EARLY MORPHO-ORTHOGRAPHIC DECOMPOSITION
IN PERSIAN SIMPLE VERBS

AREF ALAMDAR MILANI

BOĞAZIÇI UNIVERSITY

2022

EARLY MORPHO-ORTHOGRAPHIC DECOMPOSITION
IN PERSIAN SIMPLE VERBS

Thesis submitted to the

Institute for Graduate Studies in Social Sciences

in partial fulfillment of the requirements for the degree of

Masters of Arts

in

Linguistics

by

Aref Alamdar Milani

Boğaziçi University

2022

I, Aref Alamdar Milani, certify that

- I am the sole author of this thesis and I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources which have been produced or published by another person or institution;
- This thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution;
- This is a true copy of the thesis approved by my advisor and thesis committee at Boğaziçi University, including final revisions by them.

Signature: ………………

Date: ……………………

ABSTRACT

Early Morpho-Orthographic Decomposition in Persian Simple Verbs

A prevalent problem in psycholinguistic studies is lack of cross-linguistic evidence to evaluate models of language processing and production. Studies of morphological processing of written words suffer from the same issue. Most of these studies were conducted on Latin-based alphabets. The primary purpose of this thesis was to assess the findings in studies of morphological processing of written words in Persian, an under-studied language with a different writing system. This study also aimed to investigate the extent of early morpho-orthographic processing during which even pseudo-complex words like ‘corner’ are decomposed into ‘corn’ and ‘er’, in the same way that ‘farmer’ is decomposed into ‘farm’ and ‘er’. An additional aim of the study was to test the predictions of different theories of written word processing, in particular the sub-lexical and supra-lexical accounts as well as the Edge-aligned Embedded Word Activation Model and the Full Decomposition Model. The results of a masked priming lexical decision task point towards a form-based decomposition mechanism that manages to access the root in suffixed inflected verb forms with identical stems as well as inflected verb forms with an identical stem where the stem was embedded between a prefix and a suffix. However, inflected verb forms whose stems were not identical to that of the target did not yield any priming effects. These findings lend support to the sub-lexical theories of morphological processing.

ÖZET

Farsça Basit Fiillerde Erken Morfo-Ortografik Ayrıştırma

Psikodilbilim araştırmalarında yaygın bir sorun, dil işleme ve üretim modellerini değerlendirmek için diller arası kanıt eksikliğidir. Yazılıların morfolojik işleme çalışmaları da aynı sorundan muzdariptir. Bu çalışmaların çoğu Latin kökenli alfabeler üzerinde yapılmıştır. Bu tezin temel amacı, farklı bir yazı sistemine sahip, az çalışılmış bir dil olan Farsça'da yazılı kelimelerin morfolojik işlenmesiyle ilgili araştırmaların bulgularını değerlendirmektir. Bu çalışma aynı zamanda, erken dönem biçim-yazımsal işlemenin kapsamını araştırmayı amaçladı. Çalışmanın ek bir amacı, özellikle Alt-sözcük (sub-lexical) ve Sözcüklerüstü (supra-lexical) teorilerinin ve kenar-hizalı Gömülü Kelime Aktivasyon Modeli (Edge-aligned Embedded Word Activation Model) ve Tam Ayrıştırma Modeli (Full Decomposition Model) olmak üzere farklı yazılı kelime işleme teorilerinin tahminlerini test etmektir. Maskeli hazırlama sözcüksel karar görevinin sonuçları, özdeş gövdeli son ekli çekimli fiil formlarında ve bir önek ve bir sonek arasına gömülü olduğu özdeş gövdelere sahip çekimli fiil formlarına ulaşmayı başaran bir biçime dayalı ayrıştırma mekanizmasına işaret eder. Bununla birlikte, gövdeleri aynı olmayan çekimli fiil formları, herhangi bir hazırlama etkisi vermemiştir. Bu bulgular, morfolojik işlemenin alt-sözcüksel teorilerine destek vermektedir.

TABLE OF CONTENTS

ABBREVIATIONS

1	first person
FOBS	frequency ordered bin search
IMP	imperative
INF	infinitive
ms	millisecond
NEG	negative
PROG	progressive
PRS	present
PST	past
PTCP	participle
RT	reaction time
SBJV	subjunctive
SG	singular
PL	plural
SOA	stimulus onset asynchrony

LIST OF TABLES

LIST OF APPENDIX TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Overview

The unique ability of humans to comprehend and produce language has fascinated language scientists for more than half a century. Morphology, as the area in linguistics which deals with word-level computations, has a rather interesting status in the study of human language compared to other areas of linguistics in particular syntax, the area whose subject matter is sentence-level computation. Psycholinguistics, as the name suggests, is where linguistics meets psychology. This area of science tries to understand how the machinery we call language is represented mentally in the mind. More specifically, it is interested in the underlying mechanisms that are responsible for different behavioral phenomena that language users experience when they produce or comprehend language. Psycholinguistic studies are fueled by numerous properties of the different properties of language like ambiguity and word- and sentence-level complexities. Why does it take us longer to attest to the grammaticality of an ambiguous sentence and why do we make certain grammaticality errors when we produce complex sentences? These are some of the questions that puzzle psycholinguists dealing with sentence-level phenomena. There are also fascinating questions when we look at words. Do we store all the words that we produce, or only some words are stored while most other words we use are the results of some generative mental computations? Do we access the meaning of the words we see directly or do we first try to break them down into some meaningful bits before accessing their meanings? Why does it take us longer to reject why a certain string of letters is not a word than other strings which are also not words?

These are some of the questions that are relevant to word-level processes that take place in the mind. A further focused area of inquiry in word-level psycholinguistics is the sub-field of morphological processing. Studies on morphological processing aim to shed light on the status of morphemes as units that have their own representation independent from simple form-meaning co-occurrences. Morphemes are the smallest units of meaning associated with a sound (phonological form) or a character (orthographic form). This study is an expedition into this fascinating sub-field of psycholinguistics by attempting to answer what factors trigger the activation of these representations when we read words. Specifically, it tries to answer to what extent the morphological parser decomposes written complex words to access the embedded elements and hence test the existence of possible levels of representation underlying written word recognition.

In the remainder of this chapter, I give a little background on studies related to the mechanisms of word comprehension. Then I point out some of the gaps in the research along with the questions that this thesis tried to answer. Next, I state the objectives of my thesis which is followed by its significance in terms of word processing studies. Finally, after pointing out some of the limitations that I encountered in doing this project, I explain the general outline of the thesis.

1.2 Background

Two of the most frequently-seen jargons in the studies of word comprehension are ‘the mental lexicon’ and ‘lexical access’. The mental lexicon is theorized to store mental representations associated with linguistics forms, both acoustic and written (Oldfield, 1966). Lexical access is the term that refers to how these representations are activated upon exposure to their respective forms. Since languages can be communicated through different mediums, word recognition studies are further divided into different categories: auditory word recognition and visual word recognition. This study is concerned with recognition of written stimuli. So, what happens when we read words? What bits of information are processed before we recognize the meaning of a written form? Is the written word processed as a whole? Are there symbolic mental representations that we map the stimuli that we see onto? Some theories of word recognition oppose the existence of such symbolic representations and if fact they deny the existence of any kind of lexicon altogether. These theories are usually referred to as learning-based associative connectionist models (Milin et al., 2017). The strength of these models of word recognition is measured by how well they can simulate humans' behavioral as well as neuro-physiological reactions when they read. One of the widely used behavioral methods used to study the operations that underlie written word comprehension are lexical decision tasks. In a standard visual lexical decision task, people are asked to judge whether a string of letters constitutes a word in their language or not and the time that they take to accomplish this task is known as a reaction time (RT). After years of research and having contributed tremendously to the field of word recognition, findings like word superiority effect (Reicher, 1969; Wheeler, 1970) and pseudo-word superiority effect (Carr et al., 1978; McClelland & Johnston, 1977) have helped shape the theories of lexical access. Although connectionist models like the Interactive Activation models (McClelland & Rumelhart, 1981) have proven to be successful to the extent that they can explain a variety of behavioral responses obtained in psycholinguistic experiments, they have not had much success in explaining the results of masked priming studies (Forster & Davis, 1984; Milin et al., 2017). Rastle et al. (2004) reported facilitatory effects between pseudo-complex prime-target pairs like ‘corner-CORN’ which were equal to the priming effects between truly complex prime-target pairs like ‘farmer-FARM’. These findings have been interpreted as evidence in favor of a level of processing which is guided by orthography and followed by the activation of corresponding morphemic units. In other words, these results highlight the use of morphemes in the recognition of words in the earliest stages of processing. Previously and in line with associative connectionist models, word recognition was mainly thought to arise from meaning and form overlap between primes and targets, ignoring the status of morphemes as independent units of processing (Stockall & Marantz, 2006). The account that explains priming similarities between pseudo-complex words (corner-CORN) and complex words (farmer-FARMER) is known as morpho-orthographic decomposition. During this stage of processing, only form-based information is used to activate morphemes. It is a sub-lexical account because this decomposition happens before the meanings of whole words are accessed. This claim becomes sensible when we take into account the fact that unmasked priming is generally not believed to lead to any semantic priming effects (though see Van den Bussche et al., 2009).

Since the pioneering work of Taft and Forster (1975), there have been numerous studies trying to elucidate the validity of morphological processing as an independent mechanism that has a role in word recognition. After nearly half a century of research, there is general consensus that consolidates the reality of morphological processing and refutes claims that reduce it to a mere by-product of formal (phonological or orthographic) and semantic similarity (see Stockall & Marantz, 2006). Despite the abundance of agreement on the independence of morphological processing, there is little agreement on the exact nature of the underlying mechanisms. Some accounts claim that morphological processing is influenced by a combination of morphemic and orthographic information prior to lexical access (Crepaldi et al., 2010, p. 20; Rastle, 2016; Rastle et al., 2004; Taft & Nguyen-Hoan, 2010 among others); and some accounts argue that morphemic information is accessed subsequent to lexical access (Giraudo & Grainger, 2000, 2001, 2003a).

In summary, the earlier connectionist models of word recognition go as far as claiming that morphological processing does not take place, and morphemes have no special psychological status while later models maintain the position that morphological decomposition does take place but only for some complex words (Pinker & Prince, 1994; Prince & Pinker, 1988). In contrast, recent theories suggest that in the earliest stages of processing, there is decomposition as long as the complex word is segmentable into units (Allen & Badecker, 2002; Crepaldi et al., 2010; Diependaele et al., 2009; Longtin et al., 2003; Rastle et al., 2000, 2004; Stockall & Marantz, 2006; Taft & Nguyen-Hoan, 2010 among others).

This study aims to find whether stems (bound and free) can be accessed in inflectionally complex verbs with both prefixes and suffixes and test the predictions of the current morphological processing frameworks in an alphabetically different language.

1.3 Aim of the thesis and research questions

One of the main issues in psycholinguistic studies is the lack of cross-linguistic verification to test the validity of different models of language comprehension and production. Morphological processing studies suffer from the same problem. A great majority of the studies are conducted in Indo-European languages with Latin-based alphabets (Rastle & Davis, 2008). This study aims to be an endeavor to explore the morphological processing of written words in Persian, a psycholinguistics-wise under-studied language, that employs a different writing script than that of languages with Latinate alphabets. A further goal of this research is to test the predictions of three theories of word processing and discover the extent of orthography-based morphological decomposition in inflected complex verbs with allomorphic stems. The three main morphological processing accounts the predictions of which are to be tested in this thesis are:

i. Early morpho-orthographic decomposition (Crepaldi et al., 2010; Rastle et al., 2000, 2004; Taft & Nguyen-Hoan, 2010)
ii. Full Decomposition (Stockall & Marantz, 2006)
iii. The supra-lexical theory (Giraudo & Grainger, 2000, 2001, 2003a)
iv. Edge-aligned Embedded Word Activation (Grainger & Beyersmann, 2017)

The first two of these frameworks place a special emphasis on the role of form-based properties in the processing of morphologically complex words. According to these models, pairs like 'farmer-FARM', 'corner-CORN' will be decomposed due to their orthographic decomposability: 'farmer' can be segmented into two constituents 'farm' and '-er' and likewise 'corner' can be decomposed into 'corn' and '-er'. The question whether the combination of 'corn' and '-er' will mean the same thing as 'corner' is irrelevant at this stage of processing (this is why this process is called morpho-orthographic decomposition). The difference between the first and second theories is that the latter does not necessitate the need for formal orthographic information for the stem activation to take place. In other words, morphological processing does not need to be based on neat segmentation for stem activation. To this model, both 'watched' and 'gave' will be decomposed and activate their respective abstract roots. As a result, this account purports that the same root can be activated by two orthographically different yet morphologically related forms. As for the third model, the way that it differs from the first two is that it predicts constituent activation only after the lexical access has completed. In other words, according to this framework, first the whole lexical form for ‘farmer’ is accessed and only then its constituent parts ‘farm’ and ‘-er’ are activated whereas in the first two models first a segmentation process happens and then the whole lexical form is identified. And finally as regards the fourth model, for a successful stem activation, the stem needs to be situated on either edges of words.

The data was collected in a masked priming lexical decision task (Forster & Davis, 1984) to measure participants’ reaction times. In a lexical decision task, participants decide whether a visually or an auditorily presented stimulus constitutes a legitimate word in the language or not as fast and accurately as they can (Podesva & Sharma, 2014). In these experiments, participants first see (in a visual priming task) or hear (in an auditory priming task) a stimulus, called the prime (presented in lower-case letters), and then see or hear another stimulus, called the target (presented in capital letters) and decide whether this stimulus is a word in that language or not as fast and accurately as they can. For example, participants first see or hear the prime ‘tiger’, and then decide whether ‘lion’ is a word in English or not. What usually happens in these experiments is that participants respond to the lexicality (whether some stimulus is a word or not) of the target faster when the prime is in some way (semantic, phonological/orthographic or morphological) related to the target. When the prime is semantically related to the target and facilitates its recognition, it’s called semantic priming: ‘tiger-LION’; when the prime is related to the target form-wise (phonological or orthographic) and makes its recognition easier, it's called phonological or orthographic priming: 'broil-BOIL'; and when the prime has a common constituent (a morpheme) with the target and facilitates target recognition, it's called morphological priming: 'farmer-FARM'. The type of priming task that was employed in this thesis was the masked paradigm where the primes were presented for a very short time (50 milliseconds) and immediately followed by the target and the participants had to decide on the lexicality of the target as fast and accurately as possible. There were five different priming conditions. The first three of the conditions (non-ident-2, ident-2 and ident-1[1]) were morphologically related to the target and the fourth condition (ortho-overlap) was only orthographically related to the target and finally the fifth condition was unrelated to the target. This condition served as the baseline against which the other conditions were compared. To make clear how the morphologically related conditions differed we can use the following analogy:

Non-ident-2:

x-go-y → went-z

Ident-2:

x-went-y → went-z

Ident-1:

went-y → went-z

Where 'x' indicates the prefix for imperfective; 'y' indicates the suffix for Person/Number agreement; and 'z' indicates the suffix for the infinitival marker. The idea is that an extremely short duration like 50 milliseconds (ms) is not enough for the participants to access the meaning of the prime. As a result, this method is

[1] 2 means two affixes; 1 means one affix; 'ident' means the stem is orthographically identical to the stem in the target; and 'non-ident' means the stem is not orthographically identical to the stem in the target.

preferred to look into the very early and automatic stages of word processing where meaning is believed to play little to no role (Kouider & Dehaene, 2007). The written modality of prime and target presentation was used as the aim of this work was to study the extent of the role of orthography in morphological processing.

To test the predictions of the models, I chose a group of verbs from Persian which has stem allomorphy, also known as alternating simple verbs (Karimi, 1997). These verbs like the English ‘go-went’ pairs are instances of (partial) suppletion. What is different about these verbs from their English counterparts is that the alternating verbs occur as inflectional forms with bound stems and prefixes and/or suffixes as opposed to stand-alone words like ‘go’ and ‘went’ in English. Table 1 below shows the present imperfective forms of five alternating Persian simple verbs inflected for the first person singular. As you can see in the table, the stems in the present imperfective column look different from the stems in the infinitival column.

Table 1. Infinitival and Present Imperfective Forms of Alternating Persian Simple Verbs

Infinitival form	Present imperfective
شدن /ʃod-æn/ become.PST-INF ‘to become’	میشوم /mi-ʃæv-æm/ PROG-become.PRS-1.SG ‘I become’
دادن /dɑd-æn/ give.PST-INF ‘to give’	میدهم /mi-dæh-æm/ PROG-give.PRS-1.SG ‘I give’
بردن /bord-æn/ take.PST-INF ‘to take’	میبرم /mi-bær-æm/ PROG-take.PRS-1.SG ‘I take’
مردن /mord-æn/ die.PST-INF ‘to die’	میمیرم /mi-mir-æm/ PROG-die.PRS-1.SG ‘I die’
دیدن /did-æn/ see.PST-INF ‘to see’	میبینم /mi-bin-æm/ PROG-see.PRS-1.SG ‘I see’

Table 2 shows the past imperfective forms of the verbs in Table 1.1 conjugated for the first person singular. As is seen, there are no irregular stem changes and all the stems are identical to the ones in the infinitival forms.

Table 2. Infinitival and Past Imperfective Forms of Alternating Persian Simple Verbs

Infinitival form	Past imperfective
شدن /ʃod-æn/ become.PST-INF ‘to become’	میشدم /mi-ʃod-æm/ PROG-become.PST-1.SG ‘I was becoming’
دادن /dɑd-æn/ give.PST-INF ‘to give’	میدادم /mi-dɑd-æm/ PROG-give.PST-1.SG ‘I was giving’
بردن /bord-æn/ take.PST-INF ‘to take’	میبردم /mi-bord-æm/ PROG-take.PST-1.SG ‘I was taking’
مردن /mord-æn/ die.PST-INF ‘to die’	میمردم /mi-mord-æm/ PROG-die.PST-1.SG ‘I was dying’
گفتن /goft-æn/ say.PST-INF ‘to say	میگفتم /mi-goft-æm/ PROG-say.PST-1.SG ‘I was saying’

While there is still some orthographic overlap in some present imperfective forms and other forms, in cases like the ones in Table 3, there is no similarity whatsoever.

Table 3. Infinitival, Present Imperfective, Past Imperfective and Past Forms of the Verbs ‘See’ and ‘Go’ in Persian

Infinitival form	Present imperfective	Past imperfective	Past
دیدن /did-æn/ see.PST-INF ‘to see’	میبینم /mi-bin-æm/ PROG-see.PRS-1.SG ‘I see’	میدیدم /mi-did-æm/ PROG-see.PAST-1.SG ‘I was seeing’	گفتم /did-æm/ see.PST-1.SG ‘I saw’
رفتن /ræft-æn/ go.PST-INF ‘to go’	میروم /mi-ræv-æm/ PROG-go.PRS-1.SG ‘I go’	میرفتم /mi-ræft-æm/ PROG-go.PAST-1.SG ‘I was going’	رفتم /ræft-æm/ go.PST-1.SG ‘I went’

According to the Single-route Full Decomposition Model (Stockall & Marantz, 2006), the root should be accessed even in these forms where there is very little orthographic similarity between the present imperfective and infinitival forms and the fact that the stem is embedded within two affixes in the present imperfective and past imperfective forms should have no bearing on the decomposition of the complex word and activation of the stem and root. More specifically, we should see similar reaction times for prime-target pairs like ‘mi-ræv-æm’ – ‘ræft-æn’ (‘I go’ – ‘to go’) and ‘mi-ræft-æm’ – ‘ræft-æn’ (‘I went’ – ‘to go’) if we take the strong version of the theory. According to the morpho-orthographic model (Crepaldi et al., 2010; Davis & Rastle, 2010; Rastle et al., 2004; Taft & Nguyen-Hoan, 2010), more processing facilitation should be seen from the past imperfective forms than the present imperfective forms since they have differing degrees of orthographic overlap with the infinitival forms; the past imperfective has an orthographically identical stem to the infinitival stem while this is not the case for the present imperfective. This model should expect similar reaction times in both the past imperfective forms and past perfective forms if the double affixation has no effects. As for the supra-lexical account, there shouldn’t be any difference between the morphologically related conditions if the double affixation has no effect. In case there is an effect of double affixation, there shouldn’t be any difference between non-ident-2 condition and ident-2 condition as for this model first lexical access takes place and then the roots are activated. In other words, being exposed to either the non-ident-2 or ident-2 primes should result in the activation of the same underlying root. And lastly, the Edge-aligned Embedded Word Activation Model (Grainger & Beyersmann, 2017) predicts no facilitation from either the past imperfective or present imperfective forms as in these forms the stem is not situated on the edges of the word.

To conclude, this study intended to measure the strengths and weaknesses of the current accounts of morphological processing and give us a better understanding of the possible levels of representation and nature of the lexicon and add more cross-linguistic validity to the results obtained from previous studies.

1.4 Contribution of this work

This work attempted to look into the processing of inflectional forms with both prefixes and suffixes and where the stems exhibit allomorphy. Both prefixed complex words and suffixed complex words are known to be decomposed almost to the same extent (Amenta & Crepaldi, 2012). One question that I tried to answer was whether the same type of morphological decomposition that takes place in the early stages of processing provides enough time for people to decompose this pre- and suffixed complex words in Persian. Also, I tried to replicate the previous findings that hypothesize a common form-neutral abstract representation for all different allomorphic forms in the lexicon (Allen & Badecker, 1999; Crepaldi et al., 2010; Stockall & Marantz, 2006; Taft & Nguyen-Hoan, 2010) in an alphabetically under-studied language.

1.5 Limitations

Like any piece of research, this study also had its limitations. One limitation was the difficulty in recruiting participants which proved to be much more problematic that initially thought. But the biggest limitation was, to my knowledge, the absence of an accessible comprehensive corpus of Persian which included information on stem frequency, orthographic family size and other statistically relevant properties.

1.6 Outline of the thesis

In Chapter 1, the aims and questions of the thesis are outlined as well as the methodology that was employed to answer these questions. Furthermore, the word processing background and how it is tied to the current study as well as the value of the project are explained. In Chapter 2, I talk about the Persian language touching on its morphological features and focusing on its orthography. In Chapter 3, I give a comprehensive background on written word recognition studies and in particular morphological processing and its current status in the psycholinguistic literature. In Chapter 4, I present the experiment stimuli and the methodology and procedures that I followed in conducting the experiment. In Chapter 5, the statistical analysis of the study is explained followed by the obtained results. In Chapter 6, I discuss the results of the experiment along with its implications and explain whether the expectations were met or not. And finally in Chapter 7, I conclude my thesis with some possible avenues of research to pursue for future work.

CHAPTER 2

LINGUISTIC BACKGROUND

2.1 Persian

Persian is an Indo-European language that belongs to the Indo-Iranian branch of the family (Naghshbandi, 2020). It is spoken in Iran, Afghanistan and parts of Tajikistan as an official language. The variety of Persian which is spoken in Iran is also referred to as Farsi (Naghshbandi, 2020). It is a pro-drop language with a canonical word order of SOV. The verbs in Persian utilize markings for tense, aspect, mood and person-number agreement (Mahootian & Gerbhardt, 1997). It employs both head-final and head-initial phrase structures (Karimi, 2008; Mahootian, 1997). Here’s an example (read from right):

> من کتاب میخوانم.
> *Man* *ketab* *mi-xan-am.*
> I book PROG-read.PRS-1.SG
> ‘I am reading a book.’

In terms of its morphological features, Persian is a language that uses concatenation as the primary word-building strategy through the use of both prefixation and suffixation to build morphologically complex words in a linear fashion as well as some instances of stem changes to signal different types of linguistic information such as aspect, tense, person-number and so on. Both prefixes and suffixes in Persian can function as inflectional as well as derivational morphemes (Naghshbandi, 2020). Although Frommer (1982) classifies Persian as an agglutinating language, the abundance of prepositions (Aristar, 1991); periphrastic constructions like the passive, future forms, causatives and progressives; tendency towards compounding of verbs rather than using simple verbs; and an index of fusion of 1.56 (Greenberg, 1954), which is the number of morphemes divided by the number of words in a sentence, all point to Modern Persian being an analytic language similar to English (Dabir-Moghaddam, 2020).

Verbs in Persian are usually categorized into two groups: complex verbs and simple verbs. Complex verbs are those which consist of two parts. The first part is usually a non-verbal part (mostly a noun or an adjective but also a participle, prepositional phrase, adverb or a verbal constituent) and the second is a verbal one (Dabir-Moghaddam, 1997). The verb in the verbal part is usually called a light verb and the meaning of the whole complex verb is sometimes idiomatic (Dabir-Moghaddam, 1997; Karimi, 1997). A similar example from English would be 'take a shower' where the 'take' part is the light verb and the 'shower' part is the nominal part of the complex verb. Modern Persian and in particular Persian in more colloquial contexts mostly makes use of this type of verbs. The other type of verbs, simple verbs, only contain a verbal element. The number of simple verbs in Modern Persian is small, around 115 (Sadeghi, 1993; Karimi, 1997), and of this number a great majority are either obsolete or only exclusive to more formal contexts. This group can be further divided into alternating and non-alternating. The stem in the non-alternating group doesn't undergo any (unpredictable) phonological change in any of the inflectional paradigms. As an example, the stem ('خند' /xænd/) in the verb 'خندیدن' /xænd-id-æn/ (to laugh) doesn't change from present imperfective form to the past imperfective form: 'میخندم' /mi-xænd-æm/ (I laugh) and 'میخندیدم' /mi-xænd-id-æm/ (I was laughing). As it can be seen, the bound stem 'خند' /xænd/ is orthographically and phonologically the same in both inflectional forms. In contrast, the stem in alternating simple verbs undergoes some change. This change can vary from verb to verb with some stems changing slightly and with others exhibiting total cases of suppletion, which are changes of form that are not a result of any productive phonological processes and are totally unpredictable like the past form of the English verb ‘go’, ‘went’ (see Nabors (2019) for a different analysis). As an example, the stem in the verb ‘دیدن’ /did-æn/ (to see) is different in the present imperfective inflectional form than in the past imperfective inflectional form. While the stem in the present imperfective ‘میبینم’ /mi-bin-æm/ (I am seeing) is ‘بین’ /bin/, it is ‘دید’ /did/ in the past imperfective form: ‘میدیدم’ /mi-did-æm/ (I was seeing). Although some analyses point towards the predictability of these alternating stems and that they are the result of phonological processes and the dichotomy of alternating verbs and non-alternating verbs is just a taxonomic categorization (Nabors, 2019), the analyses offered in these studies are not so satisfactory since they contain too many exceptions and unsubstantiated sub-rules to their general framework. Moreover, there are other derivational forms that point to the unpredictability of these stems. For example, the ‘-esh’ suffix can only attach to present stems and the ‘-ar’ suffix only attaches to past stems and these forms have nothing to do with either the past or present tense (Naghshbandi, 2020).

Suffix ‘-esh’	Suffix ‘-ar’
‘بینش’ /bin-eʃ/ see.PRS-suffix ‘insight’	‘دیدار’ /did-ɑr/ see.PST-suffix ‘meeting’
‘گویش’ /gu(j)-eʃ/ say.PRS-suffix ‘dialect’	‘گفتار’ /goft-ɑr/ say.PST-suffix ‘speech’

We can also refer to the productivity of the past marker (this is a hypothesis) ‘-id’ and its variations ‘-ad’ and ‘-d’ used in the making of novel denominal verbs like ‘zæng-id-æn’ (to make a phone call), ‘hærf-id-æn’ (to talk), and so on. All of this is to give weight to the segmentability of ‘-id’ in the same vein as the English ‘-ed’ and further emphasize the dichotomy between alternating and non-alternating simple verbs. This is pure conjecture, however.

2.2 Persian orthography

Modern Persian uses a modified version of the Arabic script (Hariri, 1995). Nevertheless, there are a few differences between the two languages in terms of the script they use. The Persian script has four letters which are absent in the Arabic script. These letters are 'گ' /g/, 'پ' /p/, 'ژ' /ʒ/ and 'چ' /tʃ/. Persian has six vowels, three short (æ, e, o) and three long (ɑ, i, u). The long vowels are indicated through letters and the short ones through what is called diacritics. These diacritics can be placed above or below letters to signal the short vowels. However, they are most often left out and as a result of this, written forms in Persian are sometimes ambiguous and it is usually left to the reader to figure out the correct pronunciation and meaning of the word which might lead to processing difficulty in reading Persian words (Baluch, 1992). To make an analogy with English, imagine we see the stimulus "frmr" and we have to infer that it is "farmer". Predictably, this can lead to many ambiguities. The stimulus "frmr" can be "farmer", "former", "firmer" or "framer". Although it will take more than one experiment to address this question, it will nonetheless be interesting to see whether lack of orthographic information can have an influence on the morphological processing of complex words.

Another characteristic of this script is that some letters (dual-joining letters) can be realized differently depending on whether they occur word-initially, word-medially, word-finally or in isolation. Most letters come in two orthographic shapes: initial/medial-position shape and final/isolated-position shape. In Table 4 next page you can see a few examples of such letters.

Table 4. Persian Letters with Two Positional Variations

Initial and medial position	Final position	Initial and medial position	Final position
بـ /b/ بیل /bi:l/ spade	ب /b/ آب /ɑ:b/ water	شـ /ʃ/ شمع /ʃæmʔ/ candle	ش /ʃ/ آش /ɑ:ʃ/ pottage
پـ /p/ پرتقال /portæqɑl/ orange	پ /p/ توپ /tu:p/ ball	صـ /s/ صابون /sɑ:bun/ soap	ص /s/ خاص /xɑs/ special
تـ /t/ تیر /ti:r/ arrow	ت /t/ دست /dæst/ hand	فـ /f/ فرم /form/ form	ف /f/ عارف /ɑ:ref/ wise
ثـ /s/ ثابت /sɑ:bet/ constant	ث /s/ بحث /bæhs/ argument	کـ /k/ کیف /ki:f/ bag	ک /k/ پاک /pɑ:k/ clean
نـ /n/ نان /nɑ:n/ bread	ن /n/ طوفان /tu:fɑn/ storm	یـ /j/ یک /jek/ one	ی /j/ برای /bærɑ:je/ for
چـ /tʃ/ چرخ /tʃærx/ wheel	چ /tʃ/ قارچ /qɑrtʃ/ mushroom	لـ /l/ لیوان /li:vɑn/ glass	ل /l/ فال /fɑ:l/ fortune

Two letters of Persian can take on three shapes depending on their position in the word (Table 5).

Table 5. Persian Letters with Three Positional Variations

Initial position	Medial position	Final position
عـ /ʔ/ عرشه /ærʃe/ dock	ـعـ /ʔ/ معنی /mæʔni/ meaning	ع /ʔ/ دفاع /defaʔ/ defense
غـ /ɣ/ غنی /ɣæni/ abundant	ـغـ /ɣ/ مغز /mæɣz/ brain	غ /ɣ/ باغ /bɑ:ɣ/ garden

And finally, Table 6 shows the letter for the sound /h/. Word-initially it is manifested like 'هـ', word-medially like 'ـهـ', word-finally like 'ـه' and in isolation like 'ه'.

Table 6. The Only Persian Letter with Four Positional Variations

Initial position	Medial position	Joint final position	Disjoint final position
هـ /h/ هدیه /hædi(j)e/ gift	ـهـ /h/ مهربان /mehræbɑn/ affectionate	ـه /h/ به /be/ to	ه /h/ ماه /mɑ:h/ moon

The fact that the same letter can come in different forms can impose processing demand. It might make Persian, orthography-wise, a more difficult language to process or make the processing of some letters more difficult than others. Although this is just pure speculation at this point

Another speculative source of processing difficulty that might arise from the Persian orthography is the use of diacritic-like dots or small glyphs to distinguish some letters. (Protopapas & Gerakaki, 2009) defines a diacritic as a feature that is added to a regular letter to indicate a phonemic value, to provide a supra-segmental information like tone and stress or to distinguish between homophonic words. In the tables below, you can see that certain letters can be put into 'orthographic families', differentiated only by those diacritic-like dots or small glyphs. It can be hypothesized that forms with larger orthographic families can induce processing difficulty.

Table 7. Persian Letters That Can Be Put into Two Orthographic Families of Four

Letter family-1	ب /b/	پ /p/	ت /t/	ث /s/
Letter family-2	ج /dʒ/	چ /tʃ/	ح /h/	خ /x/

Table 8. Persian Letters That Can Be Put into the Same Orthographic Family of Three

Letter family-3	ر /r/	ز /z/	ژ /ʒ/

Table 9. Persian Letters That Can Be Put into Orthographic Families of Two

Letter family-4	د /d/	ذ /z/
Letter family-5	س /s/	ش /ʃ/
Letter family-6	ص /s/	ض /z/
Letter family-7	ط /t/	ظ /z/
Letter family-8	ع /ʔ/	غ /ɣ/
Letter family-9	ف /f/	ق /q/
Letter family-10	ک /k/	گ /g/

Table 10. Persian Letters without an Orthographic Family (Hermit Letters)

Hermit letters	ء No sound	ل /l/	م /m/	ن /n/	و /v/	ه /h/	ی /j/

These diacritic-like features may not be too important for the reader to extract information when words appear in sentences but in isolation they could prove challenging or even unreadable. Whether these diacritics have enough salience to help readers distinguish letters of the same family from one another in Persian is an uncharted territory. If these features are shown to be salient, then there will be the possibility that the similar-looking letters will result in inhibitory effects (Perea et al., 2021).

Yet Another characteristic of Persian orthography is that some letter sequences can be connected without any form of spacing separating the letters. Note that when we write English words, for example, there is still a tiny amount of spacing between letters. With some Persian words, however, even this little spacing could be non-existent. Table 11 shows some words from Persian with no spacing. Again, these are just pure speculations at this point.

Table 11. Persian Words with a Continuous Style Written Form

Persian word	translation
میپیچیم /mi-pitʃ-im/ PROG-twist.PRS-1.PL	We twist.
نطلبید /næ-tælæb-id/ NEG-requent.PRS-PST.3.SG	He didn't request.
میتنید /mi-tæn-id/ PROG-weave.PRS-PST.3.SG	He was weaving.

Perhaps, it is due to the difficulty of reading these forms that Persian also has another way of writing complex words with prefixed forms like the ones above (Table 12).

Table 12. Persian Verb Forms Written with Three Different Styles of Spacing

Continuous form	Zero spacing	Regular spacing	translation
میپیچیم /mi-pitʃ-im/ PROG-twist.PRS-1.PL	می‌پیچیم /mi-pitʃ-im/ PROG-twist.PRS-1.PL	می پیچیم /mi-pitʃ-im/ PROG-twist.PRS-1.PL	We twist.
میتنید /mi-tæn-id/ PROG-weave.PRS-PST.3.SG	می‌تنید /mi-tæn-id/ PROG-weave.PRS-PST.3.SG	می تنید /mi-tæn-id/ PROG-weave.PRS-PST.3.SG	He was weaving.
بیگناه /bi-gonah/ without-sin	بی‌گناه /bi-gonah/ without-sin	بی گناه /bi-gonah/ without-sin	innocent
بیسواد /bi-sævɑd/ without-literacy	بی‌سواد /bi-sævɑd/ without-literacy	بی سواد /bi-sævɑd/ without-literacy	illiterate

I hypothesize all of these characteristics of Persian script could make it a more difficult language to process in written format. The Persian word recognition system could be adversely affected by the fact that the same input (written form) can correspond to multiple outputs (Chateau et al., 2002).

There have been a number of reports of letter similarity effects that could cause difficulties in recognition speed and accuracy (Mueller & Weidemann, 2012). For example, the letter 'B' is more confusable with the letter 'R' than the letter 'G'. Consequently, if the number of letters that can be confused with other letters in a language is high, processing difficulty in these languages would not be so unlikely. Another piece of evidence that points at confusability of similar letters came from Perea and Panadero (2014). They found that one-letter substitutions with similar letters such as 'viotin' are mistaken to be words (in this case 'violin') than with dissimilar words like 'viocin' in people with dyslexia. Put it differently, 't' resembles 'l' more than does 'c', and as a result participants mistook 'viotin' for 'violin' more than 'viocin'. On the other hand, Chetail and Boursain (2019) found that letters containing diacritics have separate representations. Thus, leading to the possibility of similar letters in Persian inhibiting the recognition of one another. Feldman and Andjelkovic (1992) found differences between morphologically related and orthographically related pairs in a long-lag repetition priming experiment. Their results indicated that in short lags, orthographic similarity may lead to inhibition. But the orthography effect may be dependent on other factors like the density of the orthographic family size (Forster et al., 1987), the relative frequency of the prime and target, length similarity of prime and target (Stolz & Feldman, 1995) and the presence or absence of a mask (Segui & Grainger, 1990; Feldman & Andjelkovic, 1991). With a mask, it is the higher-frequency orthographically related primes that lead to inhibition whereas without a mask, inhibition is observed with lower-frequency primes. In addition to these, quite a few other studies have also reported inhibition effects originated from orthographic effects (Grainger et al., 1991; Grainger & Segui, 1990; Laudanna et al., 1989).

In conclusion, there is a sizeable literature that points toward the inhibitory effects of orthographic similarity and given the nature of letters in Persian, the greater inhibition might suppress morphological relatedness effects. One of the goals of the present study was to investigate the effects of morphological relatedness under masked priming conditions with an alphabetically different and possibly demanding language.

CHAPTER 3

THEORETICAL BACKGROUND

3.1 Morphological processing

As humans we have the unique ability to take a limited number of pieces and use them in an infinite number of combinations. Language is probably the best manifestation of this ability or maybe it is that ability itself. The fact that we don't store all the sentences we use (except the ones with unpredictable meanings like idioms), is a relatively easy concept to grasp. Things tend to get a little foggy when it comes to words. When we hear a novel string that has never been used before, like 'transponster', our usual reaction is to ask whether it is even a word. And yet we can still understand it in some capacity: we will know it is a noun; we will know it must follow a determiner like 'the'; we will know it has something to do with change; we will know it is something or someone that does the action of 'transponsting' and so on. So where does this split intuition come from? On the one hand we always want to have heard the words that we encounter, and on the other hand, we usually seem to be able to at least take a guess at what they can mean. Both of these responses are in fact represented by two main questions that have entertained language scientists for nearly half a century: do we keep all of these words that we know somewhere and only if we locate them there do we understand them or do we first try to perform a computational procedure on them pretty much the same way we compute sentences to understand them? To put it differently, how much of word recognition involves a process of search-and-find and how much of it involves a process of computation?

To researchers in language sciences and in particular psycholinguists working in the field of word recognition, these two questions are jargonized as: is there a lexicon (like a mental dictionary) and how does lexical processing take place for successful lexical access? How many levels of representation does the lexicon contain and how are the units in each level connected, both within levels and between levels? What is the nature of those units in each level?

3.2 Models of word processing

The field of word recognition in written format has a long history in psycholinguistics. It can be traced back to as early as 1886 when Cattell hypothesized that written words are recognized as whole units and not by their components.

One of the areas of research in psycholinguistics that has become a lively ground of inquiry in the past few decades is the area of word recognition in visual modality. Researchers working in this area try to find the cognitive mechanisms that underlie our ability to immediately and accurately understand written words from among tens of thousands of words that we know. Findings in this area can shed light on the extent we make use of the storage and computational capacity of our cognition. Whether there is even a lexicon with different levels of representation containing symbolic units is one of the most relevant questions that we can use and divide theories of (visual) word recognition into two groups: the lexicon-based models and the learning-based models (Milin et al., 2017). With respect to the lexicon-based models, the fact that we understand words is the result of an initial perception of non-linguistic input (like lines and curves or sounds) followed by linguistic forms (like letters, phonemes, spoken and written words, or gestures) which is in turn used to activate certain representations stored in a repository that is usually referred to as the mental lexicon. On the other hand, the learning-based models like connectionist models reject the idea of a mental lexicon and attribute our comprehension of words (lexical access) to graded statistically determined associations of form and meaning (Seidenberg & Gonnerman, 2000). According to these associative learning models, word recognition is only a matter of processing the visual aspects of a written stimulus (features, letters and ultimately the word as a whole). The first mathematical learning-based model of word recognition is John Morton's (1969) Logogen model (Traxler, 2011). Another learning-based associative model of lexical access was the TRACE model (McClelland & Elman, 1986; McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). The TRACE model employed an interactive activation architecture of lexical processing where the activation of a unit in one level can affect the activation of another unit in the same level or upper or lower levels. In this model, the connections between the levels could be excitatory or inhibitory and the connections within the levels are only inhibitory (lateral inhibition). Among the newer models of lexical access was Elman's Simple Recurrent Network model (Elman, 2004). This model had a similar architecture to that of the TRACE model in that it too boasted a three-layered network where words are identified as patterns of activation. In addition to the three-layered network, this model included another set of units called context units, where information about previous patterns of activation could be stored. One of the important tasks of this model was to predict the upcoming word. It was able to accomplish this task by re-adjusting the weights of the connections to match the desired output. With this model, even identical words could have different patterns of activation (different meanings) depending on the contexts they occurred. Another prominent example of parallel distributed processing models was the distributed COHORT model (Gaskell & Marslen-Wilson, 1997, 2001, 2002). This model, which had a similar architecture to that of the simple recurrent network model (SRN), took phonetic stimuli as its input and after feeding it through a set of hidden units accompanied by context units (similar to the SRN model) and output phonological and semantic units, resulting in a simultaneous activation of different words with similar sounds which can have different meanings. The core assumption of these connectionist models is that word recognition is a matter of consistent form and meaning interplay. As a result, the reason why we process 'farm' better after being exposed to 'farmer', is simply because the meanings of the two words as well as their visual aspects are related and this strength in consistent meaning and form relatedness gives more weight to the connections between 'farmer' and 'farm'. In other words, these models reject the status of morphemes as linguistic representations. Morphemes are defined as the smallest linguistic units with a consistent form-meaning correspondence (Haspelmath, 2013; Lieber, 2021). For example, in the word 'watched' there are two morphemes: one is 'watch', which is also referred to as the stem, and the other the suffix '-ed', which denotes the past tense. They can be free like words such as 'car' that can stand on their own or they can be bound. Affixes like the plural '-s' marking are an example of bound morphemes which cannot be used as independent units and have to be attached to another morpheme. The models in the symbolic lexicon-based group can also be sub-divided into different camps. One of such camps is the idea that all the words that we know are stored in the lexicon, irrespective of being complex or simple. This is the Full Listing Hypothesis (Butterworth, 1983). According to another camp, complex words and even complex-looking simple words are decomposed into morphemes prior to lexical access. An example of a lexicon-based model of lexical access was Ken Forster and Marcus Taft's frequency ordered bin search (FOBS) model (Forster, 1989; Forster & Bednall, 1976; Taft & Forster, 1975). The FOBS model was perhaps the first model of lexical processing that assigned an important role to morphemes. In this influencial model, processing was strictly bottom-up: the only direction where processing occurred was from lower levels like phonetic and orthographic features to higher levels like syllables and words. The idea that lexical access always follows a procedure of morphological analysis is called the Obligatory Decomposition Hypothesis (Taft & Forster, 1975). This is what is meant by 'morphological processing'; it is a lexicon-based model of lexical access that gives morphemes their own representations at some level in the overall architecture of the mental lexicon. According to this model, upon exposure to a written or spoken linguistic stimulus, the first step in lexical access is morphological decomposition. Morphological decomposition is the process whereby a poly-morphemic word is broken down into its smallest meaning-bearing units (morphemes).

Although the associative models continue to offer fruitful insights into the processes underlying word recognition like the new Naïve Discriminative Learning Model (Baayen et al., 2011; Baayen & Smolka, 2020), the bulk of the study over the past few decades has been in support of the lexicon-based models, and in particular those that assign an independent function to morphemes (Milin et al., 2017).

The way that researchers investigate the underlying mechanisms involved in the recognition of complex words using behavioral methods is mainly through what is called the priming lexical decision task. According to the Spreading Activation Hypothesis (Lukatela et al., 1980), the mental representations are connected to one another in a semantic network. When a representation is activated, its activation spreads to the other connected nodes, with the closest nodes receiving the highest amounts of activation. As such, the more related two words are either semantically, phonologically, orthographically or morphologically, the more activation they will receive from one another. In a priming lexical decision task, participants are first presented a stimulus (prime), and then presented another stimulus (target). If the target is presented immediately after the prime, it is called immediate priming. In another variation of the lexical decision task, there are intervening items between the prime and the target. This is called long-lag priming. The participants' task is to judge whether the target is a real word or not. They do this by pressing either a yes button, if the target is a word, or a no button, if the target is not a word as fast and accurately as they can. The outcome variable that is measured in priming lexical decision tasks is participants' accuracies and reaction times to the target in milliseconds (ms). This response latency is described as the amount of time that it takes to access a word in the lexicon and confirm it is indeed the presented word (Rueckl & Galantucci, 2005).

One technique that has gained a lot of popularity especially in the past two decades is the masked priming lexical decision paradigm (Forster & Davis, 1984). What is different about the masked priming method as opposed to unmasked/overt priming is that the prime is presented for a very short duration of time (usually between 40 and 60 ms). This enables us to tap the very early stages of lexical processing which is thought to be automatic and rather expectedly independent of meaning; how can you access the meaning of something that you don't even see!

In morphological processing studies, one thing that has to be given special attention is making sure that the observed priming effects are genuinely morphologically originated. That is, the priming effects are not due to meaning or form overlap (orthographic overlap, in the case of visual word recognition) since almost all morphologically related words are semantically and orthographically similar. This is why studies investigating morphological processing must have control measures against semantic and orthographic similarity effects. One property of masked priming lexical decision tasks is that the observed effects are generally speaking not thought to be due to semantic overlap, as there is no access to the meaning of the primes due to the very short prime presentation duration (Kouider & Dehaene, 2007).

Throughout the years many researchers using the priming technique have contributed to the symbolic lexicon-based models of word recognition that grant a special status to morphemic representations in the mental lexicon, albeit there are differences between them.

Taft and Forster (1975) measured reaction times to the non-word stems of words like ‘rejuvenate’ (juvenate) and found that the reaction times to these non-words are longer than reaction times to non-word stems of words like ‘repertoire’ (pertoire). They interpreted the results as reflecting an obligatory process whereby affixes must be first stripped off of words in order to access their stems and understand the meaning of the complex word. According to their model, all morphemes both free and bound are represented in the lexicon. The purpose of this affix stripping process was to make the lexical access as efficient as possible. Their results necessitated that any model of word recognition should incorporate morphemes into the analysis (morphological analysis). The claims of Taft and Forster (1975) needed support by further illustrating that morphological relatedness effects are independent of semantic and orthographic overlap. Feldman and Andjelković (1992) reported the results of a study in a long-lag repetition priming lexical decision task using prime and targets from two different alphabets (Roman and Cyrillic). The result was that there wasn’t any effect of alphabet and morphologically related prime-target pairs even when the prime and target were from different alphabets yielded significant priming effects. They concluded that morphological relatedness effects cannot be explained in terms of orthographic similarity effects. In addition, Bentin and Feldman (1990) also showed that morphological relatedness is an independent effect from semantic relatedness in Hebrew.

A relevant question that comes up at this point is how the recognition of complex words takes place and whther theyr are processed as whole words or they are decomposed into their constituents. In other words, are complex words represented as whole forms in the lexicon or as the combination of their parts or both? Studies over the years have shown that the answer to this question lies in a myriad of lexical properties: type of the morphological process, semantic transparency (how predictable the meaning of the complex word is from the individual meanings of its constituent parts), frequency of the stem, which is also known as the cumulative frequency (the number of times a stem occurs both as a single word and as a stem in all morphologically related words), surface frequency (the number of times the complex word occurs), regularity (whether the morphological process is applicable to all relevant categories or not), productivity, morphological family size (the total number of morphologically related words to it) and orthographic neighborhood (orthographically similar words). For an excellent review see Amenta and Crepaldi (2012).

The dichotomy found in lexical properties such as type of the morphological process (inflection versus derivation), semantic transparency (transparent versus opaque), regularity (regular versus irregular), surface and stem frequency (high versus low) gave inception to the development of dual-route models of word recognition. According to these models, decomposition is not necessary for all complex forms to be comprehended (contrary to the Obligatory Decomposition models). Those complex words that have opaque, idiosyncratic meanings (their meaning cannot be predicted from the meaning of their constituent parts), or are irregular in that they are unpredictable and unproductive exceptions to a general word formation process, or have high surface frequency and low stem frequency are directly processed as whole forms, and thus have their own representations in the lexicon (Pinker, 1991; Pinker & Prince, 1994). On the other hand, if a complex word is transparent, regular and has a low surface frequency and high stem frequency, it will be processed through decomposition. The dual-route models vary in the lexical properties that determine which route will be used and also the ordering of the routes, for example whether it is the direct route that is first consulted or the decomposed route. Some of these models predict that irregular and opaque words which cannot be readily produced are stored as whole forms in the lexicon whereas those regular and transparent complex words that can be predictable and maximally productive are not stored (Pinker, 1999; Pinker & Prince, 1994; Prince & Pinker, 1988). Other members of the dual-route models predict the surface frequency of a complex word to be the decisive factor whether the complex word is stored or not (Stemberger & MacWhinney, 1986, 1988). Their evidence is that high-frequency words are better protected against mispronunciations. Indeed, priming effects for words with high surface frequency is usually taken as evidence for direct access. Moreover, some dual-route models don’t necessitate the decomposition of fully regular and transparent complex words. One such model is the Augmented Addressed Morphology Model (Burani & Caramazza, 1987; Caramazza et al., 1988; Laudanna & Burani, 1985). All known words will take advantage of the direct route while only novel transparent complex words will use the parsing route. The second route, which works like a backup route, will only come into play after the first route fails to successfully retrieve the word. This is usually referred to as the cascaded dual-route model. It is called cascaded because in order for one route to be activated the previous route must first complete its work. The claim that only novel forms will be decomposed is a prediction of the stronger version of the model. A more lenient version of it states that complex words with low surface frequencies and high stem frequencies might also be decomposed via the parsing route (Burani & Laudanna, 1992; Chialant & Caramazza, 1995; Laudanna & Burani, 1995). Taft (1979, 1994) also argues for a cascaded dual-route model. But in contrast with the Augmented Addressed Model, here first an obligatory parsing procedure takes place and then a full lookup for the whole-word form is initiated. Another model that also favors the idea of double dissociation for the mechanisms that underlie cognitive processes is the Declarative/Procedural Model (Ullman, 2001, 2016). The model claims that everything we do (linguistics operations being one of them) is done through two systems: one is responsible for retrieving units which reside in a repository and the other is responsible for manipulating these already existing units. One of the areas where the division of labor in this model can manifest itself is some of the morphological transformations that happen in the languages of the world (Ullman, 2001). The two memory systems in this model have their own specialized neurobiological bases (they have distinct locations in the brain), distinct computational procedures and are domain-independent (they are not just responsible for different linguistic operations; they are also the underlying mechanisms for all other cognitive performances that humans do). According to this model, while the declarative memory system is responsible for processing irregularly inflected morphological forms, the procedural memory computes all the regular ones. Evidence for this dissociation comes from the dichotomous processing of regularly and irregularly inflected forms by patients with different brain injuries, neuroimaging studies showing activity in different parts of the brain for regularly and irregularly inflected forms, and psycholinguistic studies showing that frequency factors only affect irregularly formed morphologically complex forms.

One of the criticisms of the affix stripping strategy was that the big number of words with prefix-looking beginnings in languages like Dutch and English would compel the morphological parser to backtrack every time it encountered a pseudo-prefixed word and this would ultimately slow down the process of morphological analysis (Schreuder & Baayen, 1994). Following this, an intermediate version of the two models mentioned above was proposed (Baayen et al., 1997; Schreuder & Baayen, 1995): the Dual-route Parallel Model (also known as the Race Model). It is a parallel model as opposed to a cascaded model in that one route does not have to wait for the other route to finish its task. Both routes will be activated at the same time. This model has three layers: the lexeme layer (modality-specific), the lemma level and a semantic representation layer. In this model processing takes place in three stages: decomposition whereby both full forms and affix and stem constituents are activated, licensing whereby the sub-categorical compatibility of the constituents are checked (whether the affix can attach to the stem or whether the resulting derivation can be used in the relevant syntactic position or not), and the composition stage whereby the meaning is computed. There is also activation feedback from the higher semantic layer via an intermediary level down to the lexeme level to account for cumulative frequency effects. According to this model, storage is determined by lexical properties of complex words. Even regularly inflected forms can be stored provided that they have a high surface frequency as opposed to Pinker (1991).

The notion of morphological processing taking place in multiple stages was first indirectly alluded to in Taft and Forster (1975) and further developed in Schreuder and Baayen (1995). The idea is that the first stage of morphological processing consists of morphological decomposition followed by a lexical search stage for all the constituents and finally a top-down stage of checking the permissibility of the combination. This helps us distinguish between morphological processing and morphological decomposition: morphological decomposition is the first stage in morphological processing (Schreuder & Baayen, 1995; Stockall et al., 2019).

Priming effects for morphologically related pairs under masked conditions that are believed to tap the earliest stages of morphological processing namely morphological decomposition have been reported by numerous accounts in different languages: Grainger et al. (1991) for French, Drews and Zwitserlood (1995) for Dutch, Frost et al. (1997) for Hebrew, and Rastle et al. (2000) for English. The results of Rastle et al. (2000) showed that in the early stages of processing (between 42 and 73 ms), semantically opaque morphologically related pairs like ‘apartment-APART’ result in priming effects similar to the effects of semantically transparent morphologically related pairs like ‘departure-DEPART’. Additionally, the authors reported no priming effects for pairs that showed a lot of orthographic and semantic overlap ‘screech-SCREAM’ in the early stages of processing. The opaque derived forms that Rastle et al. (2000) used were of two kinds: some were like the pair ‘department-DEPART’ between which, although not readily transparently related, there is a historical morphological relatedness between them which is not directly recognized by the modern speakers of English. Other pairs were like the pair 'corner-CORN' which have no morphological relatedness whatsoever. These pairs are usually referred to as pseudo-derived forms: on the surface, they look as if they have two segmentable constituents like 'corn' and '-er', but a second analysis reveals that they are in fact morphologically simple words. They interpreted the results as evidence for a level of processing that is based on the purely formal (orthographic) representations of morphemes which is devoid of any semantic information. This level of representation has come to be known as the 'morpho-orthographic' level and the decomposition that happens at this level as the 'morpho-orthographic decomposition' and the models that assume a level of decomposition purely based on orthography before retrieval of meaning are called the sub-lexical models. According to these models, first an obligatory automatic form-based morphological decomposition takes place and it is only at later stages where meaning is extracted. The interesting status of pseudo-derived words were investigated further in French by Longtin et al. (2003). They found no semantic transparency effects under masked conditions between truly transparent, opaque and pseudo-derived conditions while they found partial inhibitory effects in the orthographic overlap condition. Their results lent more support to the sub-lexical account of morphological processing which states the early stages of processing is initiated by a purely form-based morphemic level of representation which is blind to meaning. These results were later replicated in English (Rastle et al., 2004) and a number of other languages (Rastle & Davis, 2008).

After Rastle et al. (2000) hinted at the existence of a level of morphological decomposition purely based on form and devoid of semantic information (the sub-lexical account), it didn't take long before a rival emerged: the 'supra-lexical' account (Giraudo & Grainger, 2000, 2001, 2003a). According to this model, morphemic information is obtained only after the meaning of the whole form has been retrieved. In other words, the level of representation where morphemic information is stored is above the level where the representations for words exist, hence the prefix ‘supra’. Another important difference between the sub-lexical account and the supra-lexical account is that the morphemic units that reside above the lexical level in the supra-lexical account are not form-based units; they are abstract. With the sub-lexical account, the initial morphemic level contains units that are form-based. To illustrate a little further, according to this theory, the plural suffix ‘-s’ and ‘-es’ are different units in the morpho-orthographic level while according to the supra-lexical account these two suffixes are the same abstract unit. The proponents of the supra-lexical model take the consistency in larger priming effects for transparent derivational forms over opaque and pseudo-derived forms to be evidence for the access of semantic information even in the early stages of morphological processing. Giraudo and Grainger (2001) report the results of their masked priming experiment with French derivational words to be in line with a supra-lexical account of morphological processing. They showed that free root primes create almost identical priming effects to that of transparent primes containing the same root.

Although the supra-lexical account has seen some support (Feldman et al., 2009; Giraudo & Grainger, 2000, 2001, 2003a; Voga & Giraudo, 2009), the majority of support has been in favor of the sub-lexical model (Allen & Badecker, 2002; Crepaldi et al., 2010; Diependaele et al., 2009; Järvikivi et al., 2009; Lázaro et al., 2021; Longtin et al., 2003; Rastle et al., 2004; Rastle & Davis, 2008; Taft & Nguyen-Hoan, 2010; Wray et al., 2022).

What happens in this early, automatic stage of morpho-orthographic processing? What representations are present at this level? Are all types of affixes represented at this level? Do whole-word derivations exist at this level or only minimal chunks? Does surface frequency or cumulative frequency have an effect on the representations? Do both free stems and bound stems reside at this level? Are there any representations for irregular and regular inflected forms at this level? Do other levels of representation exist between this level and the level where semantic concepts are stored?

A consistently obtained result from the investigations of early morpho-orthographic decomposition has been the difference between the magnitude of transparently derived words and opaque and pseudo-derived words (Feldman et al., 2009; Rastle & Davis, 2008). To address this issue, Taft and Nguyen-Hoan (2010), building on prior work (Taft, 2003, 2004), presented a model which took advantage of the early form-based morpho-orthographic representations level and added to it another intermediate form-neutral level that contained abstract semantic and syntactic information. Taft and Nguyen-Hoan (2010) proposed the need for such an intermediate level of processing to explain why ‘sticky’ primes ‘stick’ but ‘glue’ does not prime ‘stick’ (‘stick’ is an ambiguous word). This level is called the ‘lemma’ level and the new model is usually referred to as the Lemma Model. The first use of the word ‘lemma’ was in models of language production (Bock & Levelt, 2002). The Lemma Model is able to explain the discrepant priming effects between ‘farmer-FARM’ and ‘corner-CORN’ pairs and the absence of priming effects in ‘turnip-TURN’ pairs. In the lemma level, which itself has a hierarchical architecture, all truly morphologically related forms are related to one another (there are connections between them). But the same connection does not exist for pseudo-derived words: the activation of ‘corn’ and ‘-er’ in the lemma level will not activate ‘corner’ (Taft & Nguyen-Hoan, 2010) but the activation of ‘farm’ and ‘-er’ in the lemma level will activate ‘farmer’.

After the early morpho-orthographic decomposition model combined with the masked priming technique established itself as the de facto playground for word processing researchers, a number of studies were conducted to find which lexical properties are important in deciding the overall architecture of the model along with the units of each level of representation (both the form-based morpho-orthographic level and the form-neutral abstract lemma level). One such study was the influential word by Crepaldi et al. (2010). Using a masked priming lexical decision task, they found that even irregular past tense forms in English primed their root targets: ‘gave’ primes ‘give’. Their interpretation of the results was that at the lemma level all inflectionally related forms are only represented by one lemma representation while derivational forms might have their independent representations. For example, all inflectional forms like ‘gave’, ‘giving’, ‘gives’ are represented by one lemma. Moreover, bound morphemes are not predicted to have any independent representations at the lemma level. Their results were in line with previous claims that the reason why there is lack of priming effects from irregular inflectional forms might have been due to the orthographic similarity between the pairs and all morphologically related words both regular and irregular lead to priming effects (Allen & Badecker, 2002; Stockall & Marantz, 2006).

The early morpho-orthographic model bolstered by the lemma level with its findings that all semantically transparent complex words, semantically opaque complex words, even simple words that looked as if they have an internal structure and the decomposition of even irregular inflectional forms set the stage for a very strong version of the model: The Full Decomposition Model (Stockall & Marantz, 2006). According to this model, if a string of letters can be decomposed (leaving semantics and syntactic properties aside), it will be.

This is where my study comes into play. The questions that I sought to answer in this thesis were:

i. Does this sub-lexical, early morpho-orthographic decomposition apply to a non-Latinate script?
ii. Does it apply to inflectionally complex words with both prefixes and suffixes?
iii. Does it apply to inflectionally complex words with both prefixes and suffixes where the stem is an allomorph of the target stem? (allomorphs are different realizations of the same morpheme, for example, the part 'knive' in 'knives' is an allomorph of 'knife')
iv. How will the models of morphological processing explain the obtained results?

3.3 Lexical properties in morphological processing

Linguists distinguish between two types of word formation procedures: inflection and derivation. The difference between these two procedures is that inflection is syntactically motivated and its main purpose is changing words so they can match a certain number of syntactic requirements such as the right number (singular versus plural in English), person-number (third person singular in the present tense versus the other person-numbers), tense (present versus past in English) and so on. As a result, inflectional processes do not result in new words; they only result in another instantiation of the same thing, known as a lexeme or root. For example, while 'go', 'goes', 'going' are the same lexeme and have the same underlying root, they are three different word-forms (Lieber, 2021). On the other hand, derivational processes are needed to build new words using existing ones, for example, making a verb out of an adjective: ‘modernize’ from ‘modern’ (Haspelmath, 2013). Another difference is that inflectional processes are usually transparent whereas some derivational processes can be transparent and some not so much, meaning that the resulting words of derivational processes can be unpredictable (idiosyncratic) in terms of meaning and they can induce phonological and orthographic changes to the stems(Aronoff, 1976; Jackendoff, 1975).

These differences between inflectional morphology and derivational morphology have been utilized by researchers to investigate the architecture of the mental lexicon and the way lexical access occurs. Many models of morphological processing predict that transparent complex words should result in more priming effects than opaque complex-looking words (Andrews & Lo, 2013; Feldman et al., 2009). Being semantically transparent, regular inflectional complex words have been shown to lead to significant priming effects, a well-establish and replicated result (Fowler et al., 1985; Laudanna et al., 1992; Münte et al., 1999; W. Marslen-Wilson & Tyler, 2013). One important question that concerns inflectional morphology is whether they have their separate representations in the lexicon or not. This is an important question for two reasons:

i. Inflected forms are not new words since the processes that they undergo only give an extra feature to the original form to make it fit certain semantic and syntactic requirements.
ii. There are languages like Finnish and Turkish that have rich morphologies and allocating separate representations for each inflected form in such languages would be storage-wise very costly.

Although there is general consensus that regular inflected forms do not have their separate representations in the lexicon, the case of irregular inflected forms is more complicated. When an inflected complex form doesn't adhere to the common process that results in the same meaning, we run into inflectional irregularity. For example, the common process that is used to convey the meaning of plurality is attaching the suffix '-s' to a stem: 'car' and 'cars'. However, this process doesn't apply to some words. Take the word 'child' as an example. 'childs' is not a valid form in English. The correct plural form for 'child' is 'children'. As can be seen, the form 'children' does not bear the common marker of plurality '-s'. As a result, it is dubbed irregular.

An important question that arises at this juncture and is relevant to studies about morphological processing is whether irregular forms like 'children' are also decomposed into their stems the same way forms like 'cars' are. There are studies indicating that irregulars have to be stored (Pinker, 1999; Pinker & Prince, 1994; Prince & Pinker, 1988). Sonnenstuhl et al. (1999) reported full priming for regular inflected forms in German while only partial priming for irregular forms. Also, Stanners et al. (1979) interpreted their results as irregular forms having their own separate representations in the lexicon while regular forms are always decomposed into their stems and affixes. And likewise Kempley and Morton (1982) didn't find any facilitation from auditorily presented irregular primes and Napps (1989) found bigger priming effects for regular inflection than irregular inflection.

But recent studies, both behavioral and neuro-imaging, show that at least in the early stages of processing all morphologically complex forms, including non-segmentable irregular ones, are decomposed (Allen & Badecker, 2002; Crepaldi et al., 2010; Stockall & Marantz, 2006; Taft & Nguyen-Hoan, 2010).

Another question that relates the morphological status of a morpheme to the representational status of units at different levels of the mental lexicon concerns with free and bound morphemes. Do both free and bound morphemes have representations? There is a big body of evidence that free stems have their own representations since the recognition of targets containing the same free stem is facilitated when they are primed by complex forms containing that free stem (Beyersmann et al., 2015; Crepaldi et al., 2013; Dominguez et al., 2002; Feldman & Andjelković, 1992; Stanners et al., 1979). The case of bound stems and in particular the allomorphic ones has proven to be a less agreed-upon issue. Nevertheless, bound stem allomorphs have been shown to have their separate form-based representations (Forster & Azuma, 2000; Järvikivi & Niemi, 2002; Laudanna et al., 1989, 1992).

Another important question regarding the architecture of the lexicon and the way lexical access processes take place is the status of affixes. Are affixes processed and represented the same way as stems? Are there any differences between inflectional and derivational affixes? Are there any differences between prefixes and suffixes or other types of affixation such as infixation and circumfixation?

There are some findings indicating that the processing of stems and affixes might be different. As reported by these findings, stems are processed independently of their position (Beyersmann et al., 2016; Crepaldi et al., 2013) but the processing of affixes is position-dependent (Crepaldi et al., 2016; Laudanna et al., 1994).

Chateau et al. (2002), Ciaccio et al. (2020), Crepaldi et al. (2016) and Laudanna et al. (1994) reported facilitation effects from prefixed primes. Laudanna et al. (1994) showed that distributional properties of prefixes influence their decomposition. In other words, affixes lead to priming effects when they occur in their affixal positions (beginning of the word, end of the word and so on). In a study with Dutch prefixed words, Diependaele et al. (2009) found that the size of priming of Dutch prefixed words (both transparent and opaque) under masked conditions was similar to that of suffixed ones and the morpho-orthographic decomposition seems to be insensitive to the relative ordering of stems and affixes. In other words, derivational prefixes and suffixes are both decomposed and processed the same way. Ciaccio et al. (2020) found that both inflectionally prefixed and derivationally prefixed words lead to priming effects in Bantu. Another study related to derivational prefixes was Creemers et al. (2020). They found that both transparent and opaque prefixed words lead to priming effects, irrespective of semantic and phonological similarities. Numerous other studies have also reported similar priming effects for prefixes and suffixes (Beyersmann et al., 2016; Forster & Azuma, 2000; Giraudo & Voga, 2013; Kazanina, 2011; Nikolova & Jarema, 2002).

There have also been reports of discrepancy between priming effects of prefixes and suffixes. Meunier and Segui (2002) reported that while prefixes consistently prime their targets, suffixes prime only in phonologically transparent conditions. Giraudo and Grainger (2003b) found that only prefixed words result in priming effects in French. These results have been interpreted to be due to the word beginning advantage of prefixes (Diependaele et al., 2009). Kim et al. (2015) found that suffixed primes lead to reduced response latencies regardless of the lexicality (word or non-word) and interpretability of the primes. But prefixed words only prime their targets when the primes were actual words.

All in all, it looks like the overall view is that both suffixes and prefixes exhibit form-related decomposition in the early stages of processing and the input will always be exhaustively decomposed (Andoni Dunabeitia et al., 2008; Grainger et al., 1991; Longtin et al., 2003).

But prefixation and suffixation are not the only types of affixation among the languages of the world. Reduplication, infixation and circumfixation are also among the concatenative word-building processes that have not been used in lexical access studies. Wray et al. (2021) studied these affixation types in Tagalog and found priming effects for these types of affixation including their pseudo counterparts.

To conclude, in line with the predictions of the sub-lexical early morpho-orthographic models, all affixes are expected to be decomposed and accessed by the same mechanism utilized for stems and neither should there be any differences between inflectional and derivational affixes nor any difference between bound and free stems (Taft, 1981, 1988, 2004).

Regarding lexical properties related to affixes and stems and their representation and access mechanisms in the lexicon, the questions that the present study sought to answer were:

i. Will complex words with free stems surrounded by a prefix and a suffix be decomposed into their corresponding affixes and the free stems?
ii. Will complex words with bound allomorphic stems surrounded by a prefix and a suffix be decomposed into their corresponding affixes and bound stems?

CHAPTER 4

METHODOLODY AND EXPERIMENT

4.1 Allomorphy in Persian simple verbs

While there is now general consensus that a morphological analysis independent of form and meaning similarity does occur upon the perception of morphologically complex stimuli, there are still many unresolved questions regarding the nature of morphological processing in complex words. Specifically, it is still not clearly known whether morphological processing is driven by meaning or purely orthographic information. Is morphological processing only fueled by orthography in the very early stages of being exposed to stimuli? Another yet-to-be-answered question concerns the extent of decomposition: will all types of complexity be subject to decomposition or this early morpho-orthographic decomposition only applies to morphologically complex words of a certain nature?

Allomorphy is usually described as the process whereby an underlyingly abstract representation happens to be realized by different forms under different conditions (Haspelmath, 2013). The different realizations are sometimes phonologically motivated; sometimes semantically and sometimes morphologically. The key concept here to understand is that whatever the conditioning reasons, it is the same entity that we see or hear in different clothing. Persian simple verbs can be divided into two groups: those that exhibit allomorphy in their stems (also known as alternating stems) and those that do not exhibit allomorphy in their stems (non-alternating) (Karimi, 1997). Some verbs in Persian can have phonologically and orthographically different stems in their present imperfective, subjunctive and imperative forms than their past (both perfective and imperfective), participle and infinitival forms. For the purposes of this study, the allomorphic stem is the one that is realized in fewer contexts and is not the same stem in the most common and basic inflectional form which is the infinitival form.

Table 13 and Table 14 show an example of a verb that exhibits allomorphy in its stem: 'رفتن' /*ræft-æn/* (to go).

Table 13. Three Inflectional Forms of the Alternating Verb 'Go' with its Allomorphic Stem

Present imperfective for first person singular	Subjunctive for first person singular	Imperative
میروم mi-ræv-æm PROG-go.PRS-1.SG 'I go.'	بروم be-ræv-æm SBJV-go.PRS-1.SG 'I shall go.'	برو bo-ro IMP-go.PRS 'Go!'

Table 14. Four Inflectional Forms of the Alternating Verb 'Go' with its Non-Allomorphic Stem

Past imperfective for first person singular	Past perfective for first person singular	Participle	Infinitival
میرفتم mi-ræft-æm PROG-go.PST-1.SG 'I was going.'	رفتم ræft-æm go.PST-1.SG 'I went.'	رفته ræft-e go.PST-PTCP 'gone'	رفتن ræft-æn go.PST-INF 'to go'

As can be seen in Table 13 and Table 14 the verb for 'go' in Persian exhibits stem allomorphy: the verb stem changes depending on the inflectional paradigm. Sometimes it takes the orthographic form 'رو' (pronounced 'ræv/ro') and sometimes it takes the orthographic form 'رفت' (pronounced 'ræft').

Table 15 and Table 16 below show an example of a verb form that doesn't exhibit allomorphy in its stem: 'خندیدن' /*xændidæn/* (to laugh). Again, the parts corresponding to the stems have been underlined.

Table 15. Three Inflectional Forms of the Non-Alternating Verb 'Laugh' with its Non-Allomorphic Stem

Present imperfective for first person singular	Subjunctive for first person singular	Imperative
میخندم mi-xænd-æm PROG-laugh.PRS-1.SG 'I laugh.'	بخندم be-xænd-æm SBJV-laugh.PRS-1.SG 'I shall laugh.'	بخند be-xænd PROG-laugh.PRS 'Laugh!'

Table 16. Four Inflectional Forms of the Non-Alternating Verb 'Laugh' with its Non-Allomorphic Stem

Past imperfective for first person singular	Past perfective for first person singular	Participle	Infinitival
میخندیدم mi-xænd-id-æm PROG-laugh.PRS-PST-1.SG 'I was laughing.'	خندیدم xænd-id-æm laugh.PRS-PST-1.sg 'I laughed.'	خندیده xænd-id-e laugh.PRS-PST-PTCP 'laughed'	خندیدن xænd-id-an laugh.PRS-PST-INF 'to laugh'

As for the verb for 'laugh' in Persian (/*xændidæn/*), the stem does not change from one inflectional form to another. It looks as if some stems in Persian are fused with the 'pastness' element and therefore they are not decomposable (cases of suppletion like 'went' in English that is not decomposable) and some stems are combined with the 'pastness' element and are therefore separable (like 'watched' that can be segmented into 'watch' and '-ed').

This study aimed to see if morphological processing is guided through orthographic information using Persian simple verbs or it is influenced by abstract form-independent units. Specifically, the question is: How much does orthographic identicalness matter in the morphological processing of allomorphic stems?

Since some Persian verbs exhibit allomorphy in their stems and this leads to differences in orthography, this feature of Persian was taken advantage of to answer the questions of this study. To do so, a masked priming experiment was designed to measure the priming effects among different forms of verbs with stem allomorphy.

The different word forms which were examined are present imperfective, past imperfective, past perfective (all of which were conjugated for the first person singular) and the infinitival form.

4.2 Research questions and predictions

In this study, I tried to see if morpho-orthographic information is a decisive factor in the earliest stages of rapid morphological analysis as argued for in Rastle et al. (2004). According to this model, words which appear to be morphologically complex, e.g. ‘corner’ (corn + er), ‘brother’ (broth + er) and ‘archer’ (arch + er) are also decomposed into parts that look like morphemes (orthographic parts with consistent form-meaning relations) in the earliest stages of morphological processing in the same way as truly morphologically complex words like ‘farmer’ (farm + er), ‘acidic’ (acid + ic) and so on. While both truly morphologically complex words and pseudo-morphologically complex words are decomposed in the earlier stages of morphological processing, words like ‘brothel’ are not decomposed into ‘broth’ and ‘el’ (Davis & Rastle, 2010; Rastle et al., 2004; Rastle & Davis, 2008). The reason for this is that although ‘broth’ is a morpheme, ‘el’ is not a morpheme in English and as a result no early decomposition takes place for ‘brothel’. In other words, the morphological processor does not make the same mistake when it decomposed ‘corner’ into ‘corn’ and ‘-er’, both of which are morphemes in isolation. Over the past fifteen years, the results of Rastle et al. (2004) have been replicated in a number of studies across a few different languages: Dutch, French, Russian and English (for an overview of the studies, see Rastle & Davis, 2008).

According to this model, there is a level of processing that is only sensitive to purely orthographic information coming from the stimuli and it is this orthographic information that is taken advantage of during the earlier stages of morphological processing. However, other studies have purported that the level where morphemic units reside is above the lexical level and that these morphemic units lack any form; they are abstract entities (Giraudo & Grainger, 2000, 2001, 2003a; Voga & Giraudo, 2009). Another group of studies has hypothesized that in additional to an early purely form-based morpho-orthographic level there is a later level of representation which is independent of form (Allen & Badecker, 1999, p. 199, 2002; Crepaldi et al., 2010; Järvikivi & Niemi, 2002; Stockall & Marantz, 2006; Taft, 2004; Taft & Nguyen-Hoan, 2010). These studies explain priming effects between irregular verb forms like ‘taught-teach’ which are not readily decomposable into orthographic bits with independent meanings. This level is usually called the ‘lemma level’. Another account of word processing is the Edge-aligned Embedded Word Activation (Grainger & Beyersmann, 2017) which makes a strong prediction that stems are only morpho-orthographically accessed during the early stages of morphological decomposition if they occur on either the left edge or right edge of a bi-morphemic word. So, in complex words with stems positioned between a prefix and a suffix the underlying root will not be accessed. To my knowledge, this question has never been addressed in the morphological processing literature.

In the present study, Persian verbs that exhibit morphological allomorphy in their stems were used in a masked priming lexical decision task. The conditions employed in this study will try to address the following questions:

i. Does the early morpho-orthographic decomposition model (Rastle et al., 2004) also take place in a language with a different script and different orthographic properties?
ii. Is the process of root access initiated by purely form-based information?

iii. Does the early morpho-orthographic decomposition stage apply to morphologically complex words with both prefixes and suffixes? In other words, can the stems be activated when they occur between a prefix and suffix during this stage?

4.3 Experiment design

Fifty infinitival forms were used as the target stimuli in five different priming conditions. All the primes were first person singular conjugations as this form is one of the most frequent forms and it is morphologically more complex compared to the third person singular form in the past imperfective and perfective. The third person singular in the past tense for both imperfective and perfective lacks an overt person-number agreement suffix. In the first condition I used the present imperfective forms of allomorphic verbs conjugated for first person singular as the prime and their infinitival forms as the target. This condition, in terms of morphological complexity, is similar to prime-target pairs like 'went-GOING' in that they are transparently complex forms and the stem in the target has a different orthographic form than the stem in the prime, albeit they have the same underlying meaning and are not different lexemes. To give an example from the Persian stimuli, the prime was '*mi-ræv-æm'* (I go) and the target was '*ræft-æn'* (to go) where the '*ræv'* and '*ræft'* are the different allomorphs of the same underlying concept. I will refer to this condition as the non-ident-2 condition.

non-ident-2

prime	target
میروم	رفتن
mi-ræv-æm	ræft-æn
PROG-go.PRS-1.sg	go.PST-INF
'I go.'	'to go'

In this pairing of the stimuli, the prime has an orthographically different form than the stem in the target (‘*ræv’* vs. ‘*ræft’*).

In the second condition, the prime was the past imperfective form of the verb conjugated for the first person singular and the target its infinitival form. For instance, the prime was ‘*mi-ræft-am’* (I was going) and the target was *‘ræft-æn’* (to go) where the stem ‘*ræft’* is found in both the prime and the target. I will refer to this condition as the ident-2 condition.

ident-2

prime	target
میرفتم	رفتن
mi-ræft-æm	ræft-æn
PROG-go.PST-1.sg	go.PST-INF
‘I was going.’	‘to go’

In this condition, the prime shares the same allomorph as the one in the target (‘*ræft*’ vs. ‘*ræft*’).

In the third condition, similar to the ident-2 condition, the prime and the target share the same stem. However, it does not contain a prefix; it only has a suffix which is again conjugated for first person singular. As a result, this form, unlike the first two conditions, doesn’t have a prefix and a suffix simultaneously. It only has a suffix. I will refer to this condition as the ident-1 condition.

ident-1

prime	target
رفتم	رفتن
ræft-æm	ræft-æn
go.PST-1.SG	go.PST-INF
‘I went.’	‘to go’

To control for the effects of orthographic similarity in our experiment, in the fourth condition (the ortho-overlap condition), primes that orthography-wise partially matched our infinitival targets were used. To calculate the degree of orthographic match between the primes and the targets I used the WordPars (Esmaeelpur et al., 2021), which is a piece of software that uses the Levenshtein distance (Levenshtein, 1965) as its metric to calculate orthographic match between two strings. The Levenshtein distance is an algorithm that calculates the minimum number of substitutions, deletions or insertions required to transform one word into another word. The fewer the number of substitutions, deletions and insertions, the more similar two words are. For example, the Levenshtein distance between 'kitten' and 'sitting' is 3 since the number of transformations to change 'kitten' into 'sitting' is 3: 1. 'k' is substituted by 's' 2. 'e' is substituted by 'i' and 3. 'g' is inserted to the end of the word. The primes used in this condition were all unsegmentable words (neither opaque nor pseudo-complex) chosen from the three different lexical categories verbs, adjectives and nouns. The achieved orthographic similarity was such that it was not due to the presence or absence of certain diacritic-like dots and glyphs so that the primes would not be confused with other stimuli. To give an example, the words 'گشت' /gæʃt/ (s/he travelled) and 'کشت' /koʃt/ (s/he killed) are extremely similar and the only difference between them is that the former starts with the letter 'گ' and the latter starts with the letter 'ک'. As you can see, the first letter has a little slanted line over it while the second does not and other than this difference they are identical. This was done to exclude the possibility that these two letters might share the same underlying grapheme and one can be easily mistaken for the other (Chetail & Boursain, 2019). So in this condition I avoided using prime-target pairs like ‘گشت’ and ‘کشت’ which can be easily mistaken to be the same word and instead used pairs like ‘گشت’ and ‘دشت’ which are orthographically quire similar and not prone to being confused. The average orthographic distance between the primes and the targets are given in Table 18 on page 56.

ortho-overlap

prime	target
روشن	رفتن
roʃæn	ræft-æn
light	go.PST-INF
‘light (adj)’	‘to go’

And finally in the fifth condition, I used a target preceded by a prime which was neither morphologically, nor orthographically nor semantically related to the target. This condition (referred to as the unrelated condition) served as the baseline to compare the reaction times of the other conditions with.

unrelated

prime	target
کتاب	رفتن
ketab	ræft-æn
book.SG	go.PST-INF
‘book’	‘to go’

I didn’t include an identical condition as the target itself was a morphologically complex form as opposed to being a free stem. Normally, identical conditions are used in studies where the target is a free-standing mono-morphemic form and to make sure that the activation of the stem happens, an identical prime to the target is used. In short, there wouldn’t be any difference between the ident-1 condition in the study and an identical condition, given the purpose of including an identical condition. Having said that, it might have been a good idea to include the free-standing stem of the target. I also didn't include a semantically related condition since it has been shown that semantic relatedness effects become relevant at SOAs longer than 64 ms (Dominguez et al., 2002). The conditions are summarized in Table 17.

Table 17. Summary of the Experiment Conditions

condition	prime	target
a. different stem surrounded by affixes (non-ident-2)	میروم /mi-ræv-æm/ PROG-go.PRS-1.SG 'I go.'	رفتن /ræft-æn/ go.PST-INF 'to go'
b. same stem and surrounded by affixes (ident-2)	میرفتم /mi-ræft-æm/ PROG-go.PST-1.SG 'I was going.'	رفتن /ræft-æn/ go.PST-INF 'to go'
c. same stem and just a suffix (ident-1)	رفتم ræft-æm go.PST-1.SG 'I went.'	رفتن /ræft-æn/ go.PST-INF 'to go'
d. orthographic overlap (ortho-overlap)	روشن /roʃæn/ light 'light (adj)'	رفتن /ræft-æn/ go.PST-INF 'to go'
e. not related (unrelated)	کتاب /ketɑb/ book.SG 'book'	رفتن /ræft-æn/ go.PST-INF 'to go'

4.4 Stimuli

Fifty stem-changing verbs in their infinitival forms were chosen as the targets. These targets were primed in five different conditions (Appendix A). In similar studies, primes and targets across conditions are tried to be matched on properties like surface frequency, neighborhood size, length, morphological family size and form overlap. Unfortunately, it was not possible to strictly control our stimuli for all these properties. To my knowledge, none of the Persian corpora that exist has information about stem frequency, lemma frequency, morpheme frequency, neighborhood size or family size. Also, the number of simple verbs in Persian with allomorphic stems is very small and only around 30 of them are commonly used (Dehdari, 2006) as present-day Persian mostly employs complex light verb constructions similar to ‘take a shower’ in English. Moreover, not all of the inflected forms of already few stem-changing verbs are commonly used, especially in colloquial form. Nevertheless, I tried to match primes and targets on their surface frequency and length. The prime words in the ident-1, ortho-overlap and unrelated conditions were controlled for length as well as surface frequency. To do so, I used the WorldLex database (Pallier et al., 2019) which has brought together Twitter, Blog and News frequencies of around 600,000 Persian word forms. The average word form frequency (measured in per one million) and length (measured in the number of letters) of the targets were 76.8 and 5.02, respectively. The average frequencies and lengths of the prime stimuli are given in Table 18 below.

Table 18. The Average Surface Frequencies, Lengths and Orthographic Distance of the Primes in each Condition

Condition	Frequency per million	Length	Orthographic distance with the target
non-idnet-2	0.62	6.38	5
ident-2	0.25	7.04	3.12
ident-1	111.35	5.04	1
ortho-overlap	98.89	4.8	2.02
unrelated	107.08	5.14	5.22

Since there wasn’t a lot of freedom in terms of choosing the morphologically related test stimuli and I had to work with a very limited number of the desired stimuli, I couldn’t control them for frequency and length.

For the experiment I used a Latin Square within-items and within-groups design. The participants were divided into five groups A through E (Appendix D). All the participants saw all the targets only once in only one condition. The total number of experimental trials was 240 with 50 of them being the test trials (Appendix B). Half of the experimental trials were word and half were non-word trials. The non-word targets were created by replacing one letter in an actual word with another letter to turn it into a non-word. All the non-words were both phonotactically and ortho-tactically legitimate. Just like the words in the orthographic match condition, I avoided using non-words whose only difference with actual words was due to diacritic-like symbols. For example, I avoided non-words like 'غمر' /ɣæmr/ as there is a word 'عمر' /omr/ (life expectancy). As it can be seen, there is a minimal difference between the two strings and I tried not to use non-words which have closely-resembling word counterparts. After choosing the non-word stimuli, I asked 5 native speakers of Persian about the lexicality of the non-words. 7 of the non-words were mistaken to be words. These non-words were replaced by better non-words. Again, 5 other native Persian speaks were asked to judge the lexicality of the new non-words. This time all the non-words were judged as strings of letters with no associated meanings. Of the word trials, half of them were complex infinitival verb forms and half were simple verb forms conjugated for the third person singular. Using only verbal trials eliminated any possible confounding effects of word category. In addition to the 240 experimental trials, the participants also received 20 randomly-ordered warm-up trials with 10 being words and 10 being non-words (Appendix C). The reaction times to the warm-up trials were also recorded. All the trials were preceded by masked word primes. 60% of the experimental trials were preceded by complex primes and 40% by simple primes, mimicking the proportion of the complex and simple primes in the test trials. Of the 240 targets, 159 were preceded by verb primes (63.6%), 86 by noun primes (34.4%) and 5 by adjective primes (2%), again mimicking the proportion of verb, noun and adjective primes in the test trials. And finally, the targets were interspersed by 190 fillers (70 word fillers and 120 non-word fillers) for a total of 260 trials.

4.5 Participants and procedure

Seventy-eight native speakers of Persian participated in the experiment. They were compensated for their participation and gave their consent (Ethics Committee approval is in Appendix E). Each received thirty thousand Tomans (around 1 dollar). The number of total test items combined with the number of conditions resulted in 10 measurements per condition per participant and the sample size for each condition came to be 780.

The PCIbex platform (Zehr & Schwarz, 2018) was used to design and conduct the masked priming lexical decision experiment online (Appendix F). I used a masked priming experiment to tap into the earliest stages of word processing. To conduct the experiment, the participants were asked to press ‘F’ for word targets and ‘J’ for non-word targets. In each trail, the participants first saw a blank page for 500 milliseconds, followed by ‘+’ for 500 milliseconds, and then another blank screen for 500 milliseconds. After the second blank screen, the participants saw a mask in the form of ####### for 500 milliseconds, which was replaced by the primes. The primes stayed on the screen for 50 milliseconds and then were immediately followed by the targets, which remained until a response was made. The 240 trials were divided into 3 blocks (85 – 85 – 70). Between the blocks the participants could take a pause and rest before continuing with the next block. The total duration of the experiment was around 15 to 20 minutes.

4.6 Expected results and their possible interpretations

According to the sub-lexical model, in the early morpho-orthographic decomposition stage, words will be decomposed into form-based morphemic units prior to lexical access. Therefore, it predicts that there should be priming effects in ident-2 and ident-1 conditions because the primes in these conditions are morpho-orthographically decomposable into affixes and a stems which is orthographically identical to the stem in the target. Hence, there should be a priming effect in these conditions if the decomposition is purely form-based. Moreover, if the size of the priming effect is different between these conditions, this could be an indication of an effect of affixation complexity or length. No priming is expected in the non-ident-2 condition.

According to the supra-lexical account, there should be an effect of priming in all morphologically related conditions. Moreover, the size of the priming effect across all three conditions should be equal.

According to the model outlined in Crepaldi et al. (2010) there should be a priming effect in all three morphologically related conditions. But this model predicts more priming in ident-2 and ident-1 conditions than non-ident-2. No priming difference is expected between ident-2 and ident-1. Any priming difference between ident-2 and ident-1 conditions could be interpreted as an effect of either length or affixation complexity.

The Edge Aligned Embedded Word Model only predicts priming in the third condition since it is the only morphologically complex form where the stem happens to be on the left edge of the word (remember that Persian is written from right to left).

Finally, according to the Full Decomposition account, priming effects are expected in all non-ident-2, ident-2 and ident-1 conditions. This is similar to the prediction of the supra-lexical account. But the difference is that the supra-lexical account expects priming effects in the absence of any prior decomposition while the Full Decomposition expects priming effects as a result of a prior decomposition process.

As for the ortho-overlap and unrelated conditions, none of the models predicts any priming effects given that in the ortho-overlap condition the prime is only orthographically similar to the target and in the unrelated condition, the prime is completely unrelated to the target and it should not lead to reduced reaction times for the target.

CHAPTER 5

STATISTICAL ANALYSIS AND RESULTS

5.1 Statistical analysis

I fit four Bayesian hierarchical linear models using the brms package (Bürkner, 2017) in the R programming language (R Core Team, 2013). Each model used different comparisons of the conditions. In the first model the conditions ident-1, ortho-overlap and unrelated were compared (model_ced). The code for this model is available in Appendix G. In the second model, ident-2, ortho-overlap and unrelated conditions were compared (model_bed); in the third model the conditions non-ident-2, ortho-overlap and unrelated were compared (model_aed). In all these three models, the base-line condition against which the other two conditions were compared was the unrelated condition. As for the fourth model, the conditions non-ident-2, ident-1 and ident-2 were compared (model_acb), where ident-1 served as the base-line of the comparison. To compare the conditions in each model, I used the sliding contrasts coding scheme. The main effects were the intercepts and the slopes, which were the contrasts between the effects in the conditions and the random effects were by-subject and by-item intercepts and slopes.

I did not include frequency or length as separate predictors in my final models. With regard to length, the primes were controlled for this variable and as for frequency, although I tried to do my best to control for frequency, I only managed to control ident-1, ortho-overlap and unrelated conditions for frequency. One of the reasons I opted not to include surface frequency in the final analysis is that it was simply impossible to control for this variable given the limited number of Persian simple verbs with allomorphy and expectedly some inflectional forms of these verbs are either exclusive to very formal and literary contexts and thus have low frequency values or simply non-existent given their functionality and other aspects. Nevertheless, in a separate simple linear model comparing reaction times to ident-2, ortho-overlap and unrelated conditions with frequency as the only predictor, I did not find any effect of frequency. Another reason why I did not use frequency as a predictor was because according to the literature under masked conditions, prime surface frequency is believed to have no effect (Amenta & Crepaldi, 2012).

The reaction times were log-transformed prior to analysis. To model the log-transformed reaction times (RTs), I used a Gaussian distribution. Since reaction times are usually skewed and contain many data points away from where the highest density of the data points are, taking their logarithms helps to make the data points have a more normal distribution. I used slightly informative priors with a normal distribution for all model intercepts on a log-scale (N(mu = 6.5, sigma = 0.3)). This prior means that 95% of RT should fall between 6.5 – 2*0.3 and 6.5 + 2*0.3 logs. This amounts to saying that to our knowledge the grand mean that people respond to written stimuli is between 365 and 1212 ms. The prior for the slope was (N(mu = 0, sigma = 1)) and for the standard deviations was (N(mu = 0.3, sigma = 0.1)) again on a log-scale. I used the models' posterior MCMC samples to construct 95% credible intervals. All the models used 4 sampling chains, each with 4000 iterations, of which 1000 were warmup iterations. As a result, there was a total of 12000 sampling iterations in the analysis.

In a Bayesian model, the output is a distribution of likely values for the unknown parameters of interest. The outcome is based on the data, how the data could have been generated and prior knowledge about the possible values of the parameters values. The results are usually reported within a 95% credible interval, which denotes the range of parameter values within which we can say with 95% certainty that the true values of the parameters reside. I also used the log-transformations to report the results.

5.1.1 Model 1

In the first model, the fixed effects were the intercept and cEmC (difference between the average effect of the unrelated condition and the ident-1 condition) and cDmE (the difference between the average effect of the orthographic overlap condition and the unrelated condition). The random effects were by-subject and by-item intercepts and slopes. The response variable was log-transformed.

The model formula and the contrast matrix (Table 19):

log_RT ~ cEmC + cDmE + (1 + cEmC + cDmE | subject) + (1 + cEmC + cDmE | item)

Table 19. Contrasts Matrix for Model 1. cEmC (E Minus C) is the Contrast between the Unrelated and Ident-1 Conditions, and cDmE (D Minus E) is the Contrast between the Ortho-Overlap and Unrelated Conditions

	cEmC	cDmE
ident-1	-2/3	-1/3
unrelated	1/3	-1/3
ortho-overlap	1/3	1/3

5.1.2 Model 2

In the second model, the fixed effects were the intercept and cEmB (difference between the average effect of the unrelated condition and the ident-2 condition) and cDmE (the difference between the average effect of the orthographic overlap condition and the unrelated condition). The model formula and contrasts matrix (Table 20, next page):

log_RT ~ cEmB + cDmE + (1 + cEmB + cDmE | subject) + (1 + cEmB + cDmE | item)

Table 20. Contrasts Matrix for Model 2. cEmB (E Minus B) is the Contrast between the Unrelated and Ident-2 Conditions, and cDmE is the Contrast between the Ortho-Overlap and Unrelated Conditions

	cEmB	cDmE
ident-2	-2/3	-1/3
unrelated	1/3	-1/3
ortho-overlap	1/3	1/3

5.1.3 Model 3

In the third model, the fixed effects were the intercept and cEmA (difference between the average effect of the unrelated condition and the non-ident-2 condition with two affixes and an allomorphic stem) and cDmE (difference between the average effect of the orthographic overlap condition and the unrelated condition). The model formula and the contrasts matrix (Table 21):

log_RT ~ cEmA + cDmE + (1 + cEmA + cDmE | subject) + (1 + cEmA + cDmE | item)

Table 21. Contrasts Matrix for Model 3. cEmA (E Minus A) is the Contrast between the Unrelated and Non-Ident-2 Conditions, and cDmE is the Contrast between the Ortho-Overlap and Unrelated Conditions

	cEmA	cDmE
Non-ident-2	-2/3	-1/3
unrelated	1/3	-1/3
ortho-overlap	1/3	1/3

5.1.4 Model 4

And finally in the fourth model, the fixed effects were the intercept and cCmA (difference between the average effect of the ident-1 condition, the one with one suffix and an identical stem, and the non-ident-2 condition, the one with allomorphic stem) and cBmC (difference between the average effect of the ident-2 condition, the one with two affixes and an identical stem, and the ident-1 condition). The model formula and the contrasts matrix (Table 22, on the next page):

log_RT ~ cCmA + cBmC + (1 + cCmA + cBmC | subject) + (1 + cCmA + cBmC | item)

Table 22. Contrasts Matrix for Model 4. cCmA (C Minus A) is the Contrast between the Ident-1 and Non-Ident-2 Conditions, and cBmC is the Contrast between the Ident-2 and Ident-1 Conditions

	cCmA	cBmC
non-ident-2	-2/3	-1/3
ident-1	1/3	-1/3
ident-2	1/3	1/3

5.2 Results

There was a total of 20280 (78 * 260) data points with a total of 3900 (78 * 50) test data points. Two participants were excluded as their accuracy was below the 75% accuracy threshold. The warm-up trials and the filler trials were excluded. The incorrect answers as well as RTs longer than 2000 ms and shorter than 250 ms were also excluded. This resulted in the exclusion of 6% of the data to be used in the analysis. The R code used to clean the data is provided in Appendix F.

The cleaned results of the masked priming lexical decision task are reported in Table 23 below. As it can be seen, the facilitative effects came from ident-2 and ident-1 conditions, with the latter resulting in the biggest facilitative effect size. Non-ident-2 and ortho-overlap conditions did not result in any interpretable effect.

Table 23. Descriptive Results of the Participants' Reaction Times

	Mean reaction time (ms)	Standard deviation	Standard error (ms)	Accuracy rate (%)	Effect Size (ms)
non-ident-2	752	251	9.27	98	-3
ident-2	736	234	8.64	99	-19
ident-1	727	247	9.14	98	-28
ortho-overlap	760	245	9.11	97	5
unrelated	755	248	9.20	98	-

In the following section, I present the output of the statistical analyses. The way the plots are interpreted are as follows: the lines represent the posterior distributions. The point in the middle of the line is the median of the posterior which can be interpreted as the most likely value among all the values in the posterior distribution. The thick lines around the point represent the 50% credible intervals and the thin lines represent the 95% credible intervals. To confidently claim that there is an effect, the whole line (posterior distribution) should not cross the vertical line at zero. The measure of confidence in the existence of an effect is measured by whether the line crosses the vertical line at zero or not. If it doesn't cross the zero line, then we can confidently state that there is an effect.

5.2.1 Model 1

In Model 1, the effect of ident-1 was tested. The output of the model in Table 24 shows that the response times were faster when the targets were preceded by a simple morphologically related prime (b = 0.05, 95% credible interval [0.02, 0.07]). Also, there was a mild inhibitory effect of orthographical overlap.

Table 24. Population-Level Estimates of Model 1

	Estimate	SE	95% CI	Rhat	ESS
Intercept	6.58	0.02	[6.54, 6.62]	1.00	1318
cEmC	0.05	0.01	[0.02, 0.07]	1.00	7950
cDmE	0.01	0.01	[-0.02, 0.04]	1.00	10297

The coefficient plot in Figure 1 shows that the 95% interval for the difference between the unrelated and the simple morphologically relatedness condition is safely above zero. This means that, the ident-1 condition yields smaller reaction times that the unrelated condition. The purpose of comparing the contrast between the unrelated and ident-1 condition with the contrast between the ortho-overlap and unrelated conditions was to check whether any possible effects of morphological relatedness could have been due to orthographic similarity, as most morphologically related words also happen to look similar. The fact that there was facilitation in the morphologically related condition but no such effect in the orthographic condition tells us that the observed effect in the morphologically related condition was not due to form similarity.

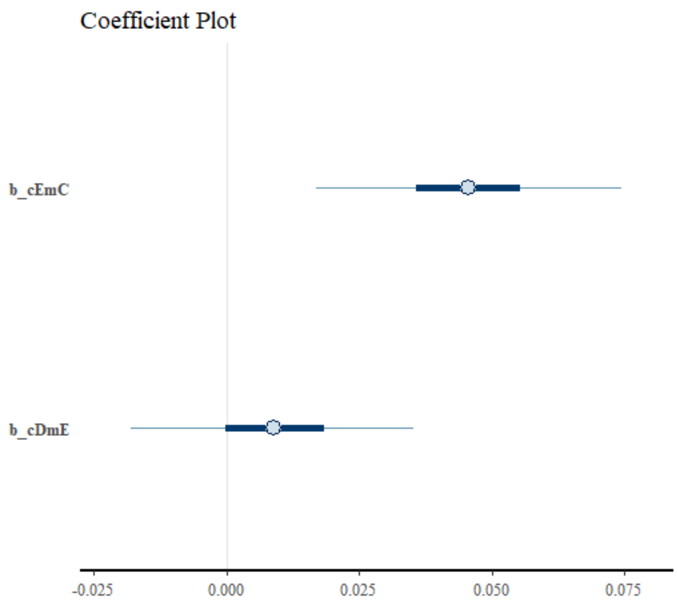

Figure 1. Posterior predictions for the contrasts in Model 1

As a different illustration, the plots in Figure 2 on the next page show the posterior distributions for the contrasts. What is important in these visualizations is the proportion of the posterior distribution above or below zero. The density plot on the left, represents the posterior distribution for the contrast between the unrelated and ident-1 conditions. This plot shows that 99% of the distribution lies above zero. This can be interpreted that there is a 99% probability that ident-1 leads to a shorter reaction time relative to an unrelated condition. Likely, in the histogram on the left, which represents the contrast between the orthographic overlap condition and the unrelated condition, 74% of the distribution lies on the positive side. This means that there is 74% chance that the ortho-overlap condition will yield longer RTs than the unrelated condition.

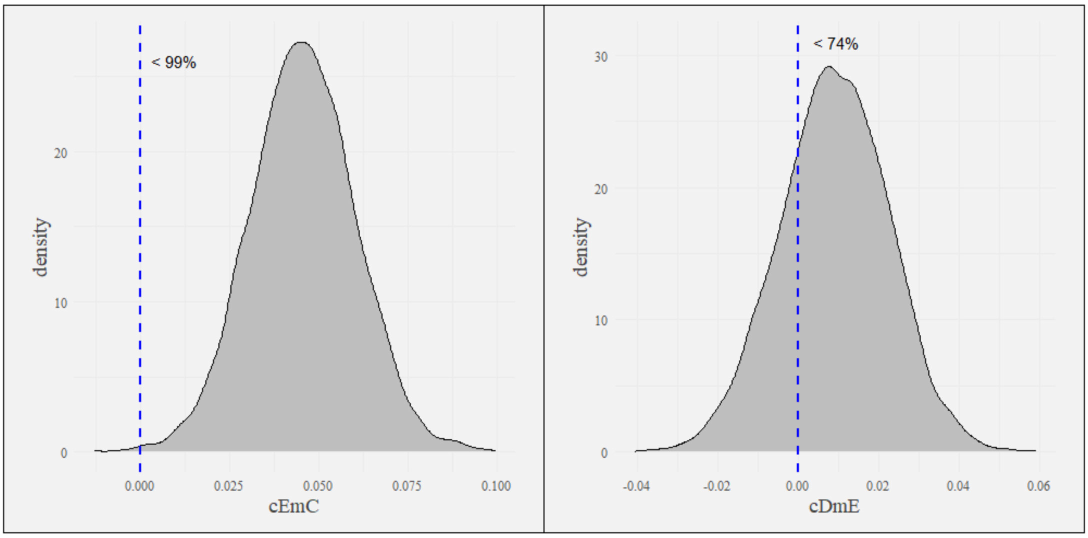

Figure 2. Posterior distributions for the contrasts in Model 1

5.2.2 Model 2

In Model 2, the effect of the ident-2 condition was tested. This was the morphologically related condition with two affixes and an identical stem. The output of the model in Table 25 on the next page shows that the response times were faster when the targets were preceded by a prime which was morphologically related to the target and happened to be affixed by a prefix and a suffix and which also contained an identical stem to that of the target (b = 0.06, 95% credible interval [0.00, 0.12]).

Table 25. Population-Level Estimates of Model 2

	Estimate	SE	95% CI	Rhat	ESS
Intercept	6.63	0.04	[6.56, 6.70]	1.01	807
cEmB	0.06	0.03	[0.00, 0.12]	1.00	5435
cDmE	-0.02	0.03	[-0.07, 0.04]	1.00	1520

The coefficient plot in Figure 3 shows that almost all of the 95% credible interval for the contrast between the unrelated and ident-2 conditions was above zero, meaning that there was an effect of this condition. In a similar vein to Model 1, comparing the contrasts between the unrelated and ident-2, and the contrast between ortho-overlap and unrelated conditions, we can be confident that the effects of ident-2 was not due to form similarity.

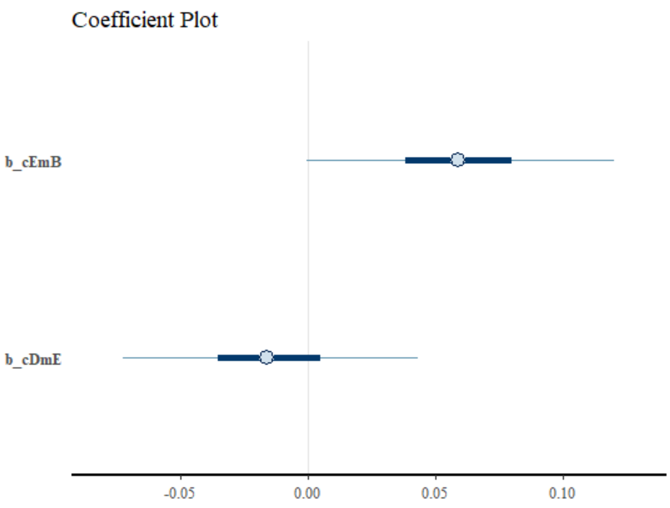

Figure 3. Posterior predictions for the contrasts in Model 2

And finally, the posterior distributions in Figure 4 show us that there is a 95% chance that a morphologically related prime surrounded by a prefix and a suffix with an identical stem will facilitate the reaction time to the same target compared to an unrelated prime. Similar to Model 1, the mild inhibitory effect that was observed in the contrast between the ortho-overlap and unrelated conditions is also present here. There is a 72% chance that orthographic similarity will lead to an inhibitory effect. In Model 1, this number was 74%. I suspect that this difference was due to sampling variation.

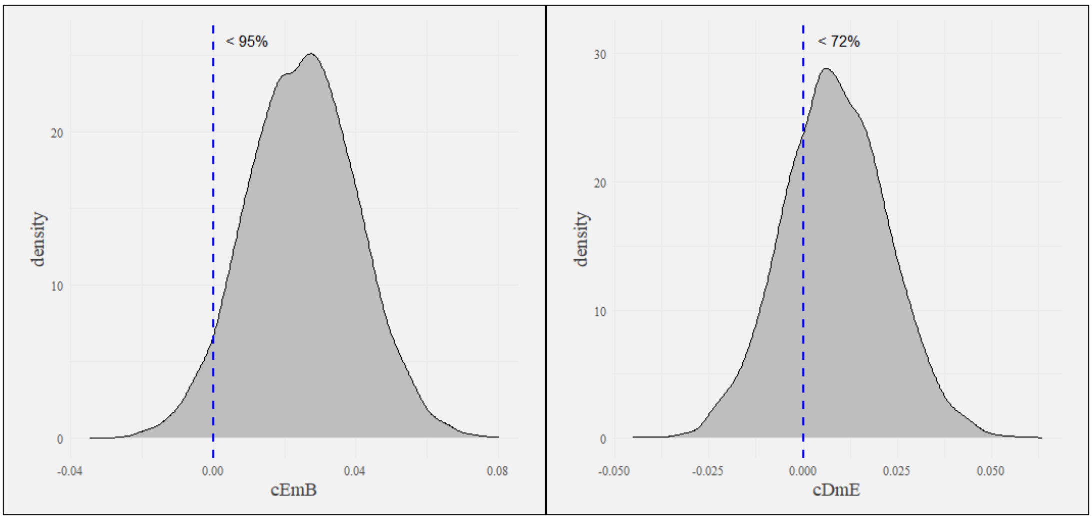

Figure 4. Posterior distributions for the contrasts in Model 2

5.2.3 Model 3

In Model 3, the effect of the non-ident-2 condition was tested. This was the morphologically related condition with two affixes and a non-identical allomorphic stem. The output of the model in Table 26 shows that there was not any effect of this condition (b = 0.01, 95% credible interval [-0.02, 0.03]).

Table 26. Population-Level Estimates of Model 3

	Estimate	SE	95% CI	Rhat	ESS
Intercept	6.59	0.02	[6.55, 6.63]	1.00	1611
cEmA	0.01	0.01	[-0.02, 0.03]	1.00	12257
cDmE	0.01	0.01	[-0.02, 0.04]	1.00	12147

As you can see in Figure 5 below, the line representing the contrast between the unrelated and non-ident-2 conditions crosses the zero line in its 50% credible interval.

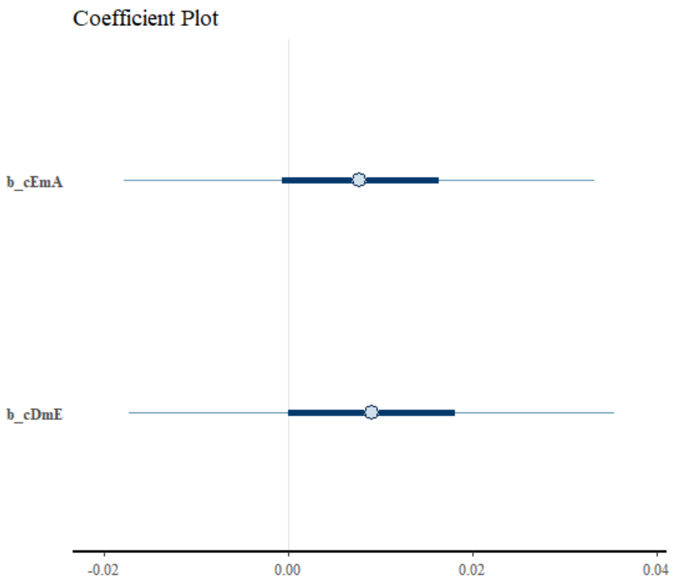

Figure 5. Posterior predictions for the contrasts in Model 3

Looking at the posterior distributions in Figure 6 below, we see a 73% chance that the non-ident-2 condition will lead to facilitation. And as for the ortho-overlap condition, it will result in larger RTs than the unrelated condition with a 75% chance (D minus E will be greater than zero).

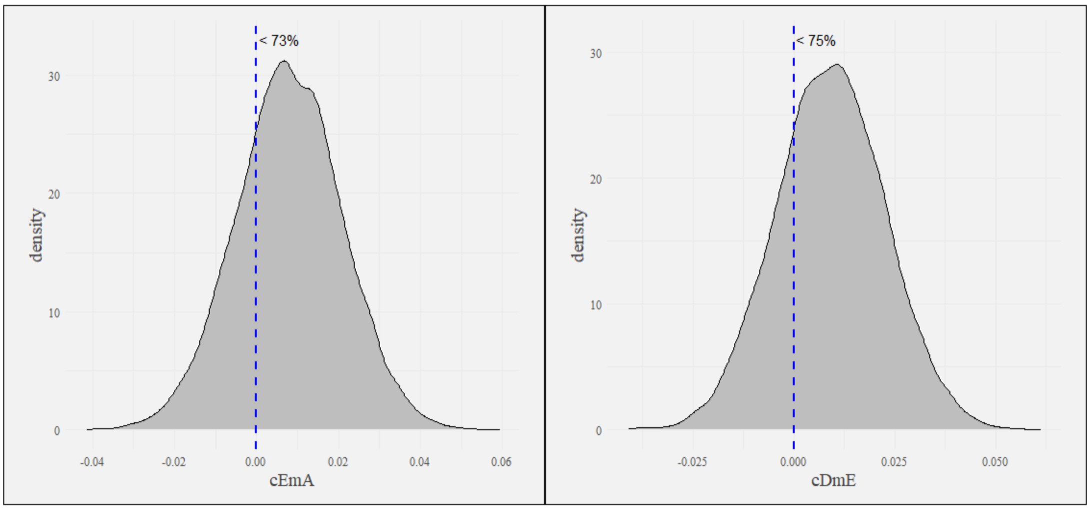

Figure 6. Posterior distributions for the contrasts in Model 3

5.2.4 Model 4

The purpose of Model 4 was to see if there would be any differences between the effects of the morphologically related conditions. The question that I wanted to answer was whether the effects of the non-ident-2, ident-2 and ident-1 conditions were similar or not. Table 27 shows the output of this model.

Table 27. Population-Level Estimates of Model 4

	Estimate	SE	95% CI	Rhat	ESS
Intercept	6.57	0.02	[6.52, 6.61]	1.00	1429
cCmA	-0.04	0.01	[-0.07, -0.01]	1.00	11305
cBmC	0.02	0.02	[-0.01, 0.05]	1.00	7428

Looking at the plot in Figure 7, although we can't claim that the effects were confidently different, the fact that a good proportion of the 95% credible interval resides to the left of the zero line, there is still a good chance that there is a difference between the priming effects of ident-2 and ident-1 conditions.

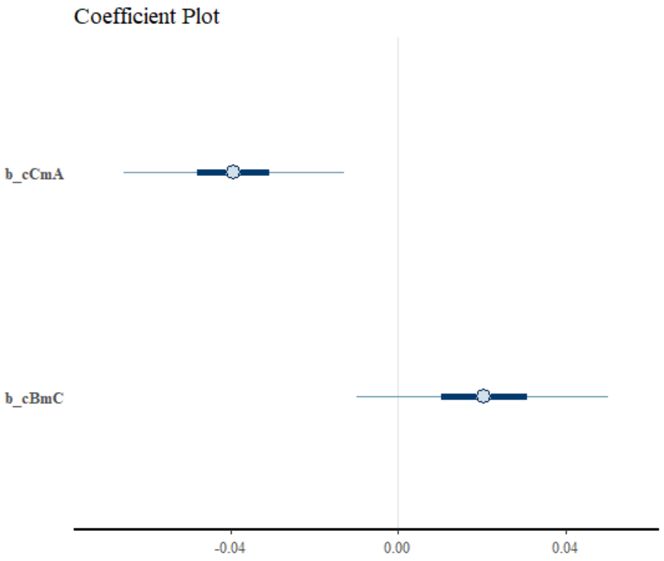

Figure 7. Posterior predictions for the contrasts in Model 4

The posterior distributions plot in Figure 8 tells us that there is a 91% chance that ident-1 will lead to more facilitation than ident-2.

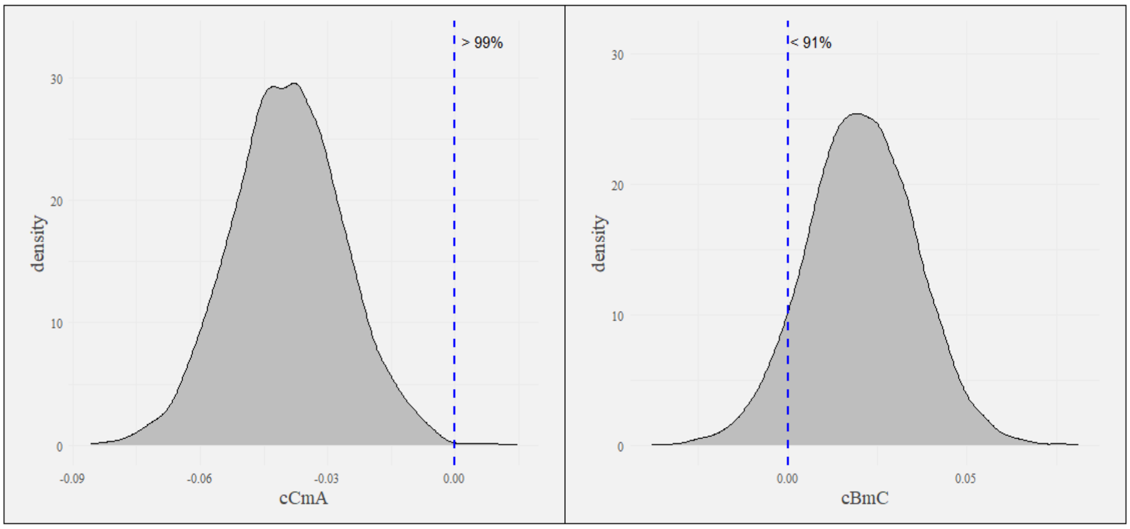

Figure 8. Posterior distributions for the contrasts in Model 4

CHAPTER 6

DISCUSSION

The aim of the present study was to find whether the early morpho-orthographic decomposition also applies to Persian inflected forms and then to further test if this decomposition extends to complex words surrounded by prefixes and suffixes as well as complex words which, in addition to being surrounded by prefixes and suffixes, also exhibit stem allomorphy. To accomplish this, a masked priming lexical decision task was carried out. There were five conditions in the experiment. In each condition the same target was primed by five different primes. The targets were infinitival forms. The primes in the first condition were pre- and suffixed verb forms with stem allomorphy (non-identical to the target stems); in the second condition, the primes were pre- and suffixed verb forms with identical stems to the target stems; in the third condition, the primes were suffixed verb forms with identical stems; in the fourth condition, the primes were orthographically similar, albeit morphologically and semantically unrelated mono-morphemic forms; and finally in the fifth condition, the primes were neither semantically nor morphologically nor orthographically related to the target stems. To give a more concrete idea about what the morphologically related primes and targets were like, we can use the parallelism below:

Non-ident-2:

x-go-y → went-z

Ident-2:

x-went-y → went-z

Ident-1:

went-y → went-z

Where ‘x’ indicates the prefix for imperfective; ‘y’ indicates the suffix for Person/Number agreement; and ‘z’ indicates the suffix for the infinitival marker.

The results of the statistical analysis revealed that the ident-2 and ident-1 resulted in facilitation of target recognition while the non-ident-2, ortho-overlap and unrelated conditions did not, with the ortho-overlap condition resulting in a slight inhibition. Importantly, the priming effects were genuinely morphological in nature since the experiment was done under masked conditions with a stimulus onset asynchrony (SOA) of 50 ms and pairs that were orthographically matched to the targets did not result in any facilitation. The priming effects obtained from the comparisons between the conditions point to a few patterns:

i. Morphologically related suffixed inflected verb forms with identical stems led to faster recognition of targets containing the same stems.
ii. Priming effects arose when embedded stems in morphologically related pre- and suffixed primes were identical to the stems in the targets, albeit with a smaller effect size than suffixed words with identical stems.
iii. No reliable priming effects arose when the embedded stems in morphologically related pre- and suffixed primes were not identical to the stems in the targets.

The obtained results point to the existence of an early purely form-based morpho-orthographic decomposition in visually presented Persian inflected forms. This finding is in line with the theory of meaning-independent early morpho-orthographic decomposition and adds more cross-linguistic evidence from a language that uses a non-Latinate script (Crepaldi et al., 2010; Davis & Rastle, 2010; Longtin et al., 2003; Rastle et al., 2000, 2004; Rastle & Davis, 2008; Stockall & Marantz, 2006; Taft & Nguyen-Hoan, 2010). In addition, the results disprove my initial hypothesis that written Persian verb forms, due to some of the characteristics of the Persian letters and writing conventions in this language, could prove too challenging for rapid morphological parsing. However, this finding still does not rule out the possibility that decomposing written Persian verb forms are processing-wise more demanding than Latinate languages like Turkish and English.

The priming effects obtained from the comparisons between the ident-2, ortho-overlap and unrelated conditions point to the fairly broad extent of this rapid early morphological decomposition as it is also capable of reaching roots embedded between prefixes and suffixes. This finding can be taken as evidence in favor of the full decomposition principle (Stockall & Marantz, 2006) that states all morphologically complex words regardless of the type of complexity should be decomposed. However, the full decomposition principle does appear to have its limitations as no priming effect was found in one of the morphologically related conditions, namely the non-ident-2 condition. This finding is also contrary to the findings of Crepaldi et al. (2010) and Taft and Nguyen-Hoan (2010) that even irregular forms the stems of which are not identical to that of the target e.g., ‘fell’ and ‘gave’ will result in facilitation of recognition of a morphologically related target.

And finally, the results from the comparisons between the non-ident-2, ident-2 and ident-1 conditions confirmed that the priming effects from the ident-2 and ident-1 conditions, both of which were morphologically related forms with identical stems to those of the targets, were different, with the priming effects from the ident-1 condition being larger than the priming effects from the ident-2 condition.

The puzzle that arises at this point is as follows:

i. Why weren’t there any priming effects in the non-ident-2 condition?

ii. Why were the priming effects of the ident-2 and ident-1 conditions different?

There are two ways in which the questions above can be answered. One way is by saying that the Crepaldi et al. (2010) and Taft and Nguyen-Hoan (2010) models fail to account for the results. But this claim at this point cannot be fully defended as there could be an independent effect of affixation number or type at work which cost additional processing and there is an interaction between affixation number and allomorphy. The other way is by hypothesizing that allomorphic complex forms also activate the underlying roots, as predicted by Crepaldi et al. (2010) and by Taft and Nguyen-Hoan (2010), but to a lesser degree than non-allomorphic complex forms. If this is the case, then it can be hypothesized that the little root activation that should have been observed was lost due to the stem being embedded between a prefix and a suffix. In summary, if it can be shown that stem-allomorphic complex words result in less activation of roots than non-stem-allomorphic complex words, then there wouldn't be a need to state that the sub-lexical models fail to explain the results of this study.

In the next parts, I will outline a detailed explanation of different models of morphological decomposition and present two analyses that show how the models can handle the results of this study.

6.1 Supra-lexical and sub-lexical accounts

According to the supra-lexical account (Giraudo & Grainger, 2000, 2001, 2003b; Voga & Giraudo, 2009), there is no form-based morpho-orthographic segmentation stage where morpho-orthographic units are represented. The first level of morphological processing is a level where whole-word forms are stored. At this level, only truly morphologically related whole-word forms are activated upon perception of written stimuli. In turn, all these whole-word morphologically related forms activate the representation of their shared morphemic unit in the next level. In this model, the morphemic units at this level are formless abstract representations. To illustrate, at the morphemic level, the plural affixes '-es' and '-s' (which have different forms) are represented by the same unit and the affix '-s' for plural and the affix '-s' for the third person singular in the present tense (which have the same form) are two different morphemic units. Figure 9 shows the general architecture of the model. After the stimulus 'amitie' is perceived by the visual system, all morphologically related word-forms to 'amitie' like 'amite' and 'amiable' are activated. The activation of these word-forms, all of which contain a common element, will lead to the activation of the abstract morpheme for this element, in this case 'AMI'. Since the connections between the whole-word level and morphemic level are bi-directional and facilitatory, the activation of 'amitie' will lead to the activation 'AMI' which will send activation back down, and this pattern of activation will continue in a circular fashion. A crucial prediction of the supra-lexical account is that all morphologically related prime-target pairs should yield the same effects. So, prime-target pairs like 'going-GO', 'goes-GO, 'went-GO', 'go-WENT', 'watched-WATCH', and 'watch-WATCHED' should result in similar priming effects. To draw an analogy between English and Persian, the test stimuli in this study were prime-target pairs like 'went-GOING' (non-ident-2) and 'watched-WATCHING' (ident-2 and ident-1), excluding the extra prefixation for the non-ident-2 and ident-2 conditions.

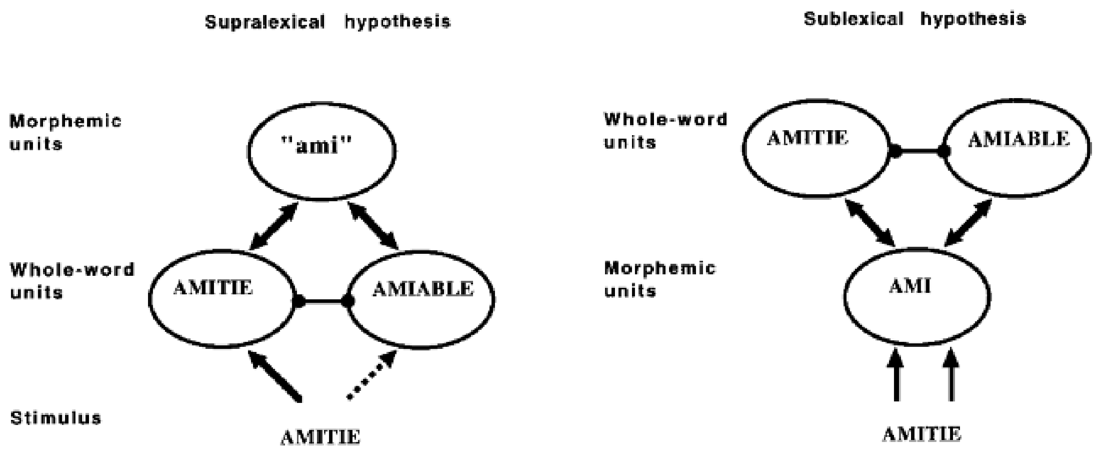

Figure 9. A comparison of the general architecture of the supra-lexical account (left) and the sub-lexical account (left)

Source: [Giraudo & Grainger, 2000]

The supra-lexical account fails to account for the results obtained in this study as it predicts no difference between the priming effects of the non-ident-2, ident-2 and ident-1 conditions. The results of this study point to an advantage of form-based identicalness between the stems of morphologically related inflectional forms. The supra-lexical account does not offer such an advantage. The sub-lexical account, on the other hand, can explain how such an advantage can lead to a stronger activation of the root. In the next two parts, I introduce two sub-lexical models of morphological decomposition and offer possible explanations for the results of this study within those models.

6.2 Crepaldi et al. (2010)

According to Crepaldi et al. (2010), morphological processing takes place in three levels: the morpho-orthographic segmentation level; the orthographic lexicon; and the lemma level. In the morpho-orthographic segmentation level, any segment that can be identified as a morphemic unit will be separated (Longtin et al., 2003; Rastle et al., 2004; Rastle & Davis, 2008). The orthographic lexicon contains all the complex and simple forms that are known by an individual and it is the different activation levels of units at this level that leads to different priming patterns. The lemma level is a form-neutral level where all the different forms of the same underlying root are represented by the same unit. Figure 10 illustrates how ‘fell’ leads to the activation of ‘fall’.

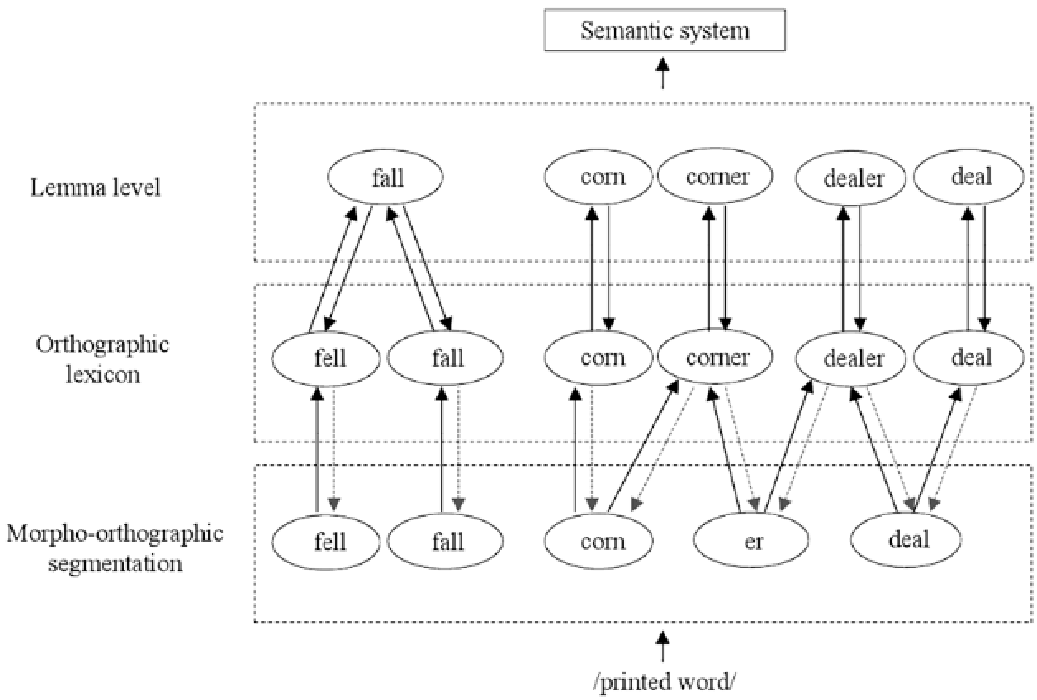

Figure 10. The general architecture of the Crepaldi et al. (2010) model
Source: [Crepaldi et al., 2010]

Upon seeing the printed form ‘fell’, the entry ‘fell’ in the orthographic lexicon will be activated. The activation of ‘fell’ in the orthographic lexicon will in turn activate the lemma for ‘FALL’. In this model, the adjacent levels are connected to each other via bi-directional arrows which makes it possible for a higher-level unit to send feedback down to a unit in a lower level and vice versa. When the lemma for ‘FALL’ is activated, it sends activation back down to all the forms that are morphologically related to it: ‘falling’, ‘falls’, ‘fell’, ‘fall’ and etc. This is how the model explains the priming effects between pairs of irregular past tense forms like ‘fell-FALL’. This model predicts that there should be priming effects for all the morphologically related conditions, but a larger one in conditions with identical stems.

Figure 11 illustrates how the non-ident-2 condition will lead to activation of the stem in the target. Upon the recognition of the written stimulus *‘mi-ræv-æm’* (I go), the lexical entry for the whole form will be activated. This will be followed by activation of the form-neutral abstract lemma for ‘GO’. This lemma will send activation back down to the orthographic lexicon to all the forms that contain the notion of ‘GO’. One of these forms will be the infinitival form of the verb for ‘go’, which is *‘ræft-æn’* ‘(to go) which was the target in the experiment. This way *‘mi-ræv-æm’* will prime *‘ræft-æn’*.

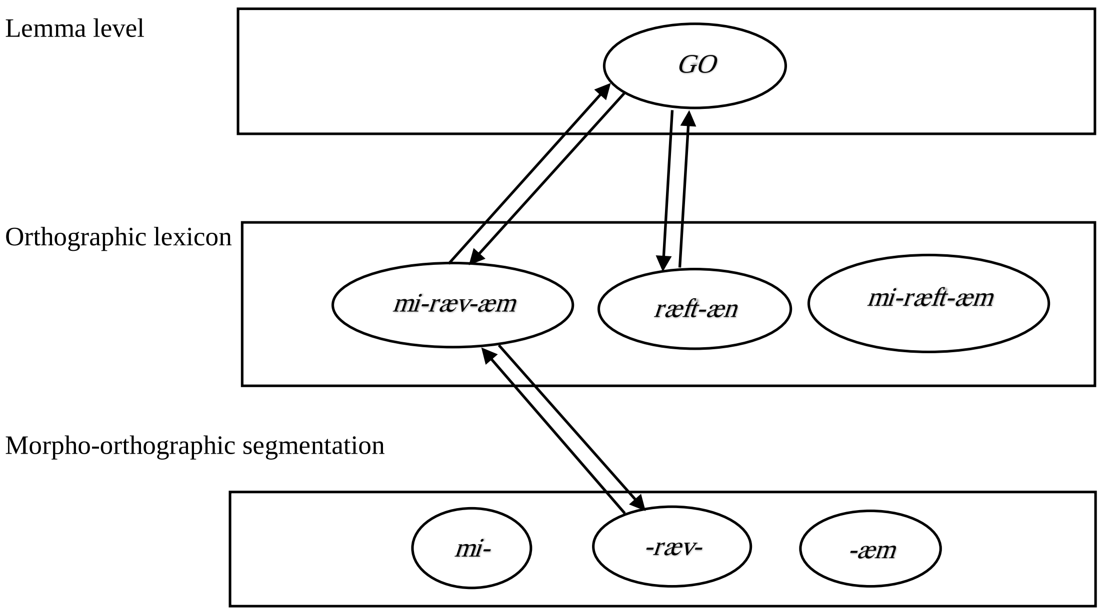

Figure 11. An illustration of how ‘mi-ræv-æm’ would be decomposed in the Crepaldi et al. (2010) model

Figure 12 next page shows how the ident-2 and ident-1 conditions will lead to the activation of the stem in the target. The constituents in these forms will be segmented in the early morpho-orthographic stage as *'mi-ræft-æm'* (I was going) and *'ræft-æm'* (I went). The decomposition of ident-2 and ident-1 conditions will lead to the activation of *'mi-ræft-æm'* and *'ræft-æm'* as well as *'ræft-æn*' (to go) since it contains the same stem as the stem in ident-2 and ident-1 conditions. The activation of *'mi-ræft-æm'* and *'ræft-æm'* will activate the lemma for 'GO' and this lemma will also send activation down to *'ræft-æn'*. As a result, under ident-2 and ident-1 conditions, the target *'ræft-æn'* will receive activation from two sources (one from the lower morpho-orthographic level and one from the lemma level), while in the non-ident-2 condition it only receives activation from one source (the lemma level).

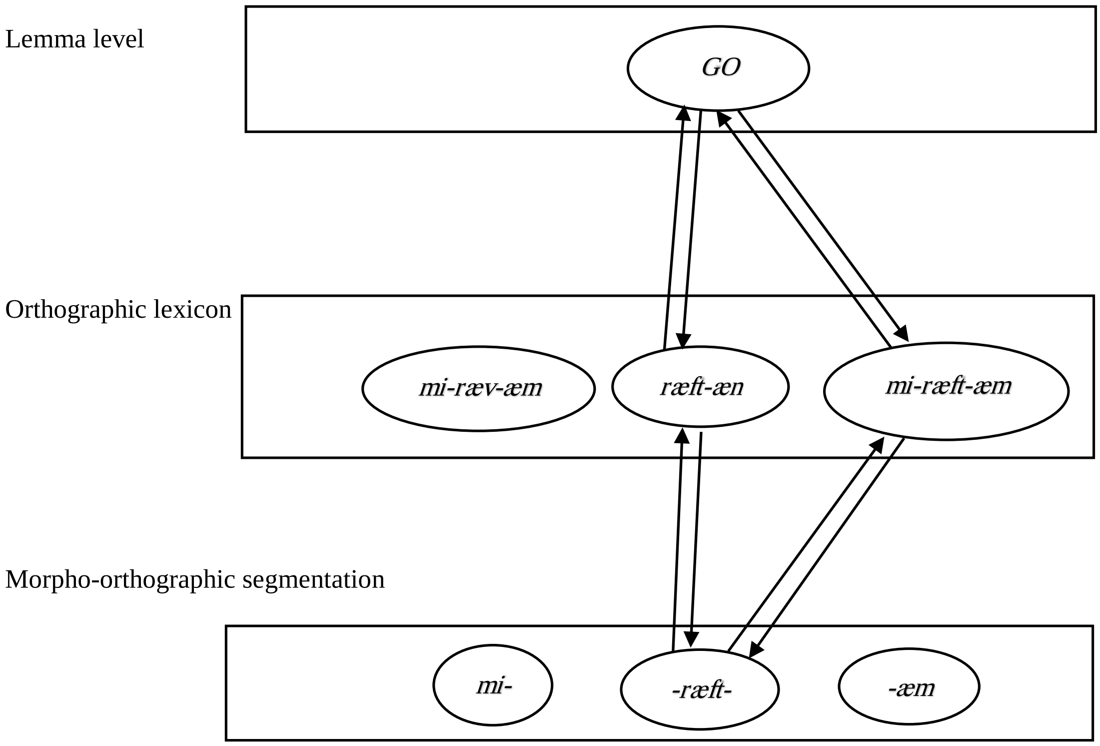

Figure 12. An illustration of how 'mi-ræft-æm' would be decomposed in the Crepaldi et al. (2010) model

One reason for the absence of any priming effect in the non-ident-2 condition could be hypothesized to be the extra cost of processing that comes with simultaneous prefixation and suffixation. Specifically, there could be an interaction between allomorphy and affixation complexity. It cannot be due to length since ident-2 was about the same length as the non-ident-2 condition, 7.04 and 6.38 respectively. As for the difference between ident-2 and ident-1, the difference can be attributed to affixation complexity (ident-2 was more complex than ident-1 in this regard) or to length (ident-2 was longer than ident-1). Further research is required to answer these questions.

6.3 Taft and Nguyen-Hoan (2010)

Figure 13 next page shows the general architecture of this model. There are three levels of representation: a morpho-orthographic level; a lemma level and a semantic concept level. There are uni-directional connections between the levels. Upon perception of the written stimulus ‘hunter’, an early morpho-orthographic segmentation breaks down ‘hunter’ into ‘hunt’ and ‘-er’. Both ‘hunt’ and ‘-er’ activate their associated lemmas in the following lemma level. At this level, similar to the orthographic lexicon in Crepaldi et al. (2010), all derived forms should have their separate lemmas along with the lemmas for their constituent parts. In this sense, it is a parallel dual-route model. The recognition of ‘hunter’ could be the result of activation of ‘hunt’ plus ‘-er’ or it could be the result of activation of ‘hunter’. At the lemma level, the lemma for ‘hunter’ will be activated by the joint activation of the lemmas for ‘hunt’ and ‘-er’. So, the lemma level in this model is hierarchically organized. This model successfully explains the slightly different priming pattern between pairs like ‘hunter-HUNT’ and ‘corner-CORN’. With regard to ‘corner-

CORN', upon seeing 'corner', the early morpho-orthographic parser will start its task and segment it into 'corn' and '-er', both of which will activate their own lemmas. Different to 'hunter-HUNT', the lemma for 'corner' will be activated not through the joint activation of two lemmas at the lemma level, but through the activation of the morpho-orthographic units at the lower morpho-orthographic level. One reason why there is less priming in 'corner-CORN' than in 'hunter-HUNT' can be that 'corner' gets activation from the morpho-orthographic level, unlike 'hunter' which is activated by the lemma units 'hunt' and '-er' at the lemma level. Another reason could be that 'corner' and 'corn' inhibit each other at the lemma level, as they are not morphologically related and are orthographically similar.

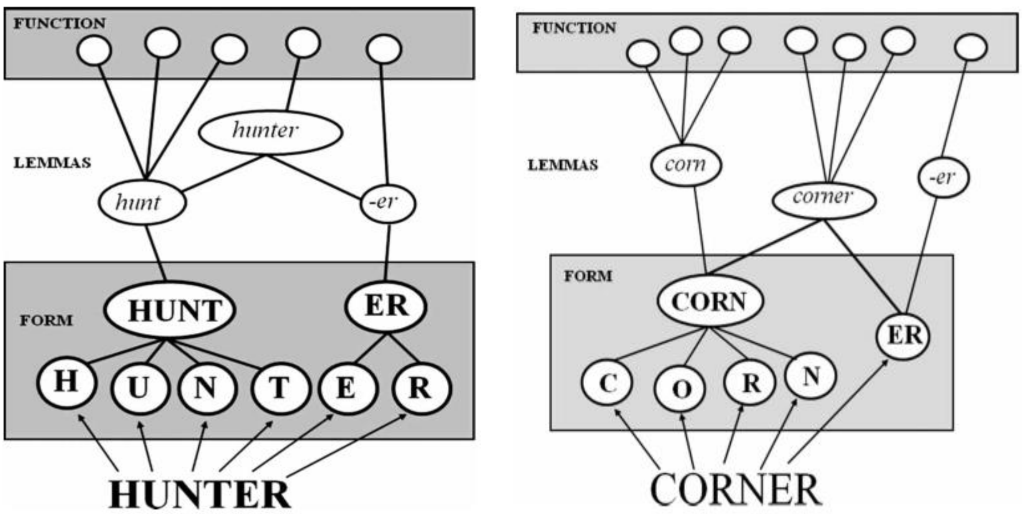

Figure 13. The general architecture of the Taft and Nguyen-Hoan (2010) model
Source: [Taft & Nguyen-Hoan, 2010]

Taft and Nguyen-Hoan (2010) do not mention how regular and irregular inflectional forms are represented at the lemma level. We can either assume that inflected verb forms are represented as whole units at the lemma level, or only their minimal constituents get to have their lemmas. Below I present two possible ways this model can explain the results of this study.

We can assume that both *'mi-ræv-æm'* (I go; the non-ident-2 condition) and *'mi-ræft-æm'* (I was going; the ident-2 condition) will be decomposed but via different routes (Figure 14 and 15 respectively). More specifically, *'mi-ræv-æm'* will use the direct route to be activated while *'mi-ræft-æm'* will use the decomposed route. Since *'mi-ræft-æm'* is decomposed into its constituents and the lemma for each one will be activated separately, we can assume the *'ræft'* stem in the target will get more activation thanks to it being already activated by decomposition of *'mi-ræft-æm'*. As this decomposition did not fully occur for *'mi-ræv-æm'*, it may be that the lemma for *'ræft'* received less activation from *'mi-ræv-am'* than from *'mi-ræft-æm'*. In the figure, the orange lines represent the direct route and the blue lines represent the decomposed route. Also, the color of the lemma circles shows the successful route: green for the winning and red for the losing route.

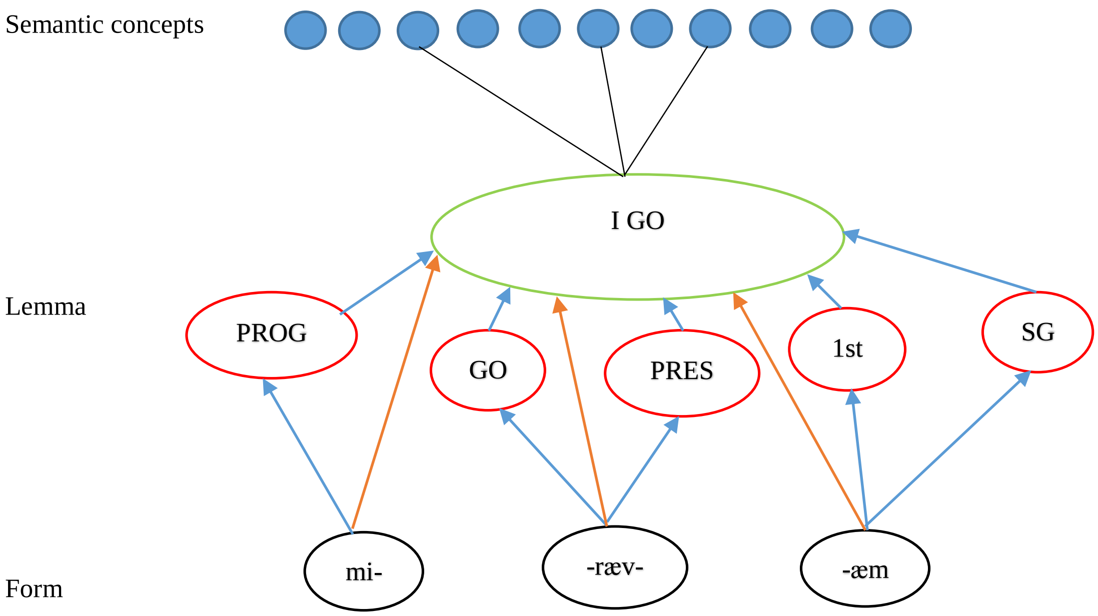

Figure 14. An illustration of how 'mi-ræv-æm' can be decomposed in the Taft and Nguyen-Hoan (2010) model

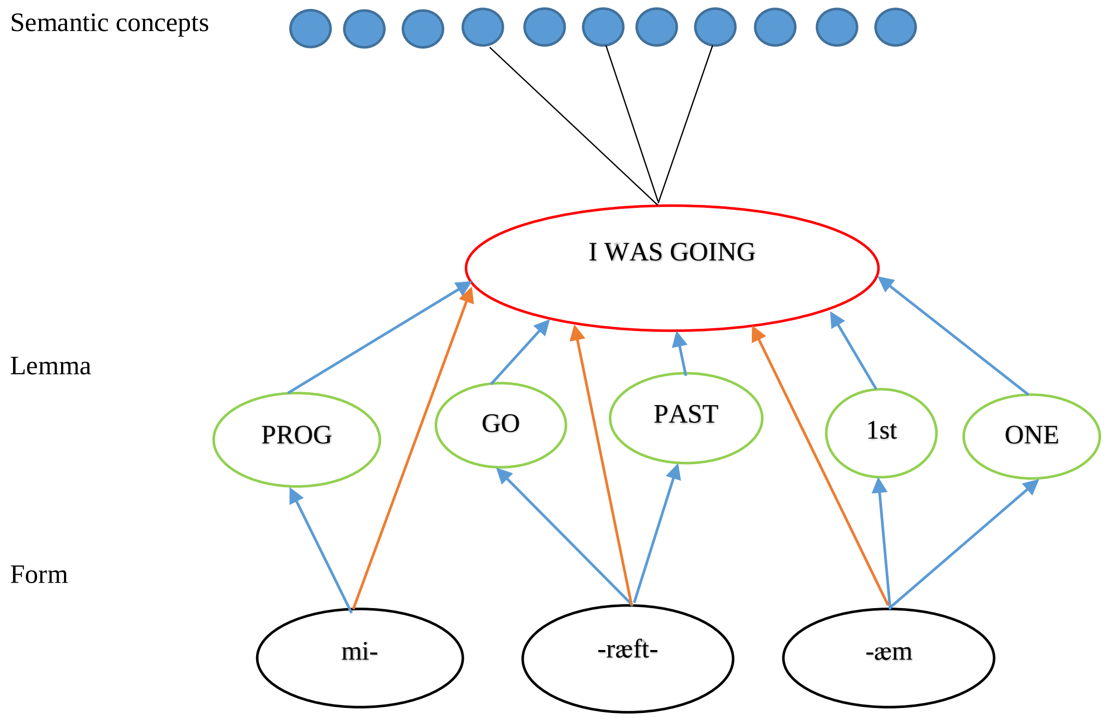

Figure 15. An illustration of how ‘mi-ræft-æm’ can be decomposed in the Taft and Nguyen-Hoan (2010) model

But why should one assume that *‘mi-ræv-æm’* (the non-ident-2 condition) will be activated via the direct route and *‘mi-ræft-æm’* (the ident-2 condition) will be activated via the decomposition route? One reason to make that assumption would that the non-ident-2 condition verbs are more frequent than ident-2 verbs. Unfortunately, this argument runs into trouble when you look at the surface frequency of the conditions. Although the non-ident-2 verbs are more frequent than ident-2 verbs, they cannot be said to be among frequent verbs; the average surface frequency of the verbs in non-ident-2 was 0.62 per million. Moreover, ident-1 verbs, which led to robust priming effects, are much more frequent than non-ident-2 verbs; they had a surface frequency of 111.35 per million. If higher frequency should mean no activation of the individual lemma for the target stem, then ident-1 should not have led to priming effects either. Another problem with this analysis is the assumption of separate lemmas for every type of complex and simple word form people know. Although this is a fair assumption for derivationally complex forms which can have opaque idiosyncratic meanings, it is hard to make the same assumption for transparent inflected forms. According to the analysis proposed above, all forms, including inflectionally complex ones, should each have their own lemma representations. This is not in accord with the idea of 'lemma' in the first place. Lemmas are supposed to be formless abstract minimal representations (Bock & Levelt, 1994; Taft, 2003, 2004). As a result, while opaque idiosyncratic derived forms can and should have their own separate lemmas, fully transparent inflectional forms do not need separate lemmas. For example, the underlying idea of 'GO' in 'went' is always the same across all the inflectional forms: 'goes', 'went', 'go' and even across all languages. Given the shortcomings of this analysis, I offer a second one in the following paragraphs.

In this second analysis I made some changes to the architecture of the Taft and Nguyen-Hoan model by including a different level of representation. This level of representation is the orthographic lexicon in the Crepaldi et al. (2010) model. Upon the perception of the stimulus and after the morpho-orthographic segmentation stage, the segmented constituents will activate all the lexical forms in the orthographic lexicon that contain those constituents. Each of these activated units at the orthographic lexicon will send activation up to the single lemma that they are associated with. The bigger the number of units this lemma gets activation from, the higher its activation will be.

The stimulus '*mi-ræft-æm*' (I was going; the ident-2 condition) is presented in Figure 16 below. It is segmented into its constituent parts *'mi-'*, *'ræft'* and *'-æm'*. The *'ræft'* segment will activate all the lexical forms in the orthographic lexicon that contain the form *'ræft'.* This includes both the forms *'mi-ræft-æm'* (I was going; the ident-2 condition) and *'ræft-æn'* (to go; the target). These two forms will cumulatively send their activation up to the lemma level where the lemma for 'GO' resides. So the lemma for 'GO' will also include the activation from the form '*ræft-æn'*. Here we can assume two things: 1. This lemma will be more active since it is fed by two units at the level below and it is this extra boost of activation that will lead to shorter reactions times to the target *'ræft-æn'*. 2. This lemma will contain the influence of *'ræft-æn'* form and it is this influence that leads to faster reaction times to the target *'ræft-æn'*.

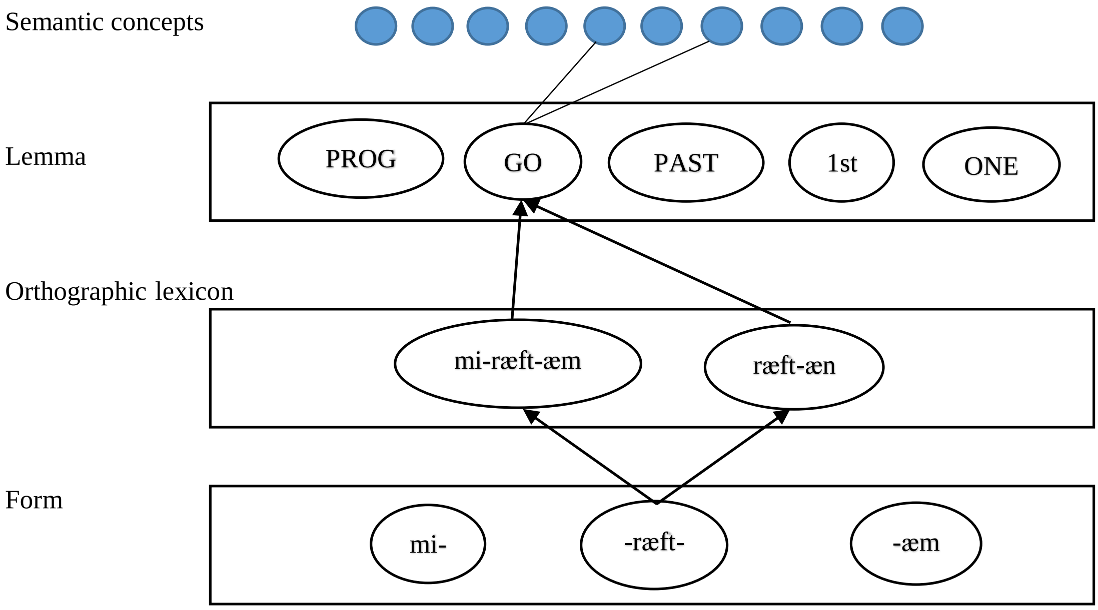

Figure 16. An illustration of how 'mi-ræft-æm' would be decomposed by adding an orthographic lexicon level to the Taft and Nguyen-Hoan (2010) model

In the case of *'mi-ræv-æm'*, the segmented part *'ræv'* will activate all the forms that contain *'ræv'* but '*ræft-æn'* (the target) is not going to be one of these forms (Figure 17). Although the same lemma for 'GO' will be activated, this lemma will not include the activation from the form '*ræft-æn'*, and as a result it will have less priming effects than *'mi-ræft-æm'* and *'ræft-æm'*. Note that this model, in contrast to the Crepaldi et al. (2010) model, does not include bi-directional connections between the levels. And finally, here as well, I have to hypothesize that the activation from *'mi-ræv-am'*, will be suppressed by the fact that the stem is situated between a prefix and a suffix.

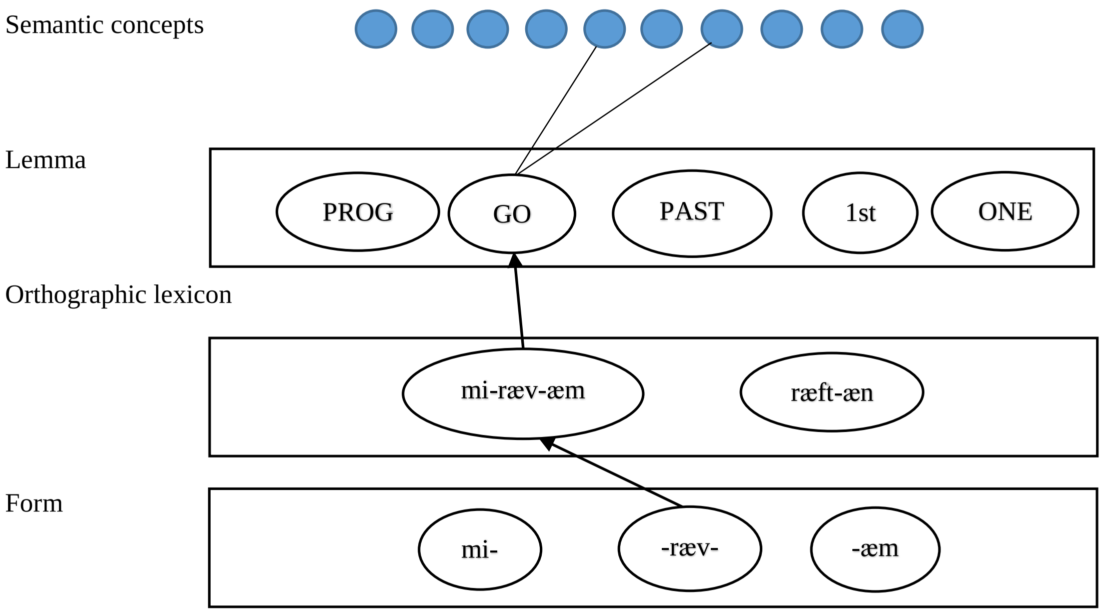

Figure 17. An illustration of how 'mi-ræv-æm' would be decomposed by adding an orthographic lexicon level to the Taft and Nguyen-Hoan (2010) model

Another difference between the Cerpaldi et al. (2010) model and the Taft and Nguyen-Hoan (2010) model that needs to be pointed out is that in the former, the activation of the units in the orthographic lexicon determines potential patterns of priming. In other words, it is the activation level of the units in the orthographic lexicon that is important. As for the Taft and Nguyen-Hoan (2010) model, it is the lemma units that have the final say whether the recognition of a subsequent target will be facilitated or not.

The results of this study point to an orthographic identicalness advantage in the early stages of morphological processing as two of the morphologically related conditions that led to priming both shared an identical stem to that of the target stem. There is at least a need for a form-based morpho-orthographic segmentation stage and also an abstract level of representations (Allen & Badecker, 1999, 2002; Diependaele et al., 2005, 2009; Järvikivi & Niemi, 2002; Laudanna et al., 1992). There is no way to account for this form-based identicalness in the framework of supra-lexical account.

6.4 Edge-Aligned Embedded Word Activation Model

This model (Grainger & Beyersmann, 2017), which is in fact a model of reading and how the skill of reading develops, using the writing conventions (such as white spaces between whole-words), assigns a special status to stems. It is an account of reading and how it develops, and its association with how we process words. The most important thing for an efficient reader is extracting the most essential part in a word which is the stem as opposed to affixes. The goal is activating all words that are edge-aligned because the most common morphologically complex words are either prefixations or suffixations. With affix stripping, after doing away with the affixes you are left with what is called a bound stem (something that is never delimited by white spaces in text). Whole-word forms are delimited by white spaces and these apparently help with the creation of these representations. It gives priority to contiguous letters. The first letters and last letters are important and this mechanism gives special priority to those letters that are contiguous with those.

Basically, word recognition success depends on under what circumstances stems are accessed. Another feature of this model, which is similar to the supra-lexical account, is that it does away with the morpho-orthographic segmentation stage. And again in a similar vein to the supra-lexical account, there is an abstract level of representation at the topmost part of the architecture (Figure 18). Different to the supra-lexical account, the first level does not only contain whole-word forms; it also contains bound stems.

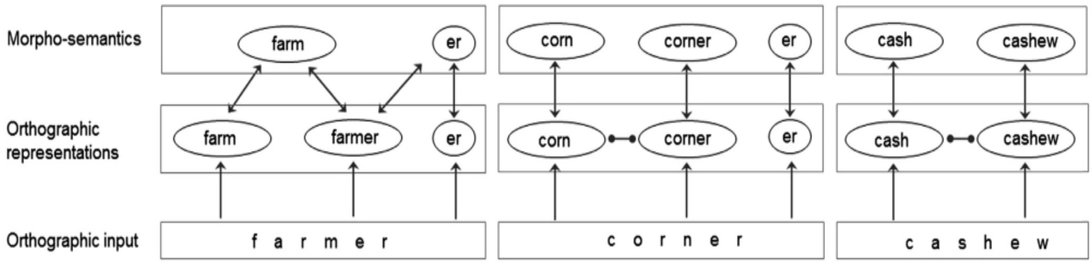

Figure 18. The general architecture of the Edge-aligned Embedded Word Activation Model Source: [Grainger & Beyersmann, 2017]

The model manages to explain the priming differences between 'farmer-FARM', 'corner-CORN' and 'cashew-CASH'. With regards to the 'farmer-FARM', the presentation of 'farmer' will activate words that contain the embedded stem 'farm' ('farm' and 'farmer') as well as the suffix '-er' as anything that resembles a bound stem will also be activated at this level. At the morpho-semantics level 'farm' and 'farmer' will activate the underlying meaning associated with both 'farm' and 'farmer'. The representations 'farm' and '-er' at the morpho-semantics level will be activated via two routes. Either directly by 'farmer' (whole-word route) or by 'farm' and '-er' (decomposition route). So, 'farm' will get activation from two sources between which there is no inhibition; neither 'farm' nor 'farmer' are inhibited by one another at the orthographic representations level. As for 'corner-CORN', the free stem and the whole word will be activated at the orthographic representations level ('corn' and 'corner') as well as the '-er' suffix. At the morpho-semantics level, 'corn' will only get activation from the orthographic representation 'corn' and 'corner' from 'corner'. What is different between the activation of 'farm' and 'corn' is that the former gets activation from two sources which are not inhibited while 'corn', on the other hand, gets its activation from a single inhibited unit (there is an inhibitory connection between ‘corn’ and ‘corner’ at the orthographic level since they are orthographically similar, morphologically unrelated pairs). The same procedure will take place for ‘cash-CASHEW’ but here the stem ‘cash’ will not get the same boost of activation that ‘corn’ gets from the activation of the ‘-er’ suffix. Exactly how, we don’t know. One explanation offered in Grainger and Beyersmann (2017) is that it comes from the full decomposition principle: through full decomposition and the segmentation of ‘-er’ the system is fooled into thinking that ‘corner’ is transparently decomposable like ‘farmer’ so for a moment there is a facilitatory connection between ‘corn’ at the morpho-semantics level and the ‘corner’ at the orthographic representations level. However, this facilitation doesn’t last long and soon the facilitatory connection is replaced by inhibition. This is how the difference between the priming effects of ‘farmer-FARM’ and ‘corner-CORN’ and ‘cash-CASHEW’ is explained.

A suggestion made by Grainger and Beyersmann (2017) is that non-edge-alignment makes it harder to activate the embedded stem, with the consequence that the presence of affixes around the stem in words will hinder the access of the stem in these words or even make it impossible altogether compared with words containing edge-aligned stems. Furthermore, if the embedded stems are not free standing morphemes, they can’t be accessed in the same way as free standing morphemes. The model at its current state completely lacks a mechanism to explain embedded stem activation and how the stem access would be hindered or prevented. It only explains stem activation when it happens to be positioned on the edges of complex words, that is either in prefixed words or in suffixed words.

The results of this study showed priming effects from ident-2 (pre- and suffixed words with identical stems to the target stems), albeit smaller compared to the effects in ident-1 (suffixed words with identical stems to the target stems). The implication that this finding offers for the Edge-aligned Embedded Word Activation Model is two-folds: it falsifies the strong version of the model that stems will be activated only if they are situated either on the beginning of a complex word or on the end of it. In other words, only if the stem is on the either edges of a word. However, if we take the more lenient version of the model that the stems will be extracted with more difficulty if they happen to be sandwiched between two affixes, this model might actually get some support from this finding, although with the present study we can’t be sure that the observed difficulty in extracting the stem in ident-2 was due to it being between two affixes or due to it being a longer word compared to ident-1. If it is shown that the difference between the priming effects in these conditions is just due to length, then we can say that affixation type doesn’t matter and even the conservative prediction of the Edge-aligned Model is wrong. This can be achieved by using ident-2 and ident-1 forms of the same length:

Ident-2: *‘mi-neʃæst-am’* (I was sitting; pre- and suffixed; length: 7)
Ident-1: *‘pendaʃt-am’* (I thought; suffixed; length: 7)

If under this manipulation, there is no difference between the priming effects, then the model is wrong. But if there is still a priming difference, then the weak version of the model may be right as it makes a right prediction that edge-alignment matters and embedded stems between affixes are difficult to be accessed and the necessary adjustments would have to be made to the model to account for these results. But even this assumption might run into problems if it can be shown that the difference is due to the number of affixes and not their alignment. Further research is required.

6.5 Full Decomposition

The gist of the Full Decomposition account in simple terms is that the early morphological parser will decompose any complex forms it encounters and access the representations of their constituent parts. The results of this study pose a challenge for this account; there was no priming in one of the morphologically related conditions (the non-ident-2 condition). This condition which houses an embedded allomorphic stem between a prefix and a suffix did not create any priming effects from that of the orthographic overlap and unrelated condition. Although the results of this study cannot be interpreted as a pure effect of morphological complexity type, it opened the possibility to such an effect. The Full Decomposition Model does not predict any difference between complex words of different type. Indeed, recent neuro-imaging studies from languages like Tagalog showed that reduplicated, infixed and circumfixed complex words are also decomposed. But still it can be argued that there should be a complexity difference between a circumfixed (stem + one affix) word and a pre- and suffixed word (stem + two affixes) (Wray et al., 2022).

Both Crepaldi et al. (2010) and Taft and Nguyen-Hoan (2010) are models that incorporate the concept of full decomposition as there is an exhaustive level of morpho-orthographic segmentation in both models and can explain how irregularly inflected forms can also be decomposed. If we take the Full Decomposition Model as a principle that states all complex forms irrespective of their level of morphological complexity (number of affixes or type of affixes or allomorphy) should be decomposed, then the behavioral results of this study casts some doubt on the limits of this claim. But if we take the Full Decomposition Model as mechanism that will at least try to decompose all complex forms but it will be bound by the limits of its processing prowess, we can attribute the absence of priming effects from the non-ident-2 condition to the exhaustion of the early morphological processor.

CHAPTER 7

CONCLUSION AND FUTURE WORK

The present study investigated morpho-orthographic decomposition and its extent in Persian simple verbs. To this end, a masked priming lexical decision task was designed to measure participants' reaction times following exposure to stimuli of different characteristics: a condition with an allomorphic stem embedded between a prefix and a suffix; a condition with a non-allomorphic stem embedded between a prefix and a suffix; a condition with a non-allomorphic stem with a suffix; an orthographic overlap condition; and finally an unrelated condition. In all the conditions, the targets following the primes were the same. The purpose of the this was to see whether the theory of early morpho-orthographic decomposition could also decompose written Persian inflected forms and whether it would also hold in processing-wise more demanding conditions. The results of the study lent support to a form-based rapid decomposition process that takes place in the very early stages of lexical processing. Another observation was that this decomposition mechanism is not without limits. Allomorphy and affixation type and/or number may put an extra processing load on this mechanism and can hinder or even prevent the activation of the root. The models that most successfully were able to account for the results were those that combined an early purely form-based segmentation stage with a subsequent level of abstract form-neutral representations. Additionally, the results necessitate the inclusion of a mechanism that can account for potential extra processing that comes with affixation type and/or number. These results cast doubt on theories of word processing that claim stems cannot be accessed when they are not positioned on the edges of words as it was shown that the non-allomorphic stems of complex words that are embedded between a prefix and a suffix can also be accessed. Furthermore, theories that claim this early morphological decomposition will apply to any complex word regardless of its morphological complexity also need to rethink their mechanisms. A puzzle that remains to be solved is why there was a difference between the priming effects of suffixed and pre- and suffixed words. The difference between the priming effects of pre- and suffixed allomorphic word forms and pre- and suffixed non-allomorphic forms which were of similar lengths point to a length-independent uniquely morphological effect: allomorphy, affixation type and affixation number. This is a puzzle for later studies. Specifically, future studies can investigate the effects of affixation manner and length and see if there are any interactions between them.

APPENDIX A

TEST STIMULI

target	non-ident-2	ident-2	ident-1	ortho-overlap	unrelated
کردن /kærd-æn/ make.PST-INF ‘to make’	میکنم /mi-kon-æm/ PROG-make.PRS-1.SG ‘I make’	میکردم /mi-kærd-æm/ PROG-make.PST-1.SG ‘I was making’	کردم /kærd-am/ make.PST-1.SG ‘I made’	کرگدن /kærgædæn/ rhino.SG ‘rhino’	هنگام /hengɑm/ during ‘during’
شدن /ʃod-æn/ become.PST-INF ‘to become’	میشوم /mi-ʃæv-æm/ PROG-become.PRS-1.SG ‘I become’	میشدم /mi-ʃod-æm/ PROG-become.PST-1.SG ‘I was becoming’	شدم /ʃod-æm/ become.PST-1.SG ‘I became’	شدت /ʃeddæt/ intensity ‘intensity’	تفاوت /tæfɑvot/ difference ‘difference’
دادن /dɑd-æn/ give.PST-INF ‘to give’	میدهم /mi-dah-æm/ PROG-give.PRS-1.SG ‘I give’	میدادم /mi-dɑd-æm/ PROG-give.PST-1.SG ‘I was giving’	دادم /dɑd-æm/ give.PST-1.SG ‘I gave’	دامن /dɑmæn/ skirt.SG ‘skirt’	تکرار /tekrɑr/ repitition ‘repitition’
زدن /zæd-æn/ hit.PST-INF ‘to hit’	میزنم /mi-zæn-æm/ PROG-hit.PRS-1.SG ‘I hit’	میزدم /mi-zæd-æm/ PROG-hit.PST-1.SG ‘I was hitting’	زدم /zæd-æm/ hit.PST-1.SG ‘I hit’	بدن /bædæn/ body.SG ‘body’	حقیقت /hægigæt/ truth.SG ‘truth’
گرفتن /gereft-æn/ take.PST-INF ‘to take’	میگیرم /mi-gir-æm/ PROG-take.PRS-1.SG ‘I take’	میگرفتم /mi-gereft-æm/ PROG-take.PST-1.SG ‘I was taking’	گرفتم /ereft-æm/ take.PST-1.SG ‘I ’	گران /gerɑn/ expensive ‘expensive’	توضیح /tozih/ explanation.SG ‘explanation’
رفتن /ræft-æn/ go.PST-INF ‘to go’	میروم /mi-ræv-æm/ PROG-go.PRS-1.SG ‘I go’	میرفتم /mi-ræft-æm/ PROG-go.PST-1.SG ‘I was going’	رفتم /ræft-æm/ go.PST-1.SG ‘I ’	روشن /roʃæn/ bright ‘bright’	اتهام /ettehɑm/ accusation.SG ‘accusation’
داشتن /dɑʃt-æn/ have.PST-INF ‘to have’	میدارم /mi-dɑr-æm/ PROG-have.PRS-1.SG ‘I have’	میداشتم /mi-dɑʃt-æm/ PROG-have.PST-1.SG ‘I was having’	داشتم /dɑʃt-æm/ have.PST-1.SG ‘I ’	داستان /dɑstɑn/ story.SG ‘story’	منتظر /montæzer/ expectant.SG ‘expectant’
نوشتن /neveʃt-æn/ write.PST-INF	مینویسم /mi-nevis-æm/ PROG-write.PRS-1.SG	مینوشتم /mi-neveʃt-æm/ PROG-write.PST-1.SG	نوشتم /neveʃt-æm/ write.PST-1.SG	بولتن /bultæn/ bulletin.SG ‘bulletin’	عدالت /edɑlæt/ justice ‘justice’

‘to write’	‘I write’	‘I was writing’	‘I ’		
گفتن /goft-æn/ say.PST-INF ‘to say’	میگویم /mi-guj-æm/ PROG-say.PRS-1.SG ‘I say’	میگفتم /mi-goft-æm/ PROG-say.PST-1.SG ‘I was saying’	گفتم /goft-æm/ say.PST-1.SG ‘I ’	فتنه /fetne/ disturbance ‘disturbanc e’	شکنجه /ʃekændʒe/ torture ‘torture’
آمدن /ɑmæd-æn/ come.PST-INF ‘to come’	میایم /mi-ɑj-æm/ PROG-come.PRS-1.SG ‘I come’	میامدم /mi-ɑmæd-æm/ PROG-come.PST-1.SG ‘I was coming’	آمدم /ɑmæd-æm/ come.PST-1.SG ‘I ’	آماده /ɑmɑde/ ready ‘ready’	موسیقی /musigi/ music.SG ‘music’
ساختن /sɑxt-æn/ build.PST-INF ‘to build’	میسازم /mi-sɑz-æm/ PROG-build.PRS-1.SG ‘I build’	میساختم /mi-sɑxt-æm/ PROG-build.PST-1.SG ‘I was build’	ساختم /sɑxt-æm/ build.PST-1.SG ‘I ’	سامان /sɑmɑn/ order ‘order’	احتمال /ehtemɑl/ probability.SG ‘probability’
گذاشتن /gozɑʃt-æn/ put.PST-INF ‘to put’	میگذارم /mi-gozɑr-æm/ PROG-put.PRS-1.SG ‘I put’	میگذاشتم /mi-gozɑʃt-æm/ PROG-put.PST-1.SG ‘I was putting’	گذاشتم /gozɑʃt-æm/ put.PST-1.SG ‘I put’	گذشت /gozæʃt/ passage ‘passage’	سرمایه /særmɑje/ asset.SG ‘asset’
بستن /bæst-æn/ close.PST-INF ‘to close’	میبندم /mi-bænd-æm/ PROG-close.PRS-1.SG ‘I close’	میبستم /mi-bæst-æm/ PROG-close.PST-1.SG ‘I was closing ’	بستم /bæst-æm/ close.PST-1.SG ‘I close’	بوستان /bustɑn/ garden.SG ‘garden’	متفاوت /motæfɑvet/ different ‘different’
انداختن /ændɑxt-æn/ throw.PST-INF ‘to throw’	میاندازم /mi-ændɑz-æm/ PROG-throw.PRS-1.SG ‘I throw’	میانداختم /mi-ændɑxt-æm/ PROG-throw.PST-1.SG ‘I was throwing’	انداختم /ændɑxt-æm/ throw.PST-1.SG ‘I throw’	اندوخت /ænduxt/ sum ‘sum’	میزان /mizɑn/ rate ‘rate’
نشستن /neʃæst-æn/ sit.PST-INF ‘to sit’	مینشینم /mi-neʃin-æm/ PROG-sit.PRS-1.SG ‘I sit’	مینشستم /mi-neʃæst-æm/ PROG-sit.PST-1.SG ‘I was sitting’	نشستم /neʃæst-æm/ sit.PST-1.SG ‘I sit’	نخست /noxost/ first ‘first’	مشغول /mæʃɣul/ busy ‘busy’
پرداختن /pærdɑxt-æn/ pay.PST-INF ‘to pay’	میپردازم /mi-pærdɑz-æm/ PROG-pay.PRS-1.SG ‘I pay’	میپرداختم /mi-pærdɑxt-æm/ PROG-pay.PST-1.SG ‘I was paying ’	پرداختم /pærdɑxt-æm/ pay.PST-1.SG ‘I paid’	انداخت /ændɑxt/ throw.PST.3.SG ‘he threw’	تعیین /tæin/ assignment ‘assignment’
نمودن /nomud-æn/ do.PST-INF ‘to do’	مینمایم /mi-nomɑj-æm/ PROG-do.PRS-1.SG ‘I do’	مینمودم /mi-nomud-æm/ PROG-do.PST-1.SG ‘I was doing’	نمودم /nomud-æm/ do.PST-1.SG ‘I did’	نمونه /nomune/ sample.SG ‘sample’	احترام /ehterɑm/ respect ‘respect’
مردن /mord-æn/ die.PST-INF ‘to die’	میمیرم /mi-mir-æm/ PROG-die.PRS-1.SG ‘I die’	میمردم /mi-mord-æm/ PROG-die.PST-1.SG ‘I was dying’	مردم /mord-æm/ die.PST-1.SG ‘I died’	مردود /mærdud/ rejected ‘rejected’	دیوار /divɑr/ wall.SG ‘wall’

دیدن /did-æn/ see.PST-INF 'to see'	میبینم /mi-bin-æm/ PROG-see.PRS-1.SG 'I see'	میدیدم /mi-did-æm/ PROG-see.PST-1.SG 'I was seeing'	دیدم /did-æm/ see.PST-1.SG 'I saw'	شدید /ʃædid/ intense 'intense'	ترجمه /tærdʒome/ translation 'translation'
خواستن /xɑst-æn/ want.PST-INF 'to want'	میخواهم /mi-xɑh-æm/ PROG-want.PRS-1.SG 'I want'	میخواستم /mi-xɑst-æm/ PROG-want.PST-1.SG 'I wanted'	خواستم /xɑst-æm/ want.PST-1.SG 'I wanted'	خراسان /xorɑsɑn/ east 'east'	مجبور /madʒbur/ obligated 'obligated'
شناختن /ʃenɑxt-æn/ recognize.PST-INF 'to recognize'	میشناسم /mi-ʃenɑs-æm/ PROG-recognize.PRS-1.SG 'I recognize'	میشناختم /mi-ʃenɑxt-æm/ PROG-recognize.PST-1.SG 'I recognized'	شناختم /ʃenɑxt-æm/ recognize.PST-1.SG 'I recognized'	نواخت /nævɑxt/ singing 'singing'	انتقال /entegɑl/ transfer.SG 'transfer'
آموختن /ɑmuxt-æn/ learn.PST-INF 'to learn'	میاموزم /mi-ɑmuz-æm/ PROG-learn.PRS-1.SG 'I learn'	میاموختم /mi-ɑmuxt-æm/ PROG-learn.PST-1.SG 'I was learning'	آموختم /ɑmuxt-æm/ learn.PST-1.SG 'I learned'	آمیخت /ɑmixt/ mix.PST.3.SG 'he mixed'	انتقاد /entegɑd/ criticism 'criticism'
شستن /ʃost-æn/ wash.PST-INF 'to wash'	میشویم /mi-ʃuj-æm/ PROG-wash.PRS-1.SG 'I wash'	میشستم /mi-ʃost-æm/ PROG-wash.PST-1.SG 'I was washing'	شستم / ʃost-æm/ wash.PST-1.SG 'I washed'	نشست /neʃæst/ convention.SG 'convention'	ولایت /velɑjæt/ province 'province'
گذشتن /gozæʃt-æn/ pass.PST-INF 'to pass'	میگذرم /mi-gozær-æm/ PROG-pass.PRS-1.SG 'I pass'	میگذشتم /mi-gozæʃt-æm/ PROG-pass.PST-1.SG 'I was passing'	گذشتم /gozæʃt-æm/ pass.PST-1.SG 'I passed'	گذاشت /gozɑʃt/ put.PST.3.SG 'he put'	مهندس /mohændes/ engineer.SG 'engineer'
سپردن /sepord-æn/ entrust.PST-INF 'to entrust'	میسپارم /mi-sepɑr-æm/ PROG-entrust.PRS-1.SG 'I entrust'	میسپردم /mi-sepord-æm/ PROG-entrust.PST-1.SG 'I was entrusting'	سپردم /sepord-æm/ entrust.PST-1.SG 'I entrusted'	پرده /pærde/ curtain.SG 'curtain'	ارسال /ersɑl/ dispatch 'dispatch'
گشتن /gæʃt-æn/ roam.PST-INF 'to roam'	میگردم /mi-gærd-æm/ PROG-roam.PRS-1.SG 'I roam'	میگشتم /mi-gæʃt-æm/ PROG-roam.PST-1.SG 'I was roaming'	گشتم /gæʃt-æm/ roam.PST-1.SG 'I roamed'	دشمن /doʃmæn/ enemy.SG 'enemy'	سیاست /sijɑsæt/ politics 'politics'
سوختن /suxt-æn/ burn.PST-INF 'to burn'	میسوزم /mi-suz-æm/ PROG-burn.PRS-1.SG 'I burn'	میسوختم /mi-suxt-æm/ PROG-burn.PST-1.SG 'I was burning'	سوختم /suxt-æm/ burn.PST-1.SG 'I burned'	دوخت /duxt/ sewing 'sewing'	مقاله /mæqɑle/ article.SG 'article'
یافتن /jɑft-æn/ find.PST-INF	مییابم /mi-jɑb-æm/ PROG-find.PRS-1.SG	مییافتم /mi-jɑft-æm/ PROG-find.PST-1.SG	یافتم /jɑft-æm/ find.PST-1.SG 'I found'	ضیافت /zijɑfæt/ feast.SG 'feast'	ورزش /værzeʃ/ exercise 'exercise'

'to find'	'I find'	'I was finding'			
جستن /dʒost-æn/ search.PST-INF 'to search'	میجویم /mi-dʒuj-æm/ PROG-search.PRS-1.SG 'I search'	میجستم /mi-dʒost-æm/ PROG-search.PST-1.SG 'I was searching'	جستم /dʒost-æm/ search.PST-1.SG 'I searched'	جهان /dʒæhɑn/ world.SG 'world'	مملکت /mæmlekæt/ country.SG 'country'
پختن /poxt-æn/ cook.PST-INF 'to cook'	میپزم /mi-pæz-æm/ PROG-cook.PRS-1.SG 'I cook'	میپختم /mi-poxt-æm/ PROG-cook.PST-1.SG 'I was cooking'	پختم /poxt-æm/ cook.PST-1.SG 'I cooked'	پوتین /putin/ boots.SG 'boots'	اختیار /extijɑr/ volition 'volition'
سرودن /sorud-æn/ sing.PST-INF 'to sing'	میسرایم /mi-sorɑj-æm/ PROG-sing.PRS-1.SG 'I sing'	میسرودم /mi-sorud-æm/ PROG-sing.PST-1.SG 'I was singing'	سرودم /sorud-æm/ sing.PST-1.SG 'I sang'	سرویس /servis/ service.SG 'service'	ابتدا /ebtedɑ/ first 'first'
باختن /bɑxt-æn/ lose.PST-INF 'to lose'	میبازم /mi-bɑz-æm/ PROG-lose.PRS-1.SG 'I lose'	میباختم /mi-bɑxt-æm/ PROG-lose.PST-1.SG 'I was losing'	باختم /bɑxt-æm/ lose.PST-1.SG 'I lost'	ساخت /sɑxt/ structure 'structure'	پنجره /pændʒære/ window.SG window
زدودن /zodud-æn/ purge.PST-INF 'to purge'	میزدایم /mi-zodɑj-æm/ PROG-purge.PRS-1.SG 'I purge''	میزدودم /mi-zodud-æm/ PROG-purge.PST-1.SG 'I was purging'	زدودم /zodud-æm/ purge.PST-1.SG 'I purged'	تدوین /tædvin/ compositio n 'compositi on'	شرایط /ʃærɑjet/ condition.PL 'conditions'
فروختن /foruxt-æn/ sell.PST-INF 'to sell'	میفروشم /mi-foruʃ-æm/ PROG-sell.PRS-1.SG 'I sell'	میفروختم /mi-foruxt-æm/ PROG-sell.PST-1.SG 'I was selling'	فروختم /foruxt-æm/ sell.PST-1.SG 'I sold'	فروزان /furuzɑn/ ablaze 'ablaze'	تاثیر /tæsir/ effect.SG 'effect'
زیستن /zist-æn/ exist.PST-INF 'to exist'	میزیم /mi-zij-æm/ PROG-exist.PRS-1.SG 'I exist'	میزیستم /mi-zist-æm/ PROG-exist.PST-1.SG 'I existed'	زیستم / zist-æm/ exist.PST-1.SG 'I existed'	سیستم /sistem/ system.SG 'system'	مشترک /moʃtæræk/ mutual 'mutual'
ریختن /rixt-æn/ pour.PST-INF 'to pour'	میریزم /mi-riz-æm/ PROG-pour.PRS-1.SG 'I pour'	میریختم /mi-rixt-æm/ PROG-pour.PST-1.SG 'I was pouring'	ریختم /rixt-æm/ pour.PST-1.SG 'I poured'	گریخت 'gorixt' escape.PST .3.SG 'he escaped'	مخالف 'moxɑlef' opposite 'opposite
کاشتن /kɑʃt-æn/ plant.PST-INF 'to plant'	میکارم /mi-kɑr-æm/ PROG-plant.PRS-1.SG 'I plant'	میکاشتم /mi-kɑʃt-æm/ PROG-plant.PST-1.SG 'I was planting'	کاشتم /kɑʃt-æm/ plant.PST-1.SG 'I planted'	ماشین /mɑʃin/ machine.S G 'machine'	برادر /bærɑdær/ brother.SG 'borther'
دوختن /duxt-æn/	میدوزم /mi-duz-æm/	میدوختم /mi-duxt-æm/	دوختم /duxt-æm/ sew.PST-1.SG	دولت /dolæt/	ازدواج /ezdevɑdʒ/ marriage

sew.PST-INF 'to sew'	PROG-sew.PRS-1.SG 'I sew'	PROG-sew.PST-1.SG 'I was sewing'	'I sewed'	government.SG 'government'	'marriage'
پیوستن /pejvæst-æn/ join.PST-INF 'to join'	میپیوندم /mi-pejvænd-æm/ PROG-join.PRS-1.SG 'I join'	میپیوستم /mi-pejvæst-æm/ PROG-join.PST-1.SG 'I was joining'	پیوستم /pejvæst-æm/ join.PST-1.SG 'I joined'	پوستر /puster/ poster.SG 'poster'	خلاصه /xolɑse/ summary 'summary'
کوفتن /kuft-æn/ smash.PST-INF 'to smash'	میکوبم /mi-kub-æm/ PROG-smash.PRS-1.SG 'I smash'	میکوفتم /mi-kuft-æm/ PROG-smash.PST-1.SG 'I was smashing'	کوفتم /kuft-æm/ smash.PST-1.SG 'I smashed'	کودتا /kudetɑ/ coup 'coup'	رییس /ræis/ boss.SG 'boss'
پنداشتن /pendɑʃt-æn/ assume.PST-INF 'to assume'	میپندارم /mi-pendɑr-æm/ PROG-assume.PRS-1.SG 'I assume'	میپنداشتم /mi-pendɑʃt-æm/ PROG-assume.PST-1.SG 'I was assuming '	پنداشتم /pendɑʃt-æm/ assume.PST-1.SG 'I assumed'	زندان /zendɑn/ prison.SG 'prison'	تعریف /tærif/ definition 'definition'
افروختن /æfruxt-æn/ ignite.PST-INF 'to ignite'	میافروزم /mi-æfruz-æm/ PROG-ignite.PRS-1.SG 'I ignite'	میافروختم /mi-æfruxt-æm/ PROG-ignite.PST-1.SG 'I was igniting'	افروختم /æfruxt-æm/ ignite.PST-1.SG 'I ignited'	افزون /æfzun/ ensemble 'ensemble'	خاموش /xɑmuʃ/ mute 'mute'
گزیدن /gozid-æn/ select.PST-INF 'to select'	میگزینم /mi-gozin-æm/ PROG-select.PRS-1.SG 'I select'	میگزیدم /mi-gozid-æm/ PROG-select.PST-1.SG 'I was selecting'	گزیدم /gozid-æm/ select.PST-1.SG 'I selected'	تزیین /taziin/ ornament 'ornament'	فرار /færɑr/ escape 'escape'
چیدن /tʃid-æn/ pick.PST-INF 'to pick'	میچینم /mi-tʃin-æm/ PROG-pick.PRS-1.SG 'I pick'	میچیدم /mi-tʃid-æm/ PROG-pick.PST-1.SG 'I was picking'	چیدم /tʃid-æm/ pick.PST-1.SG 'I picked'	گردن /gærdæn/ neck.SG 'neck'	اعتقاد /etegɑd/ faith.SG 'faith'
گریختن /gorixt-æn/ escape.PST-INF 'to escape'	میگریزم /mi-goriz-æm/ PROG-escape.PRS-1.SG 'I escape'	میگریختم /mi-gorixt-æm/ PROG-escape.PST-1.SG 'I was escaping'	گریختم /gorixt-æm/ escape.PST-1.SG 'I escaped'	گریبان /gæribɑn/ collar 'collar'	تشکیل /tæʃkil/ formation 'formation'
ریدن /rid-æn/ defecate.PST-INF 'to defecate'	میرینم /mi-rin-æm/ PROG-defecate.PRS-1.SG 'I defecate'	میریدم /mi-rid-æm/ PROG-defecate.PST-1.SG 'I was defecating'	ریدم /rid-æm/ defecate.PST-1.SG 'I defecated'	میدان /mejdɑn/ field.SG 'field'	کنترل /kontorol/ control 'control'
خاستن 'xɑst-æn' rise.PST-INF 'to rise'	میخیزم /mi-xiz-æm/ PROG-rise.PRS-1.SG 'I rise'	میخاستم /mi-xɑst-æm/ PROG-rise.PST-1.SG 'I was rising'	خاستم /xɑst-æm/ rise.PST-1.SG 'I rose'	استان 'ostɑn' province.SG 'province'	مناسب /monɑseb/ suitable 'suitable'

آمیختن ‘ɑmixt-æn’ mix.PST-INF ‘to mix’	میامیزم /mi-ɑmiz-æm/ PROG-mix.PRS-1.SG ‘I mix’	میامیختم /mi-ɑmixt-æm/ PROG-mix.PST-1.SG ‘I was mixing ’	آمیختم /ɑmixt-æm/ mix.PST-1.SG ‘I mixed’	آموخت /ɑmuxt/ learn.PST.3.SG ‘he learned’	پایان /pajan/ end ‘end’
اندوختن ‘ænduxt-æn’ amass.PST-INF ‘to amss’	میاندوزم /mi-ænduz-æm/ PROG-amass.PRS-1.SG ‘I amass’	میاندوختم /mi-ænduxt-æm/ PROG-amass.PST-1.SG ‘I was amassing’	اندوختم /ænduxt-æm/ amass.PST-1.SG ‘I amassed’	افروخت /æfruxt/ ignite.PST.3.SG ‘he ignited’	معاون /moɑven/ assistant ‘assistant’
انگاشتن ‘engɑʃt-æn’ suppose.PST-INF ‘to suppose’	میانگارم /mi-engɑr-æm/ PROG-suppose.PRS-1.SG ‘I suppose’	میانگاشتم /mi-engɑʃt-æm/ PROG-suppose.PST-1.SG ‘I supposed’	انگاشتم /engɑʃt-æm/ suppose.PST-1.SG ‘I supposed’	انگشتر /ængoʃtær/ ring.SG ‘ring’	معلوم /mælum/ apparent ‘apparent’

APPENDIX B

FILLER STIMULI

prime	target (word)	prime	target (non-word)
پیماییدم	پیماییدن	بازار	دونث
تپیدی	تپیدن	سوال	اخبزر
میتکاندیم	تکاندن	تعریف	ظاقر
میجنبیدید	جنبیدن	دروغ	انجون
میچرخاندند	چرخاندن	رفتار	مولجه
میدرخشیدم	درخشیدن	چهره	چرکیه
تجربه	روییدن	اقدام	شنادت
حرکت	سوزاندن	حقیقت	ابهار
باور	شاشیدن	رهبر	سوجیه
عاقل	شکافتن	دراز	خورغن
میکوبیدم	اندیشید	بزرگ	آراوش
میبریدی	بارید	بلند	گرکزی
میخوابید	جنگید	سینما	مثمود
میپریدم	ورزید	شیشه	دانرد
میجوشیدیم	پوشید	آرمان	مرنمی
میدمیدید	چسبید	دریا	افتاچ
میراندند	ترکید	جاده	هنخام
میترسیدم	بوسید	چاره	ظبوده
میماندی	نوشید	مخفی	خوجده
ایستادیم	خورد	وحشت	خاژمی
میزنگید	بافت	توصیه	اجراق
میحرفیدیم	بخشید	هزینه	خکینی
هوش	پوسید	سپاه	معرنی
آخر	دزدید	رقیب	نباگد
سعی	توانست	حیرت	داراخ
سمت	کشت	علامت	رسودن
گل	خندید	مشاور	روسیو
پنج	خرید	لوله	بسهار
درون	فهمید	میوه	فبریش

اسداف	حاضر	آورد	محور
ناشهار	مشکل	پرسید	تنش
دلتیل	شروع	رسید	بنا
حدادث	بورس	آفرید	نزدیک
ذرانه	سایت	چرخید	ماشین
تتویل	آسیب	دوید	دانش
دیموز	اسلام	آزمایید	آوردیم
گراهی	رژیم	پرورد	میگذراندم
قنابع	خارج	خراشید	میگاییدی
نجاهی	دوست	پسندید	میجوشاند
ضلکه	حامی	تنید	میکشاندیم
غرمال	معلم	ریسید	میخاریدید
ارشان	زندان	چکید	میپرستیدند
مانرد	اندیشیدم	جوید	میرساندم
گونخ	باریدی	نازید	آشامیدم
لویش	جنگیدیم	بویید	میفرمودی
عشیه	پاشیدید	لرزید	افراشتند
لسون	پوشیدند	سابید	میگداخت
دهران	چسبیدم	سپرد	تاریخ
گرخی	ترکیدی	خزید	نتیجه
فاقع	بوسیدیم	ترکید	اعلام
موابل	نوشیدید	پیچید	خانم
خاسنه	خوردند	لغزید	تغییر
منفطق	بافتم	کشید	اعدام
انیلیس	بخشیدی	فرستاد	فرهنگ
دقیژا	میپوسیدیم	رقصید	سیاست
اوکام	میدزدیدید	طلبید	لحظه
جوارع	توانستند	پاشید	وبلاگ
البات	کشتم	کوشید	ممکن
اخمیل	خندیدی	آموخت	مختلف
لانادا	خریدیم	افزود	زنده
نیرات	فهمیدید	پوشاند	آکندم
مزافع	آوردند	پذیرفت	آمیختی
پنباه	میپرسیدم	افکند	ایستاندیم
تحویب	میرسیدی	پژمرد	میپراکندم

نلارت	آفریدیم	بلعید	میپرهیزیدند
دندیدن	میچرخیدید	باراند	میپناهیدید
چرزیدن	میدویدند	پسندید	میدوشیدم
ترمیدن	آزماییدند	پراند	میپراندی
پیدیدن	میپروردم	بالید	میبالیدی
جیزیدن	میخراشیدی	پیچاند	میبالیدند
کنیدن	میپسندیدیم	test	test
فیستادن	میتنیدید	test	test
رقدیدن	میریسیدند	test	test
طوبیدن	میچکیدم	test	test
پیشیدن	میجویدی	test	test
کوریدن	مینازیدیم	test	test
خکیدن	میبوییدید	test	test
گسدیدن	میلرزیدند	test	test
شوثر	میسابیدم	test	test
عمیس	میسپردی	test	test
گرحن	میخزیدیم	test	test
عزخز	میترکیدند	test	test
آکاد	میپیچیدم	test	test
کعمل	میلغزیدی	test	test
وسکع	میکشیدیم	test	test
طقیر	میفرستادید	test	test
شندج	میرقصیدند	test	test
شمدث	میطلبیدم	test	test
تیزاد	میپاشیدی	test	test
قاطعمش	میکوشیدیم	test	test
سیاهسن	اندیشیدیم	test	test
عناور	میباریدند	test	test
اوباب	میکشاندم	test	test
شلقار	میپراندی	test	test
منتقر	میگردیدیم	test	test
لیوین	میکوشیدید	test	test
اسامت	میتراشیدند	test	test
اشزار	میخوراندم	test	test
فیزاک	میخواندی	test	test

test	test	میزاییدیم	ویرچن
test	test	شکاندن	افنوس
test	test	گریاندن	ارشار
test	test	گندیدن	مرازب
test	test	گوزیدن	ازهام
test	test	لنگیدن	سامیل
test	test	نالیدن	زامان
test	test	نامیدن	فیرست
test	test	نگریستن	معتار
test	test	نهاندن	تجسیس
test	test	ورزیدن	فیرتز
test	test	وزیدن	تدامل
test	test	هراسیدن	ماسمه
test	test	آغازیدن	اگباب
test	test	ارزیدن	اساسک
test	test	افشاندن	مزطفی
test	test	انجامیدن	راسقا
test	test	بازاندن	اقادث
test	test	پذیراندن	تسریک
test	test	پیراستن	ژیوان
test	test	ترکاندن	بازین

APPENDIX C

WARM-UP SET

group	prime	target	condition	target_type	expected	item
A	پرنده	تلویزیون	unrelated	warmup	f	0
A	انتخاب	کخال	unrelated	warmup	j	0
A	زن	میز	unrelated	warmup	f	0
A	مسابقه	لیوان	unrelated	warmup	f	0
A	ثروت	تیچلو	unrelated	warmup	j	0
A	زیبا	پرتشال	unrelated	warmup	j	0
A	مکالمه	پرچال	unrelated	warmup	j	0
A	جلو	برنده	unrelated	warmup	f	0
A	هفته	گروه	unrelated	warmup	f	0
A	سبب	ظیب	unrelated	warmup	j	0
A	استکان	پرواز	unrelated	warmup	f	0
A	گربه	سنباج	unrelated	warmup	j	0
A	هویج	بادبادک	unrelated	warmup	f	0
A	خبر	عروسک	unrelated	warmup	f	0
A	بازی	تکویه	unrelated	warmup	j	0
A	نوشابه	مذاله	unrelated	warmup	j	0
A	صحرا	کیاخ	unrelated	warmup	j	0
A	ساختمان	خورشید	unrelated	warmup	f	0
A	خودنویس	قبله	unrelated	warmup	f	0
A	گلوله	رکیم	unrelated	warmup	j	0

APPENDIX D

TRIAL LISTS

Table D1. Experiment List 1 (Not Randomized)

group	prime	target	condition	primetype	expected	item
A	میکنم	کردن	a	test	f	1
A	میشدم	شدن	b	test	f	2
A	دادم	دادن	c	test	f	3
A	بدن	زدن	d	test	f	4
A	توضیح	گرفتن	e	test	f	5
A	میروم	رفتن	a	test	f	6
A	میداشتم	داشتن	b	test	f	7
A	نوشتم	نوشتن	c	test	f	8
A	فتنه	گفتن	d	test	f	9
A	موسیقی	آمدن	e	test	f	10
A	میسازم	ساختن	a	test	f	11
A	میگذاشتم	گذاشتن	b	test	f	12
A	بستم	بستن	c	test	f	13
A	اندوخت	انداختن	d	test	f	14
A	مشغول	نشستن	e	test	f	15
A	میپردازم	پرداختن	a	test	f	16
A	مینمودم	نمودن	b	test	f	17
A	مردم	مردن	c	test	f	18
A	شدید	دیدن	d	test	f	19
A	مجبور	خواستن	e	test	f	20
A	میشناسم	شناختن	a	test	f	21
A	میاموختم	آموختن	b	test	f	22
A	شستم	شستن	c	test	f	23
A	گذاشت	گذشتن	d	test	f	24
A	ارسال	سپردن	e	test	f	25
A	میگردم	گشتن	a	test	f	26
A	میسوختم	سوختن	b	test	f	27
A	یافتم	یافتن	c	test	f	28
A	جهان	جستن	d	test	f	29

A	اختیار	پختن	e	test	f	30
A	میسرایم	سرودن	a	test	f	31
A	میباختم	باختن	b	test	f	32
A	زدودم	زدودن	c	test	f	33
A	فروزان	فروختن	d	test	f	34
A	مشترک	زیستن	e	test	f	35
A	میریزم	ریختن	a	test	f	36
A	میکاشتم	کاشتن	b	test	f	37
A	دوختم	دوختن	c	test	f	38
A	پوستر	پیوستن	d	test	f	39
A	رییس	کوفتن	e	test	f	40
A	میپندارم	پنداشتن	a	test	f	41
A	میافروختم	افروختن	b	test	f	42
A	گزیدم	گزیدن	c	test	f	43
A	گردن	چیدن	d	test	f	44
A	تشکیل	گریختن	e	test	f	45
A	میرینم	ریدن	a	test	f	46
A	میخاستم	خاستن	b	test	f	47
A	آمیختم	آمیختن	c	test	f	48
A	افروخت	اندوختن	d	test	f	49
A	معلوم	معلوم	e	test	f	50
A	پیماییدم	پیماییدن	filler	filler	f	0
A	تپیدی	تپیدن	filler	filler	f	0
A	میتکاندیم	تکاندن	filler	filler	f	0
A	میجنبیدید	جنبیدن	filler	filler	f	0
A	میچرخاندند	چرخاندن	filler	filler	f	0
A	میدرخشیدم	درخشیدن	filler	filler	f	0
A	تجربه	روییدن	filler	filler	f	0
A	حرکت	سوزاندن	filler	filler	f	0
A	باور	شاشیدن	filler	filler	f	0
A	عاقل	شکافتن	filler	filler	f	0
A	میکوبیدم	اندیشید	filler	filler	f	0
A	میباریدی	بارید	filler	filler	f	0
A	میخوابید	جنگید	filler	filler	f	0
A	میپریدم	ورزید	filler	filler	f	0

A	میجوشیدیم	پوشید	filler	filler	f	0
A	میدمیدید	چسبید	filler	filler	f	0
A	میراندند	ترکید	filler	filler	f	0
A	میترسیدم	بوسید	filler	filler	f	0
A	میماندی	نوشید	filler	filler	f	0
A	ایستادیم	خورد	filler	filler	f	0
A	میزنگید	بافت	filler	filler	f	0
A	میحرفیدیم	بخشید	filler	filler	f	0
A	هوش	پوسید	filler	filler	f	0
A	آخر	دزدید	filler	filler	f	0
A	سعی	توانست	filler	filler	f	0
A	سمت	کشت	filler	filler	f	0
A	گل	خندید	filler	filler	f	0
A	پنج	خرید	filler	filler	f	0
A	درون	فهمید	filler	filler	f	0
A	محور	آورد	filler	filler	f	0
A	تنش	پرسید	filler	filler	f	0
A	بنا	رسید	filler	filler	f	0
A	نزدیک	آفرید	filler	filler	f	0
A	ماشین	چرخید	filler	filler	f	0
A	دانش	دوید	filler	filler	f	0
A	آوردیم	آزمایید	filler	filler	f	0
A	میگذراندم	پرورد	filler	filler	f	0
A	میگاییدی	خراشید	filler	filler	f	0
A	میجوشاند	پسندید	filler	filler	f	0
A	میکشاندیم	تنید	filler	filler	f	0
A	میخاریدید	ریسید	filler	filler	f	0
A	میپرستیدند	چکید	filler	filler	f	0
A	میرساندم	جوید	filler	filler	f	0
A	آشامیدم	نازید	filler	filler	f	0
A	میفرمودی	بویید	filler	filler	f	0
A	افراشتند	لرزید	filler	filler	f	0
A	میگداخت	سابید	filler	filler	f	0
A	تاریخ	سپرد	filler	filler	f	0
A	نتیجه	خزید	filler	filler	f	0

A	اسلام	ترکید	filler	filler	f	0
A	خانم	پیچید	filler	filler	f	0
A	تغییر	لغزید	filler	filler	f	0
A	اعدام	کشید	filler	filler	f	0
A	فرهنگ	فرستاد	filler	filler	f	0
A	سیاست	رقصید	filler	filler	f	0
A	لحظه	طلبید	filler	filler	f	0
A	وبلاگ	پاشید	filler	filler	f	0
A	ممکن	کوشید	filler	filler	f	0
A	مختلف	آموخت	filler	filler	f	0
A	زنده	افزود	filler	filler	f	0
A	آکندم	پوشاند	filler	filler	f	0
A	آمیختی	پذیرفت	filler	filler	f	0
A	ایستاندیم	افکند	filler	filler	f	0
A	میپراکندم	پژمرد	filler	filler	f	0
A	میپرهیزیدند	بلعید	filler	filler	f	0
A	میپناهیدید	باراند	filler	filler	f	0
A	میدوشیدم	پسندید	filler	filler	f	0
A	میپراندی	پراند	filler	filler	f	0
A	میبالیدی	بالید	filler	filler	f	0
A	میبالیدند	پیچاند	filler	filler	f	0
A	بازار	دونث	filler	filler	j	0
A	سوال	اخبزر	filler	filler	j	0
A	تعریف	ظاقر	filler	filler	j	0
A	دروغ	انجون	filler	filler	j	0
A	رفتار	مولجه	filler	filler	j	0
A	چهره	چرکیه	filler	filler	j	0
A	اقدام	شنادت	filler	filler	j	0
A	حقیقت	ییهار	filler	filler	j	0
A	رهبر	سوجیه	filler	filler	j	0
A	دراز	خورغن	filler	filler	j	0
A	بزرگ	آراوش	filler	filler	j	0
A	بلند	گرکزی	filler	filler	j	0
A	سینما	متمود	filler	filler	j	0
A	شیشه	دانرد	filler	filler	j	0

A	آرمان	مرنمی	filler	filler	j	0
A	دریا	افتاچ	filler	filler	j	0
A	جاده	هنخام	filler	filler	j	0
A	چاره	ظبوده	filler	filler	j	0
A	مخفی	خوجده	filler	filler	j	0
A	وحشت	خاژمی	filler	filler	j	0
A	توصیه	اجراق	filler	filler	j	0
A	هزینه	خکینی	filler	filler	j	0
A	سپاه	معرنی	filler	filler	j	0
A	رقیب	نباگد	filler	filler	j	0
A	حیرت	داراخ	filler	filler	j	0
A	علامت	رسودن	filler	filler	j	0
A	مشاور	روسیو	filler	filler	j	0
A	لوله	بسهار	filler	filler	j	0
A	میوه	بظشار	filler	filler	j	0
A	حاضر	ابداف	filler	filler	j	0
A	مشکل	ناشهار	filler	filler	j	0
A	شروع	دلتیل	filler	filler	j	0
A	بورس	حدادث	filler	filler	j	0
A	سایت	ذرانه	filler	filler	j	0
A	آسیب	تغویل	filler	filler	j	0
A	اسلام	دیموز	filler	filler	j	0
A	رژیم	گراهی	filler	filler	j	0
A	خارج	قنابع	filler	filler	j	0
A	دوست	نژاهی	filler	filler	j	0
A	حامی	ضلکه	filler	filler	j	0
A	معلم	غسر	filler	filler	j	0
A	زندان	ارلام	filler	filler	j	0
A	اندیشیدم	مانرد	filler	filler	j	0
A	باریدی	گونخ	filler	filler	j	0
A	جنگیدیم	دویش	filler	filler	j	0
A	پاشیدید	عپیه	filler	filler	j	0
A	پوشیدند	لسون	filler	filler	j	0
A	چسبیدم	دهژان	filler	filler	j	0
A	ترکیدی	گرخی	filler	filler	j	0

A	بوسیدیم	فاقن	filler	filler	j	0
A	نوشیدید	موابل	filler	filler	j	0
A	خوردند	خاسنه	filler	filler	j	0
A	بافتم	منفطق	filler	filler	j	0
A	بخشیدی	انیلیس	filler	filler	j	0
A	میبوسیدیم	دقیژا	filler	filler	j	0
A	میدزدیدید	اوکام	filler	filler	j	0
A	توانستند	جوارع	filler	filler	j	0
A	کشتم	اچبات	filler	filler	j	0
A	خندیدی	اخمیل	filler	filler	j	0
A	خریدیم	لانادا	filler	filler	j	0
A	فهمیدید	نیرات	filler	filler	j	0
A	آوردند	مزافع	filler	filler	j	0
A	میپرسیدم	پنباه	filler	filler	j	0
A	میرسیدی	تیویب	filler	filler	j	0
A	آفریدیم	نلارت	filler	filler	j	0
A	میچرخیدید	سندیدن	filler	filler	j	0
A	میدویدند	چرزیدن	filler	filler	j	0
A	آزماییدند	لرمیدن	filler	filler	j	0
A	میپروردم	پیدیدن	filler	filler	j	0
A	میخراشیدی	جیزیدن	filler	filler	f	0
A	میپسندیدیم	کنادن	filler	filler	j	0
A	میتنیدید	فیستادن	filler	filler	j	0
A	میریسیدند	رقدیدن	filler	filler	j	0
A	میچکیدم	طوبیدن	filler	filler	j	0
A	میجویدی	پیگیدن	filler	filler	j	0
A	مینازیدیم	کوریدن	filler	filler	j	0
A	میبوییدید	خکیدن	filler	filler	j	0
A	میلرزیدند	گسدیدن	filler	filler	j	0
A	میسابیدم	فویر	filler	filler	j	0
A	میسپردی	گمیس	filler	filler	j	0
A	میخزیدیم	گرحن	filler	filler	j	0
A	میترکیدند	عزخز	filler	filler	j	0
A	میپیچیدم	آچاد	filler	filler	j	0
A	میلغزیدی	کعمل	filler	filler	j	0

A	میکشیدیم	وسکع	filler	filler	j	0
A	میفرستادید	طقیر	filler	filler	j	0
A	میرقصیدند	شندج	filler	filler	j	0
A	میطلبیدم	شمدث	filler	filler	j	0
A	میپاشیدی	تیزاد	filler	filler	j	0
A	میکوشیدیم	قاطعمش	filler	filler	j	0
A	اندیشیدیم	سیاهسن	filler	filler	j	0
A	میباریدند	ظناور	filler	filler	j	0
A	میکشاندم	اوباب	filler	filler	j	0
A	میپراندی	شلقار	filler	filler	j	0
A	میگردیدیم	مختقر	filler	filler	j	0
A	میکوشیدید	لیوین	filler	filler	j	0
A	میتراشیدند	اسامت	filler	filler	j	0
A	میخوراندم	اشزار	filler	filler	j	0
A	میخواندی	فیزاک	filler	filler	j	0
A	میزاییدیم	ویرچن	filler	filler	j	0
A	شکاندن	افنوس	filler	filler	j	0
A	گریاندن	ارشار	filler	filler	j	0
A	گندیدن	مرازب	filler	filler	j	0
A	گوزیدن	ازغام	filler	filler	j	0
A	لنگیدن	ساميل	filler	filler	j	0
A	نالیدن	زاوان	filler	filler	j	0
A	نامیدن	فیرست	filler	filler	j	0
A	نگریستن	معتار	filler	filler	j	0
A	نهاندن	تچسیس	filler	filler	j	0
A	ورزیدن	فیرتز	filler	filler	j	0
A	وزیدن	کدامل	filler	filler	j	0
A	هراسیدن	ماسمه	filler	filler	j	0
A	آغازیدن	اگباب	filler	filler	j	0
A	ارزیدن	اساسک	filler	filler	j	0
A	افشاندن	مزطفی	filler	filler	j	0
A	انجامیدن	راسقا	filler	filler	j	0
A	بازاندن	اقادث	filler	filler	j	0
A	پذیراندن	تسریک	filler	filler	j	0
A	پیراستن	پیوان	filler	filler	j	0

A	ترکاندن	باگین	filler	filler	j	0

Table D2. Experiment List 2 (Not Randomized)

group	prime	target	condition	primetype	expected	item
B	میکردم	کردن	b	test	f	1
B	شدم	شدن	c	test	f	2
B	دامن	دادن	d	test	f	3
B	حقیقت	زدن	e	test	f	4
B	میگیرم	گرفتن	a	test	f	5
B	میرفتم	رفتن	b	test	f	6
B	داشتم	داشتن	c	test	f	7
B	بولتن	نوشتن	d	test	f	8
B	شکنجه	گفتن	e	test	f	9
B	میایم	آمدن	a	test	f	10
B	میساختم	ساختن	b	test	f	11
B	گذاشتم	گذاشتن	c	test	f	12
B	بوستان	بستن	d	test	f	13
B	میزان	انداختن	e	test	f	14
B	مینشینم	نشستن	a	test	f	15
B	میپرداختم	پرداختن	b	test	f	16
B	نمودم	نمودن	c	test	f	17
B	مردود	مردن	d	test	f	18
B	ترجمه	دیدن	e	test	f	19
B	میخواهم	خواستن	a	test	f	20
B	میشناختم	شناختن	b	test	f	21
B	آموختم	آموختن	c	test	f	22
B	نشست	شستن	d	test	f	23
B	مهندس	گذشتن	e	test	f	24
B	میسپارم	سپردن	a	test	f	25
B	میگشتم	گشتن	b	test	f	26
B	سوختم	سوختن	c	test	f	27
B	ضیافت	یافتن	d	test	f	28
B	مملکت	جستن	e	test	f	29
B	میپزم	پختن	a	test	f	30
B	میسرودم	سرودن	b	test	f	31

B	باختم	باختن	c	test	f	32
B	تدوین	زدودن	d	test	f	33
B	تاثیر	فروختن	e	test	f	34
B	میزیم	زیستن	a	test	f	35
B	میریختم	ریختن	b	test	f	36
B	کاشتم	کاشتن	c	test	f	37
B	دولت	دوختن	d	test	f	38
B	خلاصه	پیوستن	e	test	f	39
B	میکوبم	کوفتن	a	test	f	40
B	میپنداشتم	پنداشتن	b	test	f	41
B	افروختم	افروختن	c	test	f	42
B	تزیین	گزیدن	d	test	f	43
B	اعتقاد	چیدن	e	test	f	44
B	میگریزم	گریختن	a	test	f	45
B	میریدم	ریدن	b	test	f	46
B	خاستم	خاستن	c	test	f	47
B	آموخت	آمیختن	d	test	f	48
B	معاون	اندوختن	e	test	f	49
B	میانگارم	انگاشتن	a	test	f	50
B	پیماییدم	پیماییدن	filler	filler	f	0
B	تپیدی	تپیدن	filler	filler	f	0
B	میتکاندیم	تکاندن	filler	filler	f	0
B	میجنبیدید	جنبیدن	filler	filler	f	0
B	میچرخاندند	چرخاندن	filler	filler	f	0
B	میدرخشیدم	درخشیدن	filler	filler	f	0
B	تجربه	روییدن	filler	filler	f	0
B	حرکت	سوزاندن	filler	filler	f	0
B	باور	شاشیدن	filler	filler	f	0
B	عاقل	شکافتن	filler	filler	f	0
B	میکوبیدم	اندیشید	filler	filler	f	0
B	میبریدی	بارید	filler	filler	f	0
B	میخوابید	جنگید	filler	filler	f	0
B	میپریدم	ورزید	filler	filler	f	0
B	میجوشیدیم	پوشید	filler	filler	f	0
B	میدمیدید	چسبید	filler	filler	f	0

B	میراندند	ترکید	filler	filler	f	0
B	میترسیدم	بوسید	filler	filler	f	0
B	میماندی	نوشید	filler	filler	f	0
B	ایستادیم	خورد	filler	filler	f	0
B	میزنگید	بافت	filler	filler	f	0
B	میحرفیدیم	بخشید	filler	filler	f	0
B	هوش	پوسید	filler	filler	f	0
B	آخر	دزدید	filler	filler	f	0
B	سعی	توانست	filler	filler	f	0
B	سمت	کشت	filler	filler	f	0
B	گل	خندید	filler	filler	f	0
B	پنج	خرید	filler	filler	f	0
B	درون	فهمید	filler	filler	f	0
B	محور	آورد	filler	filler	f	0
B	تنش	پرسید	filler	filler	f	0
B	بنا	رسید	filler	filler	f	0
B	نزدیک	آفرید	filler	filler	f	0
B	ماشین	چرخید	filler	filler	f	0
B	دانش	دوید	filler	filler	f	0
B	آوردیم	آزمایید	filler	filler	f	0
B	میگذراندم	پرورد	filler	filler	f	0
B	میگاییدی	خراشید	filler	filler	f	0
B	میجوشاند	پسندید	filler	filler	f	0
B	میکشاندیم	تنید	filler	filler	f	0
B	میخاریدید	ریسید	filler	filler	f	0
B	میپرستیدند	چکید	filler	filler	f	0
B	میرساندم	جوید	filler	filler	f	0
B	آشامیدم	نازید	filler	filler	f	0
B	میفرمودی	بویید	filler	filler	f	0
B	افراشتند	لرزید	filler	filler	f	0
B	میگداخت	سابید	filler	filler	f	0
B	تاریخ	سپرد	filler	filler	f	0
B	نتیجه	خزید	filler	filler	f	0
B	اسلام	ترکید	filler	filler	f	0
B	خانم	پیچید	filler	filler	f	0

B	تغییر	لغزید	filler	filler	f	0
B	اعدام	کشید	filler	filler	f	0
B	فرهنگ	فرستاد	filler	filler	f	0
B	سیاست	رقصید	filler	filler	f	0
B	لحظه	طلبید	filler	filler	f	0
B	وبلاگ	پاشید	filler	filler	f	0
B	ممکن	کوشید	filler	filler	f	0
B	مختلف	آموخت	filler	filler	f	0
B	زنده	افزود	filler	filler	f	0
B	آکندم	پوشاند	filler	filler	f	0
B	آمیختی	پذیرفت	filler	filler	f	0
B	ایستاندیم	افکند	filler	filler	f	0
B	میپراکندم	پژمرد	filler	filler	f	0
B	میپرهیزیدند	بلعید	filler	filler	f	0
B	میپناهیدید	باراند	filler	filler	f	0
B	میدوشیدم	پسندید	filler	filler	f	0
B	میپراندی	پراند	filler	filler	f	0
B	میبالیدی	بالید	filler	filler	f	0
B	میبالیدند	پیچاند	filler	filler	f	0
B	بازار	دونث	filler	filler	j	0
B	سوال	اخبزر	filler	filler	j	0
B	تعریف	ظاقر	filler	filler	j	0
B	دروغ	انجون	filler	filler	j	0
B	رفتار	مولجه	filler	filler	j	0
B	چهره	چرکیه	filler	filler	j	0
B	اقدام	شنادت	filler	filler	j	0
B	حقیقت	یبهار	filler	filler	j	0
B	رهبر	سوجیه	filler	filler	j	0
B	دراز	خورغن	filler	filler	j	0
B	بزرگ	آراوش	filler	filler	j	0
B	بلند	گرکزی	filler	filler	j	0
B	سینما	متمود	filler	filler	j	0
B	شیشه	دانرد	filler	filler	j	0
B	آرمان	مرنمی	filler	filler	j	0
B	دریا	افتاچ	filler	filler	j	0

B	جاده	هنخام	filler	filler	j	0
B	چاره	ظبوده	filler	filler	j	0
B	مخفی	خوجده	filler	filler	j	0
B	وحشت	خاژمی	filler	filler	j	0
B	توصیه	اجراق	filler	filler	j	0
B	هزینه	خکینی	filler	filler	j	0
B	سپاه	معرنی	filler	filler	j	0
B	رقیب	نباگد	filler	filler	j	0
B	حیرت	داراخ	filler	filler	j	0
B	علامت	رسودن	filler	filler	j	0
B	مشاور	روسیو	filler	filler	j	0
B	لوله	بسهار	filler	filler	j	0
B	میوه	بظشار	filler	filler	j	0
B	حاضر	ابداف	filler	filler	j	0
B	مشکل	ناشهار	filler	filler	j	0
B	شروع	دلتیل	filler	filler	j	0
B	بورس	حدادث	filler	filler	j	0
B	سایت	ذرانه	filler	filler	j	0
B	آسیب	تغویل	filler	filler	j	0
B	اسلام	دیموز	filler	filler	j	0
B	رژیم	گراهی	filler	filler	j	0
B	خارج	قنابع	filler	filler	j	0
B	دوست	نژاهی	filler	filler	j	0
B	حامی	ضلکه	filler	filler	j	0
B	معلم	غسر	filler	filler	j	0
B	زندان	ارلام	filler	filler	j	0
B	اندیشیدم	مانرد	filler	filler	j	0
B	باریدی	گونخ	filler	filler	j	0
B	جنگیدیم	دویش	filler	filler	j	0
B	پاشیدید	عپیه	filler	filler	j	0
B	پوشیدند	لسون	filler	filler	j	0
B	چسبیدم	دهژان	filler	filler	j	0
B	ترکیدی	گرخی	filler	filler	j	0
B	بوسیدیم	فاقن	filler	filler	j	0
B	نوشیدید	موابل	filler	filler	j	0

B	خوردند	خاسنه	filler	filler	j	0
B	بافتم	منفطق	filler	filler	j	0
B	بخشیدی	انیلیس	filler	filler	j	0
B	میپوسیدیم	دقیژا	filler	filler	j	0
B	میدزدیدید	اوکام	filler	filler	j	0
B	توانستند	جوارع	filler	filler	j	0
B	کشتم	اچبات	filler	filler	j	0
B	خندیدی	اخمیل	filler	filler	j	0
B	خریدیم	لانادا	filler	filler	j	0
B	فهمیدید	نیرات	filler	filler	j	0
B	آوردند	مزافع	filler	filler	j	0
B	میپرسیدم	پنباه	filler	filler	j	0
B	میرسیدی	تیویب	filler	filler	j	0
B	آفریدیم	نلارت	filler	filler	j	0
B	میچرخیدید	سندیدن	filler	filler	j	0
B	میدویدند	چرزیدن	filler	filler	j	0
B	آزماییدند	لرمیدن	filler	filler	j	0
B	میپروردم	پیدیدن	filler	filler	j	0
B	میخراشیدی	جیزیدن	filler	filler	j	0
B	میپسندیدیم	کنادن	filler	filler	j	0
B	میتنیدید	فیستادن	filler	filler	j	0
B	میریسیدند	رقدیدن	filler	filler	j	0
B	میچکیدم	طوبیدن	filler	filler	j	0
B	میجویدی	پیگیدن	filler	filler	j	0
B	مینازیدیم	کوریدن	filler	filler	j	0
B	میبوییدید	خکیدن	filler	filler	j	0
B	میلرزیدند	گسدیدن	filler	filler	j	0
B	میسابیدم	فویر	filler	filler	j	0
B	میسپردی	گمیس	filler	filler	j	0
B	میخزیدیم	گرحن	filler	filler	j	0
B	میترکیدند	عزخز	filler	filler	j	0
B	میپیچیدم	آچاد	filler	filler	j	0
B	میلغزیدی	کعمل	filler	filler	j	0
B	میکشیدیم	وسکع	filler	filler	j	0
B	میفرستادید	طقیر	filler	filler	j	0

B	میرقصیدند	شندج	filler	filler	j	0
B	میطلبیدم	شمدث	filler	filler	j	0
B	میپاشیدی	تیزاد	filler	filler	j	0
B	میکوشیدیم	قاطعمش	filler	filler	j	0
B	اندیشیدیم	سیاهسن	filler	filler	j	0
B	میباریدند	ظناور	filler	filler	j	0
B	میکشاندم	اوباب	filler	filler	j	0
B	میپراندی	شلقار	filler	filler	j	0
B	میگردیدیم	مختقر	filler	filler	j	0
B	میکوشیدید	لیوین	filler	filler	j	0
B	میتراشیدند	اسامت	filler	filler	j	0
B	میخوراندم	اشزار	filler	filler	j	0
B	میخواندی	فیزاک	filler	filler	j	0
B	میزاییدیم	ویرچن	filler	filler	j	0
B	شکاندن	افنوس	filler	filler	j	0
B	گریاندن	ارشار	filler	filler	j	0
B	گندیدن	مرازب	filler	filler	j	0
B	گوزیدن	ازغام	filler	filler	j	0
B	لنگیدن	سامیل	filler	filler	j	0
B	نالیدن	زاوان	filler	filler	j	0
B	نامیدن	فیرست	filler	filler	j	0
B	نگریستن	معتار	filler	filler	j	0
B	نهاندن	تچسیس	filler	filler	j	0
B	ورزیدن	فیرتز	filler	filler	j	0
B	وزیدن	کدامل	filler	filler	j	0
B	هراسیدن	ماسمه	filler	filler	j	0
B	آغازیدن	اگباب	filler	filler	j	0
B	ارزیدن	اساسک	filler	filler	j	0
B	افشاندن	مزطفی	filler	filler	j	0
B	انجامیدن	راسقا	filler	filler	j	0
B	بازاندن	اقادث	filler	filler	j	0
B	پذیراندن	تسریک	filler	filler	j	0
B	پیراستن	پیوان	filler	filler	j	0
B	ترکاندن	باگین	filler	filler	j	0

Table D3. Experiment List 3 (Not Randomized)

group	prime	target	condition	primetype	expected	item
C	کردم	کردن	c	test	f	1
C	شدت	شدن	d	test	f	2
C	تکرار	دادن	e	test	f	3
C	میزنم	زدن	a	test	f	4
C	میگرفتم	گرفتن	b	test	f	5
C	رفتم	رفتن	c	test	f	6
C	داستان	داشتن	d	test	f	7
C	عدالت	نوشتن	e	test	f	8
C	میگویم	گفتن	a	test	f	9
C	میامدم	آمدن	b	test	f	10
C	ساختم	ساختن	c	test	f	11
C	گذشت	گذاشتن	d	test	f	12
C	متفاوت	بستن	e	test	f	13
C	میاندازم	انداختن	a	test	f	14
C	مینشستم	نشستن	b	test	f	15
C	پرداختم	پرداختن	c	test	f	16
C	نمونه	نمودن	d	test	f	17
C	دیوار	مردن	e	test	f	18
C	میبینم	دیدن	a	test	f	19
C	میخواستم	خواستن	b	test	f	20
C	شناختم	شناختن	c	test	f	21
C	آمیخت	آموختن	d	test	f	22
C	ولایت	شستن	e	test	f	23
C	میگذرم	گذشتن	a	test	f	24
C	میسپردم	سپردن	b	test	f	25
C	گشتم	گشتن	c	test	f	26
C	دوخت	سوختن	d	test	f	27
C	ورزش	یافتن	e	test	f	28
C	میجویم	جستن	a	test	f	29
C	میپختم	پختن	b	test	f	30
C	سرودم	سرودن	c	test	f	31
C	ساخت	باختن	d	test	f	32
C	شرایط	زدودن	e	test	f	33

C	میفروشم	فروختن	a	test	f	34
C	میزیستم	زیستن	b	test	f	35
C	ریختم	ریختن	c	test	f	36
C	ماشین	کاشتن	d	test	f	37
C	ازدواج	دوختن	e	test	f	38
C	میپیوندم	پیوستن	a	test	f	39
C	میکوفتم	کوفتن	b	test	f	40
C	پنداشتم	پنداشتن	c	test	f	41
C	افزون	افروختن	d	test	f	42
C	فرار	گزیدن	e	test	f	43
C	میچینم	چیدن	a	test	f	44
C	میگریختم	گریختن	b	test	f	45
C	ریدم	ریدن	c	test	f	46
C	استان	خاستن	d	test	f	47
C	پایان	آمیختن	e	test	f	48
C	میاندوزم	اندوختن	a	test	f	49
C	میانگاشتم	انگاشتن	b	test	f	50
C	پیماییدم	پیماییدن	filler	filler	f	0
C	تپیدی	تپیدن	filler	filler	f	0
C	میتکاندیم	تکاندن	filler	filler	f	0
C	میجنبیدید	جنبیدن	filler	filler	f	0
C	میچرخاندند	چرخاندن	filler	filler	f	0
C	میدرخشیدم	درخشیدن	filler	filler	f	0
C	تجربه	روییدن	filler	filler	f	0
C	حرکت	سوزاندن	filler	filler	f	0
C	باور	شاشیدن	filler	filler	f	0
C	عاقل	شکافتن	filler	filler	f	0
C	میکوبیدم	اندیشید	filler	filler	f	0
C	میبریدی	بارید	filler	filler	f	0
C	میخوابید	جنگید	filler	filler	f	0
C	میپریدم	ورزید	filler	filler	f	0
C	میجوشیدیم	پوشید	filler	filler	f	0
C	میدمیدید	چسبید	filler	filler	f	0
C	میراندند	ترکید	filler	filler	f	0
C	میترسیدم	بوسید	filler	filler	f	0

C	میماندی	نوشید	filler	filler	f	0
C	ایستادیم	خورد	filler	filler	f	0
C	میزنگید	بافت	filler	filler	f	0
C	میحرفیدیم	بخشید	filler	filler	f	0
C	هوش	پوسید	filler	filler	f	0
C	آخر	دزدید	filler	filler	f	0
C	سعی	توانست	filler	filler	f	0
C	سمت	کشت	filler	filler	f	0
C	گل	خندید	filler	filler	f	0
C	پنج	خرید	filler	filler	f	0
C	درون	فهمید	filler	filler	f	0
C	محور	آورد	filler	filler	f	0
C	تنش	پرسید	filler	filler	f	0
C	بنا	رسید	filler	filler	f	0
C	نزدیک	آفرید	filler	filler	f	0
C	ماشین	چرخید	filler	filler	f	0
C	دانش	دوید	filler	filler	f	0
C	آوردیم	آزمایید	filler	filler	f	0
C	میگذراندم	پرورد	filler	filler	f	0
C	میگاییدی	خراشید	filler	filler	f	0
C	میجوشاند	پسندید	filler	filler	f	0
C	میکشاندیم	تنید	filler	filler	f	0
C	میخاریدید	ریسید	filler	filler	f	0
C	میپرستیدند	چکید	filler	filler	f	0
C	میرساندم	جوید	filler	filler	f	0
C	آشامیدم	نازید	filler	filler	f	0
C	میفرمودی	بویید	filler	filler	f	0
C	افراشتند	لرزید	filler	filler	f	0
C	میگداخت	سابید	filler	filler	f	0
C	تاریخ	سپرد	filler	filler	f	0
C	نتیجه	خزید	filler	filler	f	0
C	اسلام	ترکید	filler	filler	f	0
C	خانم	پیچید	filler	filler	f	0
C	تغییر	لغزید	filler	filler	f	0
C	اعدام	کشید	filler	filler	f	0

C	فرهنگ	فرستاد	filler	filler	f	0
C	سیاست	رقصید	filler	filler	f	0
C	لحظه	طلبید	filler	filler	f	0
C	وبلاگ	پاشید	filler	filler	f	0
C	ممکن	کوشید	filler	filler	f	0
C	مختلف	آموخت	filler	filler	f	0
C	زنده	افزود	filler	filler	f	0
C	آکندم	پوشاند	filler	filler	f	0
C	آمیختی	پذیرفت	filler	filler	f	0
C	ایستاندیم	افکند	filler	filler	f	0
C	میپراکندم	پژمرد	filler	filler	f	0
C	میپرهیزیدند	بلعید	filler	filler	f	0
C	میپناهیدید	باراند	filler	filler	f	0
C	میدوشیدم	پسندید	filler	filler	f	0
C	میپراندی	پراند	filler	filler	f	0
C	میبالیدی	بالید	filler	filler	f	0
C	میبالیدند	پیچاند	filler	filler	f	0
C	بازار	دونث	filler	filler	j	0
C	سوال	اخبزر	filler	filler	j	0
C	تعریف	ظاقر	filler	filler	j	0
C	دروغ	انجون	filler	filler	j	0
C	رفتار	مولجه	filler	filler	j	0
C	چهره	چرکیه	filler	filler	j	0
C	اقدام	شنادت	filler	filler	j	0
C	حقیقت	یبهار	filler	filler	j	0
C	رهبر	سوجیه	filler	filler	j	0
C	دراز	خورغن	filler	filler	j	0
C	بزرگ	آراوش	filler	filler	j	0
C	بلند	گرکزی	filler	filler	j	0
C	سینما	متمود	filler	filler	j	0
C	شیشه	دانرد	filler	filler	j	0
C	آرمان	مرنمی	filler	filler	j	0
C	دریا	افتاچ	filler	filler	j	0
C	جاده	هنخام	filler	filler	j	0
C	چاره	ظبوده	filler	filler	j	0

C	مخفی	خوجده	filler	filler	j	0
C	وحشت	خاژمی	filler	filler	j	0
C	توصیه	اجراق	filler	filler	j	0
C	هزینه	خکینی	filler	filler	j	0
C	سپاه	معرنی	filler	filler	j	0
C	رقیب	نباگد	filler	filler	j	0
C	حیرت	داراخ	filler	filler	j	0
C	علامت	رسودن	filler	filler	j	0
C	مشاور	روسیو	filler	filler	j	0
C	لوله	بسهار	filler	filler	j	0
C	میوه	بظشار	filler	filler	j	0
C	حاضر	ابداف	filler	filler	j	0
C	مشکل	ناشهار	filler	filler	j	0
C	شروع	دلتیل	filler	filler	j	0
C	بورس	حدادث	filler	filler	j	0
C	سایت	ذرانه	filler	filler	j	0
C	آسیب	تغویل	filler	filler	j	0
C	اسلام	دیموز	filler	filler	j	0
C	رژیم	گراهی	filler	filler	j	0
C	خارج	قنابع	filler	filler	j	0
C	دوست	نژاهی	filler	filler	j	0
C	حامی	ضلکه	filler	filler	j	0
C	معلم	غسر	filler	filler	j	0
C	زندان	ارلام	filler	filler	j	0
C	اندیشیدم	مانرد	filler	filler	j	0
C	باریدی	گونخ	filler	filler	j	0
C	جنگیدیم	دویش	filler	filler	j	0
C	پاشیدید	عپیه	filler	filler	j	0
C	پوشیدند	لسون	filler	filler	j	0
C	چسبیدم	دهژان	filler	filler	j	0
C	ترکیدی	گرخی	filler	filler	j	0
C	بوسیدیم	فاقن	filler	filler	j	0
C	نوشیدید	موابل	filler	filler	j	0
C	خوردند	خاسنه	filler	filler	j	0
C	بافتم	منفطق	filler	filler	j	0

C	بخشیدی	انیلیس	filler	filler	j	0
C	میپوسیدیم	دقیژا	filler	filler	j	0
C	میدزدیدید	اوکام	filler	filler	j	0
C	توانستند	جوارع	filler	filler	j	0
C	کشتم	اچبات	filler	filler	j	0
C	خندیدی	اخمیل	filler	filler	j	0
C	خریدیم	لانادا	filler	filler	j	0
C	فهمیدید	نیرات	filler	filler	j	0
C	آوردند	مزافع	filler	filler	j	0
C	میپرسیدم	پنباه	filler	filler	j	0
C	میرسیدی	تیویب	filler	filler	j	0
C	آفریدیم	نلارت	filler	filler	j	0
C	میچرخیدید	سندیدن	filler	filler	j	0
C	میدویدند	چرزیدن	filler	filler	j	0
C	آزماییدند	لرمیدن	filler	filler	j	0
C	میپروردم	پیدیدن	filler	filler	j	0
C	میخراشیدی	جیزیدن	filler	filler	j	0
C	میپسندیدیم	کنادن	filler	filler	j	0
C	میتنیدید	فیستادن	filler	filler	j	0
C	میریسیدند	رقدیدن	filler	filler	j	0
C	میچکیدم	طوبیدن	filler	filler	j	0
C	میجویدی	پیگیدن	filler	filler	j	0
C	مینازیدیم	کوریدن	filler	filler	j	0
C	میبوییدید	خکیدن	filler	filler	j	0
C	میلرزیدند	گسدیدن	filler	filler	j	0
C	میسابیدم	فویر	filler	filler	j	0
C	میسپردی	گمیس	filler	filler	j	0
C	میخزیدیم	گرحن	filler	filler	j	0
C	میترکیدند	عزخز	filler	filler	j	0
C	میپیچیدم	آچاد	filler	filler	j	0
C	میلغزیدی	کعمل	filler	filler	j	0
C	میکشیدیم	وسکع	filler	filler	j	0
C	میفرستادید	طقیر	filler	filler	j	0
C	میرقصیدند	شندج	filler	filler	j	0
C	میطلبیدم	شمدث	filler	filler	j	0

C	میپاشیدی	تیزاد	filler	filler	j	0
C	میکوشیدیم	قاطعمش	filler	filler	j	0
C	اندیشیدیم	سیاهسن	filler	filler	j	0
C	میباریدند	ظناور	filler	filler	j	0
C	میکشاندم	اوباب	filler	filler	j	0
C	میپراندی	شلقار	filler	filler	j	0
C	میگردیدیم	مختقر	filler	filler	j	0
C	میکوشیدید	لیوین	filler	filler	j	0
C	میتراشیدند	اسامت	filler	filler	j	0
C	میخوراندم	اشزار	filler	filler	j	0
C	میخواندی	فیزاک	filler	filler	j	0
C	میزاییدیم	ویرچن	filler	filler	j	0
C	شکاندن	افنوس	filler	filler	j	0
C	گریاندن	ارشار	filler	filler	j	0
C	گندیدن	مرازب	filler	filler	j	0
C	گوزیدن	ازغام	filler	filler	j	0
C	لنگیدن	سامیل	filler	filler	j	0
C	نالیدن	زاوان	filler	filler	j	0
C	نامیدن	فیرست	filler	filler	j	0
C	نگریستن	معتار	filler	filler	j	0
C	نهاندن	تچسیس	filler	filler	j	0
C	ورزیدن	فیرتز	filler	filler	j	0
C	وزیدن	کدامل	filler	filler	j	0
C	هراسیدن	ماسمه	filler	filler	j	0
C	آغازیدن	اگباب	filler	filler	j	0
C	ارزیدن	اساسک	filler	filler	j	0
C	افشاندن	مزطفی	filler	filler	j	0
C	انجامیدن	راسقا	filler	filler	j	0
C	بازاندن	اقادث	filler	filler	j	0
C	پذیراندن	تسریک	filler	filler	j	0
C	پیراستن	پیوان	filler	filler	j	0
C	ترکاندن	باگین	filler	filler	j	0

Table D4. Experiment List 4 (Not Randomized)

group	prime	target	condition	primetype	expected	item
D	کرگدن	کردن	d	test	f	1
D	تفاوت	شدن	e	test	f	2
D	میدهم	دادن	a	test	f	3
D	میزدم	زدن	b	test	f	4
D	گرفتم	گرفتن	c	test	f	5
D	روشن	رفتن	d	test	f	6
D	منتظر	داشتن	e	test	f	7
D	مینویسم	نوشتن	a	test	f	8
D	میگفتم	گفتن	b	test	f	9
D	آمدم	آمدن	c	test	f	10
D	سامان	ساختن	d	test	f	11
D	سرمایه	گذاشتن	e	test	f	12
D	میبندم	بستن	a	test	f	13
D	میانداختم	انداختن	b	test	f	14
D	نشستم	نشستن	c	test	f	15
D	انداخت	پرداختن	d	test	f	16
D	احترام	نمودن	e	test	f	17
D	میمیرم	مردن	a	test	f	18
D	میدیدم	دیدن	b	test	f	19
D	خواستم	خواستن	c	test	f	20
D	نواخت	شناختن	d	test	f	21
D	انتقاد	آموختن	e	test	f	22
D	میشوم	شستن	a	test	f	23
D	میگذشتم	گذشتن	b	test	f	24
D	سپردم	سپردن	c	test	f	25
D	دشمن	گشتن	d	test	f	26
D	مقاله	سوختن	e	test	f	27
D	مییابم	یافتن	a	test	f	28
D	میجستم	جستن	b	test	f	29
D	پختم	پختن	c	test	f	30
D	سرویس	سرودن	d	test	f	31
D	پنجره	باختن	e	test	f	32

D	میزدایم	زدودن	a	test	f	33
D	میفروختم	فروختن	b	test	f	34
D	زیستم	زیستن	c	test	f	35
D	گریخت	ریختن	d	test	f	36
D	برادر	کاشتن	e	test	f	37
D	میدوزم	دوختن	a	test	f	38
D	میپیوستم	پیوستن	b	test	f	39
D	کوفتم	کوفتن	c	test	f	40
D	زندان	پنداشتن	d	test	f	41
D	خاموش	افروختن	e	test	f	42
D	میگزینم	گزیدن	a	test	f	43
D	میچیدم	چیدن	b	test	f	44
D	گریختم	گریختن	c	test	f	45
D	میدان	ریدن	d	test	f	46
D	مناسب	خاستن	e	test	f	47
D	میامیزم	آمیختن	a	test	f	48
D	میاندوختم	اندوختن	b	test	f	49
D	انگاشتم	انگاشتن	c	test	f	50
D	پیماییدم	پیماییدن	filler	filler	f	0
D	تپیدی	تپیدن	filler	filler	f	0
D	میتکاندیم	تکاندن	filler	filler	f	0
D	میجنبیدید	جنبیدن	filler	filler	f	0
D	میچرخاندند	چرخاندن	filler	filler	f	0
D	میدرخشیدم	درخشیدن	filler	filler	f	0
D	تجربه	روییدن	filler	filler	f	0
D	حرکت	سوزاندن	filler	filler	f	0
D	باور	شاشیدن	filler	filler	f	0
D	عاقل	شکافتن	filler	filler	f	0
D	میکوبیدم	اندیشید	filler	filler	f	0
D	میبریدی	بارید	filler	filler	f	0
D	میخوابید	جنگید	filler	filler	f	0
D	میپریدم	ورزید	filler	filler	f	0
D	میجوشیدیم	پوشید	filler	filler	f	0
D	میدمیدید	چسبید	filler	filler	f	0
D	میراندند	ترکید	filler	filler	f	0

D	میترسیدم	بوسید	filler	filler	f	0
D	میماندی	نوشید	filler	filler	f	0
D	ایستادیم	خورد	filler	filler	f	0
D	میزنگید	بافت	filler	filler	f	0
D	میحرفیدیم	بخشید	filler	filler	f	0
D	هوش	پوسید	filler	filler	f	0
D	آخر	دزدید	filler	filler	f	0
D	سعی	توانست	filler	filler	f	0
D	سمت	کشت	filler	filler	f	0
D	گل	خندید	filler	filler	f	0
D	پنج	خرید	filler	filler	f	0
D	درون	فهمید	filler	filler	f	0
D	محور	آورد	filler	filler	f	0
D	تنش	پرسید	filler	filler	f	0
D	بنا	رسید	filler	filler	f	0
D	نزدیک	آفرید	filler	filler	f	0
D	ماشین	چرخید	filler	filler	f	0
D	دانش	دوید	filler	filler	f	0
D	آوردیم	آزمایید	filler	filler	f	0
D	میگذراندم	پرورد	filler	filler	f	0
D	میگاییدی	خراشید	filler	filler	f	0
D	میجوشاند	پسندید	filler	filler	f	0
D	میکشاندیم	تنید	filler	filler	f	0
D	میخاریدید	ریسید	filler	filler	f	0
D	میپرستیدند	چکید	filler	filler	f	0
D	میرساندم	جوید	filler	filler	f	0
D	آشامیدم	نازید	filler	filler	f	0
D	میفرمودی	بویید	filler	filler	f	0
D	افراشتند	لرزید	filler	filler	f	0
D	میگداخت	سابید	filler	filler	f	0
D	تاریخ	سپرد	filler	filler	f	0
D	نتیجه	خزید	filler	filler	f	0
D	اسلام	ترکید	filler	filler	f	0
D	خانم	پیچید	filler	filler	f	0
D	تغییر	لغزید	filler	filler	f	0

D	اعدام	کشید	filler	filler	f	0
D	فرهنگ	فرستاد	filler	filler	f	0
D	سیاست	رقصید	filler	filler	f	0
D	لحظه	طلبید	filler	filler	f	0
D	وبلاگ	پاشید	filler	filler	f	0
D	ممکن	کوشید	filler	filler	f	0
D	مختلف	آموخت	filler	filler	f	0
D	زنده	افزود	filler	filler	f	0
D	آکندم	پوشاند	filler	filler	f	0
D	آمیختی	پذیرفت	filler	filler	f	0
D	ایستاندیم	افکند	filler	filler	f	0
D	میپراکندم	پژمرد	filler	filler	f	0
D	میپرهیزیدند	بلعید	filler	filler	f	0
D	میپناهیدید	باراند	filler	filler	f	0
D	میدوشیدم	پسندید	filler	filler	f	0
D	میپراندی	پراند	filler	filler	f	0
D	میبالیدی	بالید	filler	filler	f	0
D	میبالیدند	پیچاند	filler	filler	f	0
D	بازار	دونث	filler	filler	j	0
D	سوال	اخبزر	filler	filler	j	0
D	تعریف	ظاقر	filler	filler	j	0
D	دروغ	انجون	filler	filler	j	0
D	رفتار	مولجه	filler	filler	j	0
D	چهره	چرکیه	filler	filler	j	0
D	اقدام	شنادت	filler	filler	j	0
D	حقیقت	ییهار	filler	filler	j	0
D	رهبر	سوجیه	filler	filler	j	0
D	دراز	خورغن	filler	filler	j	0
D	بزرگ	آراوش	filler	filler	j	0
D	بلند	گرکزی	filler	filler	j	0
D	سینما	متمود	filler	filler	j	0
D	شیشه	دانرد	filler	filler	j	0
D	آرمان	مرنمی	filler	filler	j	0
D	دریا	افتاچ	filler	filler	j	0
D	جاده	هنخام	filler	filler	j	0

D	چاره	ظبوده	filler	filler	j	0
D	مخفی	خوجده	filler	filler	j	0
D	وحشت	خاژمی	filler	filler	j	0
D	توصیه	اجراق	filler	filler	j	0
D	هزینه	خکینی	filler	filler	j	0
D	سپاه	معرنی	filler	filler	j	0
D	رقیب	نباگد	filler	filler	j	0
D	حیرت	داراخ	filler	filler	j	0
D	علامت	رسودن	filler	filler	j	0
D	مشاور	روسیو	filler	filler	j	0
D	لوله	بسهار	filler	filler	j	0
D	میوه	بظشار	filler	filler	j	0
D	حاضر	ابداف	filler	filler	j	0
D	مشکل	ناشهار	filler	filler	j	0
D	شروع	دلتیل	filler	filler	j	0
D	بورس	حدادث	filler	filler	j	0
D	سایت	ذرانه	filler	filler	j	0
D	آسیب	تغویل	filler	filler	j	0
D	اسلام	دیموز	filler	filler	j	0
D	رژیم	گراهی	filler	filler	j	0
D	خارج	قنابع	filler	filler	j	0
D	دوست	نژاهی	filler	filler	j	0
D	حامی	ضلکه	filler	filler	j	0
D	معلم	غسر	filler	filler	j	0
D	زندان	ارلام	filler	filler	j	0
D	اندیشیدم	مانرد	filler	filler	j	0
D	باریدی	گونخ	filler	filler	j	0
D	جنگیدیم	دویش	filler	filler	j	0
D	پاشیدید	عپیه	filler	filler	j	0
D	پوشیدند	لسون	filler	filler	j	0
D	چسبیدم	دهژان	filler	filler	j	0
D	ترکیدی	گرخی	filler	filler	j	0
D	بوسیدیم	فاقن	filler	filler	j	0
D	نوشیدید	موابل	filler	filler	j	0
D	خوردند	خاسنه	filler	filler	j	0

D	بافتم	منفطق	filler	filler	j	0
D	بخشیدی	انیلیس	filler	filler	j	0
D	میپوسیدیم	دقیژا	filler	filler	j	0
D	میدزدیدید	اوکام	filler	filler	j	0
D	توانستند	جوارع	filler	filler	j	0
D	کشتم	اچبات	filler	filler	j	0
D	خندیدی	اخمیل	filler	filler	j	0
D	خریدیم	لانادا	filler	filler	j	0
D	فهمیدید	نیرات	filler	filler	j	0
D	آوردند	مزافع	filler	filler	j	0
D	میپرسیدم	پنباه	filler	filler	j	0
D	میرسیدی	تیویب	filler	filler	j	0
D	آفریدیم	نلارت	filler	filler	j	0
D	میچرخیدید	سندیدن	filler	filler	j	0
D	میدویدند	چرزیدن	filler	filler	j	0
D	آزماییدند	لرمیدن	filler	filler	j	0
D	میپروردم	پیدیدن	filler	filler	j	0
D	میخراشیدی	جیزیدن	filler	filler	j	0
D	میپسندیدیم	کنادن	filler	filler	j	0
D	میتنیدید	فیستادن	filler	filler	j	0
D	میریسیدند	رقدیدن	filler	filler	j	0
D	میچکیدم	طوبیدن	filler	filler	j	0
D	میجویدی	پیگیدن	filler	filler	j	0
D	مینازیدیم	کوریدن	filler	filler	j	0
D	میبوییدید	خکیدن	filler	filler	j	0
D	میلرزیدند	گسدیدن	filler	filler	j	0
D	میسابیدم	فویر	filler	filler	j	0
D	میسپردی	گمیس	filler	filler	j	0
D	میخزیدیم	گرحن	filler	filler	j	0
D	میترکیدند	عزخز	filler	filler	j	0
D	میپیچیدم	آچاد	filler	filler	j	0
D	میلغزیدی	کعمل	filler	filler	j	0
D	میکشیدیم	وسکع	filler	filler	j	0
D	میفرستادید	طقیر	filler	filler	j	0
D	میرقصیدند	شندج	filler	filler	j	0

D	میطلبیدم	شمدث	filler	filler	j	0
D	میپاشیدی	تیزاد	filler	filler	j	0
D	میکوشیدیم	قاطعمش	filler	filler	j	0
D	اندیشیدیم	سیاهسن	filler	filler	j	0
D	میباریدند	ظناور	filler	filler	j	0
D	میکشاندم	اوباب	filler	filler	j	0
D	میپراندی	شلقار	filler	filler	j	0
D	میگردیدیم	مختقر	filler	filler	j	0
D	میکوشیدید	لیوین	filler	filler	j	0
D	میتراشیدند	اسامت	filler	filler	j	0
D	میخوراندم	اشزار	filler	filler	j	0
D	میخواندی	فیزاک	filler	filler	j	0
D	میزاییدیم	ویرچن	filler	filler	j	0
D	شکاندن	افنوس	filler	filler	j	0
D	گریاندن	ارشار	filler	filler	j	0
D	گندیدن	مرازب	filler	filler	j	0
D	گوزیدن	ازغام	filler	filler	j	0
D	لنگیدن	سامیل	filler	filler	j	0
D	نالیدن	زاوان	filler	filler	j	0
D	نامیدن	فیرست	filler	filler	j	0
D	نگریستن	معتار	filler	filler	j	0
D	نهاندن	تچسیس	filler	filler	j	0
D	ورزیدن	فیرتز	filler	filler	j	0
D	وزیدن	کدامل	filler	filler	j	0
D	هراسیدن	ماسمه	filler	filler	j	0
D	آغازیدن	اگباب	filler	filler	j	0
D	ارزیدن	اساسک	filler	filler	j	0
D	افشاندن	مزطفی	filler	filler	j	0
D	انجامیدن	راسقا	filler	filler	j	0
D	بازاندن	اقادث	filler	filler	j	0
D	پذیراندن	تسریک	filler	filler	j	0
D	پیراستن	پیوان	filler	filler	j	0
D	ترکاندن	باگین	filler	filler	j	0

Table D5. Experiment List 5 (Not Randomized)

group	prime	target	condition	primetype	expected	item
E	هنگام	کردن	e	test	f	1
E	میشوم	شدن	a	test	f	2
E	میدادم	دادن	b	test	f	3
E	زدم	زدن	c	test	f	4
E	گران	گرفتن	d	test	f	5
E	اتهام	رفتن	e	test	f	6
E	میدارم	داشتن	a	test	f	7
E	مینوشتم	نوشتن	b	test	f	8
E	گفتم	گفتن	c	test	f	9
E	آماده	آمدن	d	test	f	10
E	احتمال	ساختن	e	test	f	11
E	میگذارم	گذاشتن	a	test	f	12
E	میبستم	بستن	b	test	f	13
E	انداختم	انداختن	c	test	f	14
E	نخست	نشستن	d	test	f	15
E	تعیین	پرداختن	e	test	f	16
E	مینمایم	نمودن	a	test	f	17
E	میمردم	مردن	b	test	f	18
E	دیدم	دیدن	c	test	f	19
E	خراسان	خواستن	d	test	f	20
E	انتقال	شناختن	e	test	f	21
E	میاموزم	آموختن	a	test	f	22
E	میشستم	شستن	b	test	f	23
E	گذشتم	گذشتن	c	test	f	24
E	پرده	سپردن	d	test	f	25
E	سیاست	گشتن	e	test	f	26
E	میسوزم	سوختن	a	test	f	27
E	مییافتم	یافتن	b	test	f	28
E	جستم	جستن	c	test	f	29
E	پوتین	پختن	d	test	f	30
E	ابتدا	سرودن	e	test	f	31
E	میبازم	باختن	a	test	f	32

E	میزدودم	زدودن	b	test	f	33
E	فروختم	فروختن	c	test	f	34
E	سیستم	زیستن	d	test	f	35
E	مخالف	ریختن	e	test	f	36
E	میکارم	کاشتن	a	test	f	37
E	میدوختم	دوختن	b	test	f	38
E	پیوستم	پیوستن	c	test	f	39
E	کودتا	کوفتن	d	test	f	40
E	تعریف	پنداشتن	e	test	f	41
E	میافروزم	افروختن	a	test	f	42
E	میگزیدم	گزیدن	b	test	f	43
E	چیدم	چیدن	c	test	f	44
E	گریبان	گریختن	d	test	f	45
E	کنترل	ریدن	e	test	f	46
E	میخیزم	خاستن	a	test	f	47
E	میامیختم	آمیختن	b	test	f	48
E	اندوختم	اندوختن	c	test	f	49
E	انگشتر	انگاشتن	d	test	f	50
E	پیماییدم	پیماییدن	filler	filler	f	0
E	تپیدی	تپیدن	filler	filler	f	0
E	میتکاندیم	تکاندن	filler	filler	f	0
E	میجنبیدید	جنبیدن	filler	filler	f	0
E	میچرخاندند	چرخاندن	filler	filler	f	0
E	میدرخشیدم	درخشیدن	filler	filler	f	0
E	تجربه	روییدن	filler	filler	f	0
E	حرکت	سوزاندن	filler	filler	f	0
E	باور	شاشیدن	filler	filler	f	0
E	عاقل	شکافتن	filler	filler	f	0
E	میکوبیدم	اندیشید	filler	filler	f	0
E	میبریدی	بارید	filler	filler	f	0
E	میخوابید	جنگید	filler	filler	f	0
E	میپریدم	ورزید	filler	filler	f	0
E	میجوشیدیم	پوشید	filler	filler	f	0
E	میدمیدید	چسبید	filler	filler	f	0
E	میراندند	ترکید	filler	filler	f	0

E	میترسیدم	بوسید	filler	filler	f	0
E	میماندی	نوشید	filler	filler	f	0
E	ایستادیم	خورد	filler	filler	f	0
E	میزنگید	بافت	filler	filler	f	0
E	میحرفیدیم	بخشید	filler	filler	f	0
E	هوش	پوسید	filler	filler	f	0
E	آخر	دزدید	filler	filler	f	0
E	سعی	توانست	filler	filler	f	0
E	سمت	کشت	filler	filler	f	0
E	گل	خندید	filler	filler	f	0
E	پنج	خرید	filler	filler	f	0
E	درون	فهمید	filler	filler	f	0
E	محور	آورد	filler	filler	f	0
E	تنش	پرسید	filler	filler	f	0
E	بنا	رسید	filler	filler	f	0
E	نزدیک	آفرید	filler	filler	f	0
E	ماشین	چرخید	filler	filler	f	0
E	دانش	دوید	filler	filler	f	0
E	آوردیم	آزمایید	filler	filler	f	0
E	میگذراندم	پرورد	filler	filler	f	0
E	میگاییدی	خراشید	filler	filler	f	0
E	میجوشاند	پسندید	filler	filler	f	0
E	میکشاندیم	تنید	filler	filler	f	0
E	میخاریدید	ریسید	filler	filler	f	0
E	میپرستیدند	چکید	filler	filler	f	0
E	میرساندم	جوید	filler	filler	f	0
E	آشامیدم	نازید	filler	filler	f	0
E	میفرمودی	بویید	filler	filler	f	0
E	افراشتند	لرزید	filler	filler	f	0
E	میگداخت	سابید	filler	filler	f	0
E	تاریخ	سپرد	filler	filler	f	0
E	نتیجه	خزید	filler	filler	f	0
E	اسلام	ترکید	filler	filler	f	0
E	خانم	پیچید	filler	filler	f	0
E	تغییر	لغزید	filler	filler	f	0

E	اعدام	کشید	filler	filler	f	0
E	فرهنگ	فرستاد	filler	filler	f	0
E	سیاست	رقصید	filler	filler	f	0
E	لحظه	طلبید	filler	filler	f	0
E	وبلاگ	پاشید	filler	filler	f	0
E	ممکن	کوشید	filler	filler	f	0
E	مختلف	آموخت	filler	filler	f	0
E	زنده	افزود	filler	filler	f	0
E	آکندم	پوشاند	filler	filler	f	0
E	آمیختی	پذیرفت	filler	filler	f	0
E	ایستاندیم	افکند	filler	filler	f	0
E	میپراکندم	پژمرد	filler	filler	f	0
E	میپرهیزیدند	بلعید	filler	filler	f	0
E	میپناهیدید	باراند	filler	filler	f	0
E	میدوشیدم	پسندید	filler	filler	f	0
E	میپراندی	پراند	filler	filler	f	0
E	میبالیدی	بالید	filler	filler	f	0
E	میبالیدند	پیچاند	filler	filler	f	0
E	بازار	دونث	filler	filler	j	0
E	سوال	اخبزر	filler	filler	j	0
E	تعریف	ظاقر	filler	filler	j	0
E	دروغ	انجون	filler	filler	j	0
E	رفتار	مولجه	filler	filler	j	0
E	چهره	چرکیه	filler	filler	j	0
E	اقدام	شنادت	filler	filler	j	0
E	حقیقت	ییهار	filler	filler	j	0
E	رهبر	سوجیه	filler	filler	j	0
E	دراز	خورغن	filler	filler	j	0
E	بزرگ	آراوش	filler	filler	j	0
E	بلند	گرکزی	filler	filler	j	0
E	سینما	متمود	filler	filler	j	0
E	شیشه	دانرد	filler	filler	j	0
E	آرمان	مرنمی	filler	filler	j	0
E	دریا	افتاچ	filler	filler	j	0
E	جاده	هنخام	filler	filler	j	0

E	چاره	ظبوده	filler	filler	j	0
E	مخفی	خوجده	filler	filler	j	0
E	وحشت	خاژمی	filler	filler	j	0
E	توصیه	اجراق	filler	filler	j	0
E	هزینه	خکینی	filler	filler	j	0
E	سپاه	معرنی	filler	filler	j	0
E	رقیب	نباگد	filler	filler	j	0
E	حیرت	داراخ	filler	filler	j	0
E	علامت	رسودن	filler	filler	j	0
E	مشاور	روسیو	filler	filler	j	0
E	لوله	بسهار	filler	filler	j	0
E	میوه	بظشار	filler	filler	j	0
E	حاضر	ابداف	filler	filler	j	0
E	مشکل	ناشهار	filler	filler	j	0
E	شروع	دلتیل	filler	filler	j	0
E	بورس	حدادث	filler	filler	j	0
E	سایت	ذرانه	filler	filler	j	0
E	آسیب	تغویل	filler	filler	j	0
E	اسلام	دیموز	filler	filler	j	0
E	رژیم	گراهی	filler	filler	j	0
E	خارج	قنابع	filler	filler	j	0
E	دوست	نژاهی	filler	filler	j	0
E	حامی	ضلکه	filler	filler	j	0
E	معلم	غسر	filler	filler	j	0
E	زندان	ارلام	filler	filler	j	0
E	اندیشیدم	مانرد	filler	filler	j	0
E	باریدی	گونخ	filler	filler	j	0
E	جنگیدیم	دویش	filler	filler	j	0
E	پاشیدید	عپیه	filler	filler	j	0
E	پوشیدند	لسون	filler	filler	j	0
E	چسبیدم	دهژان	filler	filler	j	0
E	ترکیدی	گرخی	filler	filler	j	0
E	بوسیدیم	فاقن	filler	filler	j	0
E	نوشیدید	موابل	filler	filler	j	0
E	خوردند	خاسنه	filler	filler	j	0

E	بافتم	منفطق	filler	filler	j	0
E	بخشیدی	انیلیس	filler	filler	j	0
E	میپوسیدیم	دقیژا	filler	filler	j	0
E	میدزدیدید	اوکام	filler	filler	j	0
E	توانستند	جوارع	filler	filler	j	0
E	کشتم	اچبات	filler	filler	j	0
E	خندیدی	اخمیل	filler	filler	j	0
E	خریدیم	لانادا	filler	filler	j	0
E	فهمیدید	نیرات	filler	filler	j	0
E	آوردند	مزافع	filler	filler	j	0
E	میپرسیدم	پنباه	filler	filler	j	0
E	میرسیدی	تیویب	filler	filler	j	0
E	آفریدیم	نلارت	filler	filler	j	0
E	میچرخیدید	سندیدن	filler	filler	j	0
E	میدویدند	چرزیدن	filler	filler	j	0
E	آزماییدند	لرمیدن	filler	filler	j	0
E	میپروردم	پیدیدن	filler	filler	j	0
E	میخراشیدی	جیزیدن	filler	filler	j	0
E	میپسندیدیم	کنادن	filler	filler	j	0
E	میتنیدید	فیستادن	filler	filler	j	0
E	میریسیدند	رقدیدن	filler	filler	j	0
E	میچکیدم	طوبیدن	filler	filler	j	0
E	میجویدی	پیگیدن	filler	filler	j	0
E	مینازیدیم	کوریدن	filler	filler	j	0
E	میبوییدید	خکیدن	filler	filler	j	0
E	میلرزیدند	گسدیدن	filler	filler	j	0
E	میسابیدم	فویر	filler	filler	j	0
E	میسپردی	گمیس	filler	filler	j	0
E	میخزیدیم	گرحن	filler	filler	j	0
E	میترکیدند	عزخز	filler	filler	j	0
E	میپیچیدم	آچاد	filler	filler	j	0
E	میلغزیدی	کعمل	filler	filler	j	0
E	میکشیدیم	وسکع	filler	filler	j	0
E	میفرستادید	طقیر	filler	filler	j	0
E	میرقصیدند	شندج	filler	filler	j	0

E	میطلبیدم	شمدث	filler	filler	j	0
E	میپاشیدی	تیزاد	filler	filler	j	0
E	میکوشیدیم	قاطعمش	filler	filler	j	0
E	اندیشیدیم	سیاهسن	filler	filler	j	0
E	میباریدند	ظناور	filler	filler	j	0
E	میکشاندم	اوباب	filler	filler	j	0
E	میپراندی	شلقار	filler	filler	j	0
E	میگردیدیم	مختقر	filler	filler	j	0
E	میکوشیدید	لیوین	filler	filler	j	0
E	میتراشیدند	اسامت	filler	filler	j	0
E	میخوراندم	اشزار	filler	filler	j	0
E	میخواندی	فیزاک	filler	filler	j	0
E	میزاییدیم	ویرچن	filler	filler	j	0
E	شکاندن	افنوس	filler	filler	j	0
E	گریاندن	ارشار	filler	filler	j	0
E	گندیدن	مرازب	filler	filler	j	0
E	گوزیدن	ازغام	filler	filler	j	0
E	لنگیدن	سامیل	filler	filler	j	0
E	نالیدن	زاوان	filler	filler	j	0
E	نامیدن	فیرست	filler	filler	j	0
E	نگریستن	معتار	filler	filler	j	0
E	نهاندن	تچسیس	filler	filler	j	0
E	ورزیدن	فیرتز	filler	filler	j	0
E	وزیدن	کدامل	filler	filler	j	0
E	هراسیدن	ماسمه	filler	filler	j	0
E	آغازیدن	اگباب	filler	filler	j	0
E	ارزیدن	اساسک	filler	filler	j	0
E	افشاندن	مزطفی	filler	filler	j	0
E	انجامیدن	راسقا	filler	filler	j	0
E	بازاندن	اقادث	filler	filler	j	0
E	پذیراندن	تسریک	filler	filler	j	0
E	پیراستن	پیوان	filler	filler	j	0
E	ترکاندن	باگین	filler	filler	j	0

APPENDIX E

ETHICS COMMITTEE APPROVAL

Evrak Tarih ve Sayısı: 26.03.2022-59470

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
SOSYAL VE BEŞERİ BİLİMLER YÜKSEK LİSANS VE DOKTORA TEZLERİ ETİK İNCELEME KOMİSYONU
TOPLANTI KARAR TUTANAĞI

Toplantı Sayısı	:	29
Toplantı Tarihi	:	24.03.2022
Toplantı Saati	:	10:00
Toplantı Yeri	:	Zoom Sanal Toplantı
Bulunanlar	:	Prof. Dr. Ebru Kaya, Dr. Öğr. Üyesi Yasemin Sohtorik İlkmen
Bulunmayanlar	:	

Aref Milani
Dilbilim

Sayın Araştırmacı,
"Farsça Karmaşık Fiil Formlarında Ayrışma Kapsamı" başlıklı projeniz ile ilgili olarak yaptığınız SBB-EAK 2022/17 sayılı başvuru komisyonumuz tarafından 24 Mart 2022 tarihli toplantıda incelenmiş ve uygun bulunmuştur.

Bu karar tüm üyelerin toplantıya çevrimiçi olarak katılımı ve oybirliği ile alınmıştır. COVID-19 önlemleri kapsamında kurul üyelerinden ıslak imza alınamadığı için bu onay mektubu üye ve raportör olarak Yasemin Sohtorik İlkmen tarafından bütün üyeler adına e-imzalanmıştır.

Saygılarımızla, bilgilerinizi rica ederiz.

Dr. Öğr. Üyesi Yasemin
SOHTORİK İLKMEN
ÜYE

e-imzalıdır
Dr. Öğr. ÜyesiYasemin Sohtorik
İlkmen
Öğretim Üyesi
Raportör

SOBETİK 29 24.03.2022

Bu belge, güvenli elektronik imza ile imzalanmıştır.

APPENDIX F

THE PCIBEX CODE USED TO DESIGN THE ONLINE EXPERIMENT

```
PennController.ResetPrefix(null);
var showProgressBar = false;
var progressBarText = false;
DebugOff()
Sequence("consent", "Welcome", "instructions_1", "instructions_2",
"instructions_3",
        "instructions_4", "practice", "start", "warmup", randomize("block_1"),
"rest_pause_1",
        randomize("block_2"), "rest_pause_2", randomize("block_3"), "send", "final")
newTrial("consent",
    newHtml("consent_form", "consent.html")
        .cssContainer({"width":"720px"})
        .checkboxWarning("برای ادامه بایستی تیک باکس اعلام رضایت را بزنید")
        .print()
    ,
    newButton("continue", "برای شرکت کلیک کنید")
        .center()
        .print()
        .wait(getHtml("consent_form").test.complete()
                  .failure(getHtml("consent_form").warn())
        )
)
```

```
newTrial("Welcome",

   defaultText.settings.css("font-size", "3em").print()

   ,

   newText("welcome_1", "خوش آمدید")

   ,

newButton("welcome_button", "برای ادامه کلیک کنید")

       .settings.css("font-size", "3em")

       .center()

       .print()

       .wait()

)

newTrial("instructions_1",

   defaultText.settings.css("font-size", "0.55em").print()

   ,

   newText("instruction_1", " در این آزمایش شما تشخیص خواهید داد که آیا رشته حروفی که در وسط صفحه مرورگر نمایان میشوند کلمات واقعی را در زبان فارسی تشکیل میدهند یا خیر")

   ,

   newText("instruction_2", " منظور از کلمات واقعی در زبان فارسی کلماتی هستند که در گفتار و جامعه رایج هستند حتی اگر ریشه خارجی داشته باشند ")

   ,

   newText("instruction_4", "برای انجام این کار، اگر این رشته حروف یک کلمه واقعی در زبان فارسی را تشکیل میدهد کلید F را فشار دهید")

   ,

   newText("instruction_5", "در غیر این صورت کلید J را فشار دهید")

   ,
```

```
newText("instruction_6", "F = کلمه واقعی")

,

newText("instruction_7", "J = کلمه غیرواقعی")

,

newText("instruction_8", " به علت نیاز به کیبورد، پیشنهاد میشود برای انجام این آزمایش فقط از
لپ تاپ و یا رایانه شخصی خود استفاده کنید ")

,

newScale("check_understanding", "موارد ذکر شده را کاملا متوجه شدم")

    .checkbox()

    .settings.css("font-size", "1.3em")

    .center()

    .print()

,

newButton("continue_button", "برای ادامه کلیک کنید")

    .settings.css("font-size", "1.3em")

    .center()

    .print()

    .wait(getScale("check_understanding").test.selected())

)

newTrial("instructions_2",

defaultText.settings.css("font-size", "0.55em").print()

,

newText("instruction_9", "  به دلیل بررسی فرانید نیم کره های چپ و راست مغز و ارتباط آن با
تحلیل کلمات تاکید میشود به هنگام پاسخ دهی")

,
```

```
    newText("instruction_10", " F انگشت اشاره دست چپ خود را بر روی کلید")
    ,
    newText("instruction_11", "و انگشت اشاره دست راست خود را بر روی کلید J قرار دهید")
    ,
    newText("instruction_12", " لازم به ذکر است استفاده از یک دست برای هر دو کلید و یا پاسخ
دهی با سایر انگشت ها در روند آزمایش اخلال ایجاد میکند")
    ,
    newText("instruction_13", "لطفا پاسخ خود را در حد امکان با سرعت و دقت درج کنید")
    ,
    newText("instruction_14", " از آنجایی که خوانش بلند کلمات سرعت انجام آزمایش را کاهش
میدهد، از ادای کلمات با صدای بلند پرهیز کنید")
    ,
    newScale("check_understanding_2", "موارد ذکر شده را کاملا متوجه شدم")
        .checkbox()
        .settings.css("font-size", "1.3em")
        .center()
        .print()
    ,
    newButton("continue_button_2", "برای ادامه کلیک کنید")
        .settings.css("font-size", "1.3em")
        .center()
        .print()
        .wait(getScale("check_understanding_2").test.selected())
)
newTrial("instructions_3",
```

```
    defaultText.settings.css("font-size", "0.55em").print()
    ,
  newText("instruction_15", " قبل از انجام آزمایش، از انگلیسی بودن زبان کیبورد خود اطمینان حاصل فرمایید")
  ,
  newText("instruction_16", "مدت زمان این آزمایش حدود 15 دقیقه میباشد")
  ,
  newText("instruction_17", "لطفا سن خود را با ارقام انگلیسی درج کنید")
  ,
  newTextInput("input_age")
    .cssContainer({"margin-bottom":"2em"})
    .center()
    .print()
  ,
  newButton("wait_1", "برای ادامه کلیک کنید")
    .settings.css("font-size", "2em")
    .center()
    .print()
    .wait(getTextInput("input_age").test.text(/[1-9][0-9]/))
  ,
  getButton("wait_1").remove()
  ,
  newText("instruction_18", "لطفا جنسیت خود را female و برای مرد male انتخاب نمایید برای زن")
  ,
```

```
newScale("check_gender", "male", "female")
    .checkbox()
    .center()
    .print()
,
newButton("wait_2", "برای ادامه کلیک کنید")
    .settings.css("font-size", "2em")
    .center()
    .print()
    .wait(getScale("check_gender").test.selected())
,
getButton("wait_2").remove()
,
newText("instruction_19", "آیا به زبان فارسی تسلط بالایی دارید؟ لطفا برای بله Yes و برای خیر No را انتخاب نمایید")
,
newScale("check_language_1", "Yes", "No")
    .checkbox()
    .center()
    .print()
,
newButton("wait_3", "برای ادامه کلیک کنید")
    .settings.css("font-size", "2em")
    .center()
    .print()
```

```
    .wait(getScale("check_language_1").test.selected())
,
getButton("wait_3").remove()
,
newText("instruction_20", "آیا به زبان دیگری خیلی Yes و برای خیر No را انتخاب فرمایید
بیشتر از فارسی تسلط دارید؟ برای بله")
,
newScale("check_language_2", "Yes", "No")
    .checkbox()
    .center()
    .print()
,
newButton("wait_4", "برای ادامه کلیک کنید")
    .settings.css("font-size", "2em")
    .center()
    .print()
    .wait(getScale("check_language_2").test.selected())
,
getButton("wait_4").remove()
,
newText("instruction_21", " لطفا قبل از ادامه از درج شدن اطلاعات خود در باکسهای بالا
اطمینان حاصل فرمایید")
,
newText("instruction_22", " پس از درج نام خود با حروف انگلیسی، بر روی کلید «ادامه»
کلیک کنید")
```

```
,
newTextInput("input_ID")
    .cssContainer({"margin-bottom":"2em"})
    .center()
    .print()
,
newButton("wait_5", "برای ادامه کلیک کنید")
    .settings.css("font-size", "2em")
    .center()
    .print()
    .wait(getTextInput("input_ID").test.text(/[^0-9]/))
,
newVar("age")
    .global()
    .set(getTextInput("input_age")).log()
,
newVar("gender")
    .global()
    .set(getScale("check_gender")).log()
,
newVar("farsi_yes")
        .global()
        .set(getScale("check_language_1")).log()
,
newVar("other_yes")
```

```
        .global()
        .set(getScale("check_language_2")).log()
,
newVar("ID")
    .global()
    .set(getTextInput("input_ID")).log()
)
newTrial("instructions_4",
defaultText.settings.css("font-size", "0.55em").print()
,
newText("instruction_23", " روند آزمایش بدین گونه است که قبل از نمایش کلمات، در مرکز
صفحه نمایش، علامت + و سپس ###### نمایان خواهد شد")
,
newText("instuction_24", "پس از نمایان شدن کلمات، کلیدهای مربوطه را باید فشار دهید")
,
newText("instruction_25", "F = کلمه واقعی")
,
newText("instruction_26", "J = کلمه غیرواقعی")
,
newText("instruction_27", " لطفا در طول پاسخدهی نگاه خود را روی مرکز صفحه نمایشگر
متمرکز کنید")
,
newText("instruction_29", " و حتما قبل از دیدن کلمات، از دیدن علامت + و ###### اطمینان
حاصل فرمایید")
,
```

```
    newText("instruction_30", " همچنین، در طول پاسخدهی انگشتان مربوطه را روی کلیدهای مربوطه نگهدارید")
    ,
    newText("instruction_31", " لازم به  یادآوری است که در حین پاسخدهی امکان توقف آزمایش میسر نخواهد بود")
    ,
    newText("instruction_32", " هدف از این آزمایش، سنجش دانش زبان فارسی شما نبوده و صرفا به طبیعی ترین حالت ممکن پاسخ خود را انتخاب کنید")
    ,
    newText("instruction_33", " لطفا در انتهای آزمایش، برای دریافت نمره اضافی، کد درس مربوطه و شماره دانشجویی خود را درج نمایید")
    ,
    newText("instruction_34", " قبل از شروع آزمایش، یک نمونه از نحوه پاسخدهی انجام خواهید داد")
    ,
    newButton("wait", "برای انجام نمونه کلیک کنید")
        .settings.css("font-size", "2em")
        .center()
        .print()
        .wait()
    )
newTrial("practice"
    ,
    newText("practice_trial", "تمرین")
        .color("blue")
```

```
        .print("center at 50vw","top at 1em")
    ,
    defaultText.settings.css("font-size", "2em").center().print("center at 50vw","middle at 50vh")
    ,
    defaultTimer.start().wait()
    ,
    newText("blank_1_practice", "")
    ,
    newTimer("blank_1_timer_practice", 500)
    ,
    getText("blank_1_practice")
        .remove()
    ,
    newText("asterisk_practice", "+")
    ,
    newTimer("asterisk_timer_practice", 500)
    ,
    getText("asterisk_practice")
        .remove()
    ,
    newText("blank_2_practice", "")
    ,
    newTimer("blank_2_timer_practice", 500)
    ,
```

```
getText("blank_2_practice")
    .remove()
,
newText("practice_mask", "#######")
,
newTimer("practice_mask_timer", 500)
,
getText("practice_mask").remove()
,
newText("practice_prime", "مداد")
,
newTimer("practice_prime_timer", 50)
,
getText("practice_prime").remove()
,
newText("practice_target", "کتاب")
,
newTooltip("guide", "اگر این رشته حروف یک کلمه واقعی در زبان فارسی F را فشار دهید
است کلید")
    .position("bottom center")
    .key("", "no click")
    .print(getText("practice_target"))
,
newKey("answer_practice_Target", "FJ")
    .wait()
```

```
        .test.pressed("F")
        .success(getTooltip("guide").text("<p> بله «کتاب» یک کلمه فارسی میباشد <br> برای ادامه کلید SPACE را فشار دهید </p>"))
        .failure(getTooltip("guide").text("<p> پاسخ شما نادرست است. برای کلمات واقعی باید کلید F را فشار دهید <br> برای ادامه کلید SPACE را فشار دهید </p>"))
    ,
    getTooltip("guide")
        .label("")
        .key(" ")
        .wait()
    ,
    getText("practice_target").remove()
)

newTrial("start",
    newButton("wait", "برای شروع آزمایش کلیک کنید")
        .settings.css("font-size", "2em")
        .center()
        .print()
        .wait()
)
Template("Warm_up.csv", row =>
    newTrial("warmup"
    ,
```

```
    defaultText.settings.css("font-size", "2em").center().print("center at 50vw","middle at 50vh").log()
    ,
    defaultTimer.log().start().wait()
    ,
    newText("blank_1_warmup", "")
    ,
    newTimer("blank_1_timer_warmup", 500)
    ,
    getText("blank_1_warmup")
        .remove()
    ,
    newText("asterisk_warmup", "+")
    ,
    newTimer("asterisk_timer", 500)
    ,
    getText("asterisk_warmup")
        .remove()
    ,
    newText("blank_2_warmup", "")
    ,
    newTimer("blank_2_timer_warmup", 500)
    ,
    getText("blank_2_warmup")
        .remove()
```

```
,
newText("mask_warmup", "#######")
,
newTimer("mask_timer_warmup", 500)
,
getText("mask_warmup")
    .remove()
,
newText("prime_warmup", row.prime)
,
newTimer("prime_timer_warmup", 50)
,
getText("prime_warmup")
    .remove()
,
newText("target", row.target)
    .log()
,
newKey("answer_target", "FJ")
    .log().wait()
,
getText("target").remove
)
.log("group"     , row.group)
.log("condition" , row.condition)
```

```
    .log( "expected"  , row.expected )
    .log( "target_type", row.target_type)
    .log( "item", row.item )
    .log("ID", getVar("ID"))
    .log("age", getVar("age"))
    .log("farsi_yes", getVar("farsi_yes"))
    .log("other_yes", getVar("other_yes"))
    .log("gender", getVar("gender"))
)
Template("block_1.csv", row =>
    newTrial("block_1"
    ,
    defaultText.settings.css("font-size", "2em").center().print("center at
50vw","middle at 50vh").log()
    ,
    defaultTimer.log().start().wait()
    ,
    newText("blank_1_block_1", "")
    ,
    newTimer("blank_1_timer_block_1", 500)
    ,
    getText("blank_1_block_1")
        .remove()
    ,
    newText("asterisk_block_1", "+")
```

```
,
newTimer("asterisk_timer_block_1", 500)
,
getText("asterisk_block_1")
    .remove()
,
newText("blank_2_block_1", "")
,
newTimer("blank_2_timer_block_1", 500)
,
getText("blank_2_block_1")
    .remove()
,
newText("mask_block_1", "#######")
,
newTimer("mask_timer_block_1", 500)
,
getText("mask_block_1")
    .remove()
,
newText("prime_block_1", row.prime)
,
newTimer("prime_timer_block_1", 50)
,
getText("prime_block_1")
```

```
        .remove()
    ,
    newText("target", row.target)
        .log()
    ,
    newKey("answer_target", "FJ")
        .log().wait()
    ,
    getText("target").remove
    )
    .log("group"     , row.group)
    .log("condition" , row.condition)
    .log( "expected"  , row.expected )
    .log( "target_type", row.target_type )
    .log( "item", row.item )
    .log("ID", getVar("ID"))
    .log("age", getVar("age"))
    .log("farsi_yes", getVar("farsi_yes"))
    .log("other_yes", getVar("other_yes"))
    .log("gender", getVar("gender"))
)
newTrial("rest_pause_1",
    newText("rest_pause_1", "وقت استراحت")
        .center()
        .print()
```

```
    ,
    newButton("rest_button_1", "برای ادامه کلیک کنید")
        .center()
        .print()
        .wait()
)
Template("block_2.csv", row =>
    newTrial("block_2"
    ,
    defaultText.settings.css("font-size", "2em").center().print("center at
50vw","middle at 50vh").log()
    ,
    defaultTimer.log().start().wait()
    ,
    newText("blank_1_block_2", "")
    ,
    newTimer("blank_1_timer_block_2", 500)
    ,
    getText("blank_1_block_2")
        .remove()
    ,
    newText("asterisk_block_2", "+")
    ,
    newTimer("asterisk_timer_block_2", 500)
    ,
```

```
getText("asterisk_block_2")
    .remove()
,
newText("blank_2_block_2", "")
,
newTimer("blank_2_timer_block_2", 500)
,
getText("blank_2_block_2")
    .remove()
,
newText("mask_block_2", "#######")
,
newTimer("mask_timer_block_2", 500)
,
getText("mask_block_2")
    .remove()
,
newText("prime_block_2", row.prime)
,
newTimer("prime_timer_block_2", 50)
,
getText("prime_block_2")
    .remove()
,
newText("target", row.target)
```

```
        .log()
    ,
    newKey("answer_target", "FJ")
        .log().wait()
    ,
    getText("target").remove
    )
    .log("group"     , row.group)
    .log("condition" , row.condition)
    .log( "expected"  , row.expected )
    .log( "target_type", row.target_type )
    .log( "item", row.item )
    .log("ID", getVar("ID"))
    .log("age", getVar("age"))
    .log("farsi_yes", getVar("check_language_1"))
    .log("other_yes", getVar("check_language_2"))
    .log("gender", getVar("gender"))
)
newTrial("rest_pause_2",
    newText("rest_pause_2", "وقت استراحت")
        .center()
        .print()
    ,
    newButton("rest_button_2", "برای ادامه کلیک کنید")
        .center()
```

```
        .print()
        .wait()
)
Template("block_3.csv", row =>
    newTrial("block_3"
    ,
    defaultText.settings.css("font-size", "2em").center().print("center at
50vw","middle at 50vh").log()
    ,
    defaultTimer.log().start().wait()
    ,
    newText("blank_1_block_3", "")
    ,
    newTimer("blank_1_timer_block_3", 500)
    ,
    getText("blank_1_block_3")
        .remove()
    ,
    newText("asterisk_block_3", "+")
    ,
    newTimer("asterisk_timer_block_3", 500)
    ,
    getText("asterisk_block_3")
        .remove()
    ,
```

```
newText("blank_2_block_3", "")

,

newTimer("blank_2_timer_block_3", 500)

,

getText("blank_2_block_3")

    .remove()

,

newText("mask_block_3", "#######")

,

newTimer("mask_timer_block_3", 500)

,

getText("mask_block_3")

    .remove()

,

newText("prime_block_3", row.prime)

,

newTimer("prime_timer_block_3", 50)

,

getText("prime_block_3")

    .remove()

,

newText("target", row.target)

    .log()

,

newKey("answer_target", "FJ")
```

```
        .log().wait()
    ,
    getText("target").remove
    )
    .log("group"     , row.group)
    .log("condition" , row.condition)
    .log( "expected"  , row.expected )
    .log( "target_type", row.target_type )
    .log( "item", row.item )
    .log("ID", getVar("ID"))
    .log("age", getVar("age"))
    .log("farsi_yes", getVar("check_language_1"))
    .log("other_yes", getVar("other_yes"))
    .log("gender", getVar("gender"))
)
SendResults("send")
newTrial("final",
    defaultText.settings.css("font-size", "2em").print()
    ,
    newText("thanks_1", "ممنون از وقتتان")
    ,
    newText("thanks_2", "میتوانید مرورگرتان را ببندید")
    ,
    newButton().wait()
)
```

APPENDIX G

THE R CODE FOR MODEL 1 USED IN STATISTICAL ANALYSIS

```
library(MASS)
library(tidyverse)
library(brms)
library(lme4)
library(broom)
library(bayesplot)
library(rstanarm)
library(rstan)
library(purrr)
library(modelr)
library(ggdist)
library(tidybayes)
library(gganimate)
library(posterior)
library(magrittr)
# load in the filtered resutls of the experiment


results_filtered <- read.csv("results_filtered.csv")
accuracy_by_subject <-
  results_filtered %>% group_by(subjects) %>%
  summarize( accuracy =  mean(correct) ) %>%
  arrange(accuracy)
```

```
accuracy_by_subject %>% ggplot(aes(accuracy)) + geom_histogram()

# remove low-accuracy subjects
threshold_accuracy = .75
subjects_low_accuracy <- accuracy_by_subject %>% subset( accuracy <
threshold_accuracy ) %>% .$subjects
results_filtered %<>% subset( !subjects %in% subjects_low_accuracy )

# remove incorrect responses
results_filtered %<>% subset( correct == 1 )

# remove fillers
results_filtered %<>% subset( condition != "filler" )

# exclude 'outliers'
rt_max = 2000
rt_min = 250
results_filtered %<>%  filter(reaction_time < rt_max & reaction_time > rt_min )

# results_filtered %>% filter(reaction_time > rt_min, reaction_time < 5000) %>%
ggplot(aes(reaction_time, fill = condition == "filler")) + geom_histogram() +
#   facet_wrap(~subjects) + theme_bw() + scale_x_log10()

# convert subject and item to factors
results_filtered %<>% mutate(subject = as.factor(subjects), item = as.factor(item))
```

```
# log RT
results_filtered %<>% mutate( log_RT = log(reaction_time) )


# a summary of the data
results_simple <-
  results_filtered %>%
  group_by(condition) %>%
  summarize(n = n(),
            mean = mean(reaction_time),
            sd = sd(reaction_time),
            se = sd/sqrt(n),
            ci = qt(0.975, df = n - 1) * sd/sqrt(n),
            min = min(reaction_time),
            max = max(reaction_time)) #%>% view()


# creating contrasts
df_conditions_ced <- results_filtered %>% filter(condition %in% c('c', 'e', 'd')) %>%
mutate(condition = as.factor(condition))
df_conditions_ced$cEmC <- df_conditions_ced$condition %>% dplyr::recode("c" =
-2/3, "e" =  1/3, "d" = 1/3)
df_conditions_ced$cDmE <- df_conditions_ced$condition %>% dplyr::recode("c" =
-1/3, "e" = -1/3, "d" = 2/3)
contr.sdif(3)
df_conditions_ced %>% select(cEmC, cDmE) %>% unique()
```

```
# fitting the model
m_ced <- brm(data = df_conditions_ced,
        family = gaussian(),
        formula = log_RT ~ cEmC + cDmE + (1 + cEmC + cDmE | subject) + (1 +
cEmC + cDmE | item),
        prior = c(prior(normal(6.5, 0.3), class = Intercept),
              prior(normal(0, 1), class = b),
              prior(normal(0.3, 0.1), class = sd)),
        sample_prior = "yes",
        iter = 3000, warmup = 1000, chains = 4, cores = 4,
        control = list(adapt_delta = .8, max_treedepth = 20),
        seed = 190831, file = 'model_ced')

# check the estimates of the model
print(m_ced)

# plotting
post <- posterior_samples(m_ced, par = c("b_cEmC", "b_cDmE"))

# plot for posterior predictions
mcmc_intervals(post,
         prob = .5,
         prob_outer = 0.95,
         point_est = "median") +
```

```
  labs(title = "Coefficient Plot") +
  theme(axis.text.y  = element_text(hjust = 0),
        axis.line.x  = element_line(size = 1),
        axis.line.y  = element_blank(),
        axis.ticks.y = element_blank())

# histogram of posterior distributions
hist(post$b_cEmC, xlab = 'cEmC', main = 'Posterior predictions for e_vs_c')
hist(post$b_cDmE, xlab = 'cDmE', main = 'Posterior predictions for d_vs_e')

mean(post$b_cEmC > 0)
mean(post$b_cDmE > 0)
```

REFERENCES

Allen, M., & Badecker, W. (1999). Stem homograph inhibition and stem allomorphy: representing and processing inflected forms in a multilevel lexical system. *Journal of Memory and Language, 41*(1), 105–123.

Allen, M., & Badecker, W. (2002). Inflectional regularity: Probing the nature of lexical representation in a cross-modal priming task. *Journal of Memory and Language, 46*(4), 705–722.

Amenta, S., & Crepaldi, D. (2012). Morphological processing as we know it: An analytical review of morphological effects in visual word identification. *Frontiers in Psychology, 3*.

Andoni Dunabeitia, J., Perea, M., & Carreiras, M. (2008). Does darkness lead to happiness? Masked suffix priming effects. *Language and Cognitive Processes, 23*(7–8), 1002–1020.

Andrews, S., & Lo, S. (2013). Is morphological priming stronger for transparent than opaque words? It depends on individual differences in spelling and vocabulary. *Journal of Memory and Language, 68*(3), 279–296.

Aristar, A. R. (1991). On diachronic sources and synchronic pattern: An investigation into the origin of linguistic universals. *Language, 67*(1), 1–33.

Aronoff, M. (1976). *Word formation in generative grammar*. MIT Press.

Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language, 37*(1), 94–117.

Baayen, R. H., Milin, P., Đurđević, D. F., Hendrix, P., & Marelli, M. (2011). An amorphous model for morphological processing in visual comprehension based on naive discriminative learning. *Psychological Review, 118*(3), 438.

Baayen, R. H., & Smolka, E. (2020). Modeling morphological priming in German with naive discriminative learning. *Frontiers in Communication, 5*, 17. https://doi.org/10.3389/fcomm.2020.00017

Baluch, B. (1992). Reading with and without vowels: What are the psychological consequences? *Journal of Social and Evolutionary Systems, 15*(1), 95–104. https://doi.org/10.1016/1061-7361(92)90039-G

Bentin, S., & Feldman, L. B. (1990). The contribution of morphological and semantic relatedness to repetition priming at short and long lags: Evidence from Hebrew. *The Quarterly Journal of Experimental Psychology, 42*(4), 693–711.

Beyersmann, E., Casalis, S., Ziegler, J. C., & Grainger, J. (2015). Language proficiency and morpho-orthographic segmentation. *Psychonomic bulletin & review*, *22*(4), 1054-1061.

Beyersmann, E., Cavalli, E., Casalis, S., & Colé, P. (2016). Embedded stem priming effects in prefixed and suffixed pseudowords. *Scientific Studies of Reading, 20*(3), 220–230.

Bock, K., Levelt, W., & Gernsbacher, M. A. (2002). Language production: Grammatical encoding. *Psycholinguistics: Critical concepts in psychology*, *5*, 405-452.

Burani, C., & Caramazza, A. (1987). Representation and processing of derived words. *Language and Cognitive Processes, 2*(3–4), 217–227.

Burani, C., & Laudanna, A. (1992). Units of representation for derived words in the lexicon. In *Advances in psychology* (Vol. 94, pp. 361–376). North-Holland.

Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software, 80*, 1–28.

Butterworth, G. (1983). Structure of the mind in human infancy. *Advances in Infancy Research*.

Caramazza, A., Laudanna, A., & Romani, C. (1988). Lexical access and inflectional morphology. *Cognition, 28*(3), 297–332.

Carr, T. H., Davidson, B. J., & Hawkins, H. L. (1978). Perceptual flexibility in word recognition: Strategies affect orthographic computation but not lexical access. *Journal of Experimental Psychology: Human Perception and Performance, 4*(4), 674.

Chateau, D., Knudsen, E. V., & Jared, D. (2002). Masked priming of prefixes and the influence of spelling–meaning consistency. *Brain and Language, 81*(1–3), 587–600.

Chetail, F., & Boursain, E. (2019). Shared or separated representations for letters with diacritics? *Psychonomic Bulletin & Review, 26*(1), 347–352.

Chialant, D., & Caramazza, A. (1995). Where is morphology and how is it processed? The case of written word recognition. *Morphological Aspects of Language Processing*, 55–76.

Ciaccio, L. A., Kgolo, N., & Clahsen, H. (2020). Morphological decomposition in Bantu: A masked priming study on Setswana prefixation. *Language, Cognition and Neuroscience, 35*(10), 1257–1271.

Crepaldi, D., Hemsworth, L., Davis, C. J., & Rastle, K. (2016). Masked suffix priming and morpheme positional constraints. *Quarterly Journal of Experimental Psychology, 69*(1), 113–128.

Crepaldi, D., Rastle, K., Coltheart, M., & Nickels, L. (2010). ‘Fell’ primes ‘fall’, but does ‘bell’ prime ‘ball’? Masked priming with irregularly-inflected primes. *Journal of Memory and Language, 63*(1), 83–99.

Crepaldi, D., Rastle, K., Davis, C. J., & Lupker, S. J. (2013). Seeing stems everywhere: Position-Independent identification of stem morphemes. *Journal of Experimental Psychology: Human Perception and Performance, 39*(2), 510.

Dabir-Moghaddam, M. (2020). Typological approaches and dialects. In *The Oxford Handbook of Persian Linguistics*.

Dabir-Moghaddam, M. (1997). Compound verbs in Persian.

Davis, M. H., & Rastle, K. (2010). Form and meaning in early morphological processing: Comment on Feldman, O’Connor, and Moscoso del Prado Martín (2009). *Psychonomic Bulletin & Review, 17*(5), 749–755.

Dehdari, J. (2006). Crossing dependencies in Persian. 62.

Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological priming: Unravelling morpho-orthographic and morpho-semantic influences in early word recognition. *Language and Cognitive Processes, 20*(1–2), 75–114.

Diependaele, K., Sandra, D., & Grainger, J. (2009). Semantic transparency and masked morphological priming: The case of prefixed words. *Memory & Cognition, 37*(6), 895–908.

Dominguez, A., Segui, J., & Cuetos, F. (2002). The time-course of inflexional morphological priming.

Drews, E., & Zwitserlood, P. (1995). Morphological and orthographic similarity in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21*(5), 1098.

Elman, J. L. (2004). An alternative view of the mental lexicon. *Trends in Cognitive Sciences, 8*(7), 301–306.

Feldman, L. B., & Andjelković, D. (1992). Morphological analysis in word recognition. *Advances in Psychology, 94*, 343–360.

Feldman, L. B., O’Connor, P. A., & del Prado Martín, F. M. (2009). Early morphological processing is morphosemantic and not simply morpho-orthographic: A violation of form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review, 16*(4), 684–691.

Forster, K. I. (1989). Basic issues in lexical processing.

Forster, K. I., & Azuma, T. (2000). Masked priming for prefixed words with bound stems: Does submit prime permit? *Language and Cognitive Processes, 15*(4–5), 539–561.

Forster, K. I., & Bednall, E. S. (1976). Terminating and exhaustive search in lexical access. *Memory & Cognition, 4*(1), 53–61.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*(4), 680.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? *The Quarterly Journal of Experimental Psychology, 39*(2), 211–251.

Fowler, C. A., Napps, S. E., & Feldman, L. (1985). Relations among regular and irregular morphologically related words in the lexicon as revealed by repetition priming. *Memory & Cognition, 13*(3), 241–255.

Frommer, P. R. (1982). POST-VERBAL PHENOMENA IN COLLOQUIAL PERSIAN SYNTAX.

Frost, R., Forster, K. I., & Deutsch, A. (1997). What can we learn from the morphology of Hebrew? A masked-priming investigation of morphological representation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*(4), 829.

Gaskell, M. G., & Marslen-Wilson, W. D. (1997). Integrating form and meaning: A distributed model of speech perception. *Language and Cognitive Processes, 12*(5–6), 613–656.

Gaskell, M. G., & Marslen-Wilson, W. D. (2001). Lexical ambiguity resolution and spoken word recognition: Bridging the gap. *Journal of Memory and Language, 44*(3), 325–349.

Gaskell, M. G., & Marslen-Wilson, W. D. (2002). Representation and competition in the perception of spoken words. *Cognitive Psychology, 45*(2), 220–266.

Giraudo, H., & Grainger, J. (2000). Effects of prime word frequency and cumulative root frequency in masked morphological priming. *Language and Cognitive Processes, 15*(4–5), 421–444.

Giraudo, H., & Grainger, J. (2001). Priming complex words: Evidence for supralexical representation of morphology. *Psychonomic Bulletin & Review, 8*(1), 127–131.

Giraudo, H., & Grainger, J. (2003a). A supralexical model for French derivational morphology. In *Reading Complex Words* (pp. 139–157). Springer, Boston, MA.

Giraudo, H., & Grainger, J. (2003b). On the role of derivational affixes in recognizing complex words: Evidence from masked priming. *Trends in Linguistics Studies and Monographs, 151*, 209–232.

Giraudo, H., & Voga, M. (2013). Prefix units within the mental lexicon.

Grainger, J., & Beyersmann, E. (2017). Edge-Aligned embedded word activation initiates morpho-orthographic segmentation. In *Psychology of Learning and Motivation* (Vol. 67, pp. 285–317). Academic Press.

Grainger, J., Colé, P., & Segui, J. (1991). Masked morphological priming in visual word recognition. *Journal of Memory and Language, 30*(3), 370–384.

Grainger, J., & Segui, J. (1990). Neighborhood frequency effects in visual word recognition: A comparison of lexical decision and masked identification latencies. *Perception & Psychophysics*, *47*(2), 191–198.

Greenberg, J. H. (1954). Historical linguistics and unwritten languages in Anthropology Today, AL Kroeber, ed.

Hariri, M. S. (1995). An Introduction to Persian, by Wheeler M. Thackston (Book Review). *Middle East Journal, 49*(2), 347.

Haspelmath, M., & Sims, A. (2013). *Understanding morphology*. Routledge.

Jackendoff, R. (1975). Morphological and semantic regularities in the lexicon. *Language*, 639–671.

Järvikivi, J., & Niemi, J. (2002). Form-Based representation in the mental lexicon: Priming (with) bound stem allomorphs in Finnish. *Brain and Language, 81*(1–3), 412–423.

Järvikivi, J., Pyykkönen, P., & Niemi, J. (2009). Exploiting degrees of inflectional ambiguity: Stem form and the time course of morphological processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(1), 221.

Karimi, S. (1997). Persian complex verbs: Idiomatic or compositional. *LEXICOLOGY-BERLIN-, 3*, 273–318.

Karimi, S. (2008). A minimalist approach to scrambling. In *A Minimalist Approach to Scrambling*. De Gruyter Mouton.

Kazanina, N. (2011). Decomposition of prefixed words in Russian. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*(6), 1371–1390.

Kempley, S. T., & Morton, J. (1982). The effects of priming with regularly and irregularly related words in auditory word recognition. *British Journal of Psychology*, *73*(4), 441–454.

Kouider, S., & Dehaene, S. (2007). Levels of processing during non-conscious perception: A critical review of visual masking. *Philosophical Transactions: Biological Sciences*, *362*(1481,), 857–875.

Laudanna, A., Badecker, W., & Caramazza, A. (1989). Priming homographic stems. *Journal of Memory and Language*, *28*(5), 531–546.

Laudanna, A., Badecker, W., & Caramazza, A. (1992). Processing inflectional and derivational morphology. *Journal of Memory and Language, 31*(3), 333–348.

Laudanna, A., & Burani, C. (1985). Address mechanisms to decomposed lexical entries.

Laudanna, A., & Burani, C. (1995). Distributional properties of derivational affixes: Implications for processing. *Morphological Aspects of Language Processing*, 345–364.

Laudanna, A., Burani, C., & Cermele, A. (1994). Prefixes as processing units. *Language and Cognitive Processes*, *9*(3), 295–316.

Lázaro, M., García, L., & Illera, V. (2021). Morpho-Orthographic segmentation of opaque and transparent derived words: New evidence for Spanish. *Quarterly Journal of Experimental Psychology, 74*(5), 944–954.

Levenshtein, V. (1965). Binary codes capable of correcting spurious insertions and deletion of ones. *Problems of Information Transmission, 1*(1), 8–17.

Lieber, R. (2021). *Introducing morphology*. Cambridge University Press.

Longtin, C.-M., Segui, J., & Hallé, P. A. (2003). Morphological priming without morphological relationship. *Language and Cognitive Processes, 18*(3), 313–334.

Lukatela, G., Gligorijević, B., Kostić, A., & Turvey, M. T. (1980). Representation of inflected nouns in the internal lexicon. *Memory & Cognition, 8*(5), 415–423.

Mahootian, S., & Gerbhardt, L. (1997). *Persian*. London & New York.

Marslen-Wilson, W., & Tyler, L. K. (2013). Rules, representations, and the English past tense. *Exploring Cognition: Damaged Brains and Neural Networks*, 315-332.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology, 18*(1), 1–86.

McClelland, J. L., & Johnston, J. C. (1977). The role of familiar units in perception of words and nonwords. *Perception & Psychophysics*, *22*(3), 249–261.

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

Meunier, F., & Segui, J. (2002). Cross-modal morphological priming in French. *Brain and Language, 81*(1–3), 89–102.

Milin, P., Smolka, E., & Feldman, L. B. (2017). Models of lexical access and morphological processing. *The Handbook of Psycholinguistics*, 240–268.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76*(2), 165.

Mueller, S. T., & Weidemann, C. T. (2012). Alphabetic letter identification: Effects of perceivability, similarity, and bias. *Acta Psychologica, 139*(1), 19–37.

Münte, T. F., Say, T., Clahsen, H., Schiltz, K., & Kutas, M. (1999). Decomposition of morphologically complex words in English: Evidence from event-related brain potentials. *Cognitive Brain Research, 7*(3), 241–253.

Nabors, R. (2019). *A Comprehensive Analysis of Simple Verbs in Persian* (Doctoral dissertation, The University of Arizona).

Naghshbandi, Z. (2020). The Oxford Handbook of Persian Linguistics, Sedighi Anousha and Shabani-Jadidi Pouneh (eds.), Oxford: Oxford University Press, 2018, ISBN 978-0-19-873674-5 (hbk), 608 pp. *Iranian Studies, 53*(3–4), 664–668.

Napps, S. E. (1989). Morphemic relationships in the lexicon: Are they distinct from semantic and formal relationships? *Memory & Cognition, 17*(6), 729–739.

Nikolova, R., & Jarema, G. (2002). Interaction of morphological structure and prefix transparency in the processing of Bulgarian aspectual verb forms. *Brain and Language, 81*(1–3), 649–665.

Oldfield, R. C. (1966). Things, words and the brain. *Quarterly Journal of Experimental Psychology, 18*(4), 340–353.

Perea, M., Baciero, A., & Marcet, A. (2021). Does a mark make a difference? Visual similarity effects with accented vowels. *Psychological Research, 85*(6), 2279–2290.

Perea, M., & Panadero, V. (2014). Does viotin activate violin more than viocin? On the use of visual cues during visual-word recognition. *Experimental psychology, 61*(1), 23.

Pinker, S. (1991). Rules of language. *Science, 253*(5019), 530–535.

Pinker, S. (1999). *Words and rules: The ingredients of language*. Basic Books.

Pinker, S., & Prince, A. (1994). Regular and irregular morphology and the psychological status of rules of grammar. *The Reality of Linguistic Rules, 321*, 51.

Podesva, R. J., & Sharma, D. (2014). *Research methods in linguistics*. Cambridge University Press.

Prince, A., & Pinker, S. (1988). Rules and connections in human language. *Trends in Neurosciences, 11*(5), 195–202.

Protopapas, A., & Gerakaki, S. (2009). Development of processing stress diacritics in reading Greek. *Scientific Studies of Reading, 13*(6), 453–483.

Team, R. C. (2013). R: A language and environment for statistical computing.

Rastle, K. (2016). Visual word recognition. In *Neurobiology of language* (pp. 255–264). Academic Press.

Rastle, K., & Davis, M. H. (2008). Morphological decomposition based on the analysis of orthography. *Language and Cognitive Processes, 23*(7–8), 942–971.

Rastle, K., Davis, M. H., Marslen-Wilson, W. D., & Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes*, *15*(4–5), 507–537.

Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-Orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review, 11*(6), 1090–1098.

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology, 81*(2), 275.

Rueckl, J. G., & Galantucci, B. (2005). The locus and time course of long-term morphological priming. *Language and Cognitive Processes, 20*(1–2), 115–138.

Rumelhart, D. E., & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: II. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review, 89*(1), 60.

Schreuder, R., & Baayen, R. H. (1994). Prefix stripping re-revisited. *Journal of Memory and Language, 33*(3), 357–375.

Schreuder, R., & Baayen, R. H. (1995). *Modeling morphological processing. Morphological Aspects of Language Processing, 2,* 257–294.

Seidenberg, M. S., & Gonnerman, L. M. (2000). Explaining derivational morphology as the convergence of codes. *Trends in Cognitive Sciences, 4*(9), 353–361.

Sonnenstuhl, I., Eisenbeiss, S., & Clahsen, H. (1999). Morphological priming in the German mental lexicon. *Cognition, 72*(3), 203–236.

Stanners, R. F., Neiser, J. J., Hernon, W. P., & Hall, R. (1979). Memory representation for morphologically related words. *Journal of Verbal Learning and Verbal Behavior, 18*(4), 399–412.

Stemberger, J. P., & MacWhinney, B. (1986). Frequency and the lexical storage of regularly inflected forms. *Memory & Cognition, 14*(1), 17–26.

Stemberger, J. P., & MacWhinney, B. (1988). Are inflected forms stored in the lexicon? (pp. 101-116). na.

Stockall, L., Manouilidou, C., Gwilliams, L., Neophytou, K., & Marantz, A. (2019). Prefix stripping re-re-revisited: MEG Investigations of morphological decomposition and recomposition. *Frontiers in Psychology, 10*, 1964.

Stockall, L., & Marantz, A. (2006). A single route, full decomposition model of morphological complexity: MEG evidence. *The Mental Lexicon, 1*(1), 85–123.

Stolz, J. A., & Feldman, L. B. (1995). The role of orthographic and semantic transparency of the base morpheme in morphological processing. *Morphological Aspects of Language Processing, 17*, 412.

Taft, M. (1979). Recognition of affixed words and the word frequency effect. *Memory & Cognition, 7*(4), 263–272.

Taft, M. (1981). Prefix stripping revisited. *Journal of Verbal Learning and Verbal Behavior, 20*(3), 289–297.

Taft, M. (1988). A morphological-decomposition model of lexical representation.

Taft, M. (1994). Interactive-activation as a framework for understanding morphological processing. *Language and Cognitive Processes, 9*(3), 271–294.

Taft, M. (2003). Morphological representation as a correlation between form and meaning. In *Reading Complex Words* (pp. 113–137). Springer, Boston, MA.

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *The Quarterly Journal of Experimental Psychology Section A, 57*(4), 745–765.

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior, 14*(6), 638–647.

Taft, M., & Nguyen-Hoan, M. (2010). A sticky stick? The locus of morphological representation in the lexicon. *Language and Cognitive Processes, 25*(2), 277–296.

Traxler, M. J. (2011). *Introduction to psycholinguistics: Understanding language science.*

Ullman, M. T. (2001). The neural basis of lexicon and grammar in first and second language: The declarative/procedural model. *Bilingualism: Language and Cognition, 4*(2), 105–122.

Ullman, M. T. (2016). The declarative/procedural model: A neurobiological model of language learning, knowledge, and use. In *Neurobiology of language* (pp. 953–968). Academic Press.

Van den Bussche, E., Van den Noortgate, W., & Reynvoet, B. (2009). Mechanisms of masked priming: A meta-analysis. *Psychological Bulletin, 135*(3), 452–477.

Voga, M., & Giraudo, H. (2009). Pseudo-family size influences the processing of French inflections: Evidence in favor of a supralexical account. *Selected Proceedings of the 6th Décembrettes: Morphology in Bordeaux*, 148–155.

Wheeler, D. D. (1970). Processes in word recognition. *Cognitive Psychology, 1*(1), 59–85.

Wray, S., Stockall, L., & Marantz, A. (2022). Early form-based morphological decomposition in Tagalog: MEG evidence from reduplication, infixation, and circumfixation. *Neurobiology of Language*, *3*(2), 235–255.

Zehr, J., & Schwarz, F. (2018). Penncontroller for internet based experiments (ibex).