORKING MEMORY IN L2 MORPHOLOGICAL PROCESSING

The construct of WM can be defined as a multi-component, limited-capacity computational resource for cognitively complex operations, such as learning, information-processing and language comprehension (Baddeley & Hitch, 1974, p. 77). It involves not only processing but also temporary storage of information. The simultaneous storage of information while processing other stimuli requires strategies like sub-vocal rehearsal and visuo-spatial coding. These strategies facilitate continuous updating and storage of the information at hand. In this vein, WM is believed to tap into tasks in which there is storage/processing trade-off in contrast to short-term memory (STM), which refers to the storage of information for a few seconds without rehearsal (Petersen & Peterson, 1959) and long-term memory (LTM), where information can be retained for an indefinite period of time (Atkinson & Schiffrin, 1968).

4.1 Models of working memory

The construct of WM was proposed as an enhancement to short-term memory (Atkinson & Schifrin, 1968). The earliest and still the most widely accepted model of WM is the multi-component model of Baddeley and Hitch (1974). According to the latest version of the model (Baddeley, 2003), WM functioning relies on the central executive and its two slave subcomponents– visuo-spatial sketchpad and phonological loop. The function of the central executive is to manage the allocation of attentional resources while inhibiting sources of interference in tasks which require both processing and storage. In the phonological loop, verbal information is stored (for about 20 seconds) and rehearsed whereas visual sketches are formed in the sketchpad subcomponent in order to prevent the decay of information. The most recent addition to the model is the episodic buffer, which maintains communication between the WM subcomponents and the long term memory (Baddeley, 2000).

Like Baddeley, Caplan and Waters (1999) also support a modular view of WM. They assert that there are multiple resources of WM, serving different cognitive operations and stimuli. In terms of verbal WM, a differentiation is made between online interpretive processing for automatic and low-level processes (word recognition, lexical, syntactic activation to understanding the meaning of a sentence) and controlled post-interpretive processing (comprehension of sentence meaning to perform an activity such as remembering a to-do-list). It is suggested that the former processes rely less on WM when compared with post-interpretive processes.

Although a multicomponent model is widely accepted as the basis for the analysis of WM in many areas, other WM models adopt a unitary resource WM concept. Just and Carpenter (1992, p. 144) argue that both processing and storage components rely on shared resources. This creates a trade-off between processing and storage. It is also hypothesized that working memory capacity (WMC) varies from individual to individual. Possible sources of this variation are hypothesized to be attentional control and general cognitive resources. When the attentional demands of a task exceed the individual's computational and storage resources, performance of the WM is expected to decrease.

More recent models of WM focus on attention in the manipulation of WM resources. Cowan's (2005) Embedded-Processes Model views WM as a general ability to control attention in coordination with LTM when there are distracting sources. The LTM hosts items to be remembered at different levels of activation. An item can be brought to immediate access- focus of attention (FOA), when it is activated at a relatively conscious level. While LTM is not capacity-limited, FOA is capacity-limited, and therefore more prone to individual differences. This model does not consider WM and LTM to be separate components, but as the activated and unactivated forms of the same construct. In terms of language processing, Cowan (2011) argues that WM relies on both attention-dependent and independent processes.

Similarly, Engle and Kane (2004) place executive attention at the center of WMC. In this model, LTM traces are activated in the STM if they pass the threshold level through rehearsal processes. The role of the executive attention is to inhibit irrelevant stimuli and maintain relevant stimuli actively in the STM.

4.2 Assessment of working memory

WM tasks, in other words, complex-span tasks, measure domain-specific storage skills such as chunking and rehearsal as well as the domain-general skill of maintaining cognitive control and executive attention (Conway et al., 2005). They involve a storage and a concurrent processing component. In this respect, these complex-span tests differ from simple-span or STM tests (e.g., digit span task) which require only immediate recall of stimuli.

The most widely used measure of WM in psycholinguistics studies is the Reading Span Task (RST) (Daneman & Carpenter, 1980). In the RST, participants read sets of sentences which are presented one to two words at a time on a computer screen and judge the semantic plausibility or grammatical accuracy of the sentences at certain intervals. At the end of a set, they are asked to remember the last words of the sentences or the words presented at the end of the sentences in the order of presentation. The number of the sentences to be read increases incrementally but in general the range is between two to six sentences (Conway et al., 2005).

Since the RST requires near-native level knowledge of the language of the test, nonlinguistic measures of WM have also been developed. The Operation Span Task (Turner & Engle, 1989) and Counting Span Tasks (Case, Kurland & Goldberg, 1982) are the most frequently adopted nonlinguistic counterparts of the RST. They involve non-linguistic tasks, such as performing mathematical calculations or counting the number of specific shapes. Another way to eliminate the influence of language is to test recall of letters rather than words (Conway et al., 2005).

In the WM field, there is a controversy over the application of WM tests to individuals in a non-native language. On one hand, there is evidence suggesting that L1 and L2 WM scores usually strongly correlate (Miyake & Friedman, 1998; Osaka & Osaka, 1992). On the other hand, some studies have found evidence to the contrary. Gass and Lee (2011) found that L2 users' WM scores were higher in the L1 in the low proficiency group in their study. This implies that L2 proficiency may modulate WM performance in the L2. Vejnovic, Milin and Zdravković (2010) also found evidence that even at advanced levels of proficiency, L2 learners may not reach an automatization level in processing which is comparable to their L1. Although these results require careful investigation of WMC as a language-(in)dependent construct, more recent studies have also found evidence in favor of correlating L1 and L2 WM scores, at least in advanced proficiency groups (Alptekin & Erçetin, 2010; Çele, 2010; van den Noort, Bosch, & Hughdal, 2006). On the basis of these findings, proficiency in the task language seems to be a prerequisite for comparable WM scores in the L1 and L2. In a similar vein, Mitchell et al. (2015) advocate the use of nonlinguistic measures since L2 proficiency might influence the results. They suggest using digit span tasks for low-proficiency L2 users and more complex span tasks for high-proficiency L2 users.

Previous studies investigating the relationship between WM and language processing have usually adopted the RST (Juffs & Harrington, 2011). Nevertheless, a high correlation has been found among different WM measures (i.e., operation span task, counting span task) (Conway et al., 2005). The current norm in measuring WMC is to adopt multiple measures to eliminate task-specific effects.

4.3 The role of WM in morphological processing in the L1

In language processing, linguistic information is stored and processed simultaneously, which indicates potential exploitation of WM resources. The majority of the previous psycholinguistics research has focused on the relationship between WM and complex sentence comprehension (Miyake & Friedman, 1998). It has also been proposed that WM might play a role in the acquisition of language, particularly vocabulary learning in early years of life (Baddeley, 2001).

In terms of processing, it is suggested that WM is closely related with reading comprehension (Linck et al., 2014); however, it is assumed that word recognition processes involved in reading may be automatized and therefore do not require WM resources (Just & Carpenter, 1987; Leminen et al., 2013). For this reason, a portion of the previous related research has directed its focus to children and people with reading and learning disabilities, who may require more WM resources and attentional demands for effective word recognition (Horn & Manis, 1987; Swanson & Ashbaker, 2000).

On the other hand, there is accumulating evidence suggesting that attentional mechanisms have an influence on at least some levels of word processing (Acheson & MacDonald, 2009; Ferreria & Pashler, 2002). In reading, word recognition competes with other processes for attentional resources, and thus WM differences may lead to variation (Perfetti, 1985). Early studies have shown that low-frequency words require more WM resources than high-frequency words and performance on lexical decision and naming task in dual-task conditions is influenced by WMC (Herdman, 1992).

The reason why some studies fail to find an effect of WM in word recognition might be the task employed. Caplan & Waters (1999) suggest that a specialized WM system may subserve word recognition, an instance of interpretive processing of language, as opposed to post-interpretive processing related to semantic aspects of sentence comprehension. They argue that complex memory span tasks might not tap into interpretive operations.

Previous research on the automaticity of word recognition is mostly based on relatively short and frequent words (Rayner et al., 2012). The morphological complexity of words may present a different case with less automatic processing due to increased processing demands. In recent years, this relationship has received interest in a number of studies pointing to a relationship between the recall of morphologically complex words and WM. In two of these studies, Finnish children (dyslexics and non-dyslexics) and adults' recall of monomorphemic and multimorphemic words was compared in an auditory word span task and a reading span task (Service & Maury, 2015; Service & Tujulin, 2002). In both tasks, the recall of Finnish inflected and derived words was found to be harder than that of morphologically simple words. In addition, derived words were found to be recalled with more ease than inflected words in the simple memory span task.

In another study, Hungarian-speaking adults were given auditory and visual word span tasks consisting of inflected and derived words with differing number of syllables (2-3 syllables) and suffixes (1-2 suffixes) (Nemeth et al., 2011). In the experiments, the effects of derivational/inflectional morphology and regularity on the STM performance were examined. Regardless of the modality of the word span task (auditory vs. visual), recall performance decreased as the number of suffixes increased. Words with higher surface frequency were recalled more easily than words with higher stem frequency, mainly in the case of two-suffix words. The researchers believed that this can be explained by the chunking account of WM in that the number of morphemes that can be chunked determines the episodic buffer capacity. As for the suffix type, derived words were found to be recalled more efficiently than inflected words as evidenced in previous studies (Service & Tujulin, 2002). However, an interesting result of this study was that regularly inflected nouns were relatively easier to process than irregularly inflected nouns. This might have stemmed from the complex nature of Hungarian irregular word formation which requires both storage and composition.

Diverging results were reported in a study where Arabic-speaking children were shown to recall regularly inflected words more poorly than irregularly inflected words and base forms in a listening word span task (Cohen-Mimran et al., 2012). This could be interpreted as the involvement of decomposition in inflected words and points to language-specific factors in morphological processing.

The interaction between regular-irregular inflection and WM was also documented in English. McDonald (2008) suggests that English-speaking children's morphological errors involving regular verb production are affected by WMC. In contrast, it is argued that omission of function words and lower phonetic substance morphemes are affected by phonological ability.

More recently, Fleischhauer and Clahsen (2012) found that WMC influences the way children and adults recognize and produce regular and irregular inflected words in L1 German. Children were found to exhibit adult-like performance in the sense that they produced high frequency irregular but not high frequency regular verbs more slowly. However, the low WMC group exhibited anti-frequency effects for regular forms. This reversed frequency effect was accounted for by the activation of two routes in competition with each other. It was hypothesized that the low WMC group could not deal with two competing morphological processing routes effectively, which resulted in slower processing. However, it should be noted that WMC was measured by means of short-term memory measures (i.e., word span tasks) instead of complex-span tasks in this study.

The role of attention, a WM-related construct, has also been questioned with regard to morphological processing. In an ERP study, recognition of spoken inflected words was compared through attended (where participants judged the acceptability of the stimuli) and non-attended tasks (where participants watched silent cartoons and ignored incoming spoken stimuli) (Leminen et al., 2013). In both attended and non-attended tasks, early activation signals were found, which were interpreted as indicators of automatic processing. However, in the attended task, inflected words were found to elicit larger effects than monomorphemic words at a later time frame (200 ms). This late processing cost for inflections hints at controlled semantic-syntactic integration processes, which come into effect only in the presence of attention.

As an eye-movement monitoring study has suggested, individuals' word segmentation abilities might also play a role in their morphological processing patterns (Kuperman & van Dyke, 2011). It was observed that readers with high verbal ability experienced more competition between direct access and decompositional routes when processing suffixed English words. Readers with poor reading abilities on the other hand made use of morphological cues in word recognition and thus applied constituent-based morphological processing since they did not have strong whole-word representations. This brings to mind the question whether individuals with high WMC can handle this purported morphological competition more effectively.

Overall, studies examining the interaction between morphological complexity and WM point to the involvement of morphological factors (besides phonological, syntactic and semantic factors) in the functioning of WM resources. Whether the collected evidence can be confirmed in the case of child and adult L2 speakers is an area for further research.

4.4 The role of WM in morphological processing in the L2

Considering the role of WM in L1 processing, it is natural to expect a similar, even a greater WM effect in L2 processing since L2 processing is less automatized, especially in the earlier phases (Abutalebi & Green, 2007).

Research on the role of WM in L2 processing has mainly focused on the comprehension of complex syntactic structures such as long-distance wh-movement, relative clauses, anaphor resolution, reading comprehension (see Juffs & Harrington, 2011 for a review). It is also suggested that WMC can be an indicator of L2 aptitude (Miyake & Friedman, 1998). Furthermore, the phonological loop component is considered to be important in the learning of new L2 vocabulary (Baddeley, 2003).

Although some researchers assert that the role of WM in L2 learning is overstated (Juffs & Harrington, 2011), a recent meta-analysis has shown evidence to the contrary, suggesting that WM has a robust relationship with L2 processing (Linck et al., 2014). The strength of this relationship seems to be moderated by L2 proficiency; the correlation of L1 and L2 WM scores are expected to be higher as the proficiency increases, but the relationship between WM and performance in linguistic tasks might be less strong in this case.

Addressing the need to reach a broader understanding of the role of WM in L2 processing, Wen (2015) has recently proposed The Phonological and Executive Model. Under this view, it is suggested that phonological working memory (PWM) supports the developmental aspects of L2 learning of vocabulary, formulaic sequences and morphosyntax, whereas executive working memory (EWM) supports more attention-controlled performative processes such as L2 comprehension and production. From a developmental perspective, L2 learners are expected to rely more on the PWM in the initial stages and more on the EWM at highly proficient stages.

As in L1 processing, L2 processing of morphologically complex words can very well be linked to WMC. After all, adult L2 acquisition is subject to individual differences and most L2 learners are generally slower than native speakers, which might be due to a lower WMC in the L2 (Miyake & Friedman, 1998). Reduced automaticity in L2 word recognition might induce additional WM load in L2 processing.

From a cognitive processing viewpoint, McDonald (2006) suggests that in addition to grammatical proficiency, low L2 WMC, slower decoding and processing speed prevent late L2 learners from reaching a native-like competence level. In her study, she found evidence that WMC and decoding skills influence recognition of grammatical errors in the L2. A similar difficulty was observed in native speakers when they were exposed to extra processing load (e.g., noise, time limitations). This implies that nonnative L2 speakers might perform nativelike as their WMC, decoding skills and processing speed in the L2 improve at advanced levels of proficiency. In other words, the processing differences between native and non-native speakers are quantitative rather than qualitative in nature.

There are few studies investigating L2 morphological processing in relation to WM performance. The earliest studies in this fairly underresearched area have investigated the trade-off between allocating attentional resources to morphology in the presence of distracting lexical cues. Since it is generally reported that adult L2 learners rely on lexical processing, especially in the initial L2 state, morphological sensitivity is expected to be relatively lower (Clahsen et al., 2010; Ullman, 2004). However, it has been observed that high WMC beginner L2 learners tend to attend to (redundant) morphological cues more than low WMC learners when both morphological (e.g., past tense marker) and lexical cues (e.g., the adverb ‘yesterday’) specify the same or contradicting temporal reference adverb-verb temporal ambiguities (Sagarra & Dussias, 2001; Sagarra, 2007).

More recently, Dronjic (2013) examined the relationship between morphological processing of inflection and derivation and WMC. In a self-paced reading experiment where L1 and proficient L2 English speakers' sensitivity to morphological violations was measured, a relationship between derivation processing and STM and WM scores was demonstrated among L2 learners, but not in native speakers. Furthermore, in the presence of concurrent memory load in the self-paced reading task, instead of slowdown in the morphological violation conditions, speed-ups were observed across all groups in the processing of derivations, but not inflections.

Another factor—exposure to natural spoken language is also suggested to be a significant factor in directing attentional resources to morphological cues in a morphologically rich L2 (La Brozzi, 2009). It was reported that English-speaking learners of L2 Spanish with higher WMC focused more on morphological cues in sentences than on lexical cues after having an immersion experience. This suggests that unlike formal L2 learners, who rely mostly on lexical information rather than morphological computation, naturalistic L2 learners with increased WMC can more easily allocate attentional resources to morphological cues.

Although some researchers argue that the general trend for insensitivity to L2 morphology cannot be accounted for by cognitive resource limitations and processing speed (Clahsen et al., 2010), it is early to arrive at a conclusion until more studies with a specific focus on individual differences are conducted.

4.5 Conclusion

The relationship between WM and L2 learning and processing has received a lot of interest in the past decade. The majority of the studies have focused on the link between WM and sentence processing, with inconclusive results. With regard to L2 morphological processing, there is little evidence to suggest whether WM can explain some of the variability among learners. Some of the limited data relate WM load with the recall of inflected words as opposed to monomorphemic and derived words (Nemeth et al., 2011; Service & Maury, 2015; Service & Tujulin, 2002). Within inflected words, analysis of the regularity distinction has yielded contradictory results, with some studies reporting a higher WM load for regularly inflected words (Cohen-Mimran et al., 2012; Service & Tujulin, 2002) while others failing to find a WM load difference (Nemeth et al., 2011).

CHAPTER 5

METHODOLOGY

The aim of the present study is to compare native and nonnative English speakers' online processing of inflectional morphology (as measured by masked priming and eye-tracking tasks) in relation to the role of Working Memory Capacity (WMC). More specifically, the aim is to investigate the extent to which L2 learners' morphological processing pattern (i.e., decomposition or full listing) can be linked to high or low WMC as measured by both Reading Span and Operation Span Tasks. Online morphological processing will be investigated in inflected words both in isolation but also in a sentence context.

The study has two main components:

1. The examination of the morphological processing pattern(s) in decoding L2 morphology: Identifying the online inflectional processing pattern (i.e., decomposition versus full-listing) of L1 Turkish-L2 English speakers in comparison to native L1 English speakers
   a) at the word level via lexical decision task with masked priming
   b) at the sentence level via eye tracking
2. The assessment of WMC via two different tasks (Reading Span Task, Operation Span Task)

5.1 Research questions

The research questions and predictions are formulated as follows:

1. Is there a difference between L1 and L2 speakers of English in terms of the processing routes (i.e., decomposition or full-listing) while decoding morphologically complex words (i.e., regularly and irregularly inflected English verbs) presented in isolation (i.e., in the word context)?

Prediction:

Given their high proficiency level, advanced level L2 speakers of English are not expected to differ from L1 speakers of English in terms of morphological processing of verbal inflection in English as recent studies have established (Basnight-Brown et al., 2007; Coughlin & Tremblay, 2015). For regular verbs, decomposition effects, revealed in comparable priming facilitation (shorter RTs to the target upon seeing a related prime) in the RTs to the identity and morphological conditions in the masked priming task, are expected. In the unrelated condition RTs, a priming facilitation is not anticipated. Similarly, for the irregular verbs, decomposition effects are predicted, but the size of the facilitation in response times for the identity and morphological conditions may be smaller as claimed by Crepaldi et al. (2010) and Rastle et al. (2015). That is, decomposition is presumed for both regular and irregular forms, but the magnitude of decomposition is expected to be smaller for the irregulars.

2. How do eye movements (i.e., early and late fixation durations) of L1 and L2 speakers differ in processing regularly versus irregularly inflected words presented in the sentence context?

Prediction:

In contrast to the word context, possible processing differences between the regular and irregular forms might diminish in the sentence context. This might stem from morpho-syntactic and semantic integration efforts in sentence processing (Hyöna, 2002; Leminen, et al., 2013). Slightly higher processing costs, as revealed by longer fixation durations might emerge in the early eye fixation measures (i.e., first-fixation and gaze durations) for the regular forms as opposed to late measures (i.e., second fixation and total fixation durations) (Niswander, Pollatsek, & Rayner, 2000). As for the irregular verbs, any discrepancy between early and late eye fixation measures might be smaller. Processing pattern differences between L1 and L2 speakers are not expected since the L2 group is highly proficient.

3. Is there a relationship between WMC and processing routes (i.e., decomposition or full-listing) for accessing morphologically complex forms in the isolated word and sentence contexts?

Prediction:

In the previous literature, specifically regular inflection is associated with more processing load, that is, decomposition (Cohen-Mimran et al., 2012; Service & Maury, 2015; Service & Tujulin, 2002). Therefore, higher WM scores are expected to be facilitative in terms of handling this load both in the L1 and L2 groups. In higher WMC groups, priming effects are expected to emerge at a larger degree in the processing of regular verbs when compared with lower WMC groups. As for the irregular forms, they might not benefit from the facilitatory effects of higher WMC to the same extent as regular forms since the degree of decomposition is expected to be lower.

Alternatively, if both decomposition and storage mechanisms are available in the processing of regular forms, a higher WMC would manage the competition between the two routes more competently. In the irregular verbs, the competition between decomposition and storage routes will be less powerful; therefore, high and low WMC L2 speakers, and L1 speakers would be assumed to perform similarly.

In the sentence context, too, any WMC advantage might be useful in tackling the relatively larger processing costs for the regular verbs and the additional morpho-syntactic integration cost. In the case of the irregular forms, a WMC advantage might not emerge to the same degree.

In order to investigate these questions, three tasks were administered (Table 6). The masked priming task aimed at tracing the morphological processing patterns in the word context. The eye tracking task aimed at investigating the morphological processing patterns in the sentence context. Finally, WM tasks were performed in order to measure L1 and L2 English speakers' WMC.

Table 6. Outline of the Research Methodology

Research question	Instrument	Dependent Variable	Independent Variable	Analysis
1- Is there a difference between L1 and L2 speakers of English in terms of the processing routes they adopt (i.e., decomposition or full-listing) while decoding morphologically complex words (i.e. regularly and irregularly inflected English verbs) presented in isolation (i.e., in the word context)?	Masked Priming Task	RTs	Group Verb Type Condition	Mixed ANOVA
2- How do eye movements (i.e., early and late fixation durations) of L1 and L2 speakers differ in processing regularly versus irregularly inflected words presented in the sentence context?	Masked Priming Task	RTs	Group Verb Type	Mixed ANOVA
	Eye Tracking Task	-First fixation durations -Gaze durations -Second fixation durations -Total reading times		
3- Is there a relationship between WMC and processing routes (i.e., decomposition or full-listing) for accessing morphologically complex forms in the isolated word and sentence contexts?	WMC Tests	-L1 ARSPAN Scores -L2 ARSPAN Scores -AOSPAN Scores	Group Verb Type	Correlation Analyses Extreme Groups Analysis
	Masked Priming Task	RTs		
	Eye Tracking Task	Fixation Durations		

5.2 Participants

The participants were a group of nonnative and native English speakers.

a) L2 English group: This group consisted of sixty -six L1 Turkish students studying at an English-medium state university in Istanbul comprised the L2 English group. In order to measure the proficiency levels of L1 Turkish participants in English, Oxford Quick Placement Test (QPT) (Allan, 1995) was administered. The QPT results showed that all participants had advanced level of proficiency in English, corresponding to C1 level in The Common European Framework of Reference for Languages (CEFR). The proficiency measure was obtained to ensure that lack of L2 proficiency does not affect the measurement of WMC in the L2. At the time of testing, the L2 participants were studying at junior, senior or post-graduate levels. None of them was exposed to L2 English before the age of nine (Table 7). All L2 learners had received one-year intensive L2 English training and at the time of testing, they had been speaking English for 13 years on average. They had also passed their university's English proficiency test. Except for one participant who stayed in the United States for 11 months, none of them had lived in an English-speaking country for more than 5 months. All of the participants had majored in social sciences[7]. Students from other fields of study were also tested, but they did not meet the proficiency requirements, therefore language majors had to be included in the study[8].

[7] Students from other fields of study were also tested, but they did not meet the proficiency requirements, therefore language majors had to be included in the study.

[8] Since the majority of the L1 English participants also worked in English language related professions, any potential linguistic advantage might be disregarded.

(b) L1 English group: A total of sixty-six native English speakers participated in the study. This group mostly included English-speaking expatriates and exchange students living in Istanbul. None of the L1 English participants spoke Turkish at an advanced level. In addition, none was exposed to an L2 before the age of 10. Except for ten participants, none of them spoke a second/foreign language at an advanced level.

All participants (*N* = 66) took the masked priming task, however only subsets (give number) of these participants also took the WM tests (*n* = 45) and the sentence task (*n* = 31) (See Table 7 for background information about the participants). All participants had normal or corrected-to-normal vision and were not diagnosed with any learning or reading disorders.

Table 7. Participant Profile

	Group	Gender (*N*)	Mean Age (Range)	Mean Age of First English Exposure (Range)	Mean Length of Exposure (Range)	Mean QPT Score (Range)
Masked Priming Task	L1 English (*n*=66)	Female (40) Male (26)	28.02 (19-47)	-	-	-
	L2 English (*n*=66)	Female (51) Male (15)	22.8 (19-34)	10 (9-12)	13 years (9-22)	50.56 (48-55)
WM Tasks	L1 English (*n*=45)	Female (26) Male (19)	28.4 (20-47)	-	-	-
	L2 English (*n*=45)	Female (35) Male (10)	22.8 (19-31)	10 (9-12)	13 years (9-22)	50.8 (48-55)
Eye Tracking Task	L1 English (*n*=31)	Female (20) Male (11)	25.8 (20-36)	-	-	-
	L2 English (*n*=46)	Female (34) Male (12)	22.8 (19-31)	10 (9-12)	13 years (9-22)	50.8 (48-55)

5.3 Instruments

5.3.1 Proficiency test

In order to ensure that all L2 learners have advanced level proficiency in English, the paper-based Oxford Quick Placement Test (QPT) (Allan, 1995), was administered to the L2 English participants. The test comprised 60 multiple-choice questions on grammar and vocabulary and lasted approximately 30 minutes.

5.3.2 Masked priming task

The aim of the masked priming task was to identify participants' morphological processing routes at the word level. As described below in detail, in this masked priming task the stimulus onset asynchrony (SOA) between the prime and the target was 50 ms. Such a short duration for prime presentation was necessary to prevent any (conscious) episodic memory or strategic effects. Normally, in such brief SOA, participants cannot become aware of the prime, which enables the task to tap into implicit processing.

5.3.2.1 Items

The items of the masked priming task comprised inflected and bare verbs as well as nonwords. The verbs used in the experiment were selected from SUBTLEX-US corpus (Brysbaert & New, 2009). The target items were distributed into three groups: 'morphological relation condition' (e.g., walked – WALK; kept – KEEP), semantically, orthographically and morphologically 'unrelated condition' (e.g., cook – WALK; open - KEEP) and 'identity condition' (e.g., walk – WALK; keep - KEEP). The uninflected forms of the verbs presented in capital letters were the targets in each condition. The primes were presented in lowercase letters in order to minimize form similarity and ensure that the results reflect morphological rather than visual priming.

The critical items were 18 regular and 18 irregular verb forms (See Appendix A, Tables 31–36). The length of prime and target verbs was in the same range (4-5 letters) except for the regularly inflected prime words, which were slightly longer (mean length: 6.1 letters) than the target words (mean length: 4.3 letters) due to the –ed suffix (Table 8). One-to-one frequency matching was not possible for regular and irregular verbs; therefore, an overall mean frequency matching procedure was applied in frequency manipulation. The regular verbs had a mean root (bare verb) frequency of 127.25 per million while the irregular verbs had a mean root frequency of 126.14 per million. A 2x3 mixed ANOVA on frequency, with Verb Type (Regular vs. Irregular) as between-items factor, and Condition (Identity, Test, Unrelated) as within-items factor revealed no interaction between Verb Type and Condition, $F(2, 68) = .002$, $p = .969$, partial $\eta^2 = .00$, o. power = .050. Thus, both verb types had similar frequency counts across conditions and groups. The frequency of the identity prime words and target words was the same in both verb types since the same words was used in the Identity condition. However, test ($M = 44.35$, $SD = 19.91$) and unrelated primes ($M = 44.88$, $SD = 19.83$) had lower word frequencies than the targets ($M = 126.7$, $SD = 64.7$) regardless of verb type since the past inflected forms are less frequent than that of present forms of the target verbs.

Table 8. Properties of the Prime and Target Words

	Prime		Mean Word Frequency (per million) (*SD*)	Mean length (number of letters) (*SD*)	Mean length (number of syllables)
Regular	Identity (Target)	*'save-SAVE'*	127.25 (72.02)	4.44 (0.61)	1
	Test	*'saved-SAVE'*	44.63 (20.41)	6.28 (0.57)	1
	Unrelated	*'talked-SAVE'*	44.96 (21.26)	5.61 (0.61)	1.5
Irregular	Identity (Target)	*'build-BUILD'*	126.14 (58.58)	4.67 (0.67)	1
	Test	*'built-BUILD'*	44.06 (19.99)	4.83 (0.71)	1
	Unrelated	*'taught-BUILD'*	44.79 (18.90)	4.72 (0.49)	1.22

In terms of word length, another 2x3 mixed ANOVA, with Verb Type (Regular vs. Irregular) as between subjects factor, and Condition (Identity, Test, Unrelated) as within subjects factor revealed a significant interaction between Condition and Verb Type, $F(2, 68) = 41.034$, $p = .00$, partial $\eta^2 = .55$, o. power = 1.00. This stemmed from the fact that regular test condition primes ($M = 6.28$, $SD = 0.57$), had the additional –ed suffix, which is not required in the irregular test primes ($M = 4.72$, $SD = 0.71$).

After the analysis of the test items, three experimental lists were prepared and the critical prime-target pairs were distributed to each list in a different order (Latin square design) so that no participant saw the target verb more than once (Table 9).

Table 9. Latin Square Design

Target Item	Version 1	Version 2	Version 3
TALK	talk – TALK (identity)	talked – TALK (test)	saved – TALK (unrelated)
BREAK	thank – BREAK (unrelated)	break – BREAK (identity)	broke – BREAK (test)
THROW	Threw – THROW (test)	fought – THROW (unrelated)	throw – THROW (identity)

Each list comprised 36 prime-target pairs: 12 Identity, 12 Unrelated and 12 Morphological. In addition to this, three times as many filler items (*n* = 108) as the target items were prepared so that participants could not predict the structure of the critical stimuli (Table 10). These fillers were real words (nouns (*n* = 54), adjectives (*n* = 33), adverbs (*n* = 12). In addition to this, 144 non-words were formed by changing two letters of existing English words. Thus, half of the stimuli (*n* = 144) were real words and half were non-words (*n* = 144). Finally, the presentation order of the critical and filler items was randomized across participants.

Table 10. Distribution of the Test Items

	Version 1 (n)	Version 2 (n)	Version 3 (n)
Practice items	10	10	10
Experimental items	36	36	36
Fillers (Real Words)	108	108	108
Nonwords	144	144	144
TOTAL	288	288	288

5.3.2.2 Procedures

In the present task a forward mask of hashmarks was displayed as a fixation point for 500 ms. Then the prime appeared on the screen for 50 ms immediately followed by the target word which appeared on the screen for (500 ms). The participants were asked to indicate whether the presented target word is a real word or not by pressing colored ‘yes’ or ‘no’ keys on the keyboard. The “yes” option was always on the right for right-handed participants and on the left for left-handed participants. After the participants pressed the ‘yes’ or ‘no’ button, there was a 1500-ms pause with a blank screen and then a forward mask of hash marks appeared on the screen. No feedback was provided on the accuracy of the responses. Although there was no time limitation for giving response, the participants were asked to respond as quickly as possible. The target stayed on the screen until the participants pressed a yes or no button.

The primes were always presented in lowercase letters and targets were presented in black capital letters (Verdana font and 40 points size) over a white background on a laptop (15 inch screen) (See Figure 1). E-prime 2.0 Professional software (Schneider, Eschman, & Zuccolotto, 2002) was used for presenting the stimuli and measuring the response times.

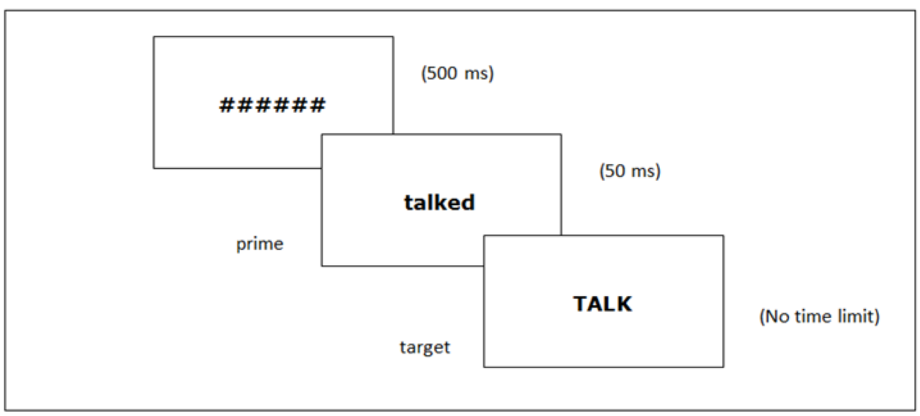

Fig. 1 The presentation of the stimuli

Prior to the experiment, a 10-trial practice session was administered. The whole experiment was administered in two blocks (each 3-4 min.) with a 4 minute-break in-between. After the completion of the task, the participants were asked to indicate what they saw on the screen in order to ensure that they did not recognize the masked primes.

Only two participants reported having seen the masked primes and their data were excluded from analysis. In addition, subsequent to the priming test, L2 English participants' knowledge of the critical words was tested by asking them to translate the target words into Turkish. The purpose of this additional task was to ensure that participants already knew the target words. All of the L2 English participants translated the words into Turkish without any errors. The experiments lasted for 15 minutes on average in the L2 English group, and 10 minutes in the L1 English group.

5.3.2.3 Analysis

Prior to data analysis, all responses were analyzed in terms of accuracy. Only the experimental stimuli were analyzed. All 'no' responses to target words (i.e., existing English verbs) were coded as errors. Those participants with an error rate higher than 15% were excluded from the study. The mean error rate across all items in the L2 group was 2.23%. The L1 speakers demonstrated 2.53% error rate. The RT analysis was carried out only on the accurate responses. Furthermore, reaction times which exceeded plus and minus three standard deviations from a participant's mean per condition were excluded from analysis (2.23% of the L1 English data and 1.43% of the L2 English data).

The identity condition was expected to yield the highest amount of priming, i.e., full priming, whereas the unrelated condition was expected to yield no priming. If there was no statistical difference between the RTs in the morphological condition and the identity condition and both RTs did not exceed that of the unrelated condition, this was interpreted as "full-priming" (Table 11) (Silva & Clahsen, 2008). However, if the test condition RTs exceeded the identity condition RTs, but did not exceed the unrelated condition RTs, this was interpreted as “partial priming”. “Lack of priming” was equated with similar RTs in the test and unrelated conditions.

Table 11. Priming Criteria

Result	Interpretation
Full priming	Identity Condition = Test Condition < Unrelated Condition
Partial priming	Identity Condition ≤ Test Condition < Unrelated Condition
No priming	Identity Condition = Test Condition = Unrelated Condition

Mixed analyses of variance (ANOVA) with the following within subject factors: Verb Type (two levels: regular, irregular), Condition (three levels: identity, test, unrelated) and the between subject factor participant group (two levels: L1 vs. L2) were adopted in order to trace priming effects. The analyses targeted both subjects (F_1) and items (F_2). In the by-subjects analysis, Group (L1 vs. L2) was treated as a between-subjects factor while Verb Type (regular vs. irregular) and Condition (identity, test, unrelated) were treated as the repeated within subjects variable. In the by-items analysis, condition was treated as a between subjects factor, while Verb Type and Group were treated as within-subjects variables. Any interactions or main effects were further assessed by planned comparisons. Bonferroni corrections were applied when necessary.

5.3.3 Working memory tasks

From the alternative WM tasks, the Automated Reading and Operation Span Tasks created in the Engle Lab of Georgia Institute of Technology were selected because they have been standardized over tests applied to large groups of participants and have been widely used in the field. In an analysis of 6000 young adults' data, the Cronbach's alpha coefficients for the automated reading and operation span tasks were reported to be .86 and .84 respectively (Redick et al., 2012).

5.3.3.1 The automated reading span task (ARSPAN)

The ARSPAN (Unsworth et al., 2005) was adopted as the first WM measure. In this task, the participant first completed three practice sessions. In the first practice, only letter recall was practiced. In the second session, a sentence was presented for assessing whether it makes sense or not. In the final practice session, the two operations were processed simultaneously; first a letter was presented for later recall, followed by a sentence to judge in order to prevent rehearsing the letters and tap into simultaneous processing. In this final practice session, the average sentence reading speed of the participant was calculated. In the experimental session, the participant saw letter-sentence judgment sets ranging from 3 to 7. At the end of each set, the participant selected the previously seen letters from among eight letters on the screen in the order of presentation (Figure 2). It was important to read the target sentences within the participant's average speed, otherwise the sentence disappeared and the program recorded this as a "Speed Error". After selecting the previously seen letters, participant's accuracy rate was shown on the screen. The participant was required to keep the accuracy level at 80%.

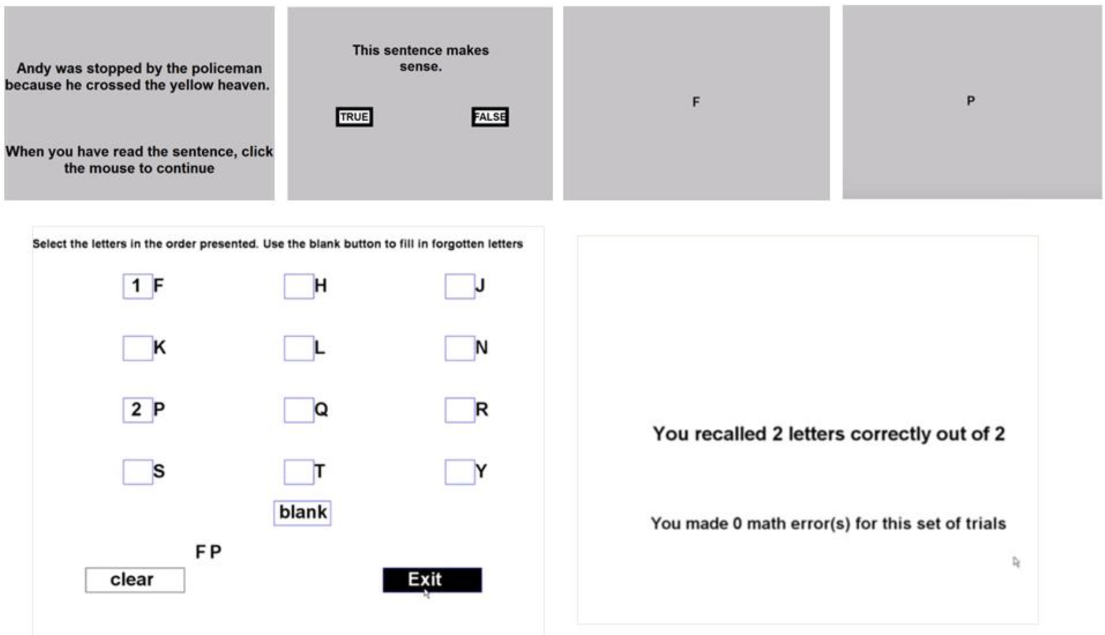

Fig. 2 Sample trial from the ARSPAN task

There were 15 practice trials and 75 sets of sentences to be judged and letters to be recalled. The task took 20-25 minutes to complete. All sets and sentences were randomized for each participant. In order to prevent participants from anticipating the number of letters to be recalled, the sets were presented in an unpredictable order.

Although WM is considered to be language-independent, in the literature it is reported that L2 learners have a lower WMC in the L2 (Gass & Lee, 2011). Therefore, L2 English participants also took the Turkish version of the task translated into Turkish by Çele (2010). In this study, the correlation between the Turkish ARSPAN and English

ARSPAN and AOSPAN was reported to be $r(20) = .61$ and $r(20) = .75$ respectively, $p < .01$.

5.3.3.2 The automated operation span task (AOSPAN)

In the measurement of WM, using multiple tests is recommended for eliminating task-specific effects (Conway et al, 2005). Therefore, the AOSPAN (Unsworth et al., 2005) was employed in order to understand whether WM is independent from linguistic effects. In this test, participants were required to check the accuracy of sets of mathematical calculations (3-7 sets) and then try to remember the letters appearing at the end of each operation in the order of presentation (Figure 3).

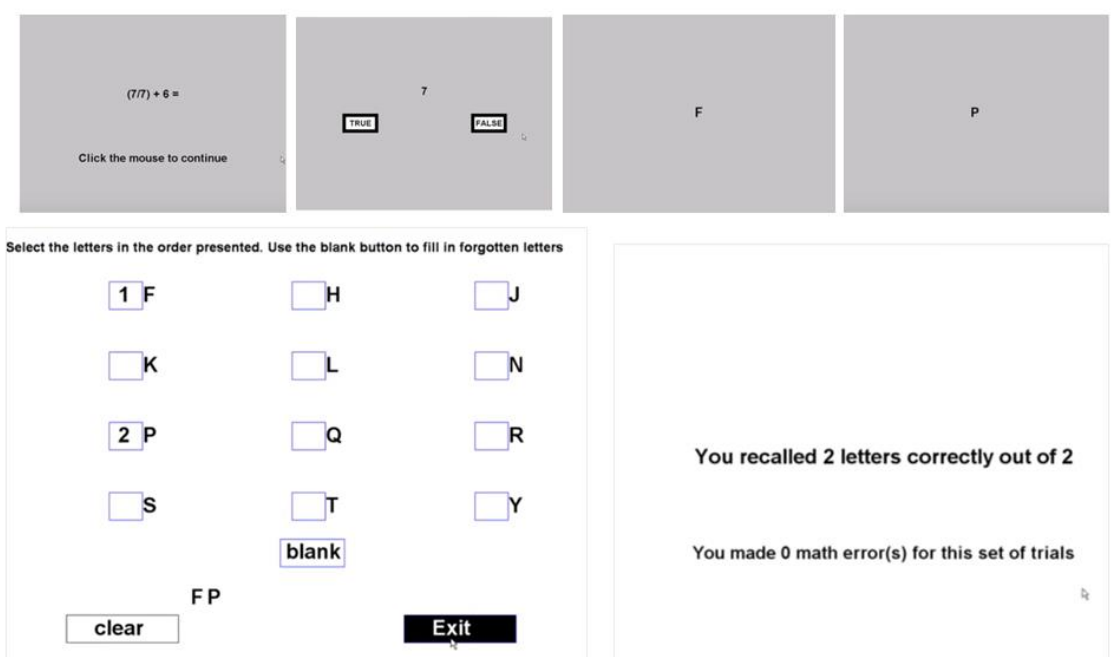

Fig. 3 Sample trial from the AOSPAN task

As in the ARSPAN, at least 80% success was expected in terms of mathematical accuracy in order to make sure that the processing skill is at work. There were 15 practice trials and 75 sets of operations and letters to be recalled. The task took 15-20 minutes to complete.

5.3.3.3 Procedures

The participants completed the tasks individually in a quiet room. The experimenter provided assistance in the practice part when necessary. Both WM tasks were administered in the same session. The order of the WM tasks was counterbalanced for each participant in order to reduce practice effects.

5.3.3.4 Analysis

In terms of scoring, both ARSPAN and AOSPAN present two scores: absolute and total, as well as error counts. The absolute score is the sum of all perfectly recalled sets. That is, if a set of 3 letters is recalled correctly and another set of 4 letters is recalled correctly, but if only 3 letters of a 5-letter set is recalled correctly, the score is 3+4+0=7. By comparison, the total score indicates the total number of letters recalled in the correct position. This is also known as partial-credit scoring in the literature, and is reported to be more reliable than absolute scoring (Conway et al., 2005). So, considering the above example, the partial-score would be 3+4+3=10.

The purpose of the present study was to understand whether WMC correlates with morphological processing in the L2. Therefore, the first analysis method was based on correlating the *z*-scores of WM tasks with that of priming task RTs in each language group. To this end, firstly the mean of each participant's ARSPAN and AOSPAN scores was calculated. For the L1 Turkish participants, two WM scores were calculated in the L1 and the L2 respectively.

In the second analysis based on "extreme groups design", the upper and lower 1/3 of the participants' performance in the masked priming and eye tracking tasks were compared. One of the disadvantages of this approach is considerable loss of data—the middle group scores are excluded from analysis. Additionally, when data are negatively skewed, dividing the scores into three is less meaningful and the creation of high and low WMC groups is rather arbitrary. Given both analyses' shortcomings, the common practice is to carry out them in combination (see Conway et al., 2005 for a review).

5.3.4 Eye tracking experiment

5.3.4.1 Items

The target verbs used in the Masked Priming Task were inserted in the same sentence context in pairs. Pairs of regular and irregular verbs were embedded in the same sentence contexts in order to avoid any contextual differences. The participant saw only one version of the sentence (either in regular or irregular verb context). For example:

The basketball team **changed** their flight to Germany at the last minute.
caught

The target words were not placed in sentence-initial and sentence-final positions and were preceded and followed by a minimum of two words. The length of the sentences varied between 11-15 words (*M* = 12.44 words). Unfortunately, the length of the regular and irregular verbs could not be matched. The regular verbs (*M* = 6.28 characters) were longer than irregular verbs (*M* = 4.83 characters) due to the –ed suffix, which is an inevitable and natural property of English addressed in previous work as well (Pliatsikas & Marinis, 2013; Rastle et al., 2015).

Two versions of the test were prepared so that the participant did not see the target sentence frame twice. Each participant saw 9 regular and 9 irregular target verbs embedded in sentences and twice as many (*n* = 36) filler sentences, resulting in 54 sentences in total (See Appendix B). Comprehension questions were presented after all target sentences and half of the filler sentences in order to make sure that the participants attend to reading the sentences.

5.3.4.2 Cloze test for norming for the eye-tracking study

Seven L1 speakers of English who did not participate in the actual test were provided with a fragment of the potential experimental sentences up to the target word (See Appendix C). They were asked to continue the incomplete sentences with the first word that comes to their mind. In the literature, if the target word is mentioned by 70% of the participants, it assumed to be predictable (Rayner, Pollatsek, & Schotter, 2012). In the present norming task, none of the target words exceeded this criterion. There were only four instances in which the target word was mentioned by some participants. These words were changed in the original test.

5.3.4.3 Naturalness Rating Test for the eye-tracking study

The naturalness of the test items were initially checked by two L1 speakers of English. After some revision and improvements, fourteen L1 speakers of English who did not participate in the actual test were given an online survey whereby they rated the naturalness of the constructed sentences on a scale from 1 (Not natural at all) to 5 (Very natural). Mean acceptability ratings were 4.04 for regular verbs and 4.07 for irregular verbs. The survey included an optional space for the participants to indicate any unusual phrases in each sentence and suggest improvements. Sentences which received a mean rating of under 3.5 were revised on the basis of these suggestions.

5.3.4.4 Apparatus

Applied Science Laboratories' (ASL) D6 Desk Mounted remote eye tracker (60 Hz) was used for recording eye movements. The device was connected to the eye tracker computer and the subject computer. The angular resolution of the eye tracker was 0.25 degree and the system accuracy was 0.5 degree visual angle. The eye tracker could track gaze over approximately a 30-35 degree vertical visual angle and a 40-45 degree horizontal visual angle. Viewing was binocular, but the movements of only the right eye were recorded since it is assumed that the two eyes fixate the same position.

The stimuli were presented on subject computer's 19 inch screen (resolution: 1024x768, font size: 18) above the optics module, which was connected to the eye-tracker computer. The eye camera monitored eye movements while the head camera followed head movements in accordance with eye movements. Since the head tracker allowed for one square foot of head movement, a chin rest was not used. This provided a more natural reading environment and increased ecological validity.

5.3.4.5 Procedures

The eye tracking task was administered in a quiet room with no direct sunlight. Fluorescent lighting was used in the room. After briefly explaining the instructions, the subject was seated approximately 61 cm (24 inch) away from the subject computer's screen. The height of the chair was adjusted to obtain an optimal eye image view in accordance with the eye camera. After adjusting the camera and the head tracker, the corneal and pupil reflection of the eye were captured and a 9-point calibration test was applied on the subject computer. The accuracy of the calibration was checked on the eye tracker computer and repeated when necessary. The participant was asked to remain relatively still during the calibration and the testing session. The setup and calibration took 10 to 20 minutes while the testing took 10 minutes to complete.

The stimuli were presented on Paradigm software (Tagliaferri, 2011). Each trial began with a blank screen with a fixation cross (750 ms), followed by display of a sentence in the middle of the screen in a single line. The participants were asked to read the sentence at their normal reading speed and press the space key when they finish reading it. There was no time limit for the sentence display. After the end of the sentence presentation, a 750 ms-pause was given. All of the target sentences and some additional sentences (two thirds of the sentences in total) were followed by a true-false comprehension question in order to make sure that the participant is attending to the sentences (See Figure 4). Each experimental session was preceded by a 7-item practice session. All sentences were displayed on a single line.

Fig. 4 Sample eye tracking test trial

5.3.4.6 Analysis

The ASL Results program which is the complimentary analysis program for ASL D6 was used for data analysis. Prior to analysis, the critical areas of interest (AOI) were determined for each target sentence: the pre-target area, the target area (i.e., the verb) and the spillover area (i.e., the post-verbal word)[9]. The regions extended to half a letter space either side (See Figure 5). The pre-target area was included to trace any possible parafoveal processing effects.

[9] In this study, only the results related to the target area are reported.

Fig. 5 Sample AOI mapping in the ASL Results program

Before running the analysis, the recordings of the inaccurately answered sentences were removed from analysis. Fixations below 80 ms and above 1000 ms were also removed since very short fixation durations imply lack of cognitive processing and very long durations are associated with track loss. Data with track loss and with bad quality were also removed from analysis.

The length of the target regular and irregular verbs could not be matched in the task; therefore, firstly the confounding effects of word length were traced. A regression analysis was performed in order to understand whether target word length predicted fixation durations. Since length significantly predicted fixation durations, Residual Reading Times were calculated following Trueswell, Tanenhaus and Garnsey (1994). The best linear fit between target length and fixation duration were calculated separately for each subject. Finally, the residual first fixation, gaze, second fixation and total fixation durations for each target area were computed and compared in terms of verb regularity. Longer fixation duration was considered to be indicator of processing cost and thus decomposition.

5.4 General procedures

The participants were tested individually in a dimly lit room. Prior to test implementation, participants were informed about the experimental procedures. L1 Turkish-L2 English participants first took the QPT, followed by the Masked Priming Task and a WM task. In the second session, which took place on a separate day, they took two WM tasks in counterbalanced order and the Sentence Task. Each session lasted approximately an hour. The L1 English participants first took the Masked Priming Task, followed by the WM tasks, which were counterbalanced. On a separate day, they took the Sentence Task. All of the tasks lasted approximately one hour. Upon completion of the tasks, the participants completed a demographic information form and signed the consent form. At the end of the study, all participants were debriefed and received either a gift or gift card in compensation for their contribution to the study.

CHAPTER 6

RESULTS

In this section, the results of the masked priming task, eye tracking task and WM tasks will be reported in relation to morphological processing patterns in L1 and L2 English groups. The performance in each task will be compared in terms of both within-groups and between-groups analyses.

6.1 The results of the masked priming task

The masked priming task comprised two components: lexical decision and response time (RT). Before performing statistical analyses on the RT data, the accuracy level of the participants needed to be checked so that participants with highly erroneous responses could be removed from the study. This analysis was also run in order to understand whether accuracy levels were comparable across different experimental conditions and verb types. The subsequent RT analyses aimed at understanding the priming patterns for regularly and irregularly inflected verbs and possible similarities or differences between L1 and L2 groups' response patterns.

6.1.1 Accuracy analysis

The descriptive statistics indicated that both native and non-native groups' responses in the lexical decision task were highly accurate, with accuracy rates ranging between 95 and 99 percent. As Table 12 displays, the error rates were slightly higher in the unrelated conditions in both verb types and participant groups. Across the conditions, L1 and L2 English groups had comparable error rates.

Table 12. Accuracy Rates per Group and Condition

Verb Type	Condition	L1 English (*N*=66)		L2 English (*N*=66)	
		%	*SD*	*%*	*SD*
Regular	Identity	98.48	0.3	97.98	0.4
	Test	98.74	0.3	98.99	0.2
	Unrelated	95.71	0.5	95.45	0.5
Irregular	Identity	97.98	0.4	98.74	0.3
	Test	96.97	0.4	98.48	0.3
	Unrelated	97.22	0.5	97.22	0.4

Before comparing the two groups' accuracy scores, the normality of each group's data was checked. The normality assumption was not upheld even after transformations conducted due to negative skewedness in both groups. Therefore, a series of non-parametric tests were applied with Bonferroni correction. Mann-Whitney U tests did not reveal any between-group (i.e., L1 vs. L2 English group) differences in accuracy scores in the regular identity (U = 2142, z = -.317, p = .797, r = -.03), regular test (U = 2145, z = -.344, p = 1.000, r = -.03), regular unrelated (U = 2170, z = -.047, p = 1.000, r = -.004), irregular identity (U = 2140, z = -.361, p = .659, r = -.03), irregular test (U = 2010, z = -1.317, p = .235, r = -.012) and irregular unrelated conditions (U = 2146, z = -.239, p = .920, r = -.02).

Further Wilcoxon Signed Ranks[10] tests separately carried out for each group revealed some differences among conditions in the regular verb type. In the L1 English

[10] Bonferroni corrected p value = .0083.

group's responses to the regular verbs, there was no difference between the "test" and "identity" conditions (z = -.302, p = 1,000, r = -.04); however, there were marginally significant differences only between "unrelated" and "identity" conditions (z = -2.202, p = .037, r = -.27) and between "unrelated" and "test" conditions" (z = -2.559, p = .013, r = -.32)[11]. In the same participant group's irregular verb accuracy scores, there were no differences between the "identity" and "test" conditions (z = .755, p = .547, r = .09), the "identity" and "unrelated" conditions (z = .037, p = 1,000, r = .05) and "test" and "unrelated" conditions (z = .380, p = .841, r = .05).

In the L2 English group's responses to the regular verbs, there was no significant difference between the "test" and "identity" scores (z = -1.07, p = .432, r = -.21) and the "unrelated" and "identity" scores (z = -1.751, p = .104, r = -.22); however, a significant difference existed only between the "unrelated" and "test" condition scores (z = -2.738, p = .007*, r = -.34). As for the irregular verb scores, there was no significant difference between the "test" and "identity" condition scores (z = -.333, p = 1.000, r = -.04), the "unrelated" and "identity" conditions" (z = -1.807, p = .119, r = -.22) and the "unrelated" and "test" scores (z = -1.213, p = .337, r = -.15).

6.1.2 Reaction time analysis

Prior to analysis, erroneous responses (0.9% of L1 English data; 1.2% of L2 English data) and outliers (3 SD above and below each participant's mean RT) (0.9% of L1 English data; 1.2% of L2 English data) were removed from the analysis. In addition, before comparing L1 English and L2 English groups' response latencies, the data were

[11] Bonferroni corrected p value = .0083.

screened for normality and other assumptions for parametric tests. Analysis of the boxplots, histograms and Q-Q plots revealed that the normality assumption was not upheld in either participant group. The data were highly positively skewed; therefore a log-transformation was applied. The box plots, histograms and Q-Q plots demonstrated that the distributions reached normality after this transformation. The Kolmogorov-Smirnov test results for all conditions in the two verb types did not reach significance ($p > .05$), presenting further support for meeting the normality assumption. There were a few univariate and multivariate outliers in each group; the values of these cases were replaced by the maximum non-outlier value in the group as suggested by Tabachnik and Fidell (2013). These replaced values did not exceed 5% of the sample. Greenhouse-Geisser correction was not applied since the sphericity assumption was held.

6.1.2.1 Mixed ANOVA results

The descriptive statistics revealed differences in mean RTs across different conditions and verb types in both groups. Table 13 reports the means and standard deviations by condition. In both groups, the identity condition yielded faster RTs than the test condition followed by the unrelated condition. Similarly, RTs to the irregular verb targets were faster than that of regular verb targets.

Table 13. Raw Mean Response Latencies (ms) per Condition

Verb Type	Condition	L1 English (*N*=66)		L2 English (*N*=66)	
		M	*SD*	*M*	*SD*
Regular	Identity	546.99	72.04	577.12	96.54
	Test	571.95	67.55	592.85	91.34
	Unrelated	599.28	74.81	611.81	75.42
Irregular	Identity	538.40	68.09	571.63	95.85
	Test	553.70	64.92	583.51	85.56
	Unrelated	582.68	69.68	601.89	70.08

In order to trace RT differences between verb types and any priming patterns in L1 and L2 English groups, mixed ANOVAs were performed separately for subjects and items. In the by-subjects analysis (F_1), a 2 (group) x 2 (verb type) x 3 (condition) mixed ANOVA was performed with group as the between subjects factor and verb type (regular vs. irregular) and condition (identity, test, unrelated) as repeated within subjects factors. In the by-items analysis (F_2), another 2 x 2 x 3 mixed ANOVA was performed with verb type as the between subjects factor and group (L1 English vs. L2 English) and condition (identity, test, unrelated) as within subjects factors.

The results of the mixed ANOVA pointed to a significant between-groups difference in the RTs in both the analysis by subjects and by items, $F_1(1, 130) = 4.07$, $p = .046$*, partial $\eta^2 = .03$, obs. power = .52, $F_2(1, 34) = 21.38$, $p = .000$*, partial $\eta^2 = .39$, obs. power = .95. As can be seen in Figures 6 and 7, on the whole, the L1 English group was faster than the L2 English group in terms of RT.

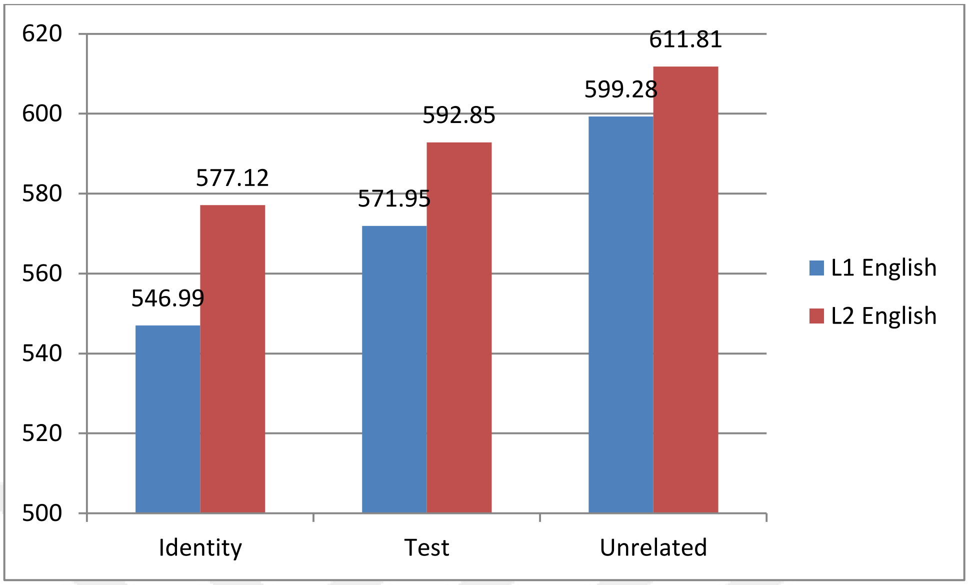

Fig. 6. Between-group comparison of mean reaction times for the regular verbs

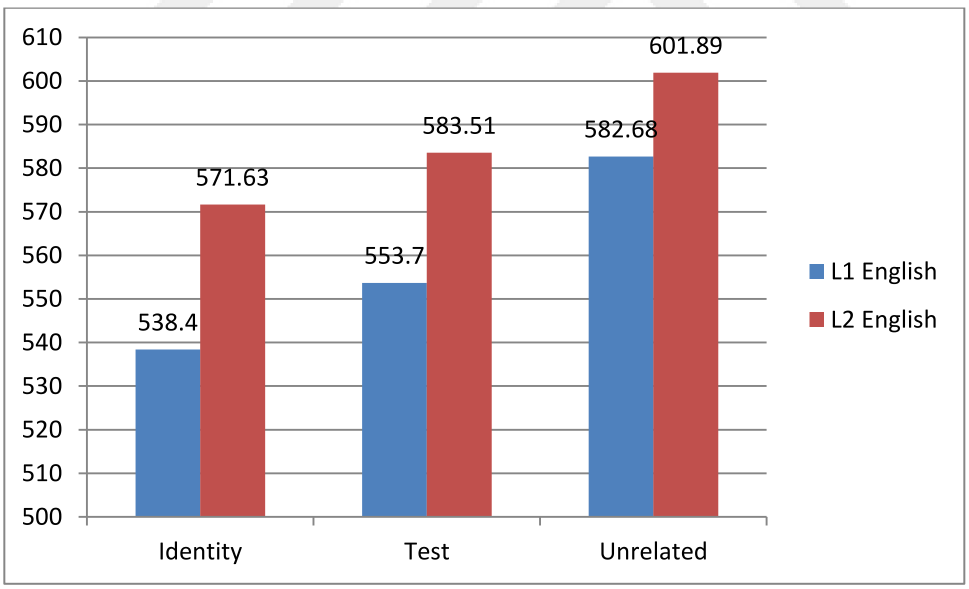

Fig. 7. Between-group comparison of mean reaction times for the irregular verbs

Another significant finding was the presence of a main effect of "verb type", $F_1(1, 130) = 13.34$, $p = .00$*, partial $\eta^2 = .093$, obs. power = .95, in the by-subjects analysis. In the analysis by items, a significant RT difference in verb type was not obtained, $F_2(1, 34) =$

2.84, p = .101, partial η^2 = .08, obs. power = .37. Post-hoc pairwise comparisons using t-tests with Bonferroni correction indicated that regardless of group and condition type, regular verbs (M = 583.34, SD = 69.74) were responded to significantly slower than irregular verbs [mean difference = -11.37, p = .00*, 95 percent confidence interval (-17.61, -5.13)] [12].

"Condition" also created a significant main effect, $F_1(2, 260)$ = 69.80, p = .00*, partial η^2 = .35, obs. power = 1, $F_2(2, 68)$ = 49.01, p = .00*, partial η^2 = .59, obs. power = 1. Post-hoc pairwise comparisons using t-tests with Bonferroni correction were conducted to explore differences among conditions. In the by-subjects analyses, regardless of group and verb type, the identity condition yielded significantly faster RTs than the test [mean difference = -16.97, p = .00*, 95 percent confidence interval (-25.59, -8.35)] and unrelated conditions [mean difference = -40.38, p = .00*, 95 percent confidence interval, (-50.53, -30.23)]. Overall, the test condition also yielded significantly faster RTs than the unrelated condition [mean difference = -23.41, p = .00*, 95 percent confidence interval (-32.69, -14.13)]. Similarly, in the by-items analyses, the identity condition yielded significantly faster RTs than the test [mean difference = -0.15, p = .001*, 95 percent confidence interval, (-.025, -.005)] and unrelated conditions [mean difference = -.037, p = .00*, 95 percent confidence interval, (-.047, -.027)] and the test condition yielded significantly faster RTs than the unrelated condition [mean difference = -.022, p = .00*, 95 percent confidence interval, (-.03, -.013)].

The two-way interactions "condition x group", $F_1(2, 260)$ = 1.284, p = .279, partial η^2 = .01, obs. power = .28, $F_2(2, 68)$ = .604, p = .55, partial η^2 = .028, obs. power

[12] Unadjusted (raw) difference scores are reported.

= .15, and “verb type x condition”, $F_1(2, 260) = 522$, $p = .594$, partial $\eta^2 = .004$, obs. power = .136, $F_2(2, 68) = .986$, $p = .378$, partial $\eta^2 = .028$, obs. power = .22, were not significant.

The mixed ANOVA results did not reveal a significant “verb type x condition x group interaction”, $F_1(2, 260) = .034$, $p = 0.97$, partial $\eta^2 = .00$ obs. power = .55, $F_2(2, 68) = .40$, $p = .672$, partial $\eta^2 = .01$ obs. power = .11. This indicates that the two groups do not seem to differ in terms of processing patterns. Profile plots of the interaction in Figure 8 illustrate similar priming patterns for both groups.

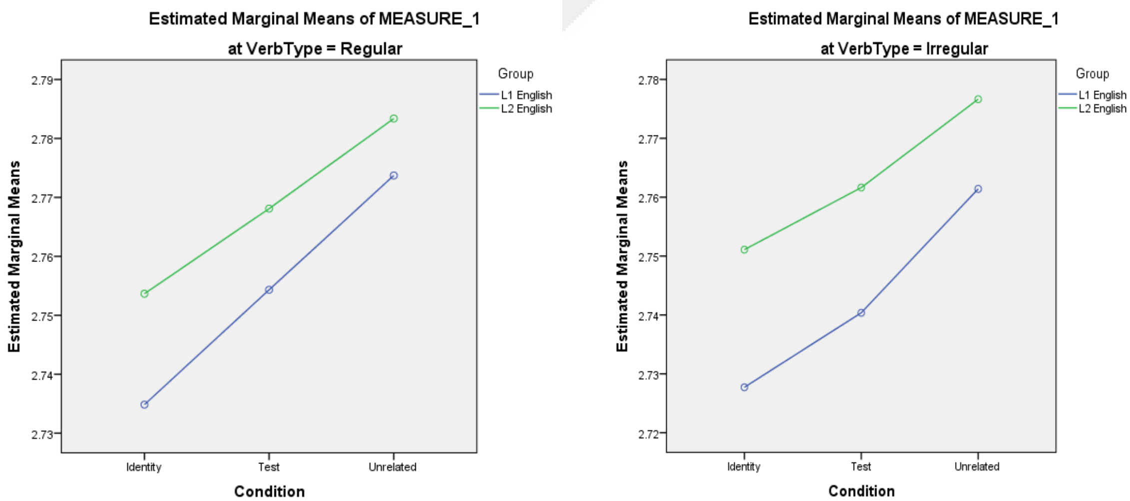

Fig. 8. Priming patterns in log-transformed RTs of regular and irregular verbs

In statistical analyses, running further pairwise comparisons despite the absence of an interaction is not recommended (Tabachnick & Fidell, 2013); however, in psycholinguistics, further pairwise comparisons may be applied in order to trace any subtle between-group differences and to understand the priming pattern more clearly (Feldman et al., 2010). Therefore, six pairwise comparisons were applied in each participant group (Table 14).

Table 14. Pairwise Comparisons of RTs for Regular and Irregular Verbs in Subjects Analysis

	Comparisons	Regular		Irregular	
		Mean Difference	*p*	Mean Difference	*p*
L1 English	Identity-Test	-24.95	.003*	-15.31	.074
	Identity-Unrelated	-52.28	.000*	-44.28	.000*
	Test-Unrelated	-27.34	.002*	-28.97	.000*
L2 English	Identity-Test	-15.73	.039*	-11.88	.180
	Identity-Unrelated	-34.69	.000*	-30.26	.000*
	Test-Unrelated	-18.95	.019*	-18.38	.016*

[1]Unadjusted mean scores are reported.
[2]Bonferroni adjustment was applied.

The pairwise comparisons revealed slightly different results for regular and irregular verbs. In both participant groups, the RTs to regular forms followed an incrementally increasing RT pattern from the identity to the unrelated condition (i.e., identity < test < unrelated). In other words, for both groups, the RT differences between the following conditions were statistically significant: identity-test, identity-unrelated, and test-unrelated. In other words, while the RTs in the test condition were significantly longer than those in the identity condition, they were significantly faster than the unrelated condition. As for the irregular verbs, a similar RT pattern (i.e., an increasing RT from the identity towards the unrelated condition) was found. Nevertheless, in this verb type, the RT difference between the identity and test conditions was not significant while the RT differences between the identity and unrelated as well as the test and unrelated conditions were significant in both participant groups, revealing the pattern: identity ≤ test < unrelated. Although technically, the pattern found in the regular verbs is referred to as "partial priming", the pattern found in the irregular verbs is interpreted as "full priming" (Silva & Clahsen, 2008, p. 247). Crucially, however, in both regular and irregular verbs, the RTs to the test condition were shorter than those to the unrelated condition, suggesting that in both cases there were priming effects.

Another series of pairwise comparisons were carried out in the items analysis (See Table 15). In the L1 English group, regular verbs yielded a partial priming pattern, while the irregular verbs yielded a full priming pattern. In the L2 English group, both verb types yielded full priming effects.

Table 15. Pairwise Comparisons of RTs for Regular and Irregular Verbs in Items Analysis

	Comparisons	Regular		Irregular	
		Mean Difference	*p*	Mean Difference	*p*
L1 English	Identity-Test	-0.23	.005*	-0.15	.303
	Identity-Unrelated	-.039	.000*	-.044	.000*
	Test-Unrelated	-.016	.028*	-.029	.001*
L2 English	Identity-Test	-.012	.233	-.010	.813
	Identity-Unrelated	-.032	.000*	-031	.001*
	Test-Unrelated	-.020	.006*	-.022	.011*

[1]Adjusted mean scores are reported.
[2]Bonferroni adjustment was applied.

In order to understand whether strength[13] in irregular verbs influences RTs, a further analysis was carried out on only irregular verb data. The normality of the data points allowed for parametric tests. Therefore, a mixed ANOVA was applied with strength (similarity to regulars) of the irregular verbs as the between-subjects variable and group (L1 English vs. L2 English) and condition (Identity, Test, Unrelated) as within subjects variables. Greenhouse-Geisser correction was not applied since the sphericity assumption was held. The descriptive statistics showed differences in the mean RTs to different conditions in both verb types (Table 16).

Table 16. Raw Mean Response Latencies (ms) for Irregular Verbs

Verb Type	Condition	L1 English (n=66)		L2 English (n=66)	
		M	*SD*	*M*	*SD*
Weak (n=11)	Identity	531.84	44.37	541.61	22.71
	Test	557.97	30.70	568.53	42.87
	Unrelated	574.34	28.89	592.99	21.94
Strong (n=7)	Identity	544.34	25.95	572.23	39.76
	Test	552.38	26.00	575.87	35.13
	Unrelated	584.95	27.27	607.40	31.01

The mixed ANOVA did not reveal any main effect of “verb type”; the RTs to strong irregular verbs did not differ from those to weak irregular verbs, $F(1, 16) = 1.73$, $p = .207$, partial $\eta^2 = .98$ obs. power = .24. There was a significant main effect of “participant group” (L1 English vs. L2 English), $F(1, 16) = .034$, $p = .001$*, partial $\eta^2 = .53$, obs. power = .98. Post-hoc pairwise comparisons revealed that overall, the L1 English group’s RTs to irregular verbs were significantly faster than those of L2 English

[13] Strong irregular verbs in participle form do not end in –d or –t (e.g., sing-sang) while weak irregular verbs in participle form end in –d or –t. (e.g., teach-taught).

speakers [Mean difference = -18.80, p = .001*, 95 percent confidence interval (-28.18, -9.42)], as was the case in the overall masked priming data analysis.

There was also a main effect of "condition", $F(2, 32) = 17.82$, p = .000*, partial η^2 = .53, obs. power = 1.00. Pairwise comparisons with Bonferroni correction revealed a significant difference between the identity and test conditions [Mean difference = -.015, p = .001*, 95 percent confidence interval (-0.25, -.005)]; between identity and unrelated conditions [Mean difference = -.037, p = .000*, 95 percent confidence interval (-.047, -.027)] and between test and unrelated conditions [Mean difference = -0.22, p = .000*, 95 percent confidence interval (-.030, -0.13)].

As for two-way interactions, significant "group x verb type", $F(1, 16) = 1.72$, p = .208, partial η^2 = .097, obs. power = .24, "condition x verb type", $F(2, 32) = 1.05$, p = .363, partial η^2 = .061, obs. power = .22, and "group x condition" interactions, $F(2, 32)$ = 0.26, p = .974, partial η^2 = .002, obs. power = .05, were not established.

A significant interaction between "participant group and verb type and condition" was not found, $F(2, 32) = .11$, p = .90, partial η^2 = .007, obs. power = .065. In the same way, the profile plots demonstrated comparable RT patterns in L1 and L2 groups in both verb types. However, there was a slight difference between strong and weak verbs' plots. Figure 9 shows that the RT difference between identity and test conditions is more pronounced in weak verbs when compared to strong verbs. This means that the priming facilitation might be greater for strong irregular verbs when compared to weak irregular verbs.

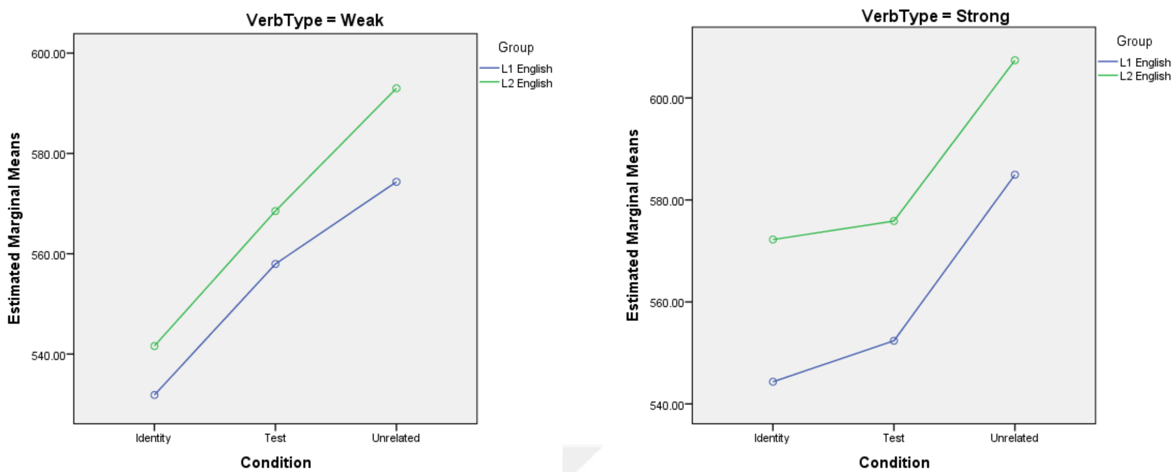

Fig. 9. Priming patterns of strong and weak irregular verbs

Despite the similarity in RT patterns in both participant groups, further pairwise comparisons revealed a slight difference in priming effects for strong and weak irregular verbs (Table 17). While no priming was obtained in weak verbs in both groups, a priming facilitation was obtained in strong irregular verbs only in the L1 English group. In the L2 English group, this effect was marginally significant.

Table 17. Pairwise Comparisons of RTs for Strong and Weak Irregular Verbs

	Comparisons	Weak		Strong	
		Mean Difference	*p*	Mean Difference	*p*
L1 English	Identity-Test	-26.13	.411	-08.04	1.00
	Identity-Unrelated	-42.50	.034*	-40.61	.011*
	Test-Unrelated	-16.38	.719	-32.56	.023*
L2 English	Identity-Test	-26.92	. 594	-3.639	1.00
	Identity-Unrelated	-51.39	.019*	-35.17	.047*
	Test-Unrelated	-24.47	.497	-31.53	.097

[1]Unadjusted mean scores are reported.
[2]Bonferroni adjustment was applied.

Overall, the mixed ANOVAs on the masked priming task RTs revealed slower RTs in the L2 group in comparison to the L1 group, but similar priming patterns for both participant groups in the two verb types. The RT pattern across the conditions was characterized as $Identity_{RT} < Test_{RT} < Unrelated_{RT}$, which can be interpreted as partial priming. However, further analyses demonstrated slight differences between the verb types in both participant groups. Whereas a partial priming pattern emerged in the case of regular verbs, a full priming pattern emerged for irregular verbs. An additional analysis on the irregular verbs did not indicate divergences in the RTs for strong and weak irregular verbs.

6.2 The correlation between masked priming and WMC tasks

In this section, firstly the results obtained from the WM tasks will be reported. Later in the section, the results of the WM tasks and the masked priming tasks will be analyzed. In order to understand whether WM has a relationship with morphological processing, two analyses will be discussed. In the first analysis, any correlations between WMC and morphological priming effects will be traced. Secondly, in the extreme-groups analysis, participants with high and low WM will be compared to each other in terms of morphological priming.

The WMC measures included the Automated Reading Span (ARSPAN) score, Automated Operation Span (AOSPAN) score, and English WM composite score[14], which comprised the average of the ARSPAN and AOSPAN *z*-scores. For the L2 English group, two extra measures were employed: the Turkish version of the ARSPAN

[14] The English WM composite score was accepted as the L1 WM score for the L1 English group and L2 WM score for the L2 English group.

and Turkish WM composite score (i.e., L1 WM score), which comprised the average of the Turkish ARSPAN and AOSPAN *z*-scores. In order to form a single priming measure for each verb type, a priming score was calculated by subtracting the mean RTs from the unrelated condition from the test condition.

According to descriptive statistics, the mean ARSPAN, AOSPAN and composite WM scores in both groups were relatively high (the maximum score is 75). As can be seen in Table 18, both participant groups had comparable scores, except for the English ARSPAN. The L1 group's mean ARSPAN and AOSPAN scores were comparable. The L2 group's AOSPAN and Turkish ARSPAN scores were very similar. However, the participants' mean English ARSPAN scores were slightly lower than their AOSPAN and Turkish ARSPAN scores.

Table 18. Descriptive Statistics of the WM Tasks

Tests and groups	*M*	*SD*	Skewness	Kurtosis	Minimum	Maximum
ARSPAN-English						
L1 English (*n*=45)	60.38	12.55	-1.73	3.14	19	75
L2 English (*n*=45)	56.96	10.21	-.156	-1.08	37	75
AOSPAN						
L1 English (*n*=45)	62.00	12.36	-1.67	3.21	22	75
L2 English (*n*=45)	63.98	8.91	-.871	-.12	43	75
ARSPAN-Turkish						
L2 English (*n*=45)	62.53	7.92	-.580	-1.01	42	75
English WM Composite (Raw)						
L1 English (*n* = 45)	61.04	12.24	-.1.89	3.92	27	75
L2 English (*n* = 45)	60.52	7.67	-.205	-.89	45.5	75
Turkish WM Composite (Raw)						
L2 English (*n*=45)	63.2	8.46	-.732	-.45	43	74.5

Before running the statistical tests, the normality of the data was checked. The Kolgomorov-Smirnov tests together with boxplots and Q-Q plots demonstrated non-normal distributions for the WM measures in the L1 English group. Therefore, non-parametric tests were employed in the analyses. A series of Mann-Whitney U tests revealed that the two groups differ significantly in terms of ARSPAN English (U = 746, p = .031*, z = -2.15), but not AOSPAN (U = 962.5, p = .69, z = -.404), English WM composite score (U = 959, p = .66, z = -.432) and L1 WM composite score (U = 964, p = .97, z = -.004). These tests ensured that overall, the two groups were comparable in terms of WMC scores.

6.2.1 Correlations among the WMC tasks

Although not of direct relevance to the present study, the correlation between ARSPAN and AOSPAN scores were also scrutinized separately in each participant group. This provided additional information on whether linguistic and non-linguistic measures of WM would yield converging measurements of the construct, given that the L2 participant group took some of the WM tasks in their L2.

Since the normality assumption was not met, non-parametric correlation analyses were carried out. In the L1 English group, the Kendall's tau-b correlation between ARSPAN and AOSPAN scores was found to be τ = .51, n = 45, p = 0.00*, showing a moderate relationship (see Table 19). As for the L2 English group, the correlation between the English ARSPAN and AOSPAN was lower, τ = .35, n = 45, p = 0.00*, while the correlation between the English and Turkish ARSPAN was slightly higher

τ = .50, n = 45, p = 0.00* (see Table 20). Finally, the correlation between AOSPAN and Turkish ARSPAN was moderate, τ = .41, n = 45, p = 0.00*.

Table 19. Kendall's tau-b Correlation Coefficients for the L1 English Group (n = 45)

		AOSPAN	WM Composite Score
ARSPAN	Correlation Coefficient	.512**	.736**
	Sig. (2-tailed)	.000	.000
AOSPAN	Correlation Coefficient		.783**
	Sig. (2-tailed)		.000

p < .001**

Table 20. Kendall's tau-b Correlation Coefficients for the L2 English Group (n = 45)

		AOSPAN	Turkish ARSPAN	English Composite WM	Turkish Composite WM
English ARSPAN	Correlation Coefficient	.351**	.502**	.696**	.471**
	Sig. (2-tailed)	.001	.000	.000	.000
AOSPAN	Correlation Coefficient		.410**	.666**	.699**
	Sig. (2-tailed)		.000	.000	.000
Turkish ARSPAN	Correlation Coefficient			.575**	.723**
	Sig. (2-tailed)			.000	.000
English Composite WM	Correlation Coefficient				.721**
	Sig. (2-tailed)				.000

6.2.2 Comparing WMC and masked priming results: A correlation analysis

In the correlation analysis, the two groups were analyzed separately. Both L1 and L2 English groups' data were negatively skewed and the normality assumption could not be met. Therefore, the non-parametric equivalent of Pearson's product-moment correlation, Kendall's tau-b was performed in each group. Kendall's tau-b generated a correlation matrix containing the WM scores (Composite English WM score, ARSPAN *z*-score and AOSPAN *z*-score) and priming scores.

The descriptive statistics of the L1 English group demonstrated that the mean priming score of the irregular verbs was greater than that of the regular verbs' priming score (see Table 21). In other words, in the L1 group's RTs to irregular verbs, the mean RT difference between the unrelated condition and test condition was found to be larger than the difference between the same conditions in the regular verbs.

Table 21. Descriptive Statistics for the L1 English Group's WMC and Priming Scores

	M	*SD*
ARSPAN	60.38	12.55
AOSPAN	62.00	12.36
WM Composite Score (*z*-score)	.00	.95
Irregular Priming Score	-36.88	63.19
Regular Priming Score	-18.19	56.52

In the L1 English group, the Kendall's tau-b correlation analyses did not reveal any significant relationship between the WM scores and priming scores as can be seen in Table 22.

Table 22. Kendall's tau-b Correlation Coefficients for the L1 English Group (n = 45)

		Irregular Priming Score	Regular Priming Score
	Correlation Coefficient	.025	.085
ARSPAN	Sig. (2-tailed)	.814	.416
	Correlation Coefficient	.077	.076
AOSPAN	Sig. (2-tailed)	.462	.468
WM Composite	Correlation Coefficient	.041	.105
	Sig. (2-tailed)	.688	.309
Irregular Priming	Correlation Coefficient		-.195
Score	Sig. (2-tailed)		.059

The descriptive statistics for the L2 English group were similar to those of the L1 English group (Table 23). The difference in the priming scores was lower than that of the L1 English group, with a relatively smaller difference between regular and irregular priming scores.

Table 23. Descriptive Statistics for the L2 English Group's WMC and Priming Scores (n = 45)

	M	*SD*
English ARSPAN	56.96	10.21
AOSPAN	63.98	8.907
Turkish ARSPAN	62.53	9.78
English WM Composite Score (*z*-score)	.00	.84
Turkish WM Composite Score (*z*-score)	.00	.89
Irregular Priming Score	-13.26	62.61
Regular Priming Score	-15.97	66.22

The Kendall's tau-b analyses did not reveal any relationships between various WM scores and priming scores (Table 24).

Table 24. Kendall's tau-b Correlation Coefficients for the L2 English Group (*n* = 45)

		Irregular Priming	Regular Priming
English ARSPAN	Correlation Coefficient	-.051	-.024
	Sig. (2-tailed)	.624	.822
AOSPAN	Correlation Coefficient	.110	.033
	Sig. (2-tailed)	.294	.754
Turkish ARSPAN	Correlation Coefficient	.006	.053
	Sig. (2-tailed)	.953	.617
English Composite WM	Correlation Coefficient	.041	.024
	Sig. (2-tailed)	.688	.814
Turkish Composite WM	Correlation Coefficient	.079	.039
	Sig. (2-tailed)	.445	.703
Irregular Priming	Correlation Coefficient		.070
	Sig. (2-tailed)		.500

6.2.3 Extreme groups analysis

In the extreme group comparisons, each participant group was analyzed separately. The top 1/3 and low 1/3 of each participant group were determined on the basis of English WM composite scores and categorized as two separate subgroups: higher and lower WM groups.

In both groups, the average WM scores were moderately high. Therefore, before running the ANOVA analysis in each participant group, a series of t-tests were performed in order to ensure that higher and lower WM groups had significantly different WM scores. The t-tests confirmed that in both L1 and L2 participant groups, higher and lower WM subgroups had significantly different WM scores (Table 25).

Table 25. Comparisons of Higher and Lower WMC Groups' WM Scores

	t-test for Equality of Means						
						95% Confidence Interval of the Difference	
	t	*df*	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Composite WM-English							
L1 English	13.65	28	.000**	1.87	.14	1.59	2.15
L2 English	6.81	14.81	.000**	1.78	.26	1.22	2.34
ARSPAN English							
L1 English	8.63	28	.000**	19.93	2.31	15.20	24.67
L2 English	6.1	15.18	.000**	22.20	3.64	14.45	29.95
AOSPAN							
L1 English	6.53	16.76	.000**	15.93	2.44	10.78	21.09
L2 English	6.28	15.32	.000**	22.13	3.52	14.63	29.63
Composite WM-Turkish							
L2 English	4.69	28	.000**	1.49	.32	.84	2.14
ARSPAN Turkish							
L2 English	5.8	24.53	.000**	15	2.57	9.71	20.3

$p < .001$**

The normality of the data allowed for parametric tests. Therefore, mixed ANOVA with verb type and condition as within-groups factor and WMC group as between-groups variable (higher vs. lower WMC) was run for each participant group. Greenhouse-Geisser correction was not applied since the sphericity assumption was held.

The mixed ANOVA on the L1 English group's RTs in the masked priming task revealed a marginally significant main effect of "verb type", $F(1, 28) = 4.38$, $p = .046$*, partial $\eta^2 = .14$, obs. power = .52, and a significant main effect of "condition", $F(1, 28) = 16.53$, $p = .00$*, partial $\eta^2 = .37$, obs. power = .99.

Post-hoc pairwise comparisons using t-tests with Bonferroni correction indicated that regardless of group and condition type, regular verbs (*M* = 570.58, *SD* = 12.59) were responded to significantly more slowly than irregular verbs (*M* = 556.41, *SD* = 11.59), mean difference = -20.63, *p* = .046*, 95 percent confidence interval (.751, -25.82). Another set of pairwise comparisons demonstrated that regardless of group and verb type, the identity condition (*M* = 540.57, *SD* = 12.94) yielded comparable RTs with the test condition (*M* = 561.2, *SD* = 11.73), mean difference = -16.97, *p* = .06, 95 percent confidence interval (-25.59, -8.35) and significantly different RTs than the unrelated condition, (*M* = 588.71, *SD* = 13.04), mean difference = -27.51, *p* = .00*, 95 percent confidence interval, (-70.47, -25.82). Overall, the test condition also yielded significantly faster RTs than the unrelated condition, mean difference = -23.41, *p* = .006*, 95 percent confidence interval (-47.23, -7.091).

There was no "verb type x condition" interaction, $F(2, 56) = .820$, $p = .45$, partial $\eta^2 = .028$, obs. power = .18, or "group x verb type x condition" interaction, $F(2, 56) =$

.018, p = .98, partial η^2 = .001, obs. power = .08, suggesting that both groups had similar RTs across verb types and conditions. The two-way interactions of “verb type x group”, $F(1, 28)$ = .009, p = .925, partial η^2 = .00, obs. power = .05, and “condition x group”, $F(2, 56)$ = .323, p = .725, partial η^2 = .011, obs. power = .01, were not found to be significant. Thus, it could be argued that RTs across conditions and between verb types did not differ in the two groups.

In addition, the two WM groups did not differ in terms of RT speed, $F(1, 28)$ = .801, p = .38, partial η^2 = .028, obs. power = .05. However, plots of the two groups’ RTs in different verb types and conditions showed that the higher WM group had faster RTs although the difference did not reach significance (Figure 10).

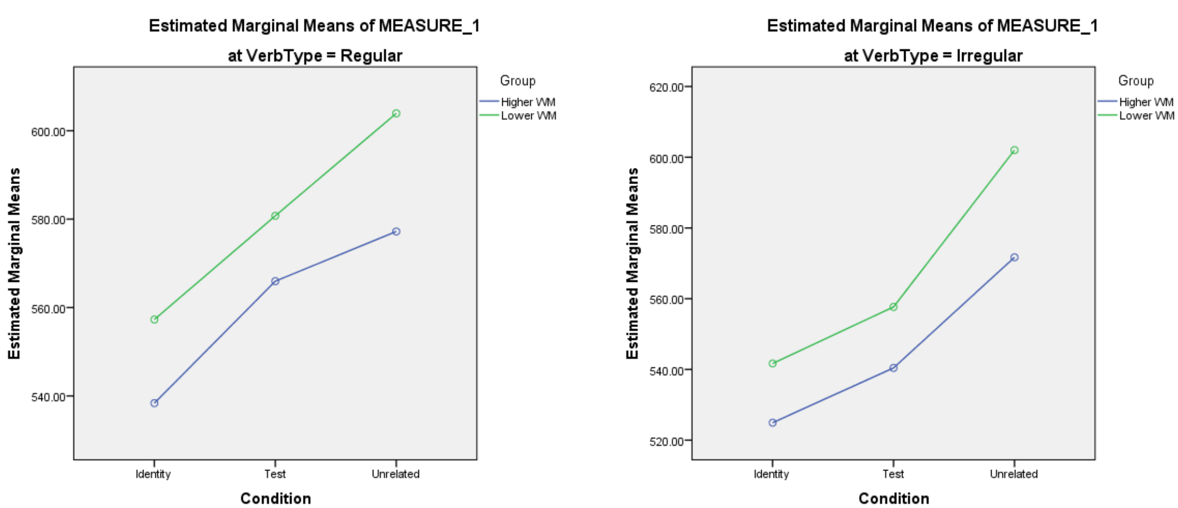

Fig. 10. RTs to regular and irregular verbs in the L1 English group

As for the L2 English group, the mixed ANOVA revealed a non-significant main effect of “verb type”, $F(1, 28) = .378$, $p = .543$, partial $\eta^2 = .013$, obs. power = .091 and a significant main effect of “condition”, $F(1, 28) = 11.64$, $p = .00$*, partial $\eta^2 = .29$, obs. power = .99. A set of pairwise comparisons demonstrated that regardless of the group and verb type, the identity condition RTs ($M = 563.58$, $SD = 14.29$) significantly differed from that of the test condition, ($M = 583.65$, $SD = 15.32$), mean difference = -20.07, $p = .04$*, 95 percent confidence interval (-39.27, -.87), and from that of the unrelated condition, ($M = 601.94$, $SD = 12.18$), mean difference = -38.36, $p = .00$*, 95 percent confidence interval, (-56.35, -19.38). However, the test condition did not yield significantly faster RTs than the unrelated condition, mean difference = -18.3, p = .140, 95 percent confidence interval (-40.68, -4.09).

There was no “verb type x condition” interaction, $F(2, 56) = .200$, $p = .819$, partial $\eta^2 = .007$, obs. power = .08, or “group x verb type x condition” interaction, $F(2, 56) = 1.76$, $p = .18$, partial $\eta^2 = .06$, obs. power = .35, suggesting that both groups had similar RTs across verb types and conditions. The two-way interactions of “verb type x group”, $F(1, 28) = .350$, $p = .559$, partial $\eta^2 = .012$, obs. power = .09, “condition x group”, $F(2, 56) = .740$, $p = .482$, partial $\eta^2 = .026$, obs. power = .17, were not found to be significant.

In addition, the two WM groups did not differ in terms of RT speed, $F(1, 28) = .53$, $p = .474$, partial $\eta^2 = .018$, obs. power = .11. However, plots of the two groups’ RTs in different verb types and conditions showed that the higher WM group had slower RTs although the difference did not reach significance (Figure 11). This contrasted with the L1 English group in which the lower WM group was the slower group.

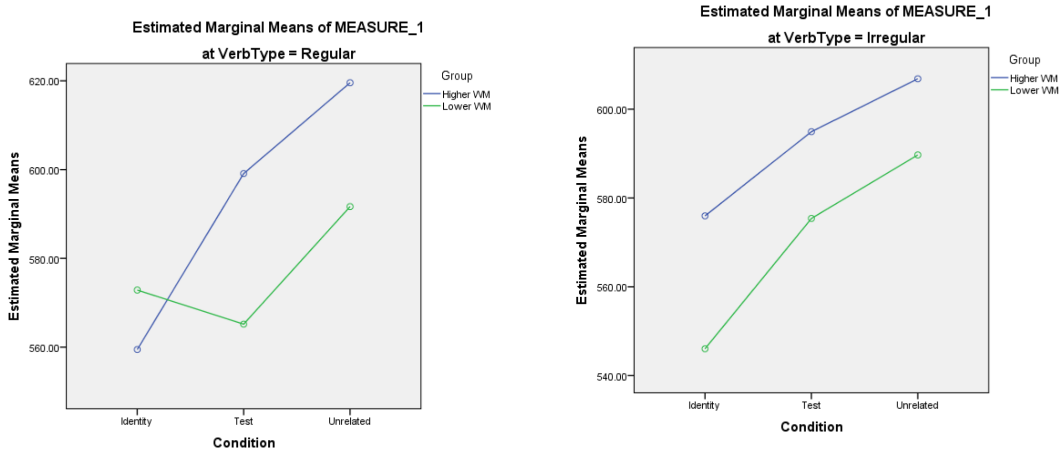

Fig. 11. RTs to regular and irregular verbs in the L2 English group

In brief, in both correlation and extreme-groups analyses, a relationship between WM and morphological priming was not found. A key finding of the extreme-groups analysis was the lack of RT speed differences between the high- and low-WMC subgroups in both L1 and L2 groups. Interestingly, the higher WM group had faster RTs than the low WM group in the L1 participant group, while it was the lower WM group which had faster RTs in the L2 group. This difference did not reach significance, however.

6.3 The results of the eye tracking task

In the eye tracking task, the fixation durations for regular and irregular verbs were compared in each participant group separately. Prior to the analysis, the eye movement data were screened for erroneous responses, blinks and track loss. Data points with track loss and erroneous responses were removed from the analysis.

6.3.1 Accuracy results

In terms of accuracy in the comprehension questions which accompany the target sentences, both participant groups had high accuracy rates (L1 English group: 99.1%, L2 English group: 97.5%). The eye movement data belonging to erroneous answers were removed from the analysis (1.8% of L1 English data and 0.05% of the L2 English data).

6.3.2 Fixation duration analysis

Since the word length (i.e., number of letters) of the regular inflected verbs exceeded the length of the irregular inflected verbs, length-corrected residual reading times were calculated on the basis of each participant's data, following prior research (Trueswell, Tanenhaus, & Garnsey, 1994, p. 310), which was explained in Section 5.3.4.6.

The descriptive statistics of the raw data revealed that regular verbs received slightly shorter first fixation and gaze durations than irregular verbs in the L1 English group (see Table 26). The second pass fixation durations and total fixation durations were very similar in regular and irregular verbs. Similarly, in the L2 English group, the first fixation duration and gaze durations were slightly shorter in regular verbs. However, the second pass and total fixation durations were longer in regular verbs compared to irregular verbs. Overall, the fixation durations in the L2 English group were longer than that of the L1 English group.

Table 26. Unadjusted Raw Reading Fixation Durations (ms)

Verb Type	Reading Measure	L1 English (*n* = 31)		L2 English (*n* = 46)	
		M	*SD*	*M*	*SD*
Regular	First Fixation Duration	188	0.02	207	0.03
	Gaze Duration	202	0.03	230	0.03
	Second Fixation Duration	110	0.05	209	0.06
	Total Fixation Duration	312	0.07	438	0.07
	Skipping Rate	29.3 %		14.5 %	
Irregular	First Fixation Duration	198	0.02	226	0.04
	Gaze Duration	207	0.03	240	0.04
	Second Fixation Duration	97	0.06	175	0.06
	Total Fixation Duration	304	0.06	415	0.07
	Skipping Rate	44 %		17.9%	

In order to understand whether these differences between fixation durations across verb types and groups were statistically significant, a mixed ANOVA was run with participant group (L1 and L2 English) as the between-groups factor and verb type (regular vs. irregular) as the within-groups factor (ANOVA by subjects; F_1). Another mixed ANOVA was run with verb type as the between-groups factor and participant group as the within-subjects factor (ANOVA by items; F_2).

The first mixed ANOVA run on residual first fixation durations did not reveal an effect of verb type, $F_1(1, 75) = 3.41$, $p = .069$, partial $\eta^2 = .04$, obs. power = .45, $F_2(1, 34) = 3.993$, $p = .054$, partial $\eta^2 = .105$, obs. power = .493. In addition, no interaction was found between participant group and fixation durations for verb types, $F_1(1, 75) = .35$, $p = .56$, partial $\eta^2 = .005$, obs. power = .09, $F_2(1, 34) = .401$, $p = .531$, partial $\eta^2 = .012$, obs. power = .09. A significant between-groups difference in terms of first-fixation durations was not evident, $F_1(1, 75) = .735$, $p = .394$, partial $\eta^2 = .010$, obs. power = .06, $F_2(1, 34) = .175$, $p = .678$, partial $\eta^2 = .005$, obs. power = .07.

The second mixed ANOVA on residual gaze durations did not reveal an effect of verb type, $F_1(1, 75) = 2.307$, $p = .133$, partial $\eta^2 = .03$, obs. power = .32, $F_2(1, 34) = 2.861$, $p = .1$, partial $\eta^2 = .078$, obs. power = .38. However, there was an interaction between participant group and verb type, $F_1(1, 75) = 5.04$, $p = .028$*, partial $\eta^2 = .06$, obs. power = .6, $F_2(1, 34) = 6.946$, $p = .013$*, partial $\eta^2 = .17$, obs. power = .73. The post-hoc pairwise comparisons demonstrated that in the L1 English group, gaze durations for regular verbs ($M_1 = -.016$, $SD_1 = .02$) were significantly shorter than that for irregular verbs ($M_1 = .022$, $SD_1 = .02$) [Mean difference = -.038, $p = .017$*, 95 percent confidence interval (-0.69, -.007)]. However, in the L2 English group, there was no significant difference between regular ($M_1 = -.016$, $SD_1 = .02$) and irregular verbs ($M_1 = -.024$, $SD_1 = .02$) with regard to residual gaze durations [Mean difference = .007, $p = .569$, 95 percent confidence interval (-.018, .033)]. In the by-subjects analysis, there was no significant between-groups difference evident $F_1(1, 75) = 1.468$, $p = .229$, partial $\eta^2 = .019$, obs. power = .06. However, in the by-items analysis a significant difference was found $F_2(1, 34) = 5.604$, $p = .024$*, partial $\eta^2 = .142$, obs. power = .63. The L1 English group ($M_1 = .022$, $SD_1 = .02$) was found to have longer gaze durations than the L2 English group ($M_1 = -.015$, $SD_1 = .01$) [Mean difference = .025, $p = .024$*, 95 percent confidence interval (0.003, .046)].

In terms of residual second fixation durations, there was no effect of verb type [$F_1(1, 75) = .036$, p = .849, partial $\eta^2 = .00$, obs. power = .054, $F_2(1, 34) = .257$, p = .616, partial $\eta^2 = .007$, obs. power = .08], nor any participant group x verb type interaction [$F_1(1, 75) = .664$, $p = .849$, partial $\eta^2 = .06$, obs. power = .01, $F_2(1, 34) = .200$, $p = .657$, partial $\eta^2 = .006$, obs. power = .07]. A significant between-groups difference in terms of residual second fixation durations was not found $F_1(1, 75) = .137$, $p = .713$, partial $\eta^2 = .002$, obs. power = .07, $F_2(1, 34) = 1.18$, $p = .285$, partial $\eta^2 = .034$, obs. power = .18.

Finally, with regard to residual total fixation durations, there was no significant effect of verb type, $F_1(1, 75) = 1.45$, $p = .232$, partial $\eta^2 = .02$, obs. power = .22, $F_2(1, 34) = 2.115$, $p = .155$, partial $\eta^2 = .059$, obs. power = .29. Similarly, there was no interaction between participant group and verb type, $F_1(1, 75) = .887$, $p = .349$, partial $\eta^2 = .01$, obs. power = .15, $F_2(1, 34) = 2.032$, $p = .163$, partial $\eta^2 = .056$, obs. power = .28. A significant between-groups difference in terms of residual total fixation durations was not evident $F_1(1, 75) = .784$, $p = .379$, partial $\eta^2 = .01$, obs. power = .14, $F_2(1, 34) = .473$, $p = .496$, partial $\eta^2 = .014$, obs. power = .1.

Overall, the results of the eye tracking task were similar in both participant groups. Significant differences with regard to verb type were not found in both groups' early and late eye movements. One of the few significant differences was in the L1 group's gaze durations; the regular verbs yielded faster gaze durations than irregular verbs in this participant group. In addition, in the by-items analysis, the L1 group's gaze durations in general were found to be longer than that of the L2 English group.

6.4 The correlation between eye tracking and WMC tasks

As a final analysis, any correlations between fixation durations and WMC were traced. Here extreme-groups analysis was not carried out due to low sample size. The correlation analyses did not reveal any correlation between fixation durations for regular and irregular verbs and WM scores in the L1 group (see Tables 27-28).

Table 27. Correlation between WM and Fixation Durations for Regular Verbs in the L1 English Group (n = 31)

		FFD	GD	SFD	TFD
ARSPAN	Pearson Correlation	-.301	-.303	.135	.014
	Sig. (2-tailed)	.100	.098	.470	.940
AOSPAN	Pearson Correlation	-.153	-.060	.192	.173
	Sig. (2-tailed)	.411	.747	.301	.353
WM Composite	Pearson Correlation	-.254	-.203	.182	.104
Score	Sig. (2-tailed)	.168	.274	.326	.576
FFD	Pearson Correlation		.788**	-.289	.025
	Sig. (2-tailed)		.000	.114	.895
GD	Pearson Correlation			-.274	.129
	Sig. (2-tailed)			.136	.489
SFD	Pearson Correlation				.918**
	Sig. (2-tailed)				.000

* . Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
(FFD = First fixation duration, GD = Gaze duration, SFD = Second fixation duration, TFD = Total fixation duration)

Table 28. Correlation between WM and Fixation Durations for Irregular Verbs in the L1 English group (n = 31)

		FFD	GD	SFD	TFD
ARSPAN	Pearson Correlation	.351	.190	-.185	.022
	Sig. (2-tailed)	.053	.305	.318	.908
AOSPAN	Pearson Correlation	.023	.065	-.413*	-.219
	Sig. (2-tailed)	.904	.729	.021	.237
WM Composite	Pearson Correlation	.209	.143	-.334	-.110
Score	Sig. (2-tailed)	.260	.444	.066	.555
FFD	Pearson Correlation		.658**	.022	.503**
	Sig. (2-tailed)		.000	.906	.004
GD	Pearson Correlation			.030	.761**
	Sig. (2-tailed)			.872	.000
SFD	Pearson Correlation				.671**
	Sig. (2-tailed)				.000

* . Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
(FFD = First fixation duration, GD = Gaze duration, SFD = Second fixation duration, TFD = Total fixation duration)

The findings from the L2 English group mirrored those of the L1 English group. No significant correlations were found between the WM scores and early and late fixation durations for regular and irregular verbs (Tables 29-30).

Table 29. Correlation between WM and Fixation Durations for Regular Verbs in the L2 English Group (*n* = 41)

		FFD	GD	SFD	TFD
ARSPAN	Pearson Cor.	-.234	-.075	.014	-.064
English	Sig. (2-tailed)	.141	.640	.932	.693
AOSPAN	Pearson Cor.	-.144	-.012	.096	.043
	Sig. (2-tailed)	.371	.942	.551	.792
English WM	Pearson Cor.	-.226	-.052	.066	-.012
	Sig. (2-tailed)	.155	.745	.680	.938
ARSPAN Turkish	Pearson Cor.	-.049	.106	-.084	.050
	Sig. (2-tailed)	.761	.511	.601	.756
Turkish WM	Pearson Cor.	-.108	.052	.007	.051
	Sig. (2-tailed)	.503	.746	.968	.750
FFD	Pearson Cor.		.483**	-.021	.439**
	Sig. (2-tailed)		.001	.896	.004
GD	Pearson Cor.			-.186	.822**
	Sig. (2-tailed)			.244	.000
SFD	Pearson Cor.				.406**
	Sig. (2-tailed)				.008

* . Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
(FFD = First fixation duration, GD = Gaze duration, SFD = Second fixation duration, TFD = Total fixation duration)

Table 30. Correlation between WM and Fixation Durations for Irregular Verbs in the L2 English Group (*n* = 41)

		FFD	GD	SFD	TFD
ARSPAN	Pearson Cor.	-.083	.136	-.063	.103
English	Sig. (2-tailed)	.604	.396	.695	.523
AOSPAN	Pearson Cor.	-.210	-.043	.116	.023
	Sig. (2-tailed)	.188	.787	.470	.888
English WM	Pearson Cor.	-.176	.054	.031	.074
	Sig. (2-tailed)	.270	.735	.846	.647
ARSPAN Turkish	Pearson Cor.	-.150	.087	.056	.114
	Sig. (2-tailed)	.348	.590	.726	.476
Turkish WM	Pearson Cor.	-.200	.025	.096	.077
	Sig. (2-tailed)	.210	.878	.551	.633
FFD	Pearson Cor.		.502**	-.109	.438**
	Sig. (2-tailed)		.001	.496	.004
GD	Pearson Cor.			-.263	.847**
	Sig. (2-tailed)			.096	.000
SFD	Pearson Cor.				.290
	Sig. (2-tailed)				.065

* . Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). (FFD = First fixation duration, GD = Gaze duration, SFD = Second fixation duration, TFD = Total fixation duration)

To summarize, the findings from the correlation analyses between fixation durations and WM tasks did not reveal any significant relationships in either participant group.

6.5 Summary of findings

The findings of the masked priming task revealed slower RTs in the L2 English group in comparison to the L1 English group. In addition, the regular verbs were responded to slower than irregular verbs in both groups. Despite the absence of a group x verb type x condition interaction, further pairwise comparisons were performed, which revealed a partial priming pattern across the conditions for regular verbs (identity < test < unrelated) and full priming pattern for the irregular verbs (identity = test < unrelated) in both groups.

With regard to morphological processing in the sentence context, early (first fixation duration, gaze duration) and late processing measures (second fixation duration, total fixation duration) did not indicate major differences between regular and irregular verbs in either group. Regular and irregular verbs yielded significantly different fixation durations (i.e., faster fixation durations for regular verbs) only in the L1 English group with regard to gaze duration. In addition, in the by-items analysis, the L1 group's overall gaze durations were found to be longer than that of the L2 English group.

The correlation analyses did not point to any relationship between WM and masked priming and eye tracking results in either group. The extreme-groups analysis, whereby high and low WM subgroups in each participant group were compared, did not result in significant between-group differences in the masked priming task results. Overall, the findings of the L1 English participants were similar to that of L2 English participants.

CHAPTER 7

DISCUSSION

In this section, the results of the masked priming task, the eye tracking task and the WM tasks will be discussed with specific reference to the research questions of the study and the previous literature.

7.1 Morphological processing in the single word context

The first research question concerned the possible differences between L1 and L2 participants' morphological priming patterns in the masked priming task. In relation to this, the question of whether similar or distinct processing routes (i.e., decomposition or storage) are at work in the processing of regular and irregular English inflected words was investigated.

7.1.2 Dual-system vs. unitary system processing of inflections

In terms of a distinction between the processing of regular and irregular forms, the results of the masked priming experiment give partial support to accounts which propose distinct morphological processing patterns for regularly and irregularly inflected verbs in English as the nature of this distinction between regular and irregular verb processing found in the present study is slightly different from what was reported in earlier research. Recall that dual-system accounts presume decomposition (i.e., full priming in the form of an "identity < test < unrelated" pattern for regularly inflected verbs; and storage (i.e., identity ≤ test = unrelated) for irregular verbs (e.g., Babcock et al., 2012;

Neubauer & Clahsen, 2009; Ullman, 2004). In the current study, while the regular verbs under investigation induced partial priming (i.e., identity < test < unrelated), irregular verbs induced full priming (i.e., identity ≤ test < unrelated). Crucially, for both regular and irregular verbs there was a priming effect as the RTs in the morphological test condition were significantly shorter than the RTs in the unrelated condition. This is not in line with the central arguments of dual-system accounts of processing as this study not only found negligible difference between the regular and irregular verbs in terms of the involvement of decomposition but also full priming (i.e., stronger decomposition effects) effects for irregular verbs.

The finding of reduced facilitation, namely reduced decomposition for regular verbs was an unexpected finding of the study. In the previous literature, lexical decision experiments with or without masked priming have usually resulted in strong priming effects for regular verbs (Basnight-Brown et al., 2007; Feldman et al., 2010; Kielar, Joanisse & Hare, 2008; Pliatsikas & Marinis, 2013; Silva & Clahsen, 2008). However, the majority of these studies did not have an identity condition (Basnight-Brown et al., 2007; Feldman et al., 2010; Kielar, Joanisse & Hare, 2008; Pliatsikas & Marinis, 2013); priming effects were explained by differences between morphologically related and unrelated conditions. As for those studies which included an identity condition (Fruchter, Stockall & Marantz, 2013; Silva & Clahsen, 2008), they did not directly test regular and irregular types for comparison. Therefore, the present results should not be taken as completely startling.

In the literature, partial priming effects are interpreted as an indirect activation of shared lexical entries of the target word, which points to a processing mechanism distinct from the one indicated by full priming effects (Clahsen & Fleischhauer, 2014;

Pinker, 1999). However, this interpretation is disputable since partial priming effects can also be interpreted as a lower amount of priming induced in the same processing mechanism as full priming. According to Crepaldi et al. (2010), regular verb roots can be accessed by both direct morphological access and indirect lexical activation by means of shared representations. The dominance of one route over the other may depend on the word characteristics. Thus, one explanation for the reduced priming effect for regular forms may be the relatively high frequency of the target regular verbs, which might have decreased decomposition effects in this verb group, leading to a decreased need for relying on morphological decomposition in lexical decision. As discussed previously, it has been suggested that English words with a frequency of over six per million are expected to be stored (Alegre & Gordon, 1997). Seen in this light, the current findings are not unexpected.

However, frequency cannot be the sole reason for the decreased decomposition of regular verbs since the irregular verb targets were matched with regular verb targets in terms of overall frequency; they also had a considerably high mean root frequency. Nevertheless, they were prone to slightly more priming effects, i.e., decomposition than regulars.

Another possibility is that decomposition may have become more automatized for regular verbs and thus the effects of morphological facilitation emerge less in this verb category. In other words, regularly inflected verbs might have already undergone an automatized computational processing, which looks like storage. Thus, when the participants become exposed to inflected forms as primes (in the test condition), they do not access the roots as fast as they do in the identity condition.

With regard to the irregular forms, full-listing or storage effects were not found. On the contrary, the presence of priming effects in irregular forms was more salient in the present study. This particular finding is not a very common pattern in the morphological processing literature and dual-system accounts. Nevertheless, evidence for priming in irregular verbs has been reported in recent years (Crepaldi et al., 2010; Kielar, Joanisse & Hare, 2008; Rastle et al., 2015). This priming effect is explained by the activation of shared lemma representations with the root when an irregularly inflected verb is accessed (Crepaldi et al., 2010). This implies that activation of irregular roots will be less direct and powerful than that of regular verbs. However, contrary to the studies mentioned previously, we found stronger priming effects for irregular verbs in comparison to regular verbs. This might have stemmed from the shorter length of the irregular primes when compared with regular primes. As previously discussed, another possibility might be that irregular verbs benefited more from the facilitatory effect of seeing the base prime, as reaching the lemma representation is considered to be less direct for this verb type.

One might also argue that the specific irregular verbs selected for analysis might have induced more decomposition due to their internal features, such as strength. However, further analysis did not reveal any differences between RTs to weak irregulars which resemble regular verbs as opposed to strong irregulars, which do not have this resemblance. As a matter of fact, the RT facilitation was greater for the strong irregulars.

It might be hypothesized that the obtained priming effects, partial or full, are based on pure orthographic overlap. Given that the amount of priming was actually slightly greater in the irregular verb group, which has less orthographic prime-target overlap than the regular verb group, this view does not seem to be plausible. On the basis of this anti-orthographic transparency effect, it can be inferred that priming facilitation is greater for less transparent morphological relationships in the present study and thus the degree of orthographic similarity between the prime and the target does not seem to explain the priming effect.

It should be noted that it is rather challenging to interpret the findings on the basis of the literature; this partly stems from the inconsistency in the previous studies' results. One explanation for this variance in results is the use of different instruments and paradigms for obtaining and interpreting the results. Even when the same measurement instrument is used, e.g., masked priming, the SOA, item size, frequency measures or manipulation of frequency effects greatly differ across studies. Needless to say, variability among participants is another potential source of variability in L2 processing studies.

Overall, the present findings converge with accounts of unitary processing of inflected forms. Priming, namely decomposition effects were documented for both regular and irregular verbs, but the degree of priming was slightly smaller for the regular forms. Despite the reduced priming in regular verbs, access to lemma representations took place in both L1 and L2 speakers of English. However, the RTs to the regular verbs were slower than that of length- and frequency-matched irregular verbs regardless of condition. Therefore, it could be argued that the difference between the processing of regular and irregular verbs seems to be quantitative rather than qualitative in nature.

7.1.3 Nativelike vs. non-nativelike morphological processing

The results of the masked priming task revealed that L1 and advanced level L2 speakers of English, who are late L2 learners, display similar patterns of morphological processing. Both groups showed evidence of priming for both regular and irregular verbs. In both groups, regular verbs yielded partial priming effects while the irregular verbs yielded full priming.

The results of the present study are in line with accounts which emphasize the possibility of nativelike processing of inflected words, at least in highly proficient English learners (Basnight-Brown et al., 2007; Feldman et al., 2010). The present evidence is in favor of sensitivity to the internal structure of morphologically complex forms among L2 speakers. The results mirror the presence of decomposition effects obtained in L2 speakers with varying L1 backgrounds by means of different methodologies and paradigms (Coughlin & Tremblay, 2015; Gor & Jackson, 2013; Kırkıcı, 2005, 2010). There is also support for the argument that language processing can be nativelike even for late L2 speakers who learned the L2 after the critical period for language acquisition, provided they reach a certain level of L2 proficiency (Epstein, Flynn, & Martohardjono, 1996; Flege, Yeni-Komshian, & Liu, 1999) as opposed to accounts claiming the impossibility of nativelike processing (Bley-Vroman, 1989; Johnson & Newport, 1989).

The results do not pattern with the non-nativelike processing accounts such as shallow processing and declarative-procedural model. Studies supporting these accounts underestimate the possibility of decomposition in L2 speakers, even at advanced levels of proficiency (Babcock et al., 2008; Clahsen et al., 2013; Neubauer & Clahsen, 2009;

Silva & Clahsen, 2008). Although decompositional processing has not been reported for L2 speakers in these studies, in the present study it has been documented that L2 speakers can decompose morphologically complex forms. As a matter of fact, the degree of decomposition was even larger in L2 participants than L1 speakers, as will be discussed later.

One area where L1 and L2 speakers diverged was the response speed. L2 speakers' overall RTs were lower than that of L1 speakers in the masked priming experiment. This difference was merely quantitative in nature since the general response patterns across conditions and verbs were similar in both groups. This finding is in line with accounts that favor nativelike but slower L2 processing (Gor, 2015; McDonald, 2006).

An unexpected result was the presence of slightly stronger priming effects in both verb types in the L2 English group. One possibility is that L1 speakers are more automatic in decomposition and thus benefit from masked priming facilitation to a lower extent than L2 speakers (see also Gürel, 1999; Gürel & Uygun, 2013 for reduced decomposition in L1 speakers in the simple lexical decision paradigm). Another reason for the stronger priming facilitation might be the L1 background of the L2 speakers. In Turkish, the inflection paradigm is rich and this might have increased the L2 participants' morphological awareness. This sensitivity may also have been enhanced by the formal L2 English instruction in Turkey. The majority of the learners had received intensive explicit grammar-based instruction of English for about ten years and thus their metalinguistic awareness might be above average. This also contrasts with the hypothesis that formal learning environments might trigger storage effects in morphological processing, whereas more naturalistic learning environments, such as immersion contexts enhance decomposition effects (Kırkıcı, 2005; Portin et al., 2008; see Gürel & Uygun, 2013 for counter arguments)

On the basis of these accounts, it could be argued that L2 speakers exhibit similar morphological processing patterns with L1 speakers, provided they are highly advanced and automatized. Any processing differences between the two groups seem to be limited to response speed and automatization in lexical access.

7.2 Morphological processing in the sentence context

One of the primary questions in the present study was whether the morphological processing patterns for regular and irregular forms differ between single word and sentence contexts. The masked priming task results, which are based on highly implicit and early stages of processing, were contrasted with that of another processing measure, eye fixation durations, through which it is possible to differentiate between early and late stages of processing. Furthermore, lexical access in a sentence context provides a more natural context for processing of words.

In the masked priming task, the RTs for regular verbs were longer than that for irregular verbs, and there were slight differences in terms of priming facilitation. The regular verb primes yielded less morphological facilitation than the irregular verb primes. In the eye tracking task, however, the fixation durations to regular verbs did not differ from that of irregular verbs. In general, both early and late measures of eye fixation did not reveal any significant processing discrepancies between the two verb types. The only noticeable difference was in the residual gaze duration; regular verbs received shorter gaze duration than irregular verbs in the L1 English group, whereas both verb types received equal amounts of gaze duration in the L2 English group. Gaze duration is an indicator of early processing; therefore, it could be speculated that at the early stages of processing, decomposition is less likely for L1 speakers' processing of regular forms in a sentence context. However, it should be kept in mind that skipping rates were higher for irregular verbs, which resulted in fewer data points in this verb group. This might also indicate that irregular verbs are actually processed more quickly without requiring much computation. The skipping rates were overall higher and the skipping rate difference between verb types was more pronounced in the L1 English group, which might be another indicator of faster processing in L1 processing.

With regard to second-pass durations and total fixation durations, the regular verbs were fixated longer than irregular verbs, yet this difference did not reach significance. Thus, it could be argued that at later stages of processing which indicate integration of morphological information with the sentence context, there are no fixation duration differences between the two verb types in both participant groups.

The findings of the present study diverge from previous studies carried out in the sentence context, which report processing costs for regularly inflected verbs in English (Allen, Badecker, & Osterhout, 2003; Luke & Christianson, 2011; Newman et al., 2007). These studies are of indirect relevance to the present study since they did not use the eye-tracking paradigm; the only related eye-tracking study that examined processing differences between regular and irregular verbs belong to Niswander, Pollatsek and Rayner (2000). Our results converged with those of this study in that processing costs could not be established for regular verbs in either early or late processing measures.

On the basis of these findings, it could be argued that when morpho-syntactic integration of information is necessary, any RT differences between verb types diminish.

This highlights the importance of task effects in detecting processing differences. The masked priming task might induce more decompositional processing than the sentence task by exposing learners to the root of the inflected forms. Another possibility is that contextual and semantic effects may override the morphological processing effects in the sentence context (Gor, 2015). The inflected verb forms are mostly encountered in the sentence context in daily life and thus processing them in their natural context might be easier than in the single word context.

7.3 Working memory and L2 morphological processing

Another question investigated in the present study was the potential relationship between WMC and morphological processing routes. More specifically we aimed to investigate whether high or low WMC might be associated with more decomposition or storage effects and faster or lower RTs.

It has been generally agreed that L2 speakers are slower than L1 speakers in terms of processing speed (Clahsen & Felser, 2006). In the present study, this processing delay was replicated in L2 speakers in the masked priming task; however, the morphological processing patterns did not differ between the two participant groups. A processing difference was observed in the morphological facilitation between verbs.

According to some researchers, the reason underlying the slower response speed of L2 speakers might be lack of sufficient WM resources (McDonald, 2006). However, the findings of the present study hint that lack of general WM resources for computation is not related to L2 processing, at least in terms of processing morphologically complex English words in general and processing of tense-inflected verbs in particular. One can argue that in highly automatized L2 learners and also L1 speakers, WMC does not influence the processing of morphological processing.

One reason for the lack of WM effects in the L2 group may be that the proficient L2 speakers who participated in the study are highly automatized. This group was deliberately chosen so as to avoid the confounding effects of language proficiency on WM tasks. Even after this precaution, the mean English verbal WM score (ARSPAN) of the L2 group was found to be slightly lower than that of the L1 group, with the composite WM scores and AOSPAN scores being equivalent in both groups. This implies that lower cognitive resources, as is the case with the L2 group's marginally lower scores in the linguistic component of the WM tasks, is not a viable explanation for differences between native and nonnative processing since both groups' morphological processing patterns were similar to each other.

In addition, although WMC did not significantly correlate with morphological priming and processing, overall, the lower WM participants were found to have faster RTs than the higher WM participants in the L2 English group. This difference did not reach statistical significance; however, it demonstrated that a higher WM in the L2 does not necessarily imply faster RTs.

Another reason for the lack of WM effects might be the implicit nature of word recognition. The tasks we have adopted–masked priming and eye tracking– tap into implicit processing. With the presence of an interference task, any individual differences in WM might surface at a higher level of L2 proficiency.

The homogeneity of the participants might be another reason for the lack of WM effects. The participants of the L2 English were especially homogeneous in terms of educational background and cognitive skills. Most participants had high WM scores and this may have prevented teasing apart any processing differences between the lower and higher WM participants.

The results of the present study are not compatible with the arguments of the cognitive processing accounts which link variances in L2 processing to individual and cognitive differences, such as memory and attention. Similarly, the results raise doubts about the accounts which support native or non-nativelike L2 processing, and link any quantitative or qualitative processing differences to WM constraints. In the present study, high WM scores did not correlate with faster processing. In addition, in the extreme-groups comparison of the L2 group, higher WM participants' responses were found to be slower than that of lower WM participants. In the light of these findings, it could be argued that automatization in L2 processing, rather than WM resources account for any divergences from nativelike processing.

Based on the present findings, it is still premature to argue that WMC does not have any relationship with morphological processing at early stages of proficiency. As Linck and Weiss (2015) have put forward, WMC advantages may be confined to the early stages of L2 learning and the participants tested in the present study were beyond that stage.

The results of the WMC tasks have also some implications about the correlation between L1 and L2 WM scores. A moderate correlation was found between WMCs measured in the first and second languages. Despite their high proficiency level, the L2 participants' L2 WM scores were lower than their L1 WM scores, but the difference was not statistically significant. This finding provides evidence that measurement of WM only in the L2 might be misleading. In the same way, the scores of the AOSPAN were moderately correlated with the ARSPAN. Although this is not directly related to the scope of this study, this gives support for the argument that linguistic and non-linguistic WMC tasks may yield differing results and validates the use of multiple measures in WM research.

CHAPTER 8

CONCLUSION

8.1 General evaluation

Across the three components of the study, the outline of the results indicates similar processing patterns for L1 and L2 English speakers. These findings complement past work investigating morphological processing of regular and irregular inflected verbs in English. In terms of processing differences between regular and irregular morphology, decomposition effects were found for both verb types. The results diverged from the previous literature by demonstrating reduced priming for regular verbs and stronger priming for irregular verbs. The reduced decomposition for regular verbs can be explained by the highly automatized decomposition skills of the L1 speakers, as was also evident by their overall faster RTs than the L2 English group. The presence of stronger priming effects in the L2 English group might indicate greater morphological facilitation from exposure to the base prime. The L1 speakers, on the other hand, might benefit from this facilitation to a lesser degree as they access the base form of the inflected form more automatically.

Although regular verbs were responded to more slowly than irregular verbs in the masked priming task, this response pattern was not replicated in the early and late reading time measures of the sentence-based eye tracking task. It can be hypothesized that any processing costs or differences in processing inflection might disappear when morpho-syntactic integration of information is necessary.

WMC does not seem to explain the quantitative processing differences between L1 and L2 speakers. L2 speakers are generally slower in processing tasks; however, lack of WM resources in the L2 is not related to this discrepancy. In the L2 English group, the lower WM participants tended to give faster responses than high WM participants in the masked priming task although this difference was not statistically significant.

The results obtained in the study mostly differed from those of previous studies. The varying results in L2 processing of morphology research can be attributed to the use of different instruments and paradigms for the comparison of response latencies and items. Some studies adopt masked priming tasks, which tap into highly implicit and automatic stages of processing (Silva & Clahsen, 2008) while others use cross-modal priming tasks (Basnight-Brown et al., 2007), which control for form overlap between the prime and the target. The results of the experimental studies should be evaluated on the basis of their measurement instrument's characteristics. In addition, the frequency measures greatly differ across morphological processing studies; the majority of the previous studies are based on written English corpora, which may not be contemporary. All of these should be considered when interpreting and comparing the results and assessing the reproducibility of the previous works.

8.2 Limitations to the study

The results of the present study should be considered along with its limitations. One limitation to the research was the limited number of experimental items in the masked priming and eye tracking tasks. The main reason for this was the small number of regular and irregular verbs which could be matched in terms of frequency and length as measured by the number of syllables and letters. This partly stemmed from the limited number of irregular verbs (with a rate of 5% among all English verbs, Marcus et al., 1995). This limitation also prevented us from manipulating the frequency within regular and irregular verbs and tracing frequency effects for high and low frequency items. The number of weak and strong irregular verbs could not be equalized for the same reason.

Another limitation was the uniformity in WM scores in both participant groups. This might have obscured potential WM differences in morphological processing. The participant group was also uniform in terms of having an extended explicit L2 learning history, which might have increased their metalinguistic awareness and thus boosted decompositional processing.

The unequal length of the regular and irregular verbs also caused complications in the eye tracking task. Since the irregular verbs were shorter than regular verbs, they had higher skipping rates, which resulted in fewer data points in this verb type.

8.3 Implications and suggestions for future research

Although the present study is not directly related to learning of an L2, we can make some inferences based on the findings. It has been understood that at advanced levels of L2 proficiency, it is possible to process an L2 in a nativelike fashion, even for late L2 learners. Decomposition might be more taxing for L2 speakers, but with increased automaticity reached at higher levels of proficiency, this processing mechanism will become more readily available. This requires sufficient exposure to the target forms. In addition, depending on the frequency of the target forms, even decomposable forms might be accessed via stored representations. When the L2 speakers' lexicon becomes larger with sufficient proficiency, storage of highly frequent items seems to be more likely (Gor, 2015).

Further research is required to understand broader aspects of L2 morphological processing and its possible links with various individual differences. In order to trace the influence of cognitive factors, L2 speakers with a lower proficiency should also be investigated. Individual differences such as WMC may be more pronounced at the early stages of L2 learning and may diminish once the learner becomes more automatized in the L2. In addition, in future studies the WMC can be measured by other instruments, such as n-back, listening span task which may offer different insights and results.

Another suggestion might be to add an interference effect in the lexical decision task so that the participants' WM resources would be more exhausted and WM effects, if any, could be uncovered. This may also enable us to understand how online morphological processing occurs under more time-constrained conditions, which presents more challenges to L2 speakers in real life communication. Shifting the focus to production of morphologically complex forms might also produce different results from visual recognition studies with regard to WM effects. Apart from these, recall of inflected words can be analyzed with regard to regularity.

More strict control of regular and irregular verb characteristics should also be aimed at in future studies. Further characteristics of the items, such as neighborhood density, family size, and phonological similarity can be controlled for. Apart from this, an orthographic control condition might ensure whether any priming effects are based on pure orthographic overlap.

Future research might also investigate participants speaking an L1 which is closer to English in terms of morphology. This would enable us to understand whether any differences in L2 processing have connections with L2 speakers' L1 background.

APPENDIX A

EXPERIMENTAL STIMULI IN THE MASKED PRIMING TASK

Table 31. Regular Verbs (Targets, Identity Condition Prime Words)

Target (Also Prime)	**Word Frequency**	**Log10 Frequency**	**Length**	
			Number of Letters	**Number of Syllables**
FILL	43.94	3.35	4	1
LOCK	56.57	3.46	4	1
RAISE	55.20	3.45	5	1
REACH	56.92	3.46	5	1
SERVE	37.94	3.29	5	1
KICK	73.41	3.57	4	1
TOUCH	147.73	3.88	5	1
SIGN	133.27	3.83	4	1
PASS	108.12	3.74	4	1
DROP	130.61	3.82	4	1
CHANGE	240.35	4.09	6	1
SEEM	139.82	3.85	4	1
PULL	146.45	3.87	4	1
SAVE	162.31	3.92	4	1
CHECK	278.98	4.15	5	1
WALK	215.86	4.04	4	1
PICK	198.39	4.01	4	1
KNOCK	64.69	3.52	5	1
Average	127.25	3.74	4.44	1
SD	72.02	0.27	0.62	0.00

Table 32. Regular Verbs - Morphological Relation Condition Prime Words

Prime	**Word Frequency**	**Log10 Frequency**	**Length**	
			Number of Letters	**Number of Syllables**
filled	26.92	3.14	6	1
locked	48.37	3.43	6	1
raised	25.04	3.12	6	1
reached	24.73	3.10	7	1
served	19.75	3.00	6	1
kicked	30.55	3.19	6	1
touched	28.96	3.18	7	1
signed	34.08	3.26	6	1
passed	51.51	3.42	6	1
dropped	48.63	3.39	7	1
changed	98.96	3.71	7	1
seemed	54.25	3.44	6	1
pulled	48.47	3.40	6	1
saved	69.22	3.55	5	1
checked	46.51	3.38	7	1
walked	53.67	3.44	6	1
picked	68.98	3.55	6	1
knocked	24.73	3.10	7	1
Average	44.63	3.32	6.28	1
SD	20.41	0.19	0.57	0.00

Table 33. Regular Verbs - Unrelated Condition Prime Words

Prime	**Word Frequency**	**Log10 Frequency**	**Length**	
			Number of Letters	**Number of Syllables**
strike	27.47	3.37	6	1
search	48.37	3.39	6	1
create	25.27	3.11	5	2
intend	23.20	3.07	6	2
climb	19.75	3.00	5	1
spread	31.29	3.20	5	1
freeze	32.16	3.22	6	1
prefer	32.92	3.23	6	2
treat	51.88	3.42	5	1
breathe	48.51	3.39	7	1
marry	104.35	3.73	5	2
begin	56.98	3.46	5	2
decide	50.41	3.41	6	2
carry	65.88	3.53	5	2
escape	44.27	3.35	6	2
accept	52.78	3.43	6	2
prove	70.39	3.56	5	1
appear	23.37	3.08	6	2
Average	44.96	3.33	5.61	1.56
SD	21.26	0.19	0.61	0.51

Table 34. Irregular Verbs (Targets, Identity Condition Prime Words)

Target (Also Prime)	**Word Frequency**	**Log10 Frequency**	**Length**		**Strength***
			Number of Letters	**Number of Syllables**	
BUILD	48.08	3.39	5	1	Weak
STEAL	53.33	3.43	5	1	Strong
GROW	59.49	3.48	4	1	Strong
TEACH	72.84	3.57	5	1	Weak
BLOW	97.57	3.70	4	1	Strong
FALL	118.51	3.78	4	1	Strong
SELL	92.25	3.67	4	1	Weak
SPEND	93.27	3.68	5	1	Weak
WAKE	105.22	3.73	4	1	Strong
WEAR	109.33	3.75	4	1	Strong
CATCH	135.51	3.84	5	1	Weak
DRIVE	153.14	3.89	5	1	Strong
WRITE	126.80	3.81	5	1	Strong
BREAK	221.08	4.05	5	1	Strong
THROW	128.82	3.82	5	1	Strong
FIGHT	201.08	4.01	5	1	Weak
STAND	226.20	4.06	5	1	Strong
SLEEP	227.94	4.07	5	1	Weak
Average	126.14	3.76	4.67	1	
SD	74.28	0.21	0.49	0.00	

* Weak=addition of t

Table 35. Irregular Verbs – Morphological Condition Prime Words

Prime	**Word Frequency**	**Log10 Frequency**	**Length**	
			Number of Letters	**Number of Syllables**
built	41.16	3.32	5	1
stole	52.33	3.43	5	1
grew	29.25	3.17	4	1
taught	43.61	3.35	6	1
blew	31.57	3.21	4	1
fell	69.78	3.57	4	1
sold	51.31	3.42	4	1
spent	69.67	3.55	5	1
woke	26.35	3.13	4	1
wore	21.20	3.03	4	1
caught	92.78	3.68	6	1
drove	28.86	3.17	5	1
wrote	71.16	3.56	5	1
broke	35.49	3.73	5	1
threw	40.82	3.32	5	1
fought	26.71	3.13	6	1
stood	25.78	3.12	5	1
slept	35.49	3.26	5	1
Average	44.07	3.34	4.83	1
SD	19.99	0.21	0.71	0.00

Table 36. Irregular Verbs – Unrelated Condition Prime Words

Prime	**Word Frequency**	**Log10 Frequency**	**Length**	
			Number of Letters	**Number of Syllables**
split	38.31	3.29	5	1
share	51.69	3.55	5	1
ruin	28.53	3.16	4	1
settle	42.02	3.33	6	2
vote	34.33	3.24	4	1
grab	70.86	3.56	4	1
dare	55.41	3.45	4	1
smoke	65.43	3.52	5	1
drag	26.45	3.13	4	1
deny	21.39	3.04	4	2
swear	88.16	3.65	5	1
scare	33.57	3.23	5	1
offer	74.71	3.58	5	2
paint	36.80	3.27	5	1
wash	40.73	3.32	4	1
borrow	29.31	3.17	6	2
exist	28.96	3.17	5	2
shake	39.63	3.31	5	1
Average	44.79	3.33	4.72	1.28
SD	18.90	0.18	0.67	0.46

APPENDIX B

NORMING CLOZE TASK

EYE TRACKING TEST ITEMS

1	The elderly couple	**served** **grew**	organic fruit and vegetables in this place.
2	The young boy	**knocked** **stood**	at the window, waiting impatiently for someone to open it.
3	The little girl	**reached** **woke**	her older sister after several unsuccessful attempts.
4	The king's brother	**raised** **fought**	the prince at the beginning of the 19^{th} century.
5	The nursery children	**filled** **wore**	socks with toys at the Christmas party.
6	The small boy	**touched** **drove**	his new toy car and then clapped his hands with joy.
7	The two campers	**kicked** **blew**	out the fire in the tent very quickly.
8	The new President	**signed** **broke**	the new cyber security laws and regulations.
9	The retired man	**checked** **taught**	the sick children in the refugee camp once a week.
10	The company owners	**locked** **built**	their new office in the city center due to security reasons.
11	The house owners	**pulled** **threw**	out the damaged furniture after the flood.
12	The antique painting	**dropped** **fell**	to the floor with a loud bang.
13	After the couple	**passed** **sold**	their old house, they cried, remembering the good old days.
14	The angry group	**walked** **wrote**	on the sidewalk outside of the minister's house, protesting the war.
15	The two boys	**seemed** **slept**	well after taking some painkillers and antibiotics.
16	A young man	**picked** **stole**	two valuable items from the art collection.
17	The computer engineer	**saved** **spent**	a lot of time learning the new software.
18	The basketball team	**changed** **caught**	their flight to Germany at the last minute.

APPENDIX C

Please continue each sentence fragment with an appropriate word. Write the first word that comes to your mind.

E.g. The beautiful woman bought <u>a dress</u>

1. The newly-married couple served ________________________
2. The newly-married couple grew ________________________
3. The young boy knocked ________________________
4. The young boy stood ________________________
5. The little girl reached ________________________
6. The little girl woke ________________________
7. The king's brother raised ________________________
8. The king's brother fought ________________________
9. The young woman filled ________________________
10. The young woman wore ________________________
11. The small boy touched ________________________
12. The small boy drove ________________________
13. The police officers kicked ________________________
14. The police officers blew ________________________
15. The new President signed ________________________
16. The new President broke ________________________
17. The young man checked ________________________
18. The young man taught ________________________
19. The company owners built ________________________
20. The company owners locked ________________________
21. The owners of the house pulled ________________________
22. The owners of the house threw ________________________
23. The antique painting fell ________________________
24. The antique painting dropped ________________________
25. As the couple passed ________________________
26. As the couple sold ________________________
27. The angry group walked ________________________
28. The angry group wrote ________________________
29. The two boys seemed ________________________
30. The two boys slept ________________________
31. A young man picked ________________________
32. A young man stole ________________________
33. The computer engineer saved ________________________
34. The computer engineer spent ________________________
35. The sports team changed ________________________
36. The sports team caught ________________________

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