HEARING WORDS WITHOUT STRUCTURE: SUBLIMINAL SPEECH PRIMING AND THE ORGANIZATION OF THE MOROCCAN ARABIC LEXICON

by

Kevin Thomas Schluter

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF LINGUISTICS

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA
2013

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Kevin Thomas Schluter entitled Hearing Words Without Structure: Subliminal Speech Priming and the Organization of the Moroccan Arabic Lexicon and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Date: 15 April 2013

Adam Ussishkin

Date: 15 April 2013

Samira Farwaneh

Date: 15 April 2013

Kenneth Forster

Date: 15 April 2013

Michael Hammond

Date: 15 April 2013

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copies of the dissertation to the Graduate College.
I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Date: 15 April 2013

Dissertation Director: Adam Ussishkin

STATEMENT BY AUTHOR

SIGNED: Kevin Thomas Schluter

ACKNOWLEDGEMENTS

This dissertation would never have been written without the support–moral and occasionally physical–from countless people, who must be counted here.

First and foremost, thanks go to everyone who made me feel like I had a home in one of over a dozen places I called home in the past five years, especially: My family, Zack, Levi, Sajida, Katherine, Alan, Brian, Shannon, Eugene, Javier, Alex, Colin, Curtis, Mike, Adam, Andy, Dan, Yusuf, Doug, Megan, Tim, Mark, Libby, Erin, Ute, Justin, Safaa, Charles, and Matt.

Next, I must thank everyone who helped in Morocco, whether or not they know it, especially Terri, Brandon, Ute, Mounir, Cherif, Oussama, Hicham, Oumayma, Hassan, Ayoub, Fatima, Safaa, Tamam, Rachael, Samantha, and Madame Gentille, as well as Drs. Lahrouchi, Louriz, and Bensoukas.

Without my amazing committee members and their advice, I would have left Morocco with a much inferior product. I also have to thank Diana Archangeli, Janet Nicol, and Amy Fountain for all their help and advice.

Colin Gorrie and Megan Schildmier Stone helped keep me on track through the whole process, and I can only hope that I returned the favor.

Last, but not least, I am very grateful for the American Institute for Maghreb Studies who supported my research in Morocco, along with the Grad College at the U of A, the U of A Linguistics department, and the Social and Behavioral Sciences Research Institute.

DEDICATION

To all sentient beings.

TABLE OF CONTENTS

TABLE OF CONTENTS – *Continued*

TABLE OF CONTENTS – *Continued*

TABLE OF CONTENTS – *Continued*

TABLE OF CONTENTS – *Continued*

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This dissertation investigates the mental representation of the root in the Moroccan dialect of spoken Arabic. While morphemes like roots have traditionally been defined as the smallest unit of sound-meaning correspondence, this definition has been long known to be problematic (Hockett, 1954). Other theories suggest that roots may be abstract units devoid of phonological or semantic content (Pfau, 2009; Harley, 2012) or that words are the basic unit of the mental lexicon (Aronoff, 1994, 2007; Blevins, 2006). The root of Moroccan words is examined with auditory priming experiments, using auditory lexical decision tasks, including the subliminal speech priming technique (Kouider and Dupoux, 2005). Chapter 2 shows that the subliminal speech priming technique should be modified with primes compressed uniformly to 240ms for Moroccan Arabic (the compression rate varies to achieve the uniform 240ms prime duration).

Chapters 3 and 4 apply supraliminal and subliminal speech priming technique to Moroccan Arabic. The priming effect of words that share a root are found to be robust and distinct from words which simply share semantic or phonological content. Furthermore, roots which are instantiated as novel coinages produce priming effects, which further suggests that the root is a structural unit. Each related word in a morphological family, however, does not prime all of its relatives, contradicting the idea of a root as a structural unit. These subliminal effects also differ from supraliminal effects, where overlap in phonological form between the prime and target results in facilitation when identifying the target. The results of these experiments suggest that the word is the basic unit of speech perception, rather

than the root. The root is is not an mental unit but a property of words or relationship among a morphological family. Competition from phonological neighbors is a late effect, since shared phonology facilitates only with the supraliminal technique but not the subliminal technique. Finally, realizational theories of morphology are supported, since take the word as the basic unit of the lexicon.

While the root may not have phonological content *per se*, root phonology is important for deriving morphological families. Chapter 4 uses weak roots (which do not consistently show three root consonants in each derived form) to show that semi-vowels are encoded as root consonants.

CHAPTER 1

INTRODUCTION – SEMITIC ROOTS, MOROCCAN ARABIC, AND LEXICAL ORGANIZATION

1.1 Introduction

Since the inception of modern linguistics with Baodouin de Courtenay and Ferdinand de Saussure at the end of the 19th and beginning of the 20th century, the field of linguistics has sought to understand the system of language in the minds of its speakers. One key aspect of the field is morphology, the study of words and their composition. Morphemes, or compositional word-elements, were defined early on as "the smallest individually meaningful element in the utterances of a language" (Hockett 1958:123). Though this definition is not without trouble (cf. Aronoff 1976; Anderson 1992; Aronoff 1994; Blevins 2006, etc.), the desire to explain the structure of words with a clear number of sound-meaning correspondences is still alive and well within the field. While concatenative morphology is relatively simple to dissect (e.g., the word *unbelievable* is composed of the prefix *un-* and stem *believable*. *Believable* itself is composed of the root *believe* and the suffix *-able*), non-concatenative morphology of the *sing–sang–sung* type is problematic for grammatical theories and psycholinguistic theories since the sound-meaning correspondences are less clear and more difficult to chop into meaningful chunks. In other words, prefixation and suffixation are so easy to account for in grammatical theories that they are almost uninteresting. Many languages of the world, however, display morphology much more complex than simple affixation. The affixes of Navajo blend with stems and one another, making it difficult to determine where one morpheme ends and another begins (Fountain, 1998). Tohono O'odham words loose phonological material in derived forms (Hill and Zepeda, 1992; Fitzgerald, 1997). Dinka, a Nilo-Saharan language of the Sudan, utilizes vowel length, tone, and voice quality in multimorphemic but monosyllabic verb stems (Andersen, 1995). Lakhota final vowels undergo stem-conditioned ablaut and sound-symbolism (Ingham, 2003; Ullrich, 2008). Even Latin–and other well-known European languages–shows an array of verbal conjugation types with meaningless, but regular, morphemes (Aronoff, 1976; Matthews, 1972). These complex types of morphology represent the margins of morphological systems in the world's languages, and it is these exquisite types of word-formation and inflection that require deeper explanations.

There are many challenges to morpheme-based theories of word-formation, including: zero-morphemes, null-morphemes, stem-internal changes, and multiple exponence. This is because each of these violates the 1:1 form-meaning correspondence which is the canonical morpheme. Take English plural formation, for example. While the plural *-s* is our standard, we also have *sheep*, *fish*, and *moose* which are both singular and plural. There is no overt minimal sound-meaning unit these plurals. Furthermore, there are morpheme-like elements which are semantically empty, rather than phonologically empty. The *buccan-* of <u>*buccan*</u>*eer*, the *o* of *music*<u>*o*</u>*logy*, and the *caboodle* of *kit and* <u>*caboodle*</u> all appear to be morpheme-like because they have other morpheme-like parts. However these "morphemes" have no meaning in and of themselves. A single unit of sound may also correspond to multiple units of meaning, as in English *am* 'first person singular' and *ain't* 'second person singular negative' or Latin *amic-i* ' FRIEND- MASCULINE.NOMINATIVE.SINGULAR'. A "morpheme" can even be subtractive, such as French *œuf* [œf] 'egg' ∼ *œfs* [ø] 'eggs' Tohono O'odham perfectives are related to the imperfective by truncation as in [hɨhɨm] 'to laugh' and[hɨhɨ] 'laughed (perfective)' or [cɨpʂiɖ] 'to brand' ∼ [cɨpoʂ] 'brand (perfective)' (Zepeda, 1983). Some "morphemes" also occur word-internally, such as in English *sing*, *sang*, and *sung*. Thus, we might argue distinct stems are used for the verbal SING concept in English, but it is also plausible to consider the alternating vowel an infix as well. Problematic morphemes such as these can even occur in combinations, such as in English words *concept*, *conceive*, *perceive*, *perception*, *deceive*, *deception*, or *inception*. The prefixes in these examples (i.e., *per*-, *de*-, and *in*-) do not have a meaning on their own, neither does the root *-ceive*. The root itself has an allomorph *-cept-* in conjunction with the suffix *-ion*. Furthermore, not each of these prefixes, stem allomorphs, and suffixes can be used, such as the nonword **inceive*. Most speakers would prefer *begin* to **inceive*. Semitic roots fall into the same class of problems as the preceding examples.

Complex stem changes of the type seen in Semitic languages (e.g., /katab-/ 'wrote', /kaatib/ 'author') perplex linguists because these are not a small number of words confined within some ghetto of the mental lexicon, but a pervasive system used by speakers of all Semitic languages from Akkadian to Zway. The system of non-concatenative morphology seen in Semitic languages can even be considered *the* defining feature of the language family. These types of complex stem modification can be distilled into a number of abstract grammatical templates, but how such templates are represented and manipulated is the true debate for non-concatenative morphophonology, both in terms of linguistic and psycholinguistic theory.

This dissertation investigates how morphologically complex words are represented in the mind. Specifically, it investigates the underlying reality of the discontinuous root morpheme in Moroccan Arabic. The focus here is on the lexical properties of the root and how they can inform linguistic theory. Is the root a discontinuous element of sound-meaning correspondence? Testing this hypothesis requires developing a methodology appropriate to test the earliest and most automatic aspects of word recognition (chapter 2), distinguishing morphological processing from phonological and semantic processing (chapter 3), and investigating distinct classes of roots (chapter 4).

1.1.1 What this dissertation is about

This dissertation accomplishes three things. First, it adapts the subliminal speech priming technique–an all-auditory experimental technique–for Moroccan Arabic. Second, it shows that the root cannot be reduced to semantics or phonology alone, and that this is a property of words. Finally, despite the fact that the root is a property of words, I show that the sort of phonological content theorists would associate with roots is, in fact, vital to the root representation.

1.1.2 What this dissertation does not cover

This dissertation remains agnostic on a number of issues. First and foremost, I focus on the root, testing whether or not it is a morpheme. While we can assume that the results related to roots as morphemes might be applicable to the pattern as a morpheme (or McCarthy (1981)'s skeleton and melody) or even prefixes and suffixes, those remain unexplored areas of researchdom.

Next, this dissertation focuses on auditory processing of a spoken dialect of Arabic. On the assumption that root and pattern morphology defines the Semitic family and roots are used in the lexical access process, all Semitic languages should show a similar pattern of results. Though the empirical scope is solely Moroccan Arabic, we may likewise assume that the results will generalize to Hebrew, Standard Arabic, Amharic, Tigrinya, Tigré, the Aramaic languages, the Gurage languages of Ethiopia, Maltese, and the modern Mahrian language of Yemen and Oman, as well as ancient languages like Akkadian, Phonecian, and Ugaritic. It is worth noting that, if roots do not enable processing in some way, that not all Semitic languages should be expected to use roots or patterns.

Finally, I assume that a more complete theory of language must incorporate not only the symbolic evidence of language competence, but behavioral and neurophysiological evidence from language processing and performance as well. Thus, in light of two competing formal linguistic theories, behavioral or neurophysiological data may be used to distinguish which formal theory is more plausible.

1.2 Conclusion

This chapter first reviews templatic morphology in general. Second, I briefly examine Moroccan Arabic, the empirical focus of this dissertation. Next I review linguistic theory as it applies to the root morpheme in Semitic (in general). Finally I review the psycholinguistic evidence for the Semitic root morpheme.

1.3 What is Templatic Morphology?

Templatic morphology is a specific type of word-formation which is unlike the familiar affixation (prefixes and suffixes) of most European languages. Before turning to Moroccan Arabic specifically, it is worthwhile to look at templatic morphology from a broader perspective. This section looks at templatic morphology from a cross-linguistic perspective so that the oddities of Semitic can be brought to light.

1.3.1 Templatic Morphology from a Cross-Linguistic Perspective

The naïve notion of a template in general is a pattern or outline that is used for reproducing things. Like an artist's stencil, templates allow the same basic shape to be repeated though the precise contents of that shape can vary (e.g., in terms of color, texture, etc.). The same concept applies to words in human language.

As a phenomenon, rather than a theoretical construct, linguistic templates refer not types of prefixes, suffixes, or infixes, but rather to the (re)arrangement of segmental and supersegmental material between related words in a morphological paradigm (broadly construed to include derivational as well as inflectional morphology). Templates are a stable phonological shape, and can be described with consonant or vowel slots, or in more general prosodic terms. Thus, the basic Semitic verbal template is often described as CVCVC because the Semitic verb stem usually has three consonants and two vowels in the same arrangement (e.g., Hebrew /katav/ 'he wrote', Standard Arabic /katab-a/ 'he wrote'). Templates are sometimes called grades, measures, stems, *'awzaan* (Arabic, singular *wazn*) or *binyanim* (Hebrew, singular *binyan*). In Semitic, we see at least one more part to the template, because consonant quality indicates (broadly speaking) the lexical meaning. Thus, Interleaved with the Semitic vocalic and prosodic pattern is the consonantal root, which is also known as the *shoresh* (Hebrew), *jidher* (Arabic), *zär* (Ge'ez) or *asrew* (Ge'ez, singular *särw*).

In most languages, related words vary primarily in terms of prefixes and suffixes. In English, for example, verbs have related forms like *grow* and *growing*. The GROW family, in this sense, is just like any other verb in English having the bare and the *-ing* forms. Templates, on the other hand, enforce a specific arrangement of two or more segments, subsegments, supersegments, or morphemes. Nothing templatic can be identified in a vacuum; a template must be identified based on some level of shared form and meaning (i.e., semantic, morphological and/or phonological). In English, the GROW family has a non-concatenative relationship between the non-past (*grow*) and past (*grew*, not **growed*) forms. When multiple word families show the same pattern of relations (including Blow, Know, and THROW) we can call that a template, and define a rule which captures the alternations between word forms. In this case, the past form and the non-past form differ in vowel quality [oʊ] versus [u]. Novel or nonstandard forms can be expected to follow this pattern, such as *snow* and ?*snew*.

Complex templates can be found in many languages. A few examples are given below:

1. Tiene (Bantu; Hyman, 2006; Hyman and Inkelas, 1997) shows a template sensitive to both prosodic and segmental content. The stative or reversive morpheme has two allomorphs: /l/ and /k/ (with predictable vowel qualities). These are used as suffixes or infixes to fit a bisyllabic pattern in which the final consonant is not coronal while the medial consonant is ([CV[+Coronal]V[-Coronal]): compare /ból-a/ 'break' and /bólek-ɛ/ 'be broken' with /kab-a/ 'divide' and /kalab-a/ 'be divided'.

2. Choctaw (Muskogean; Broadwell, 2006) displays approximately five or six stem-internal modifications which express different meanings. Compare the following three basic verbs with their derived counterparts: basic /bashlih/ 'he cut it' with the nasalized N-grade /bã́shlih/ 'he keeps cutting it' with nasalization and stress on the first syllable, basic /habishkoh/ 'he sneezed' with HN-grade /habihĩ́shkoh/ 'he sneezed repeatedly' with [-hĩ́-]] added as the penultimate syllable, and basic /taloowah/ 'he is singing' with the geminating G-grade /tálloowah/ 'he finally sang' with gemination of the initial consonant of the second syllable. The internal changes affect all verbs of a given grade identically, and include nasalization and high tone in the N-grade, an additional internal syllable (also nasalized and bearing high tone) in the HN-grade, and high tone and gemination in the G-grade.

3. Dutch (Germanic; Booij, 1998) has plurals, which take the allomorphs *-en* or *-s* in plural formation allowing one to predict which allomorph is to be selected based on the phonological structure of the base, notably there is an

output restriction that the Dutch plural should fill a trochaic template. Thus, trochaic *kánon* [kaːnɔn] 'canon' takes the *-s* plural (*kanons*) while iambic *kanón* [kaːnɔn] takes the *-en* plural (*kanonnen* [kaːnɔnən]) to create a word-final trochee).

4. In Hausa (Chadic; Newman, 2000), each verb grade is associated with a specific tone pattern which overwrites the basic grade 2 low-high pattern for bisyllabic stems: /sàyaː/ 'G2 sell', /sayèː/ 'G4 buy up', /sayaɾ/ 'G5 sell', /sayoː/ 'G6 buy and bring', and /sàyu/ 'G7 be well bought'. Again, each grade in Hausa affects each stem in the same way.

5. Not all templates hold only of words within a word family. Sometimes every word of a language may be subject to a templatic restriction, such as minimal or maximal size constraints in terms of the syllable or mora. Turkish (Turkic; Inkelas and Orgun, 1995) shows this for some speakers /fa + m/ [faːm] 'my note *Fa* (musical term)' where the vowel is lengthened to reach the bimoraic minimal word requirement.

What is striking about these templates is that all of them can be captured in terms of prosodic and morphological units, even in Tiene where coronals are dispreferred at the edge of the stem. I turn now to a discussion of why Semitic defies these conventions.

1.3.2 Templatic Morphology in Semitic–Roots and Patterns

Where templatic behavior has been observed, modern linguistic theory relies on using prosodic elements to account for this uniformity. Semitic languages display what is probably the clearest example known templatic system of any of the languages of the world. Not only are there templates for distinct verb forms (causatives, passives, comittatives, etc.) but they also exist for many noun types (place nouns, instrument nouns, occupational nouns, deverbal nouns, etc.). From the $\sqrt{ktb}$ family, we find Arabic forms like kataba 'he wrote', maktaba 'bookstore, library', and kaatib 'author, writer' which differ in terms of the root consonants and meaning from the $\sqrt{drs}$ family (darasa 'he studied', madrasa 'school', and daaris 'student, one who studies'). What is striking about Semitic languages, however, is that the templatic behavior is described as root-governed, rather than prosodically (i.e., rhythmically) governed. Such a morphologically dominated description ignores the prosodic descriptions that characterize Semitic and other languages. Thus, linguists talk about second-consonant gemination (i.e., doubling) or roots with abstract phonemes as one of the three phonemes of the root (e.g., deriving the Arabic word *qam* from the root $\sqrt{qwm}$.). The root seems to always require three consonantal elements and position-targeting rules (Faust and Hever, 2010). This makes Semitic morphology seem unique in the world's languages, as there are not morphological or phonological boundaries which seem to correspond to descriptive statements like 'second root consonant'.

1.3.3 Conclusion

As this brief survey shows, many languages of the world, from typologically and genetically diverse language families, have abstract restrictions on the shape of words which cannot be easily defined in terms of prefixation or suffixation. This makes templatic morphology interesting and raises questions of what the mental representation of templatic morphology might look like. I turn now to survey how linguistic theory interprets Semitic morphology.

1.4 Why Moroccan Arabic?

Moroccan Arabic provides a new way to address the problem of the Semitic root which has yet to be well-tested. Hebrew, as a revived language, may show non-Semitic influence. Similarly Classical Arabic is a fossilized formal language; it is no one's first language. Even Maltese which shows some evidence for the root (Twist, 2006; Ussishkin et al., 2013) has lost half of its Semitic vocabulary which makes finding items difficult. Furthermore, Moroccan Arabic is a spoken dialect only. Speakers rarely write it, because there is no standard orthography for the dialect. When writing in the Arabic script, for example, the sound [g] does not exist in classical Arabic, so it can be written with the graphemes <غ> (Classical [ɣ], typical in formal writing), <گ> (Persian, sometimes found in handwriting or on computers because it is a more easily accessible symbol), or <ڭ> (Offical Moroccan, found on official signs and rarely elsewhere). Moroccan Arabic is sometimes written in the Roman alphabet as well, often with French-style grapheme-phoneme correspondences such that the word /ʃnu/ 'what' might be written *chnou* though the English-style is also found *shnoo*, while the word /bɣa/ 'he wanted' might be written *bra* or *bgha*. Moroccan Arabic is interesting, then, because it a) is living Arabic dialect, b) has unique properties when it comes to vowels and their representation, and c) its speakers know it is not the same as the Classical language. In this section I examine these properties first and then the templatic morphology of Moroccan Arabic.

1.4.1 Linguistic Properties of Moroccan Arabic

First, as a dialect of Arabic, Moroccan Arabic is learned as a first language in the home, which cannot entirely be said of any formal, written language (Arabic, Hebrew, or elsewhere in Semitic). Arabic is a dialect continuum with diglossia, meaning the language varies systematically and gradually from Casablanca to Dubai, and from Damascus to San'a. The disparate dialects, however, are united by the formal standard language, which is based on the usage in the Qur'an, the holy book of Islam. Arabic displays a highly diglossic situation, where the variety used in literature, news broadcasting, political speeches, and academic discourse is based on the Classical language of the Qur'an, while the language of daily life differs along an extremely large dialect continuum. Moroccan Arabic is a variety of this dialect continuum and may be free from some of the influences of an artificially preserved Classical language which is formally taught in school, and the consonant-heavy writing system of Standard and Classical Arabic.

Second, Moroccan Arabic has a dramatically reduced vowel inventory, where discontinuity of the root morphemes is called into question. While some dialects of Arabic have truly discontinuous roots, Moroccan Arabic contains many words with simply a single schwa [ə] as their lone vowel. Thus, from the root $\sqrt{ktb}$ we find words like /ktəb/ 'he wrote', /ktab/ 'book; it got written in the book of destiny', /ktub/ 'books', and /ttəktəb/ 'it was written'. It is worth noting that the CCaC verbal pattern, analogous to the Classical Arabic Form IX pattern, has over three dozen members and appears to still be productive in Moroccan Arabic (Harrell, 2004; Harrell et al., 2004), unlike Palestinian Arabic which only has five verbs in its Form IX reflex (Elihay, 2007). While the root of Hebrew or Standard Arabic is ineffable on its own, in Moroccan Arabic the three consonants of $\sqrt{ktb}$ are simply syllabified into forms like /ktəb and /kəttəb/. While it is still debated whether Moroccan Arabic includes a phonemic [ə] and what its role in syllable structure may be (Dell and Elmedlaoui, 2002; Shaw et al., 2009; Gafos et al., 2010), I remain agnostic. For the purposes of this dissertation, [ə] can be considered phonologically present and the syllable structure of /ktəb/ could be either monosyllabic [.ktəb.] or bisyllabic [.k.təb.]. This assumption has no impact on the data or analysis presented herein.

Third, Moroccans seem to realize that their dialect is quite distinct from the formal, written variety of Arabic. This is evidenced by the number of language schools in Morocco which explicitly teach the dialect in a dialect-only course, a phenomenon which is not as widespread elsewhere in the Arabic-speaking world. A number of vocabulary items seem to have been assimilated from the neighboring and distantly related Amazigh (i.e., Berber) dialects, as well as some from French or Spanish, which means a number of lexical items are distinctly not Classical Arabic and may eliminate some orthographic confounds (the Arabic script differentially represents consonants and vowels).

1.4.2 The Root and Pattern in Moroccan Arabic

Though perhaps not as robust as Classical Arabic, Moroccan Arabic shows a large number of templatic stem-internal changes. Here I survey those in the verbal system and then the nominal system. One cannot clearly distinguish so-called 'verbal' from 'nominal' roots. Nouns, however, have clear templatic morphology in the diminutive and plural forms.

Verbs have a basic template of CCəC, an intensive template of CəCCəC, and an inchoative template CCaC. The basic and intensive templates also can be passivized with a (t)t- prefix. Each verbal form also has a verbal noun. Verbal nouns have a variety of templatic shapes, as well as deverbal nouns for instruments and places məCCəC

Nouns, in addition to the instrument and place forms described above, also have professional forms CəCCaC, diminutives C^{w}CiyyəC and some plural forms CwaCəC, CyaCəC, CCayəC.

1.4.3 Conclusion

These properties, along with a grant from the American Institute of Maghrib Studies, make Moroccan Arabic an ideal place to test the lexical representation of the root. I turn next to the methods use in examining this question.

1.5 Grammatical Theory and Templatic Morphology

Linguists have a number of theories that deal specifically with Semitic morphology, and these are couched in some basic assumptions. In this section I first treat the assumptions of universalism and abstraction. Then I review theories of Semitic morphology.

1.5.1 Universalism and Abstraction

Because Semitic languages seem to make use of this language-specific, abstract root, grammatical theories of Semitic morphology differ crucially in two ideas: universalism and abstraction.

Universalism is an assumption about the human language faculty. The universalist position assumes that there are some general constraints on human language; all languages are built from the same fundamental pieces. At its strongest (Chomsky, 1965), universalism assumes that the human brain is hard-wired for language; the brain only has access to a limited number of ways to construct words and sentences. A non-universalist perspective assumes that human languages are only constrained by the human body itself, and there are no *a priori* limits to word and sentence formation. A universalist theory of Semitic morphophonology can rely only on universal processes and phenomena, those which are independently motivated and required to account for other languages of the world. A non-universalist position has no qualms about positing language-specific structures.

The truth, of course, is likely to be somewhere in the middle of these extreme position.

Abstraction is the second major issue in the analysis of Semitic morphophonology. Earlier theories of grammar favor minimizing representations and maximizing computation. This continues into many current grammatical theories (e.g., autosegmental theories (Goldsmith, 1976; McCarthy, 1981), optimality theory (Prince and Smolensky, 1993/2004; McCarthy and Prince, 1995), *etc.*). On the other hand, some theories explicitly favor storage over computation (e.g., exemplar-based theories (Bybee, 1985), evolutionary phonology (Blevins, 2004), etc.). The crucial distinction here is whether or not evidence for abstract templatic units can be found. If there is evidence for abstract elements, theories of computation are supported. If there is no evidence for abstract units, storage-based theories are supported.

Both universalism and abstraction can be viewed as a continuum rather than as binary distinctions. It is conceivable that one universal process available to the human language faculty is found clearly only in a limited number of languages, or that languages might differ in their storage-to-computation ratios. Any theory of language must address which aspects of the theory (if any) are universal, and what level of abstraction is necessary to account for the phenomena we find in human language. The assumptions one makes based on these two principles are key to understanding the differences between linguistic theories. I turn next to briefly describing two theories which have been used to analyze Semitic morphophonology.

1.5.2 Autosegmental and Prosodic theories of Semitic morphology

Previously, Semitic languages have been analyzed with two main theories: Autosegmental Theory in the 1980s and Prosodic Theories which gained more traction in the early to mid 1990s. The prosodic theories are, generally, outgrowths of autosegmental insights and this should not be taken to assume autosegmental theory does not rely on prosody or prosodic units.

Autosegmental theory (McCarthy, 1979, 1981) makes use of advancements in tonal phonology to capture facts of Semitic morphology. Specifically, as tones are manipulated distinctly from the rest of the segmental content of the word, they are conceived of as occupying a distinct tier which links them to the syllabic positions independently of the segmental tier. Turning to Semitic, it is not tones but vowels themselves which are segregated onto their own tiers. This allows vowels, consonants, or even morphemes to be adjacent at some level in a derivation and makes sense of the discontinuous nature of the root. Autosegmental theory is very much an item-and-arrangement theory of morphophonology, in which morphemes are mental units which are arranged by the grammar. Autosegmental theory in universalist, as it takes the notion of tiers which were developed to model tone systems, and applies the tier notion to morphology. It is also a very abstract theory, since elements like the cv-skeleton have no segmental content.

Prosody theories (Bat-El, 1994; McCarthy, 1983; McCarthy and Prince, 1990; Laks, 2009; Ratcliffe, 1997; Schluter, 2007; Tucker, 2010; Ussishkin, 2000, 2003, 2005) follow McCarthy's prosodic morphology hypothesis and generalized template theory by linking the internal changes in Semitic morphology to prosodic units. Thus, bisyllabic feet and the stem are aligned, additional material must be inserted stem-internally due to the highly-ranked constraints enforcing bisyllabic stem size. The best solution to the conflicting constraints is to modify or overwrite stem-internal material, such as the second root consonant or the vowels. Some of these theories accept a discontinuous root (McCarthy, 1983; Tucker, 2010) while others deny the existence of the discontinuous root as an independent morpheme (Bat-El, 1994, 2003; Schluter, 2007; Ussishkin, 2000, 2003, 2005). The main difference between autosegmental theory and prosodic theories is the prosodic theories eliminate the need for the cv-skeleton and replace it with prosodic elements, which are independently needed for other languages of the world. This makes the prosodic theories more appealing from the universalist perspective, because the cv-skeleton can be captured with more general properties of language (i.e., prosody).

1.5.3 Surface True morphology

Opposed to the autosegmental approach is the Surface True (Hudson, 1985, 1986, 1991) theory, which states that underlying representations can only be surface true in an explicit mapping of root to pattern. This leads to representations in which phonetic processes (i.e., lenition and other context-specific allophony) are represented in the root as sets of segments. The surface true theory of Semitic morphology is anti-abstractionist in the sense that there are only fully specified segments and rules for the selection of allomorphs and allophones. It is also an item-and-arrangement theory of morphology, in that morphemes are explicit sound-meaning correspondences.

1.5.4 Lexeme and Paradigm-Based theories

Many modern theories of word-formation reject the notion of absolute sound-meaning correspondences (Anderson, 1992; Aronoff, 1994, 2007; Beard, 1995; Blevins, 2006; Stump, 2001, among others). Essentially, these theories are not morpheme-based, but lexeme- or paradigm-based. These theories primarily focus on inflectional morphology, and deal with the problems of multiple exponence, zero-exponence, and null-morphemes detailed above. The great insight of these theories, as (Blevins, 2006) puts it, is that full phonological word forms can predict the inflectional features (i.e., person, gender, number, case, etc.) better than a root with inflectional features can predict the phonological word-form. The paradigms for English words like *cat*, *dog*, *fox*, *ox*, *sheep*, and *octopus* are all structured identically: one cell for the singular and one for the plural. The phonological material in the plural cell might vary, but each word has a singular and plural form. When the concept CAT with the feature PLURAL is needed, one simply looks up the CAT paradigm and select the lexeme in the plural cell. Finding the plural for *sheep* or *octopus* works no differently. While these theories are generally used to cover inflectional data, they show potential to be applied to the deriviational "macroparadigm" structure of Semitic.

Word-based theories suffer from two criticisms. The first is they are computationally inefficient. Redundant information must be stored, when it would be more efficient to simply compute all instances of the regular plural. However, the brain may have much more room for storage than earlier linguistic theories suggest. Principled lexeme listing (Blevins, 2004) may as well solve many other linguistic problems, such as the problem of the missing base. Why, for example, should we need to compute a Moroccan word like /kəlb/ 'dog' from the root $\sqrt{klb}$ and the nominal pattern /CəCC/ constantly? The root-related verb /kəlləb/ 'to search for' likewise doesn't seem to need a core DOG concept put into a verbal form. Likewise, English *concept* would be constantly derived from the meaningless morphemes *con-* and *-ceive*. Lexeme listing must be done in any theory of language, but it seems redundant to require computation as well as listing for the same irregular items.

The more damaging criticism of lexeme or paradigm-based theories is the lack of specificity in creating new lexemes. Analogy is used to create novel words, such that *dog* is to *dogs* as **glork* is to *X* (presumably **glorks*). It is not clear why, in language with richer morphology than English, a plural would take one or another form. For example, the English loanword /taksi/ 'taxi' in Arabic may take the internal plural /takaasi/ in some dialects or the suffixal plural /taksiyaat/ in others. When base forms are not lexically listed, word-based theories suffer because there is not always one underlying form from which to derive each related form. The criticisms of Bat-El (1994, 2003) and Ussishkin (1999, 2003, 2005) show the lack of basic words or stems (i.e., the basic CVCVC form I stem) to be the input for derivations are problematic.

One crucial benefit of a word-based theory is that it allows for morphological relations without explicit morphemes. Thus, a computationally explicit theory like Ussishkin (2005) (which is based on both prosody and whole words) derives new forms by overwriting elements of the base. Thus, we can derive the Hebrew intensive /(ki.tev)/ from basic /(ka.tav)/ by the addition of the vowels /i e/, which overwrite the original vowels due to the prosodic constraints. This theory give the insight that, using universal principles of phonology and morphology, Hebrew stem consonants may have a different status in a word than vowels (which can be overwritten), and the root emerges as an epiphenomonon from stem consonants. Thus, word-based theories may provide a good explanation if there is little experimental support for roots as morphemes.

Word-based theories tend to be realizational theories, in the sense of Stump (2001). That is to say, morphemes are not sound-meaning correspondences *per se*, but abstract computational elements which associate with particular lexemes. This theoretical development attempts to avoid the problems of null and multiple exponence and lack of clear form-meaning correspondences in item-and-arrangement theories. In this sense, the notion of gradient morphology Hay (2003, 2001); Hay and Baayen (2002); Hay (2002); Hay and Baayen (2003); Hay and Plag (2004); Hay and Baayen (2005) may be appealed to: some abstract processing units (i.e., morphemes) have stronger links to sound-sequences in a phonological word-form than others. This may also be a useful notion if there is mixed or weak evidence for the behavior of roots as processing units.

1.5.5 Contentless Roots

One interesting aspect of realizational theories is that morphemes are, or can be, taken to have no phonological content *per se*. Harley (2012), following Pfau (2009) and Acquaviva (2008), suggests that Distributed Morphology (Halle and Marantz, 1994) has no need for roots with semantic or phonological content, but they are abstract structural units, linked to encyclopedic (i.e., conceptual) content and spelled out phonologically by vocabulary items (i.e., phonological words). Though the theoretical details and mechanisms differ, this idea of realizational morphology can be found in many disparate theories (e.g., Blevins, 2006; Anderson, 1992; Beard, 1995, among others).

1.5.6 Summary

Different theories make different predictions about the root and the pattern, but psycholinguistic evidence is coming down firmly in favor of the root being a psychologically real element involved in accessing words (Boudelaa and Marslen-Wilson, 2001a, 2004a,b, 2005; Boudelaa et al., 2010; Boudelaa and Marslen-Wilson, 2011; Deutsch et al., 1998; Frost et al., 1997, 2000, 2005; Prunet, 2006; Twist, 2006; Ussishkin and Twist, 2009; Velan et al., 2005). The nature of this representation, and its relation to linguistic theory, is the subject of this dissertation. I turn now to a review of the linguistic arguments in favor of and opposed to the root.

1.6 Arguments for and against the root

The root, as detailed above, is the pivotal morpheme–in the sense of Yu (2007)–which makes Semitic languages unique. Here I survey the reasons why the root might be rejected in terms of linguistic theory, why it might be defended, and some additional problems that previous literature has not treated well.

1.6.1 Why Reject the Root?

The anti-root position can be summed up as follows: There exist Semitic derivations which are clearly directional, non-concatenative, and based in universal elements of prosody. Each of the three elements here is discussed below:

1. Directional: These derivations are directional in the sense that there is a clear base whence another form is derived. This is the clear case in terms of denominal verbs, diminuatives, hypochoristics, and some plurals.

2. Non-concatenative: Such derivations are not characterized by simple prefixation or suffixation, but by stem-internal modifications.

3. Universal Units of Prosody: The derivations are describable in terms of units of sound which are independently needed in any analysis of the language and of language in general, including the syllable, mora, foot, stem, and prosodic word. This follows the prosodic morphology hypothesis and the generalized template theory (McCarthy and Prince, 1995) as well as Yu's theory of infixation (Yu, 2007) in which morphological and phonological units and their boundaries are the locus for stem-internal changes.

Once it is accepted that some derivation in the language requires a fully-formed word or stem as it's base, it could be concluded that all such derivations should take such elements as the base. Put another way, word-based mechanisms are required, so that gives us clear reason to question the necessity of the root. These processes are clearly productive as they rely on new coinages and needn't reference an abstract, underlying, language-specific root.

1.6.2 Why Defend the Root?

The pro-root position takes exception to the notion that there are always clear base forms from which to derive related forms, only an abstract element could be the base in some derivations. Faust and Hever (2010) eloquently defends the necessity of the root, allowing for some instances of word-formation to be word or stem-based but suggesting that others cannot be. They provide three clear arguments:

1. In most derivations there is a lack of a clear, surface-true base form. Thus, there is no basic form to reference in deriving a novel form.

2. The root has structure which certain morphological derivations reference, such as a rule that requires the medial consonant to be geminated.

3. The existence of word or stem-based derivations does not eliminate the need for an abstract root.

Beyond these, Prunet (2006) provides a summary of behavioral evidence arguing that evidence of an abstract root is seen in language games, the speech errors of at least one aphasiac patient, and verbal processing (e.g., lexical priming).

Crucially, in order for the anti-root position to prevail, the problem of the base and the problem of morphological processes which seem to target specific root consonants must be overcome.

1.6.3 Further Problems with the Root

A hybrid model that uses both roots and stems as the basis of derivations could account for some of the anti-root criticism (Faust and Hever, 2010, for example), but it cannot fully satisfy the anti-root position. The root represents an excess of abstraction. Derivations which are root-based may reference non-universal units like ‘penultimate root segment’. The anti-root position, then, is actually so strong that it cannot compromise on a hybrid theory, whereas the pro-root position is less extreme and can admit word or stem-based derivations. Here, in an attempt to clarify what a root must look like, I level three more criticisms at the pro-root position: first, the structure and mapping of root and template are unclear; second, principled lexical listing eliminates the need for some computation; and third, differences in production and perception may lead to a role for the root which the anti-root position can accept.

Before we begin this excursion, it is crucial to keep in mind that the root in Semitic is not consonantal. The segments are most often consonants, but many roots exist in different Semitic languages which must be analyzed as containing a semi-vowel, vocalic segment, or abstract segment which does not surface. This can be seen in the Amharic verb s’af- ‘write’. Historically, the root was $\sqrt{s'hf}$ but the gutteral (i.e.,sub-velar) segment was lost and only survives in some derivations like məs’haf ‘notebook’. If the root is taken to be $\sqrt{s'hf}$, the gutteral segment must be specified to be inert or vocalic in verbal derivations and only active in deriving the noun. These types of roots are often called weak roots. The treatment of these so-called weak roots means that semi-vocalic or wholly vocalic segments must be allowed as root segments. The Semitic root, then, is discontinuous and segmental, not purely consonantal. Many pro-root positions acknowledge this, including (Bender and Fulass, 1978; Faust and Hever, 2010; Hudson, 1985, 1986).

First, the root representation is unclear. Earlier theories like Hudson (1985, 1986) and McCarthy (1981) explicitly give conventions for associating radicals–root segments–into a template, but the naïve expressions of empty slots or simple linear order is not always explicit enough to withstand scientific scrutiny.

Take, for example, the notation used in Faust and Hever (2010). Roots are described in the C-C-C style, where C stands for a radical[1]. These appear to be ordered linearly, but the mapping algorithm is not always explicit, such as from an Arabic form 1 CaCCaC where the two medial segments are identical. There are two basic methods of associating the radicals with the template: slot indexation and directionality.

Slot indexation labels the radicals and associates them to their relevant slot. Thus, a root takes a shape like k_1-t_2-b_3. It is associated to a template such as the perfective verb stem $C_1aC_2aC_3$ or the geminated form $C_1aC_2C_2aC_3$. This method, however, does not capture the generalization that the geminated form of the verb is used by Hebrew and Arabic for quadraliteral patterns as well, such as $C_1aC_2C_3aC_4$.

Another association convention is the more nuanced linear techniques used in the developments of McCarthy's version of autosegmental theory of Semitic morphophonology. Here we can assume the association technique of Yip (1988), where the two edges are first associated and then the middle segments, from left to right. This accounts for the spread of some consonants, such as in the quadraliteral pattern CaCCaC. A triliteral root will geminate it's medial consonant, whereas a quadraliteral root has no need. This is slightly problematic, however, when extended to Ethiosemitic and its frequentative pattern, CəCaCCəC. For triliteral roots, the medial consonant is geminated and duplicated, giving fəlalləg- from the root $\sqrt{flg}$. Quadraliteral roots, however, do not simply fill more internal slots, but they extend the template (Rose, 2003; Schluter, 2007). Tucker (2010) suggests that roots can be organized linearly and fit into prosodic templates, which is a promising theory for unifying the triliteral and quadraliteral templates. Here, linear order does the work, but word-based derivations may still be necessary to account for some templates, like the Amharic frequentitive (see above).

---

[1]Clearly this notation harkens back to the idea that these radicals are consonantal, or at least letters (Standard Arabic ħuruuf حُرُوف) in the orthography.

Second, the pro-root position is, in general, vehemently opposed to lexical listing. To the best of my knowledge, there is no accepted algorithm for computing the cost of storage versus computation in formal theories of language. It is clear from word-frequency effects that humans store a large number of morphologically complex words, but also that we must have a mechanism for computing words as well. Computational theories of language arose at a time when storage for computers was costly, and may reflect silicone biases, rather than flesh-based ones. It is not entirely clear, however, that all forms can be computed. A principled approach to lexical listing can be found in Blevins (2004). Blevins reminds us that only those elements which are synchronically productive are the realm of phonology proper, while historical residue is stored. Thus, when the concatenation (or interdigitation in Semitic) of morphemes are not productive, we can simply list them in the lexicon, whether or not they could potentially be generated. Faust and Hever (2010), however, maintain that each word of Hebrew which could be decomposed into root and pattern morphemes ought to be. Hebrew agentive nouns, for example, have two possible formations: root and stem. When the agentive suffix *-an* attaches to a stem there are no prosodic changes and the meaning is compositional. When it attaches at the root level, the root is forced into the CaCC template with the *-an* suffix.[2]. Taking the Evolutionary Phonology approach (Blevins, 2004), one might check to see if both the stem and root possibilities[3] are, in fact, productive. If novel forms (either as nonce words or agentive nouns from recent borrowings which conform to Hebrew root phonotactics) attach at the stem level, that may indicate that the root derivations are not, in fact, synchronic and can simply be listed in the lexicon[4].

Third, since the antiroot position is so extreme, a hybrid of stem and root-based

[2]Or, possibly, the CaCCan template.

[3]In terms of Distributed Morphology, the root attachment is lower than the stem attachment.

[4]The Faust and Hever (2010) analysis in terms of DM can still be utilized if the phonological word is simply a listed vocabulary item, not something synchronically constructed

derivations is not likely to satisfy the antiroot criticisms. A hybrid theory still engages in an extravagance of abstraction by reifying root and templates as psychologically real and language-specific[5]. If the antiroot position is to be falsified, it must be done in terms of derivations (or inflections?) which are synchronic and productive, where novel forms are produced with clear reference to the root. Note the emphasis on production. Perception has rarely been treated within formal linguistics, and the processes of affix stripping and abstraction required to identify morphemes has not been the focus of generative theories of linguistics. It is not implausible that perception has unique mechanisms which are distinct from and perhaps inaccessible to the mechanisms responsible for productive derivation. Evidence which suggests that the root is active in perception does not conflict with the anti-root position *per se* which denies it's applications in derivation.

Fourth, the properties of the root assumed by linguists and psycholinguists are not identical. Linguistic theory, particularly generative theories, assume that all roots are created equally. That is, each word has a root representation which can be used to generate it and related novel coinages. Psycholinguistically, however, we know that a root which does not occur in many distinct words may not be psychologically active. In fact, some Hebrew words clearly do not have psychologically active roots at all (Velan and Frost, 2011). Thus, linguists and psycholinguists are often discussing different theoretical entities with the same label. Linguists cannot simply accept experimental evidence which favors a root without first aligning their basic assumptions about what a root is with those of the experimenters.

One notion that preserves the idea of a root morpheme in a way that is consistent with the antiroot position, however, is by using the ideas of realizational theories of morphology to divorce conceptual meaning from phonological form. If roots are abstract processing units instead of structural units with phonological

[5] *n.b.* Tucker (2010) adapts Ussishkin (2005, 2003, 2000)'s Fixed Prosody to include the root alone, with the template emerging from prosodic facts of the language.

content, the antiroot arguments no longer apply. All languages would presumably use similar abstract processing units, and those units are free from semantic and phonological content.

1.6.4 Summary

The anti-root position, then, rejects the root as a unit of sound-meaning correspondence because it is overly abstract and language-specific rather than universal. The pro-root position argues that the root easily accounts for Semitic languages and may be combined with word-based derivations for a complete account of the languages. Both positions, however, are largely couched in item-and-arrangement theories of morphology. This dissertation, then, is concerned with lexical representations and morphophonological computation. Itsgoal is to answer the questions: how are words represented mentally in Moroccan Arabic and what role does the root play in lexical storage and access? Does any evidence from linguistic theory converge with psycholinguistic evidence for the representation of Semitic words? What role should lexical listing and productivity play in linguistic theory? Specifically, I will examine how the lexical properties of the root may help us to identify a discontinuous root morpheme which is behaviorally valid and amenable to some of the concerns from formal linguists.

1.7 Lexical Representations and Lexical Processing

When discussing the root, I assume that the general theoretical descriptions of the root are correct. Thus, the root is the entity of sound-meaning correspondence which recurs in any given family of related words or stems. As a morpheme, the root is identified by its phonological content. I assume that this theoretical definition of the root so we can test for evidence of the theoretical construct with behavioral evidence. Note that weak roots, which have a slightly different theoretical definition, are covered in chapter 4. There is no other clear and concise way to discuss the root, so the search here is to see whether or not this mental entity (or some other) is supported.

I also assume a binary definition of lexical entrenchment. That is, a word either has a lexical representation, or it doesn't. A lexical representation is a cover term for the linkages between phonological word-forms, abstract roots or stems, and the links to morphosyntactic, semantic, and encyclopedic information. Multiple levels of representation are implicit in the types of examples linguists often use, but they become crucial when searching for behavioral correlates of theoretical constructs.

Finally, I assume that words have multiple levels of representation. This is widely assumed in psycholinguistic (e.g., Dell et al., 1997) and formal linguistic literature (e.g., Halle and Marantz, 1994). Thus, a word is composed of multiple elements, such as its phonological form, which itself has morphological structure, and links to a semantic or conceptual form. The Moroccan citation form for the word *he writes*, for example, is /iktəb/ 'he wrote'; this word includes many levels of representation. The phonological word-form is /iktəb/. Articulated phonetic instances of the word may vary slightly, including [iktəb] and [iktəp] where the final consonant is fully or partially devoiced, and the auditory system processes this phonetic input, which the phonological system recognizes as a set of phonemes, which constitute one phonological word-form. Above the phonological representation is a morphosyntactic representation of some kind. Linguists would often gloss this as *write/imperfective/3ms* indicating that this word is a form of *write* in the imperfective aspect and indicates a third person masculine singular subject. We also know this form is a verb, based on the morphosyntactic structure (e.g., the perfective morpheme or agreement inflections), semantics (e.g., actions tend to be verbs), or context (e.g., word order may indicate this is a verb). At some level this word is linked to the speaker's encyclopedic knowledge of writing; a speaker knows: which implements are required to write, which artifacts are produced by the act of writing, why people might write, who notable writers may be, their own experience of writing, prominent instances of the word's use, and so forth. When a word is established or entrenched in the speakers' lexicon, all of these connections and more[6] are made.

Furthermore, the structure of a word's representation is a theoretical construct in and of itself. When linguists describe the symbolic patterns of language, many aspects of these links are abbreviated or simplified. A psycholinguistic theory of language, however, must spell these connections out so they can be tested. Here, I assume a theory of lexical representations which is largely in-line with Dell et al. (1997, among others), shown in Figure 1.1. The speaker hears a phonetic form [ktəb] or 👂, which is mapped onto phonemes /k/, /t/, /ə/, and /b/. Phonemes are mapped onto a phonological word-form /ktəb/. The phonological word-form is analyzed into its root or stem $\sqrt{ktb}$ (morphosyntactic level), which is mapped into some semantic, conceptual, and encyclopedic representations (e.g., WRITE or ✍). Going the other way, the path from concepts to speech naturally diverges around the phonological word-form level, when words are converted into motor commands for speech (e.g., 🗣).

In Figure 1.1 the morphosyntactic level is represented as one linear relation, but it may be an entire system of representations of its own, shown by the tree in Figure 1.2. I ignore the complex structure of this level to focus solely on root representations.

This assumed structure of a word isn't entirely uncontroversial, though it is familiar in the field. Caramazza (1997), for example, might eliminate the root (i.e., lemma) representation alltogether in favor of semantic-conceptual knowl-

[6] I set aside issues related to orthographic word-forms, which aren't entirely germane here.

Figure 1.1: Levels of Representation in the Lexicon (cf Dell et al., 1997) – Encyclopedic concepts (represented by the checkmark, book, writing hand, computer, and Egyptian scribal outfit) are connected to root morphemes (e.g., $\sqrt{write}$) at the morphosyntax level. The morphemes themeselves are abstract elements connected to whole phonological word-forms (e.g., /iktəb/). These wordforms are connected both to input phoneme categories (i.e., /k/, /b/, /ə/, /i/ and /t/), and to the output system (e.g.,).

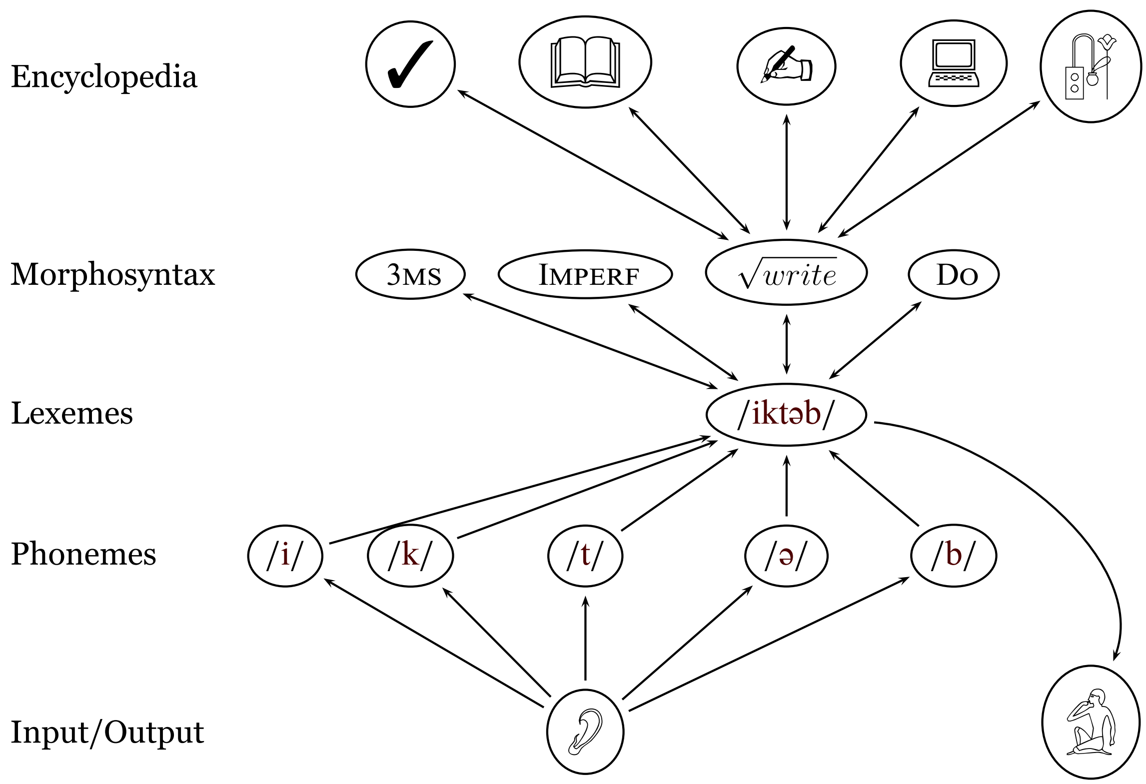
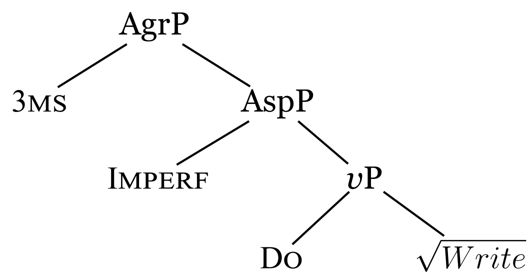


Figure 1.2: Morphosyntactic representation of /ikteb/ – A Distributed Morphology account of imperfective aspect, 3ms subject agreement, the verbalizer Do, and the root $\sqrt{write}$. This complex is spelled out as /ikteb/ 'he writes'.



edge linking directly to a generic verbal representation (here Do) *and* the phonological lexeme /ktəb/. While such a model does have its advantages, it fails to explain morphological priming, particularly in light of a lack of semantic priming. Caramazza argues against a modality independent lemma, which is similar to–but not identical with–this type of root node. The root node is retained in this model because it explains the lack of semantic priming, but retains morphological family priming. In the Caramazza model, it is not clear how priming between /kteb/ 3ms/Perfective/Do/Write and /ketteb/ 3ms/Perfective/Make/Write would obtain, since the conceptual representation of Do/Write and Make/Write may not overlap with one another any more than with the morphologically unrelated /ħənnəʃ/ 3ms/Perfective/Make/Snake 'he scribbled' (a denominal verb from /ħənʃ/ or /ħanaʃ/ حنش 'snake', remembering that the Arabic script is always written in a connected, cursive or snake-like style).

1.7.1 Speech Errors and the structure of the lexicon.

Abd-El-Jawad and Abu-Salim (1987) compile a corpus of Arabic speech errors, noting a number of root exchange errors. These errors involve exchanging the root consonants in two words, but not the grammatical patterns. This supports theories in which root consonants and vocalic patterns are distinct mental entities. The results from Jordanian Arabic speech errors are not replicated in Tunisian.

Hamrouni (2010) uses an induced error task to try to induce the root exchange errors found in (Abd-El-Jawad and Abu-Salim, 1987) for Tunisian Arabic. These errors are hypothesized to occur whether or not the resulting word exists in the lexicon or not, because they are root-based. Subjects heard a verb-noun pairing, such as /lawwan ʕuud/ 'make.colored stick' asked to turn the words into the pattern *VERB the NOUN* such as /y-lawwan ʕuud/ 'color the stick'. Most of the trials asked the participants to use the two words in the same order, but some asked participants to reverse the lexeme order. For these reversed trials, subjects were expected to produce /y-ʕawwad l-luun 'familiarizes the color', exchanging the roots but using the correct grammatical patterns. Some roots, however, are not lexicalized in every grammatical pattern. These trials manipulate real words such as /mannʕa liʕba/ 'save game' into /y-laʕʕab l-minʕa/ 'play (Nonword)'. If roots are manipulated, there should be no difference between errors which produce real words versus those which produce nonwords.

The results in Hamrouni (2010), however, do not replicate the spontaneous errors reported by Abd-El-Jawad and Abu-Salim (1987). Root exchange errors comprised so little of the data that no analysis could be conducted. Of the 1920 responses analyzed, only 291 were errors of interest. Of these, only 15 were root exchange errors, and only 9 were vocalic pattern errors. A foll 86% of the speech errors exchanged the entire stem – both the consonantal root and the vocalic pattern – indicating speakers do not regularly synthesize roots and patterns during speech production, since the roots and patterns did not appear to be manipulated independently with any regularity. The lack of independent manipulation of roots and patterns may be for one of three reasons. First, there may be a reporting bias in the speech error corpus. Root exchange errors might be so noticeable for Arabic speakers (despite their incredible rarity) that they stand out much more than other errors. Second, the paradigm used by Hamrouni (2010) may produce these errors in languages with concatenative morphology, but non-concatenative morphology may be resistant to this particular technique. Another technique may prove more fruitful for inducing root-based speech errors. Finally, root exchange errors may simply not be common errors because Semitic speech production doesn't involve the regular manipulation of roots and patterns. A paucity of root exchange errors may come about because stems are stored and accessed and computation of stems (i.e., synthesis of independent roots and patterns) is slow, impeded, or otherwise difficult.

The results reported by Hamrouni (2010) suggest that roots may play little role in speech production. This negative evidence, however, cannot be taken as clear support for any model, as there may be other factors which influenced the lack of root effects. Until these findings are replicated, the evidence from speech errors must be considered inconclusive.

In addition to disfluent speech in normal speakers, disfluent speech can be studied in abnormal speakers. Two lesion-deficit studies of one aphasic patient show a significant number of root-based errors.

1.7.2 Aphasia

Prunet et al. (2000) and Idrissi et al. (2008) examine one Lebanese aphasic patient, ZT, with damage to the left perisylvian region of his brain, the areas generally though responsible for many aspects of language. ZT could comprehend orally with only mild problems, but is severely impaired in reading and writing in both Arabic and French. ZT makes one peculiar type of speech error in Arabic that does not happen in French: root metathesis errors.

ZT is shown to consistently have more metathesis errors in Arabic than French. This is attributed to a phonologically contentful root morpheme, though there is no mechanism given for why metathesis errors might occur. Prunet, Béland and Idrissi take this as support of McCarthy (1981)'s theory whereby roots are consonantal entities on one tier, and thus adjacent to one another. The damage ZT suffered results in root morphemes, and generally only root morphemes, to occasionally scramble their linear order. Prefixes and infixes remain in situ, while root consonants may be reordered within the fixed prosodic pattern. Furthermore, weak glide root consonants, which do not always surface faithfully, can also be subject to scrambling. This metathesis is argued to be purely morphophonological, and not influenced by the consonant-heavy writing system of Arabic.

Of more interest, is the fact that these metathesis errors often produce non-words. The nature of Semitic roots makes it such that any such metathesis is quite liable to produce real-words, so ZTs root metathesis is argued to be unaffected by lexical biases.

Evidence for the permutability of Semitic root consonants is also found in language games and speech errors, but the evidence from speech errors is not conclusive (Hamrouni, 2010). Furthermore, other Semitic-speaking aphasic patients are not reported to make metathesis errors Barkai (1980), but the patient Dudu does make root and pattern selection errors which results in non-occurring words in spontaneous speech. Finally, the theoretical argument for the permutability of root consonants, as well as pattern selection errors, is based on the generation of existing word-forms in the manner of McCarthy (1981) in spontaneous speech. It is not clear how fast the spontaneous speech of ZT (or Dudu) is, and a reaction time study might illuminate whether or not nonword metatheses and real-word metatheses are indeed identical, as well as normal access time versus error access time.

1.7.3 Behavioral experiments: visual masked priming, cross-modal priming, word-picture interference

Numerous experimental studies use psycholinguistic tasks that involve deciding if a series of letters makes a word or naming the word that letters represent. All of these find evidence in support of the root and pattern as morphemes in Hebrew and in Arabic. Root effects are generally quite robust, but pattern effects are more fragile.

The groundbreaking work of Frost et al. (1997) demonstrates that the roots and patterns play an important role during visual lexical access in Hebrew. Numerous studies have confirmed this with visual masked priming Frost et al. (1997); Deutsch et al. (1998); Frost et al. (2000); Deutsch et al. (2003); Boudelaa and Marslen-Wilson (2004b,a, 2005); Frost et al. (2005); Velan et al. (2005); Boudelaa et al. (2010); Velan and Frost (2011), cross modal priming Boudelaa and Marslen-Wilson (2004b), auditory priming (Boudelaa and Marslen-Wilson, 2004b), and word-picture interference tasks (Kolan et al., 2011).

Pattern priming for verbs obtains, but not nouns (Frost et al., 1997; Deutsch et al., 1998) in Hebrew. In Arabic, pattern effects obtain for both Boudelaa and Marslen-Wilson (2004b,a, 2005). Boudelaa and Marslen-Wilson (2004a) further deconstructs the pattern into the prosodic skeleton and vocalic melody (cf. McCarthy, 1981) and shows that in visual masked, cross-modal, and supraliminal auditory priming there are consistent effects of the prosodic skeleton, but not vocalic melody. These consistent effects suggest that the skeleton is one underlying processing unit. Boudelaa and Marslen-Wilson (2004a) suggest that the Tunisian dialect interferes with vowel melody priming, but it isn't entirely clear that we should expect priming from any morpheme. The melody, for example, distinguishes active from passive verbs. The melodic passive is not particularly common in Standard Arabic, and it isn't clear that this the active or passive melodies would be efficient ways of organizing the lexicon.

There are no effects of semantic priming, only morphological (Frost et al., 1997; Deutsch et al., 1998; Boudelaa and Marslen-Wilson, 2004b). Likewise, effects of orthographic form in Hebrew or Standard Arabic do not usually obtain. Bilinguals do show form effects in English (Frost et al., 2000), and orthographic effects obtained at the when prime duration was quite short (32ms Boudelaa and Marslen-Wilson, 2005). Frost et al. (2000) claims that lexical factors including neighborhood density and prime lexicality do not mediate or moderate form priming. Thus, there appears to be no form priming in Hebrew. Morphological effects, however, are consistent for strong verbs for both roots and patterns.

The time course of roots and patterns is different, however. Boudelaa and Marslen-Wilson (2005) shows that roots and patterns have a different time-course of access in a visual masked priming lexical decision task. Roots show consistent effects at 32ms, 48ms, 64ms, and 80ms. Patterns, however, only induce facilitation at the 48ms prime duration (and 64ms prime duration for nouns).

Verbal pattern priming obtains when the prime is a nonroot in a real pattern (Deutsch et al., 1998), but verbal pattern priming only obtains when the root is strong and displays three letters. Masked presentation of weak roots may facilitate reaction times, but so can presenting the partial root consisting of the stable root consonants for roots whose first consonant is defective (Velan et al., 2005). Boudelaa and Marslen-Wilson (2004b) shows that weak roots (in this case glide-initial roots) which display stem allomorphy do show priming effects in a cross-modal lexical decision task. With roots, significant facilitation obtains when the the target and prime share a root, regardless of the root's strength or semantic distance between the words. For patterns, however, effects obtain only when the target is a strong root (i.e., a canonical exemplar of the pattern). It appears that, visually speaking, the pattern needs to be complete in its canonical form for priming effects.

Nonword priming, however, shows interesting effects. Nonwords which are presented as just the root consonants (indistinguishable from some verbal or nominal forms of the word) consistently show effects for strong verbs. Nonwords consisting of real roots in augmented patterns (i.e., hif'il הפעיל) which do not create an existing word, however, fail to facilitate reaction times to existing words which share the root (Frost et al., 1997). Thus, the Hebrew-speaking mind may, essentially, show form effects for root consonants, but not when those accessing those consonants requires the affixal material to be parsed off.

Neurophysiological data confirms the differing role of roots and patterns. Boudelaa et al. (2010) reports a mismatched negativity (MMN) EEG study, finding a 160ms MMN for roots measuring from the deviation point, but a 250ms MMN for patterns. Thus, roots show fronto-central effects earlier than patterns, and these effects are left-lateralized. This suggests that roots have more semantic function and patterns have more grammatical functions.

Furthermore, roots appear to drive the productivity of words in terms of root family size Moscoso del Prado Martín et al. (2005); Boudelaa and Marslen-Wilson (2011). Orphan words, which do not have any related words, also do not show pattern priming effects (Velan and Frost, 2011).

1.7.4 Subliminal Speech Priming

The subliminal speech priming technique (Kouider and Dupoux, 2005) was designed to be an all-auditory analog of visual masked priming. This auditory only technique is uniquely situated to investigate dialectal differences, unwritten languages or dialects, preliterate populations, and any others who do not access language visually.

Two pilot experiments prepared for this dissertation, however, failed to induce identity priming effects. This indicated that there was some aspect of Moroccan Arabic which made it unsuited to scrutiny with this auditory masked priming technique. chapter 2 details how the technique can be modified so that it could be fruitfully applied in chapter 3 and chapter 4.

1.7.5 Summary

Experimental evidence largely supports the idea of the root morpheme as a containing phonological, or at least orthographic, content. However, the inability of Hamrouni (2010) to induce the types of speech errors reported in Abd-El-Jawad and Abu-Salim (1987), Prunet et al. (2000), and Idrissi et al. (2008), as well as the lack of priming from real roots instantiated in legal but unlexicalized patterns (Frost et al., 1997) suggest that there may be less to the root than meets the ear. If the subliminal speech priming technique can be applied to a Semitic dialect, it may give us new data to direct the debate.

1.8 A note on terms and symbols

In this dissertation I must adopt the terminology of roots and patterns in order to investigate their cognitive reality. While I assume the root from a descriptive point of view, the descriptions should not be taken as an assumption that roots must be present in any model of language or language behavior. The traditional description of the root as triconsonantal is clear and concise, nothing else is.

I took no care to make transcriptions uniform or standard between languages presented here, except for the Semitic languages. English transcriptions are a broad for American English in IPA. Moroccan Arabic –along with the rest of the Semitic languages–is described as a hybrid between IPA and traditional Semitic conventions. Emphatic (pharyngealized or uvularized) consonants are represented with a sublinear dot and the palatal glide as /y/. Other consonants are represented in IPA. Amharic and Ethiopian Semitic languages have their emphatic consonants represented with an apostrophe after the consonant (e.g., /t'/) since they are ejectives. Other languages are not converted from their sources. Slashes (/ /) are used for lexemes or word-forms and phonetic forms unless the phonetic form must be distinguished, in which case square brackest ([ ]) are used.

1.9 Conclusion

As noted above, the notion of the root as a sound-meaning correspondence is problematic for theories of word formation. In chapter 2, I modify the subliminal speech priming technique, the most promising technique for examining the morphological structure of an unwritten dialect from an all-auditory perspective, for use with Moroccan Arabic.

CHAPTER 2

WORD DURATION AND SUBLIMINAL SPEECH PRIMING

2.1 Introduction

Subliminal priming techniques are one of the most promising ways to investigate morphological representations, and have been extensively used in visual lexical decision tasks (Forster and Davis, 1984; Forster, 1998; Prunet, 2006, among many others). The subliminal speech priming technique (Kouider and Dupoux, 2005) is an auditory analog of visual masked priming, which masks compressed prime words with speech-like noises. If the subliminal speech priming technique can be applied to a spoken Arabic dialect, we will have a reliable spoken word recognition technique to investigate the organization of the Semitic lexicon. Three pilot studies on Moroccan Arabic with the subliminal speech priming technique, however, failed to detect identity priming, the most basic effect expected if the technique is working (cf. Taft et al., 2008, who modified the technique when monosyllabic words of English failed to produce identity priming). After pursuing multiple causes, it was discovered that the duration of Moroccan words was, on average, much shorter than the duration of English words. The mean duration of all Moroccan Words (monosyllabic and bisyllabic) recorded for chapter 3 and chapter 4 is 525ms ($SD = 95ms, range = 213 - 875ms$) while the mean duration of all English (monosyllabic) words recorded for the experiment reported in this chapter is 643ms ($SD = 99ms, range = 424 - 977ms$). This 118ms difference in average word duration suggests that prime duration is crucial for the technique in terms of a fixed number of milliseconds (rather than relative to a word's normal duration).

There may be, for example, a threshold, below which a prime is unintelligible. If this threshold is around 210ms, most English monosyllabic woulds would be near that target when compressed to 35% of their original duration but Moroccan words would be unintelligible, accounting for a lack of repetition priming effects. This chapter presents five experiments designed to test the limits of human perception in the well-studied English language: how short can primes be compressed and still produce repetition effects? Assuming that perception of compressed words is similar in English and Moroccan Arabic, the compression rates which prove to be useful for English will serve as the basis to refine the subliminal speech priming technique so it can be used to study other language and dialects, including Moroccan Arabic.

In the domain of lexical access research, visual studies dominate the field. Visual studies are less time consuming than auditory studies because manipulating text-based stimuli and word lists doesn't require the additional step of recording and manipulating auditory files. Visual studies further benefit from clear timing: it can be easily determined when a visual stimulus is presented. Auditory stimuli are not simply presented at one point in time, but unfold over time. There is less certainty about when the clock should be turned on when measuring reaction time in auditory tasks (see Goldinger, 1996, for a review of auditory techniques). Visual studies also benefit from the visual masked priming technique, which utilizes words which are not consciously perceived to influence a subjects' behavior. Unconscious presentation of stimuli is viewed as an ideal method for testing language behavior: unconscious aspects of language processing are early, automatic, and immune to any conscious strategies that participants might use. Linguists, however, generally assume that spoken (or signed) language is the most natural mode of language because it is the mode naturally acquired by children. Learning to read and write is learned later in life, compared to spoken (or signed) language. Until recently, however, there was no satisfactory auditory analogue to visual masked priming.

Kouider and Dupoux (2005) propose the subliminal speech priming technique as a method of investigating the earliest stages of spoken word recognition. The technique uses compressed and attenuated prime words embedded in speech-like noise (see Figure 2.1). The structure of each trial with the subliminal speech priming technique is analogous to the masks and briefly presented primes of visual masked priming (Forster and Davis, 1984). This technique has been shown to be sensitive to repetition of real words and insensitive to the repetition of nonwords (Kouider and Dupoux, 2005; Kouider et al., 2007; Davis et al., 2010). Real word priming effects indicate that the technique detects lexical processes. A lack of effects for nonwords, however, shows that it is only lexical processes which are detected: memory or phonological processing alone cannot be responsible for the real word effects. Recently, the technique has also been shown to be sensitive to morphological relations (Ussishkin et al., 2013) in Maltese.

Thus, the subliminal speech priming technique is promising for investigating the morphological representations of Moroccan Arabic, but first an appropriate compression method must be determined which will allow for repetition priming for real words, but not nonwords. Here I test English monosyllabic words to see if there is such a limit to human perception, beyond which there will be no repetition priming. It is not clear if there is a hard cognitive limit for recognizing compressed words, or if the limit is related to the average word duration in the language, but the results from English are an expedient way to determine a likely compression duration target for Moroccan Arabic and other languages.

The following experiments test the compression limit of English monosyllabic words. In these experiments, subjects hear both a prime and a target word. Then subjects decide whether or not they recognize the second word they hear–the only

Figure 2.1: Elements of a Subliminal Speech Priming Trial. The subliminal speech priming technique (Kouider and Dupoux, 2005) includes four elements on two simultaneous tiers. The target word is the only element on the target tier is played at a normal volume and contemporaneous with the masking tier. The masking tier is attenuated and includes a forward mask, a prime, and four backwards masks. The masks are attenuated, compressed, and reversed words, shown graphically by being rotated 180 degrees. The prime is simply attenuated and compressed. Kouider and Dupoux (2005) recommends compressing the prime to 35% of its original duration, but the experiments herein test fixed prime durations between 200 and 280ms. The target begins immediately when the prime ends.

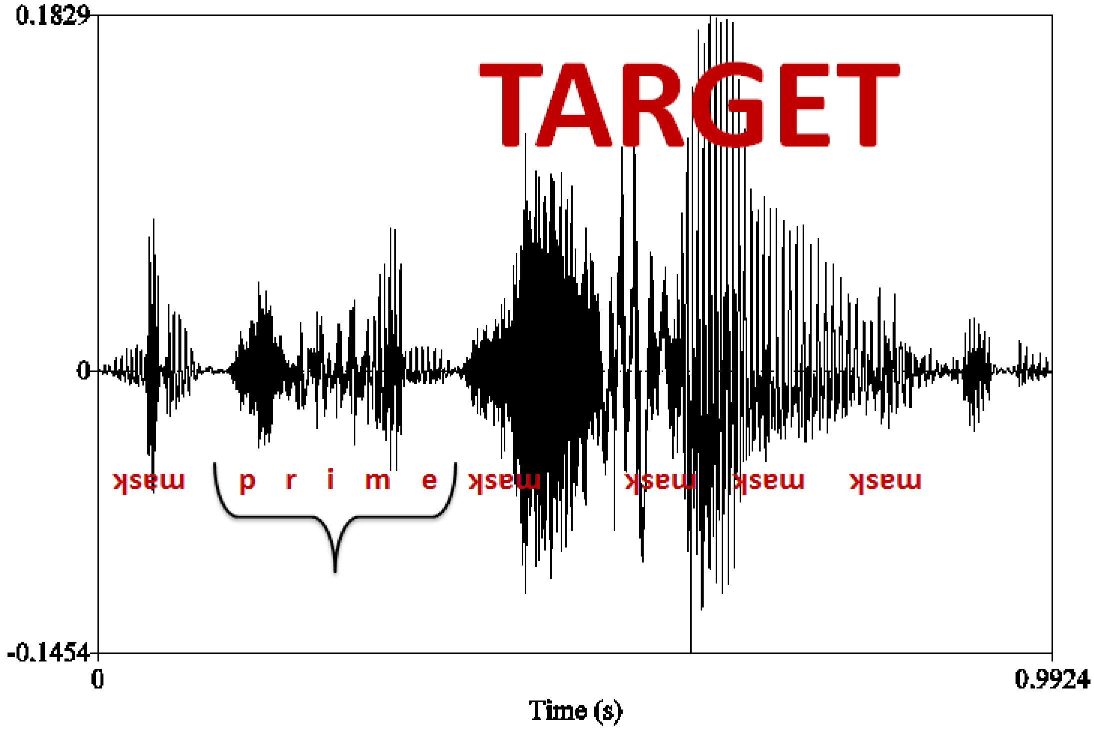


Figure 2.2: Time course of priming – Over the course of time in the experiment, subjects hear two words. The access time for word 1 and word 2 are symbolized by lines. Note that the processing times for words 1 and 2 overlap, meaning the words should be processed at the same point in time. If the two words are similar (in terms of phonological form, semantics, or morphology), there may be a facilitation effect, because some shared portion the lexical access process for the first word may be still active when it comes time to process the second.

word they consciously hear in the subliminal situation–as a word. If subjects are faster (compared to the control condition) at responding to this target word, we can conclude that the two words somehow share a route of access or a symbolic representation. The first word primes the subject to respond to the target word because of some similarity in morphological, phonological, or semantic representation (see Figure 2.2). The relationship tested here is identity: subjects hear the same word twice in succession. This should be the strongest priming effect, since subjects are assumed to use the same mechanisms for processing the word a second time.

How facilitation occurs in priming tasks, particularly subconscious priming, is a matter that psychologists debate (cf. e.g., Forster, 1998). I assume that the subliminal speech priming technique taps into earlier stages of lexical access than the regular auditory priming technique (Kouider and Dupoux, 2005). The subliminal speech priming technique gives subjects a very short window to process the prime word, so any processing that happens in that short window must be early and automatic, at least when compared to the overt, supraliminal priming technique. Facilitation effects in these experiments answer the linguist's question: are these two words closely related? The qualifier in that question, *closely*, warrants some discussion. Linguistic theory tends to make heavy use of categories and binary distinctions, so what use is judging distantly related words from closely related ones in a synchronic sense? How could two words possibly be distantly morphologically related? Psychological techniques measure in analog scales, not digital ones. There may be a number of non-lexical factors involved in performance. Those factors which appear to be early, strong, and automatic–measured in milliseconds by response times–are likely to be the ones most relevant to the structure and organization of the lexicon (cf. Prunet, 2006).

While repetition and morphological form priming are detected in Maltese (Ussishkin et al., 2013), pilot studies did not detect repetition priming in Moroccan Arabic. The lack of repetition priming suggests the technique needs to be modified. One key difference between Moroccan words and English words, which did show repetition priming, is their duration (measured in seconds). Kouider and Dupoux (2005) recommend that the prime word be compressed to 35% or 40% of its original duration with the subliminal speech priming technique. For some Moroccan words, however, the 35% compression rate left the word's compressed duration less than 100ms. This experiment tests monosyllabic words of English to see if there is an compression goal beyond which words do not induce repetition effects. The ideal compression goal, in milliseconds, should serve as a floor for prime durations in Moroccan Arabic. If Moroccan Arabic words are simply shorter than English or French words and using (Kouider and Dupoux, 2005)'s relative 35% compression rate compresses the primes beyond the point of recognition, this compression goal will tell us what the true prime duration should be for Moroccan Arabic.

When the prime is too short, we expect to see effects of neither real word nor nonword repetition. This is because the word is too compressed to be recognized at all. As the prime duration increases, we should see a “sweet spot” where repetition effects obtain but not nonword repetition (cf. Kouider and Dupoux, 2005). Prime durations which see real-word repetition but not nonword repetition are the desired compression goal. Longer prime durations will see both real-word and nonword repetition effects, and these are undesirable. Nonword repetition effects indicate that the technique is detecting non-lexical effects, such as priming based on the phonemes alone or some form of memory of the prime word. This experiment tests prime durations at 200ms, 220ms, 240ms, 260ms, and 280ms. Contra (Kouider and Dupoux, 2005), the compression goal in this study is sought with fixed durations, rather than a compression rate relative to the word’s original duration. This is intentional. If, for example, the “sweet spot” is a relatively small window in terms of absolute prime duration (rather than relative compression rate), a 100ms difference in a word’s original duration (the type that may come about from a speaker carefully pronouncing some words in a word list and using a more casual style for others) may make the difference between a compressed prime falling within the “sweet spot” or outside of it.

2.2 Experiment 1

Given that prime duration must play some role in subliminal speech priming, what is the shortest compression goal which can be used for monosyllabic words? This experiment investigates the prime duration for real word repetition and nonword repetition effects. Those durations which show real-word repetition priming but not nonword repetition priming are the appropriate duration for use with the subliminal speech priming technique. The language used for this experiment is English. There are two benefits of using English. First, English-speaking subjects were readily accessible. Second, we can compare the results of English to other languages (such as Moroccan Arabic) to see if the human perception system functions the same across different languages. The factors tested are the experimental condition (Identity, Control), lexicality (word, nonword), and prime duration (200ms, 220ms, 240ms, 260ms, 280ms) for a $(2 \times 2) \times 5$ design. Prime duration is a between-subjects factor.

2.2.1 Methods

Participants

Participants were recruited either via Amazon's Mechanical Turk or were University of Arizona undergraduates. Regardless of recruitment platform, subjects were tested with the remote application of DMDX and used their own computers at a place and time convenient to them. Mechanical Turkers were paid $0.70 US for their time, while University of Arizona students received course credit. Approximately 25 participants were recruited for each experiment to achieve a goal of 20 subjects per experiment. Data was excluded from subjects who were a) non-native speakers, b) neither using headphones nor occupying a quiet room, c) achieved less than 70% accuracy on experimental trials, d) achieved greater than 70% accuracy on a post-test of prime awareness, or e) reported a history of hearing problems. 16 subjects participated in the 280ms prime duration condition (32 recruited and 14 excluded–4 non-native speakers, 4 for low accuracy, 9 for prime awareness with some reasons overlapping). 19 subjects participated in the 260ms prime duration condition (30 recruited and 11 excluded–4 non-native speakers, 1 for accuracy, 6 for prime awareness). 19 subjects participated in the 240ms prime duration condition, 25 recruited and 6 excluded–3 non-native speakers, 2 for history of hearing problems, 1 for accuracy, 3 for awareness with some reasons overlapping). 24 subjects participated in the 220ms prime duration condition (27 recruited and 3 excluded–1 non-native speaker, 1 for low accuracy, and 1 for prime awareness). 25 subjects participated in the 200ms prime duration condition (28 recruited and 3 excluded–1 non-native speaker and 2 for low accuracy).

Materials

English words were selected in two factors with two levels each – Lexicality (Real word, nonce word) and Condition (Identity, Control) – with five prime durations for a $2 \times 2 \times 5$ design. 72 real-words and 72 nonwords were used. The real words had a frequency between 50 and 150 times per million (mean frequency 84 times per million, $SD = 26$) in the SUBTLEXUS corpus (Brysbaert and New, 2009). The unstressed neighborhood density varied between 18 and 27 (mean density 22.2, $SD = 3.1$ Vaden et al., 2009). The lexical uniqueness point of the word was always at the end of the word. These words were tested at five different prime durations (200ms, 220ms, 240ms, 260ms, 280ms). Earlier studies suggested that no repetition priming would obtain when words were compressed to 120ms or 160ms, so 200ms is the shortest duration reported here since the 200ms duration is indicative of the shorter durations as well. An interaction between the lexicality factor and the experimental condition factor will show that there are differential effects for words and nonwords. Such an interaction indicates the prime duration is our compression goal. When real words and nonce words show differential effects (i.e., a facilitation effect for the real-word identity condition but not the nonce word identity condition) we will have identified the sweet spot in terms of prime duration. The real and nonword stimuli are presented in Appendix A.

Procedure

The experiment was presented with the remote application of DMDX for all subjects, meaning subjects may have participated at home, in an office, or at a local café. Subjects read the instructions and consented via button press. Subjects were instructed to use headphones and occupy a quiet room if possible, eliminating as many distractions as they could. Subjects also heard one sample word at the volume level of the target words, and a second at the level of the primes. They were instructed to adjust their volume so they could comfortably hear both words, and not to adjust it again for the duration of the experiment. A pilot experiment showed no difference between subjects who used speakers in a quiet room or headphones outside of a quiet room when this volume check was in place. Data from subjects was discarded if they did not report either a) occupying a quiet room and using speakers or b) using headphones regardless of their location.

Subjects responded with the left and right arrow keys (*yes* and *no*, respectively). After the experiment proper, subjects preformed a second lexical decision task, this time on the subliminal primes from a new set of stimuli. Subjects were instructed to expect hearing the prime before the target word, and to base their decision on whether or not the prime was a word they recognized or not. Data from subjects who were aware of the compressed primes–measured by greater than 70% accuracy on the post-test–was discarded.

2.2.2 Results

A linear mixed-effects regression (LMER) model was used to analyze the data (Baayen, 2008). When the inclusion of random slopes improve the fit of the model, p-values are simulated, otherwise they are derived according to Baayen (2008)[1]. While some have questioned the reliability of LMER models in recent years, those models which consider random slopes as well as random intercepts appear more viable than traditional F1 and F2 ANOVA analyses (Barr et al., 2013). Reaction times were measured from target offset, and target duration and trial number were included in the models. Target and uncompressed prime duration, as well as the prime's compression ratio (as a percentage), trial number, and subject's age were

[1] i.e., `2 * (1-pt(abs(t), NumberOfObservations-FixedFactors)`

Table 2.1: Experiment 1 – Table of Means

	Real Control	ID	Difference	Nonwords Control	ID	Difference
280ms	279ms	191ms	88ms	280ms	246ms	34ms
260ms	278ms	236ms	42ms	274ms	253ms	21ms
240ms	350ms	339ms	11ms	335ms	336ms	-1ms
220ms	329ms	311ms	18ms	310ms	309ms	1ms
200ms	350ms	339ms	11ms	335ms	336ms	-1ms

tested in each model. The means of each compression rate are presented in Table 2.1.

Two words (*pull* and *wind* [wɪnd]) and five nonwords ([gaʊnt], [θæst], [ðɪn], [wɑɹt], and [jɪs]) did not achieve 70% accuracy from subjects and were excluded in the analysis. 2.8% of the observations were excluded as outliers. An interaction was detected between the experimental manipulation and the prime duration factor at the 280ms ($p < .0001$) level as well as the experimental manipulation and the lexicality factor ($p < .03$) with the experimental condition, lexicality, and trial number as random slopes for subjects. This motivates examining the effects of each prime duration separately. Here I treat each of the prime durations as its own experiment.

For the 280ms prime duration, one word (*bank*) and six nonwords ([gaʊnt], [lænd͡ʒ], [pɹoʊs], [wɑɹt], [waʊnt], and [jɪs]) did not achieve 70% accuracy and were excluded from the analysis. 2.5% of the observations were excluded as outliers. There was no interaction detected between the two factors ($p > .05$), indicating that the same effects obtained for both words and nonwords. The best fitting model includes random slopes for lexicality and trial number by subject. The experimental condition was significant ($Estimate = -51ms, SE = 5.7615, t = -8.908, p < .0001$)

and lexicality ($Estimate = -52ms, SE = 14.0995, t = -3.693, p < 0005$). Trial number ($Estimate = -0.4ms, SE = 0.1629, t = -2.302, p < .05$) , subject age in years ($Estimate = 4ms, SE = 2.0487, t = 2.072, p < .05$), and target duration ($Estimate = -345ms, SE = 57.2396t = -6.025, p < .0001$) were also significant. This indicates that nonwords are slower to respond to, but the effect of repetition priming is identical at this prime duration.

For the 260ms prime duration, four words (*join*, *shop*, *song*, and *wind* (i.e., the noun [wɪnd]) did not achieve 70% accuracy from subjects, along with 5 nonwords ([kweɪt], [θæst], [wɑst], [waʊnt], and [jɪs]) and were excluded from the analysis. 2.4% of the observations were excluded as outliers. The best fitting model tested the experimental condition, target lexicality, trial number, and target duration with random slopes for lexicality and trial number for subjects. There was an interaction detected between the experimental condition and lexicality ($Estimate = -29ms, SE = 12.46372, t = -2.321, pMCMC = 0.0136$), indicating that words and nonwords show differential effects. Repetition priming obtains for nonwords words ($Estimate = -22ms, SE = 7.7606, t = -2.878, p < .005$) with trial number as a random slope for subjects significant along with target duration ($Estimate = -380ms, SE = 77.3855, t = -4.909, p < .0001$) and trial number ($Estimate = -0.7ms, SE = 0.1583, t = -4.267, p < .0001$) as well as for real word repetition ($Estimate = -42ms, SE = 7.763, t = -5.446, pMCMC = .0001$) and target duration ($Estimate = -334ms, SE = 81.470, t = -4.097, pMCMC = .0002$) were significant. Both real words and nonwords show facilitation, though the estimate for real words is significantly greater than for nonwords at this prime duration.

For the 240ms prime duration, two real words (*meant*, *pull*, and *thin*) and seven nonwords ([gaɪnd], [lænd͡ʒ], [mænd͡ʒ], [θæst], [ðɪn], [wɑɹt], and [jɪs]) did not reach 70% accuracy after removing inaccurate subjects, so they were excluded.

2.4% of the observations were excluded as outliers. There was no interaction detected between the experimental condition and lexicality ($p > .05$), but there was an effect of repetition ($Estimate = -20ms, SE = 5.6128, t = -3.489, p < .0005$) as well as target duration ($Estimate - 241ms, SE = 53.9638, t = -4.474, p < .0001$), age ($Estimate = 3ms, SE = 0.8661, t = 3.354, p < .001$), and prime compression percentage ($Estimate = -219ms, SE = 1028.2517, t = -2.131, p < 05$) with random slopes for the experimental condition for items and target duration for subjects. This result is quite odd, because it resembles the results for the 280ms prime duration, not the 260ms prime duration. This suggests that both words and nonwords show repetition effects equally (as in the 280ms rate) rather a differential effect or no repetition effects at all (predicted if words are excessively compressed). A post-hoc test of just the real words indicated effects of repetition priming ($Estimate = -27ms, SE = 8.3255, t = -3.211, p < .005$) and age ($Estimate3.ms, SE = 0.9621, t = 3.063, p < .005$) but not target duration ($p > .05$) when random slopes for the experimental condition were included for items. For nonwords, only target duration was significant ($Estimate = -411ms, SE = 59.12, t = -6.955, p < .0001$), not the experimental condition ($p > .05$). This post-hoc test reveals that the real-words and nonwords may not behave identically after all.

For the 220ms prime duration, one real word (*pull*) and four nonwords ([θæst], [ðɪn], [wɑɹt], and [jɪs]) did not reach 70% accuracy after removing inaccurate subjects, so they were excluded. 2.4% of the observations were excluded as outliers. There was no interaction detected between the experimental condition and lexicality ($p > .05$). There was an effect of repetition ($Estimate = -15.73, SE = 4.35, t = -3.616, pMCMC = 0.0004$) but not lexicality ($p > .05$).Target duration was also significant ($Estimate = -320ms, SE = 46.88, t = -6.820, pMCMC = 0.0001$). As in experiment 1c, this motivates a post-hoc analysis since it is unexpected.

When only real words are considered, there is a significant effect of repetition ($Estimate = -24ms, SE = 5.998, t = -3.939, pMCMC = 0.0001$), target duration ($Estimate = -315.903, SE = 86.317, t = -3.660, pMCMC = 0.0004$), and the prime compression percentage ($Estimate = -2303.625, SE = 1110.608, t = -2.074, pMCMC = 0.0368$). When only nonwords are considered, only the target duration is significant ($Estimate = -389ms, SE = 58.54, t = -6.646, p < 0.0001$). There is no effect of repetition (p>.05).

For the 200ms prime duration, two real words (*pull* and *wind* [wɪnd]) and nine nonwords ([bænt͡ʃ], [gaʊnt], [land͡ʒ], [θæst], [ðɪn], [wɑɹt], [jɪs], and [jɪt]) did not reach 70% accuracy after removing inaccurate subjects, so they were excluded. 2.2% of the observations were excluded as outliers. There was no interaction detected between the experimental condition and lexicality (p>.05). There was no effect of repetition ($p > .05$) or lexicality ($p > .05$). Target duration was significant ($Estimate = -330ms, SE = 50.84, t = -6289, pMCMC = 0.0001$). A post hoc analysis shows no repetition effects for either real words or nonwords alone (both $p > .05$).

It is also of note that the percentage of the total recruited subjects who were excluded for the post test of awareness decreases along with prime duration ($280ms = 28.1\%, 260ms = 20\%, 240ms = 4\%, 220ms = 3.7\%, 220ms = 0\%$).

2.2.3 Discussion

Real word priming was detected between 280ms and 220ms. Nonword priming was detected at 280ms and 260ms. The interaction of the factors did not reveal differential priming effects at the 240ms and 220ms rates, perhaps because of the small size of priming effects and lack of power. At the 240ms and 220ms rates, the distinction between real word and nonword effects was only detected with a post-hoc analysis. Nonetheless, these results suggest that monosyllabic primes with the

Table 2.2: Summary of Prime Durations – The "sweet spot" for the technique (shown in gray) is between 240ms and 220ms, where real word repetition obtains but not nonword repetition.

Prime Duration	Real Word Repetition	Nonword Repetition
280ms	Yes	Yes
260ms	Yes	Yes
240ms	Yes	No
220ms	Yes	No
200ms	No	No

subliminal speech priming technique should be compressed to between 240ms and 220ms. The higher rate of 260ms may produce larger (and thus more reliable) effect sizes, but risks nonword priming. The upper bound of 240ms may be expected to produce larger priming effects than the lower bound of 220ms, but that is not born out by the results here. Different speakers and recording techniques may not provide results with the relative 35-40% rate, so it should be adjusted so that prime duration falls within 220-240ms. The optimal compression rate here is suggested for monosyllabic words of English.

2.3 General Discussion

Experiment 1 was designed to test the limits of human perception and identify a prime duration in terms of milliseconds which would induce repetition effects for real monosyllabic words of English but not nonwords. The appropriate duration for compression of monosyllabic English words with a frequency between 50 and 150 times per million is 240ms, which is the longest duration which produces repetition effects for real words but not nonwords.

These results suggest that a floor of 220ms for prime durations is recommended with the subliminal speech priming technique. 260ms primes should give maximal effect size (increasing statistical power) with minimal risk of nonword repetition effects obtaining. Any attempt to use this technique as presented by Kouider and Dupoux (2005) where the 35% compression ratio would result in prime durations below 220ms may not be sensitive to repetition priming at all. This recommended floor ought to obtain for longer words as well: if monosyllabic words are unrecognizable when compressed beyond 220ms, surely bisyllabic, trisyllabic, quadrisyllabic, or longer words would also be unrecognizable. Furthermore, prime durations of 260ms or longer risk detecting non-lexical phenomena since nonword repetition priming may obtain. Here it is not certain that this ceiling should be applied to polysyllabic words.

It is also not yet clear, however, if the compression goal discovered here is appropriate for all words of any given language. Further research is required to see how word length (measured by syllables, segments, or average duration in milliseconds), lexical frequency, neighborhood density, morphological family size, and other lexical factors may be relevant for the compression rate required to detect real word repetition effects without nonword repetition effects.

Moreover, languages may have different ideal compression rates. One pilot study in English failed to detect nonword repetition effects at the 260ms duration. Some experiments (see chapter 4) detect nonword repetition effects at the 240ms rate, so other factors may yet influence the ideal prime duration for this technique. If average word duration in Moroccan Arabic is shorter than the average English word duration, a difference in the “sweet spot” of priming is not entirely unexpected. Researchers should carefully consider the compression of primes with the subliminal speech priming technique, and test for nonword repetition priming until compression rates for a given language or speech community are established. The “sweet spot” identified in these experiments, however, can be taken as a baseline to more easily adapt the technique in the future.

Further research may determine whether the limits of the technique discussed here are language and community specific, or if this represents the limits of human cognition. The percentage of recruits who can reliably identify prime words falls to 0% when words produce no priming, which may indicate that there is a hard limit to the the lexical system. Lexical factors such as frequency and density may also play a role in the optimal prime duration for this technique. Certainly it is no surprise that compressed words can be understood, as even academic lectures can be recorded and played back at double speed comprehensibly. Data from subjects who achieved 70% accuracy on the post-test of prime awareness was discarded in these experiments, so some speakers may individually be able to detect primes with shorter duration. It is not known what factors (age, gender, familial handedness, socioeconomic status, vocabulary size, average speech rate, genetic endowment, intoxication, etc.) may influence a subject's ability to perceive (or not perceive) compressed primes.

2.4 Conclusion

The subliminal speech priming technique is still in its infancy, but the results presented here, and in the following chapters, suggest that this technique is a fruitful domain of future research. The technique may open up the field of lexical access to all sorts of questions, most notably how unwritten dialects are processed, the effects of bilingualism and diglossia with unwritten dialects, prosody and supersegmental features of spoken language, auditory studies on illiterate and preliterate populations, etc.

Next, I apply the technique technique to Moroccan Arabic to investigate if the Moroccan Arabic lexicon includes root morpheme elements in chapter 3.

CHAPTER 3

SUPRALIMINAL AND SUBLIMINAL ROOT PRIMING IN MOROCCAN ARABIC

3.1 Introduction

Semitic words are often described as being composed of a discontinuous triconsonantal root (e.g. /k_t_b/, which is synthesized with a mostly vocalic pattern e.g. /_a_a_/) to produce word-forms, such as the Standard Arabic /katab-/ 'wrote' (see chapter 1 for more details). The triconsonantal root theory is a compelling formal description of Semitic morphology, but is there evidence that the root plays a processing role in spoken word recognition? This chapter provides such evidence from supraliminal and subliminal auditory priming in five experiments that test semantic, phonological, and morphological (i.e., root) relationships between Moroccan words. The semantic relationship is tested with synonymous word pairs, the phonological with word pairs which differ by one root consonant, and the morphological with word pairs that share the root. I show that auditory repetition and morphological priming effects robustly obtain across experiments and that root priming effects are distinct from semantic and phonological effects in Moroccan Arabic. The morphological relationship, however, is a property of words: the morphological or root relationships tested are not uniformly applicable to all words within a morphological family. The implications for a cluster analysis of morphologically related words in speech perception are discussed below.

Semitic languages are known for a peculiar set of language-family specific alternations: these alternations are generally referred to as *Root and Pattern* (R&P) morphology (see chapter 1) and are characterized by a large number of word-internal changes. These changes are exemplified by the Moroccan Arabic forms /ktəb/ 'he wrote', /kəttəb/ 'he made someone write', /katəb/ 'he corresponded with', and /ktab/ 'it was destined (i.e., written in a cosmic sense)' Harrell (1962). In each of the proceeding Moroccan words, three consonantal phonemes–the root $\sqrt{ktb}$ – occur in the same linear order, but each word has a different prosodic and vocalic pattern. Linguists differ on the best way to represent R&P morphology, or even if a root representation is necessary when accounting for these languages (see chapter 1). Many formal models of language posit the root as a mental entity (e.g., Arad, 2005; Bachra, 2001; Bender and Fulass, 1978; Boudlal, 2009; Faust and Hever, 2010; Hudson, 1986; McCarthy, 1981; Rose, 2003; Tucker, 2010, amongst many others). Here I assume these theories are correct and search for evidence of the root morpheme from the perspective of language behavior by measuring subjects' reaction times in auditory lexical decision tasks. This chapter reports a series of experiments that use auditory priming techniques to test if there are morphological relationships between words in the mind of Morocan Arabic speakers, and if those morphological relationships are best described by a root morpheme of the abstract, triconsonantal type proposed by McCarthy (1981); Arad (2005); Faust and Hever (2010) and others. I show that neither semantics nor phonology alone account for the results of auditory priming, suggesting the formal root is represented in the mind. While the root accounts for the facts of auditory priming with real words, There are no root-effects for novel words which are not part of the speaker's lexicon. The root cannot be an independent, sublexical entity since these non-words–words which were built with real roots and patterns like novel coinages–do not facilitate lexical access at the earliest levels of lexical access as well-attested words do.

Moroccan Arabic has four main verbal patterns equivalent to their standard Arabic cognates: Form I (CCəC), Form II (CəCCəC), Form III (CaCəC) and Form

IX (CCaC) (see chapter 1). If there is a priming effect between words like /ṛṭab/ 'it became smooth, soft (Form IX)' and /ṛəṭṭəb/ 'he made something smooth, soft (Form II)', the amount of phonological and semantic similarity is substantial: not only are the two words nearly homophonous, they're nearly synonymous. We should not accept root priming effects without first seeing whether they are distinct from semantic and phonological effects. These experiments use new data (Moroccan Arabic) and methodology (auditory priming) to replicate earlier results of root priming (Boudelaa and Marslen-Wilson, 2011; Boudelaa et al., 2010; Boudelaa and Marslen-Wilson, 2005; Frost et al., 2005; Boudelaa and Marslen-Wilson, 2004a,b, 2001a,b; Frost et al., 2000; Deutsch et al., 1998; Frost et al., 1997; Twist, 2006; Ussishkin and Twist, 2009; Ussishkin et al., 2013; Velan and Frost, 2011; Velan et al., 2005) and extend those to examining all aspects of the root as a morpheme.

Whether or not the mind represents morphemes independently remains an important issue for formal linguistics. The lexicon has historically been the place where sound-meaning relationships reside. Furthermore, this theoretical entity has often become a dumping ground for irregularity. On the lexicon, Chomsky states: "I understand the lexicon in a rather traditional sense: as a list of 'exceptions', whatever does not follow from general principles," Chomsky (1995, p. 235). Words, however defined, are said to reside in the lexicon as there is no set of general principles which can predict how a semantic concept is linked to any given phonological form. Moreover, exactly what is listed in the lexicon is up for debate. Is it fully-specified word-forms? Or are bound and free morphemes all listed in the same place, facilitating analysis and synthesis of word-forms?

Stockall and Marantz (2006) call attention to the arbitrariness of previous analysts by criticizing dual-route models, where allomorphs are simply lexically listed. Stockall and Marantz (2006) suggests that a theory where allomorphs are simply lexically listed is nonsensical in terms of priming or paradigms. That is to say, if two lexical entries have absolutely no connections between them (as separate listing would suggest), there is no reason that *teach* and *taught* should be related in the mind other than the fact that these words have shared semantics and some phonological similarity. Worse yet are allomorphs, such as *go* and *went* which have no phonological similarity. If *go* and *went* are simply listed in the lexicon as two distinct words, we would expect semantic priming at best, but no phonological or morphological priming between the two distinct words. This is not the case. Stockall and Marantz (2006) suggests that there must be some level of mental representation or processing where allomorphs such as *teach* and *taught* are linked, since data from MEG recordings show priming effects. In the same way, these experiments will show that Semitic verbal derivations, including forms like /ktəb/ and /kəttəb/ share some level of mental representation that is distinct from simply phonological form and semantics because these words prime one another, as measured in supraliminal and subliminal lexical decision tasks (see Figure 1.1 in chapter 1). Experiments 2, 3a, and 3b show that morphological, root-based, effects obtain when semantic or phonological facilitation effects do not. This suggests that the root exists as an abstract mental entity, or at least that there are morphological connections between words which are not the same as similarity in phonological form or meaning.

Novel coinages, as used in experiments 4a and 4b, are non-existing words derived from existing roots and patterns, but the word itself has no lexical representation of its own. These are logically possible words from the perspective of both phonology and morphology, but these phonological forms (i.e., the particular combination of roots and patterns as a phonological word) are not part of the speaker's lexicon. For example, the Moroccan nonword */həttər/ shares the consonants of /htər/ 'he talked nonsense; wandered' and the legal pattern CəCCəC. The novel coinage*/həttər/ might plausibly mean 'he made someone talk nonsense; made someone get lost; or kept on talking a lot of nonsense', but speakers reported difficulty in interpreting words like this. English equivalents to the Moroccan novel coinages used in experiments 4a and 4b would include words like *inceive* or *circumception*, both of which are plausible words of English. Most English speakers, however, may have never read or heard either *inceive* or *circumception*. Furthermore, many speakers might have difficulty assigning these novel coinages a meaning, particularly without any context. Novel coinages have been used in the visual domain (Duñabeitia et al., 2008) to suggest that orthographic word-forms show evidence of composition in word processing, and that individual morphemes have their own orthographic representations listed. Thus, we know that orthographic words like *darkness* prime *happiness* and that even non-word sequences of letters and symbols like *%&%&ness* will prime *happiness*. This autonomous morphological decomposition process seems to be specific to word recognition tasks, rather than a property of vision in general (Duñabeitia et al., 2011). If root morphemes are represented independently of words, we expect that the novel coinage should be able to activate such a root representation and produce significant priming effects.

Furthermore, not only should a root processing unit be able to be activated by phonology alone, but roots should activate all of their family members. Experiment 5 tests this by looking at the three major verbal forms in Moroccan Arabic and testing the priming effects of verb forms. If roots are processing units with phonological content, we may expect roots to preferentially activate one related form or another, but how a root is initially activated should be irrelevant to the later activation.

While formal models of language differ from models of language behavior, the crossroads of the two, where models of language and language behavior converge, leads us towards a better understanding of both types of models. Uniting the formal, symbolic system of language with evidence from language behavior will give us a more parsimonious theory of language (Chomsky, 2000; Poeppel and Hickok, 2004, among others). In this chapter, I present behavioral evidence against the consonantal root in Semitic using only auditory techniques. These experiments look for priming effects to investigate which factors are important during lexical access. While behavioral evidence cannot show what a lexical representation or the access process looks like, it is strong evidence for the existence of particular entities or pathways in the lexicon. Though there is evidence suggesting that root relationships are important in the lexical system, the relationship itself does not constitute a root processing unit or morpheme.

Before we can test if Semitic root effects correlate with all aspects of the formal root definition (see chapter 4), we first need to establish that the root is a mental entity that can be detected with behavioral techniques. Furthermore, it must be shown that root-based morphological effects are distinct from semantic and phonological effects. If semantics or phonology alone can account for these effects, there is no reason to assume that the root is a distinct mental entity (See chapter 1). If either semantics and phonology do not produce similar effects as the root, then we can confidently assume that what we call the root is some sort of mental entity form a behavioral perspective. I use verbs to test these possibilities.

Six experimental priming conditions can untangle the effects of semantics and phonology from the representation of the root (if any): repetition, phonology, semantics, morphology, and a control. Each experiment tests a morphological (root related) condition, along with repetition (identity) and control (unrelated) conditions. Repetition and control conditions establish the baselines to test the phonological, semantic, and morphological conditions. Experiment 2 tests the semantic relationships. Experiments 3a and 3b test for phonological priming. Experiments 4a and 4b test for an independent existence of a root morpheme by using novel coinages. Finally, experiment 5 tests the ability of the three major forms of the

Moroccan Arabic verb to prime equally. If there are root priming effects without semantic and phonological effects, we can conclude that the root-relationship plays a major role in lexical access, and may therefore have some lexical representation. Furthermore, if nonwords built from real roots show priming effects, that is evidence that roots would have an independent existence apart from the words in which they are incarnated. If all verbal forms can activate their related forms, we will have strong evidence for a root-based theory of morphological families in speech perception. These six experiments show that the morphological relationship is distinct from both semantics and phonology. Furthermore, the morphological relationship is quite strong, as it is detectable with both priming techniques. There are differences between supraliminal priming, which tests these relationships at a late stage of lexical access, and subliminal priming, which tests the earliest levels. The lack of each root to equally prime its family members, however, casts doubt on the root as an independent entity in the lexicon. These experiments show that morphological families have a place in linguistic theory, and morphological cluster theory of lexical access (e.g., Frost et al., 1997) for Semitic languages.

3.2 Experiment 2: Semantics

First, to what extent does the meaning of a word interact with the word's morphology? This experiment tests whether root effects are similar to semantic effects, and if semantics affects root priming. Since morphemes are defined as meaningful units, the meaning of the word or morpheme may be a key factor when recognizing words. Similarity in meaning is known to affect auditory word recognition (Radeau, 1983), though it might not interact with morphological effects (Emmorey, 1989). This experiment manipulates one experimental factor with four different prime types (a 1×4 repeated measures design): identity, an unrelated control, semantics, and root. Semantics is defined as synonyms, and the root is the theoretical construct defined by linguists and philologists in theoretical, descriptive and prescriptive grammars. If root priming and semantic priming are equivalent, we can conclude that there is no need for a root morpheme to account for root effects.

This experiment is designed to show whether identical, semantically related, and morphologically related items show priming effects compared to the unrelated control condition. Furthermore, the morphologically related words were divided in half: half were judged by one or two native speakers as close in meaning, and half judged as distant in meaning. Thus, the results of priming can be tested not for just semantically related words, but also two classes of morphologically related words: those which are related both morphologically (by the root) and semantically, and those which are semantically unrelated but share the root (cf. Frost et al., 1997). If there is a semantic effect either from the main experimental condition or within the morphologically related items, we can conclude that semantics plays a role in lexical access for Moroccan Arabic speakers, and such effects can be compared to those for repetition priming. Based on numerous studies of morphological processing in general and Semitic in particular (e.g., Frost et al., 1997; Boudelaa and Marslen-Wilson, 2001a; Emmorey, 1989; Velan and Frost, 2011; Ussishkin and Twist, 2009, among others), root priming, if not semantic priming, is expected to obtain in this task.

3.2.1 Methods

Experiment 2 is an auditory lexical decision task. Participants heard two words in each trial: a prime word, a 150ms interstimulus interval of silence, and then the target word. Subjects were instructed to disregard the primes and focus on the targets. Rather than a yes/no lexical decision, the experiment uses a go/no-go response (following Perea, 2002) in an effort to increase accuracy. In a go/no-go task, subjects are instructed to only respond to real-word stimuli, thus subjects were asked to only respond to words that they recognize. No response will time out, allowing for accuracy to be measured but no reaction time data is then collected for nonwords and reaction times for incorrect responses cannot be analyzed.

Participants

60 subjects were recruited for this experiment. Five recruiters were hired to spread word of mouth, each recruiter was pursuing either a BA or MA in linguistics at a Moroccan university. 0 The subjects, then, represent the people most likely to interact with younger Moroccans attending university such as their friends, family, and colleagues.

Participant data was discarded for lack of accuracy, skipping demographic questions, being too young to give consent, abnormal hearing, etc. Thus, the recruitment target was set at 60 participants, in order to reach a target goal of 48 subjects. Data was excluded from subjects who did not speak Arabic as their first language (4), reported problems with hearing (1), and did not use headphones to complete the experiment (2), leaving data from 42 subjects (cf. Simmons et al., 2011).

Materials

A total of 54 target words were selected to appear in four counterbalanced conditions, and 54 phonotactically legal nonwords were created as filler items. The Moroccan words for this–and all other Moroccan experiments–were based on a list of verbs taken from (Harrell et al., 2004), which was vetted by two native speakers. Words which the speakers did not recognize or considered only classical words were eliminated from consideration. The identity condition is an exact repetition of the target using the same token (e.g. sound file) as the target. The semantic

Table 3.1: Experiment 2 – Conditions

Condition	Prime	Target
Identity	hbəṭ 'come down'	hbəṭ
Control	ftəq 'unsew, unseam'	hbəṭ
Semantics	nzəl 'go down'	hbəṭ
Root	həbbəṭ 'lower, bring down'	hbəṭ

condition represents synonyms of the target as judged by two native speakers. The morphological condition is a word related via the root. The full set of priming conditions for one target word, hbəṭ, is given in Table 3.1. In this experiment, there was no attempt to control for the morphological form of the target or prime, so both targets and primes vary in verbal pattern. Furthermore, half the root-related items were divided into opaque (distant in meaning) or transparent (close in meaning) relations. The real word stimuli are presented in Appendix B.

The nonword filler items were constructed from legitimate phonemes, syllable structure, and verb patterns of Moroccan Arabic, though none of the verbal roots occurred in dictionaries of Moroccan Arabic (Harrell, 2004), Standard Arabic (Wehr and Cowan, 1979), or the Palestinian (Elihay, 2007) or the Gulf (Qafisheh, 1997) dialects (chosen because of their wide geographic coverage and the availability of dictionaries which were readily accessible). Words and nonwords were vetted by two native speakers to avoid inclusion of nonwords as real words (and vice versa) in the study. In every case the nonword was preceded by a real-word prime. This was designed to avoid an anticipation strategy.

Items were recorded by one phonetically-trained male speaker from Rabat. He repeated each word three times, and the middle token was selected in each case unless the token was unclear or contained non-linguistic noises. All the verbs of the language (as found in Harrell (2004)) were recorded over a span of approximately two months, and the speaker was unaware of any experimental conditions at that time. The recordings used as primes and targets were manipulated only so they were similar in terms of volume, they were otherwise identical.

Procedure

Subjects participated in the experiment on laptop computers running DMDX (Forster and Forster, 2003) using the keyboard (left and right arrows) to collect responses. No data was collected on the location of participation by subjects. Written instructions were provided in both French and Arabic simultaneously, and the instructions were read aloud (or paraphrased in the spoken dialect) to subjects upon request in the language of their choice. Consent was obtained via button press as subjects began the experiment. Subjects were instructed to use headphones, and consider all Arabic words they know (i.e., their local dialect and the formal, standardized dialect), though the stimuli were presented as spoken in the local dialect. Each trial consisted of two words presented binaurally. There was a 150ms interstimulus interval between the prime and target. There was a 2200ms timeout measured from target onset. Because the lexical uniqueness point of each target word cannot be calculated, the reaction times are measured from both target onset and target offset. Subjects were asked to only respond to Arabic words that they recognized, broadly defined since some words of Classical Arabic or French are used in the Moroccan dialect. Subjects received visual feedback for correct (*Correcte* صحيح) and incorrect (*Incorrecte* غير صحيح) responses.

Many additional quasi-independent variables were tracked for use in the statistical model. Order of presentation (Trial number) was recorded, as well as target and prime duration. Participants also responded to 11 demographic questions (see Figure 3.1) which could be used to control sociolinguistic factors that might influence the results, since lexical factors such as word frequency and neighborhood

Figure 3.1: Demographic Questions – These questions were asked of subjects for each experiment, and could be entered into the model as quasi-experimental factors.

Age: Numeric	How old are you?
MotherTongue: Arabic / Other	Which language is your mother tongue?
Dialect: Casablanca or Rabat / Other	Which dialect do you speak?
Gender: Male/Female	Are you male or female?
Hearing: Normal/Abnormal	Have you had medical problems with your hearing?
SES: Hi/Low	Have you or either of your parents attended university?
Headphones: Headphones/Speakers	Are you using headphones or speakers?
Home: Arabic / Other	Which language do you usually speak at home?
Lefthanded: Right/Left	Are you left handed or right handed?
Read: Arabic / Other	Which language do you prefer to read in?
French: Highly Proficient / Not	Do you speak French very well?

density were not available. These demographic questions could also be used to exclude data from subjects who were not taking enough time to read these questions (a median time of less than 500ms for reading and responding to all the questions) or recruiters who were answering questions quickly (and presumably inaccurately) for subjects. Statistical models did not consider interaction of more than the number of experimental factors plus one, to avoid unnecessary statistical tests. Except for Age, each question was recorded as a binary choice, though in some cases (Dialect, Home language, etc) subjects choose from more options (e.g. for MotherTongue, subjects had a choice of Arabic, Berber, French, English, Spanish, and Other, with Berber, French, English, and Spanish all being considered "other"). It was expected that SES, Home, Read, and French would all measure some degree of bilingualism, and the only one might be appropriate in the final model. Of course, these factors might not be consistently significant across each experiment since the particular sample population in each experiment differs. Participants were first asked to complete the short demographic survey on the computer, then they received 20 practice items. Next they began the experiment proper.

3.2.2 Results

One real word (/ʕda/) and two nonwords were removed from the analysis because of accuracy below 70%. Data was trimmed so that responses greater than 2.5 standard deviations from each subject's mean was discarded. 2.7% of the total observations were eliminated as outliers. A linear mixed-effects regression (LMER) model was used to analyze the data. P-values are simulated with a monte carlo simulation (pMCMC) when the inclusion of random slopes does not significantly alter the model, otherwise calculated according to Baayen (2008) as in experiment 1 in chapter 2.

Models including just the experimental manipulation (the basic models) and models including quasi-experimental factors (the full models) were tested, measuring from both target onset and target offset (cf. Goldinger, 1996). Random slopes, as well as random intercepts were examined and random slopes were included whenever they improved the fit of the model. Only interactions of the experimental condition(s) and one quasiexperimental factor were investigated: given the number of participants in this and the following experiments, such three or four way interactions are likely to be uninterpretable and only risk type 1 error.

The primary model of these four, however, is the full model measured from target offset. Lexical Uniqueness point may be a key measure for target identification (Radeau et al., 1989); it is likely to be near the end of each word due to the structure of Semitic languages (Ussishkin and Twist, 2009). Using target onset and offset as points of measurement provide near approximations, particularly since the target's duration can be included in the model. Thus, the two different measurement points are provided in the interest of being conservative (Goldinger, 1996, and references therein). Nonetheless, in this and the following experiments the basic and

Table 3.2: Experiment 2 – Means and Percent Error

Mean RTs	Control	ID	Root	Semantic
RT Onset	969	794	823	959
RT Offset	494	321	351	485
Percent Error	6.9	4.7	4.9	6.2

full models, along with onset and offset measurements, generally converge. I report only the full model measuring from target offset here unless the patterns of significance between the models fail to converge.

The total factors which could be considered in the statistical model include: Experimental Condition (Control, Repetition, Morphology, Semantics), Age, MotherTongue, Dialect, Gender, Hearing, SES, Headphones, Home, Lefthanded, Read, French, and Trial Number (see Figure 3.1). Quasi-experimental factors are only included in models reported here when they are statistically significant. MotherTongue and Hearing were used to exclude subjects *a priori*, and not considered in the full model. Target and prime duration were also known (measured in seconds) and could be included in the full model. No other conditions or variables were considered in this analysis (cf. Simmons et al., 2011).

The raw means can be seen in table Table 3.2. Only correct responses were considered. Latencies less than 200ms or greater than 1500ms from the target onset were discarded.

The experimental condition was significant, with the identity ($Estimate = -174ms, SE = 15.59, t = -11.19, pMCMC = .0001$) and root ($Estimate = -139ms, SE = 15.57, t = -8.92, pMCMC = .0001$) conditions differing from the control, but not the semantic condition ($Estimate = -6ms, SE = 15.67, t = -0.36, pMCMC = .736$). Prime duration (in seconds, $estimate = -367ms, SE = 118.33, t = -3.11, pMCMC = .002$) was also significant. The inclusion of ran-

Table 3.3: Experiment 2 – Means for morphologically related trials

	Close	Distant
Onset	823	824
Offset	350	351
Percent Error	7.6	8.4

dom slopes did not significantly improve the fit of the model. It is interesting to note that the effect sizes are not mediated by the inclusion of target duration in the analysis: these effects are quite robust.

While the semantic and control conditions do not differ significantly, the morphological condition was divided into words judged by two native speakers to be close in meaning and those pairs judged to be far in meaning. There is no significant distinction between morphologically related trials which were judged to be close in meaning and those judged to be dissimilar ($Estimate = 19ms, SE = 28.437, t = 0.659, pMCMC > .05$). Target duration ($Estimate = -558ms, SE = 169.869, t = -3.287, pMCMC = 0.003$) was, however, significant. There is no detectable effect of semantic relatedness within the morphological condition when tested in isolation or with the aid of other factors. The means are given in Table 3.3 where only the trials in the morphological condition are considered.

3.2.3 Discussion

These results suggest that semantics plays little or no role in early lexical access of Moroccan Arabic verbs. I made two distinct attempts to detect semantic effects: first, I used synonymous prime-target pairs as one of the main experimental conditions. Second, half the morphologically related words were judged to be close in meaning, while consultants judged half the words to be distant in meaning.

The question consultants responded to was: /wəʃ l-məʕna qrib wla bʕidʔ/ ‘Is the meaning distant or close?’. Thus, if there were a distinction between morphologically related items which are semantically similar and those which are semantically different, it should have been detected. Neither of these attempts uncovered any effect of semantic priming.

The lack of an effect for semantic relationships between words is, perhaps, surprising, since semantic effects obtain in other languages with auditory techniques (Emmorey, 1989; Holcomb and Neville, 1990; Radeau, 1983; Radeau et al., 1998). There are three possible explanations. First, the lexical decision task may tap primarily into the level of phonological word-form, not deeper into semantic and conceptual representations. Second, semantic effects may simply be delayed in the processing of Moroccan Arabic, perhaps due to widespread bilingualism or the morphological structure of Semitic languages. Subjects do not appear have enough time to access word meaning with a 150ms ISI. Assuming a morphological access route (cf. Frost et al., 1997; Boudelaa and Marslen-Wilson, 2004a,b, et seq.) exists (see chapter 1), it appears to be so important that a semantic route, if available, may be significantly underdeveloped in Moroccan Arabic. Another explanation is that both attempts at defining semantic relatedness have simply failed.

While synonymy could be a poor measure of semantic relatedness in Moroccan Arabic, the lack of any difference within the morphological condition is striking. Semantically close morphologically related items generally differ only in argument structure: the different forms of Moroccan Arabic verbs are generally transitive/intransitive, causative/inchoative, active/passive, comittative/reciprocal, etc. (Harrell, 1962). The non-significant facilitation effect measured by the means may indicate that a more sophisticated test could detect semantic differences. However, neither (Frost et al., 1997) nor Boudelaa and Marslen-Wilson (2004b) find semantic effects. Future research might use a longer ISI to test for later semantic effects, test associative relationships, or make use of different tasks in a more extensive battery of tests to detect semantic effects in Arabic or related languages.

The strong and significant effect of morphology (i.e., the root), however, suggests that it is a major contributer of lexical access in Moroccan Arabic, regardless of the meaning. A lack of semantic effects for Semitic morphology was also shown visually in Hebrew (Frost et al., 1997). Both Hebrew and Moroccan Arabic show productive root & pattern morphology, so there is no reason to expect major differences between the two languages or the two modalities. We can also see that morphological effects are distinct from repetition effects in this case, where the morphological form of the verb was not controlled or limited for targets or primes. This experiment has demonstrated that root processing is distinct from semantic processing, since morphological effects robustly obtained while semantic effects did not. I turn now to the relationship between roots and the phonological form of words.

3.3 Experiment 3a: Supraliminal Phonology

To what extent does the phonological form of a word interact with the morphology of the word? This experiment uses supraliminal auditory priming to test the factor experimental condition with four levels of relationship – a 1×4 design: identity, control, phonological, and root related. This experiment allows for a direct comparison between the phonologically related condition and morphologically related condition, as well as identity and control conditions. This experiment uses supraliminal auditory priming (experiment 3b uses the same materials with the subliminal speech priming technique). Theories of spoken word recognition often rely on the cohort effect (e.g., Norris et al., 2000; Marslen-Wilson and Tyler, 1980; McClelland and Elman, 1986; Luce and Pisoni, 1998), where phonologically similar words are activated at the same time as the target word because they share the same sounds. Because of this cohort effect, I expect to see phonological priming in addition to the root-based priming seen in Experiment 2.

This experiment tests if identical, phonologically similar, and morphologically related items show priming effects compared to the neutral unrelated control condition. Furthermore, it shows that there is a distinction between phonological and morphological effects with supraliminal priming.

3.3.1 Methods

The same methods as Experiment 2 were employed, except that experiment 3a used the items from experiment 5a (described in chapter 4) as additional distractors. This made efficient use of subjects time and provided a variety of word patterns for subjects to respond to.

Participants

Participants were recruited in the same way as Experiment 2. 86 participants were recruited, though the target number was only 60. A communication error with two recruiters caused the excessive number of subjects. Data from 22 subjects was excluded because they were not native speakers of Arabic (7), reported hearing problems (2), did not use headphones (1), answered demographic questions without reading them (9), or for less than 70% accuracy (3). Data from 64 subjects was analyzed.

Materials

48 target words were selected to appear in four counterbalanced conditions. Primes in the phonological condition shared the first and third consonants as the targets, but differed in the second consonant (e.g. /xmər/ $\sim$ /xtər/). The morpho-

Table 3.4: Experiment 3a – Experimental Conditions

	Prime	Target
Identity	xtər 'become thick (e.g. of liquids)'	xtər
Control	mrəʒ 'spoil (of fruits & vegetables)'	xtər
Phonology	xmər 'rise (of bread), ferment'	xtər
Root	xəttər 'make thick, thicken'	xtər

logical condition is a word related via the theoretical root. These conditions are shown in Table 3.4 for the verb /xtər/. Words related by phonological form share two consonants, words related by the morphological root share three. Unlike Experiment 2, the verbal forms used in this experiment were consistent. Targets were all form I verbs (of the CCəC shape), and morphologically related items were all form II verbs (CəCCəC shape). Nonword filler items were constructed in the same way as in Experiment 2. The real word stimuli are presented in Appendix C.

Procedure

The procedure was identical to the one used in Experiment 2.

3.3.2 Results

Statistical models were constructed in the same way as experiment 2. Two real words (/hḍər/ and /nkəd/) failed to obtain 70% accuracy, along with 13 nonwords. These were excluded from the analysis. Data was trimmed so that responses greater than 2.5 deviations from the subjects mean were discarded, this consisted of 2.3% of the total data.The experimental condition was significant for the identity ($Estimate = -179, SE = 11.11, t = -16.07, pMCMC = .0001$), phonology ($Estimate = -79, SE = 12.99, t = -7.11, pMCMC = .0001$), and

Table 3.5: Experiment 3a – Table of Means and Percent Error

Mean RTs	Cont	ID	Morph	Phon
RT Onset	957	781	782	881
Rt Offset	497	324	206	421
Percent Error	5.4	2.7	2.2	3.6

root ($Estimate = -179, SE = 11.17, T = -13.80, pMCMC = .0001$) levels. The raw means can be seen in Table 3.5. Also significant were age (in years, $estimate = 15ms, SE = 3.14, t = 4.6, pMCMC = .0001$), target duration (in seconds, $estimate = 533ms, SE = 112.49, t = 4.74, pMCMC = .0001$), prime duration (in seconds, $Estimate = -992ms, SE = 58.79, t = -16.88, pMCMC = .0001$), and high proficiency in French ($Estimate = 74ms, SE = 34.67, t = -2.12, pMCMC = .015$), though prime duration was not significant when measuring from target onset ($p > .05$).

A post-hoc analysis shows that the morphological and identity conditions are not significantly different from one another, contrasting with the results of Experiment 2 ($p > .05$). This difference does not hold, however, when in the basic model measuring from target offset where the root and identity conditions do differ ($Estimate = -102ms, SE = 20.05, t = -5.86, pMCMC = .0001$).

3.3.3 Discussion

This experiment shows effects of repetition, morphology, and phonology, though the effects of morphology and repetition here are identical. These effects suggest that the lexicon is structured with links between words based on both their morphological and phonological structure. In addition, the morphological effects are indistinguishable from repetition (in three of the four models), unlike the phonology condition; this indicates that the morphological relations between words are stronger than purely phonological relations. The stark difference between morphology and phonology is also seen in the effect estimates of the model, where morphological facilitation effects are over twice the size of phonological facilitation effects.[1]

The lack of a distinction between morphological and identity conditions may be an artifact of strictly controlling for verb form in the task: all the targets in this experiment are form I verbs (i.e.CCəC) and root-related primes are form II verbs (i.e., CəCCəC). An analysis process, which distinguishes roots from patterns, may be highly activated due to the repetitive nature of the task subjects preformed. Nonetheless, the root relationship appears to be as strong as the identity one, as measured by reaction times in this task.

It is also interesting to note that the root condition appears to be faster than the identity condition, which is not entirely expected. Form II words are naturally longer than form I words, though target and prime durations were included in the model which should account for differences in length. There are more form II words in the dictionary than form I (Harrell, 2004), it may be the case that form II verbs are quicker to identify than form I and a morphological route is therefore quicker when form II is the prime compared to form I. Experiment 5 (this chapter), however, does not bear this prediction out and the cause remains a mystery.

3.4 Experiment 3b: Subliminal Phonology

This is the subliminal speech priming version of experiment 2, which tests the earliest stages of auditory word recognition. The subliminal speech priming technique compresses primes to 240 milliseconds and masks with reversed and compressed words. This compressed technique is analogous to visual masked priming. See

[1] Closer phonological relationships are tested in chapter 4.

chapter 2 for more details. Since phonological effects are not normally detected with this technique(Kouider and Dupoux, 2005), this experiment will further detangle root-effects from phonological effects.

3.4.1 Methods

The same method as experiment 3a was used.

Participants

Participants were recruited in the same manner as experiment 3a. 50 subjects were recruited, data is analyzed from 33 of the 50 subjects. Seven subjects were excluded for being non-native speakers, 4 for a history of hearing problems, and 12 for low accuracy with some overlap.

Materials

As experiment 3a, except some of the poorly preforming items from experiment 3a (less than 70% accuracy) were replaced with new items. After these replacements, two real words (/hḍər/ and /nkəd/) and three nonwords failed to achieve 70% accuracy and were excluded from the analysis.

Procedure

The procedure was identical to the one used in Experiment 2, except rather than supraliminal priming the subliminal speech priming technique (Kouider and Dupoux, 2005) was used, with modifications as detailed in chapter 2. As noted earlier, testing for nonword repetition ensures that the technique is truly subliminal and no non-lexical factors are influencing the subjects, so rather than a go/no-go

Table 3.6: Experiment 3b – Table of Means

Mean RTs	Control	ID	Root	Phonology
RT Onset	967	905	887	964
RT Offset	507	452	432	505
Percent Error	3.6	3.0	3.8	3.1

design a yes/no lexical decision task was used. Accuracy was facilitated by replacing poorly performing non-words with better-performing ones (see above).

3.4.2 Results

Statistical models were constructed in the same way as experiment 2. 0.9% of the data was eliminated as outliers. The means can be seen in Table 3.6. Including the experimental condition as a random slope improved the fit of the model. Both repetition ($Estimate = -57.79ms, SE = 18.840, t = -3.067, p < .003$) and root ($Estimate = -76ms, SE = 19.392, t = -3.915, p < .001$) priming obtain here, though there are no effects of phonological form ($Estimate - 3ms, SE = 17.06, t = -0.173, p > .05$). Target duration was significant ($Estimate = 469ms, SE = 119.346, t = 3.926, p < .001$), as well as high proficiency in French ($Estimate = 55ms, SE = 27.316, t = 2.031, p < .05$). This is same pattern emerges as in experiment 3a, with the exception that there is no effect of the phonological condition.

There is no significant effect of nonword repetition priming ($p < .05$), so we can assume that the subliminal speech priming technique is working properly and only lexical effects are being captured.

3.4.3 Discussion

Here we see the same pattern of results as with the overt auditory priming technique (experiment 3a) with one difference; there is no phonological priming at all. Phonological priming must take place at a later stage of lexical access, since phonological priming is detectable with supraliminal techniques. The earliest stage of lexical access–as measured by the subliminal speech priming technique–only shows repetition and root effects.

The lack of phonological effects is troubling for models of spoken word recognition which rely on a cohort effect (Marslen-Wilson, 1987). This is, however, in line with the results found by Kouider and Dupoux (2005) for French. This may indicate that the subliminal speech priming technique examines a very early stage of lexical processing where phonological neighbors are not yet activated, or a two-pass system where neighbor activation has already decayed, and the cohort effect seen in experiment 3a represents a second-pass verification system. It should be noted that the phonologically related forms here do show a small, non-significant 6ms facilitation effect. Once again, we see the effects of root priming as larger than repetition priming. This remains unexpected.

One caveat must be applied here as well. All of the primes were real words. If there is a prime lexicality effect with the subliminal speech priming technique, we might expect non-words to produce facilitation since there would be no competition between forms at the lexical level. I address this issue in experiments 4a and 4b.

3.5 Experiment 4a: Roots without words

To what extent does the root need to be instantiated in an occurring word in order to produce priming? We have seen above (Experiments 2, 3a, and 3b) that morphological effects do not seem to be additive of phonological form and semantics. If nonwords can produce morphological effects, this suggests that morphemes have their own independent existence, since lexical effects can only come about when there is a lexical representation of some kind (as in Frost et al., 1997). To test whether non-words can prime real words, a number of novel coinages were produced. Novel coinages are a particular type of nonwords which are created with legal morphemes in combinations that are not already part of the speaker's the lexicon. These novel coinages were created by using roots that occur as Form I words, but incarnating them in Form II patterns which were judged by one native speaker as possible but not occurring words. These novel coinages were thus plausible real words which displayed real roots (and real verbal patterns), but should not be solidly represented in the mental lexicon of Moroccan Arabic. Thus, these novel coinages test prime lexicality. If the root morpheme is independently represented in the lexicon, there should be priming effects from novel coinages. If the root morpheme cannot be activated by nonwords, it cannot be represented in the mind independent of real-word representations.

This experiment tests the experimental condition factor with three levels: repetition, control, root-related and the factor form II lexicality (Real, Nonce). Whether the form II version of the root exists may play a role in the morphological processing of the word. The design is thus 2×3.

This experiment shows that a word need not be an established member of the lexicon to produce priming, for novel coinages also produce root effects. However, there is a differential effect for real-word primes and new coinages, which suggests that these root effects are weak, like phonological priming.

3.5.1 Methods

The same methods as Experiment 2 were employed.

Table 3.7: Experiment 4a – Conditions

	Form II - Real		Form II - Nonce	
	Prime	Target	Prime	Target
Id.	sʕəd 'be happy'	sʕəd	htər 'talk nonsense, wander'	htər
Cont.	səbbəq 'do first, give in advance'	sʕəd	bləɣ 'reach'	htər
Root	səʕʕəd 'make happy'	sʕəd	həttər Nonce Word	htər

Participants

Participants were recruited in the same way as Experiment 2. 40 participants were recruited. Data was excluded from participants who reported being non-native speakers of Arabic (6), a histoy of abnormal hearing (1), who had less then 70% accuracy (5), or had a median reaction time of less than 500ms on the demographic questions (13, 4 of these having also been rejected for accuracy). This left 19 subjects in the analysis.

Materials

72 target words were selected to appear in six counterbalanced conditions. The identity condition is an exact repetition of the target. The theoretical root links items morphologically. An unrelated control represents the baseline for comparison. Crossed with this factor is Form II (Real, Nonce), a measure of prime lexicality. Half of the verbs have a well-established morphological relationship, while the other half do not. The conditions can be seen in Table 3.7. Nonword filler items were constructed in the same way as in Experiment 2. 10 real words (/ħdət/, /fʒəṛ/, /hbəl/, /htər/, /nfəd/, /nhəq/, /nʒəṛ/, /nkəd/, /qṛəṭ/, and /xrəz/) and 18 nonwords did not achieve the 70% accuracy threshold and were eliminated from the analysis. The real word stimuli are presented in Appendix C.

Table 3.8: Experiment 4a – Means

	Onset		Offset		Percent Error	
	Nonce	Real	Nonce	Real	Nonce	Real
Control	1144	1043	665	593	5.9	4.8
ID	926	843	463	934	0.8	1.5
Root	975	960	510	514	1.7	1.4

Procedure

The procedure was identical to the one used in Experiment 2.

3.5.2 Results

The means of the experimental conditions can be seen in Table 3.8. 2.6% of the data was excluded as outliers. An interaction between Form II lexicality and the experimental condition was found at the root level ($Estimate = 84ms, SE = 25.756, t = 3.271, p < .002$), but not for the basic models which did not include target duration ($p > .05$)[2] The full model measuring from offset was *a priori* decided as the best model, but it should be noted that the target duration appears to moderate the interaction, so we may expect interaction to be subtle. The full model measuring from target onset also detects this interaction. The effect of the experimental condition at every level of form II lexicality must be examined to isolate these differential effects.

When only the words which have an existing form II neighbor are considered, the experimental condition is significant at the identity ($Estimate =$

[2]The basic offset model finds effects of repetition ($Estimate = -210ms, SE = 16.89, t = -12.433$), root ($Estimate = -122ms, SE = 14.06, t = -8.668$), and prime lexicality ($Estimate = -37ms, SE = 14.75, t = -2.510$) while the onset model finds only effects of the repetition ($Estimate = -212.61, SE = 17.05, t = -12.47$) and root ($Estimate = -123ms, SE = 14.12, t = -8.70$) conditions. Both basic models include random slopes for the experimental condition.

$-70ms, SE = 18.98, t = -8.991, pMCMC = 0.0001$) and root ($Estimate = 121ms, SE = 18.61, t = -6.511, pMCMC = 0.0001$) levels, as well as target duration ($Estimate = 570ms, SE = 98.85, t = 5.772, pMCMC = 0.0001$). This root condition in this case contains real word primes, not novel coinages. For words whose form II neighbor is a novel coinage, both the identity ($Estimate = -193ms, SE = 18.86, t = -10.287, pMCMC = 0.001$) and root ($Estimate = -171ms, SE = 21.60, t = -7.898, pMCMC = 0.001$) conditions are significant, as well as target duration ($Estimate = 236ms, SE = 107.66, t = 2.194, pMCMC = 0.290$). The inclusion of random slopes did not significantly improve the models. While the pattern of significance is the same, the measures of effect size are dramatically different, suggesting this is the source of the interaction. An examination of the estimates of effect sizes for the full models, as well as the raw means, suggest that novel coinage root priming has an advantage over real word root priming. This may, however, be confounded by morphological family size effects.

Further post hoc effects support the differential behavior of the identity and control conditions for prime lexicality. When the root condition is examined alone there are no effects of form II lexicality ($p > .05$), indicating that real and nonce primes may produce similar root priming effects. What differs is the identity and control conditions. When the root condition is excluded, there is a significant effect of form II lexicality ($Estimate = -48ms, SE = 20.67, t = -2.331, pMCMC = 0.0201$) as well as target duration ($Estimate = 859ms, SE = 93.62, t = 9.172, pMCMC = 0.0001$). When the root condition is excluded, form II lexicality measures morphologial family size, and the existence of a form II family member means words are faster to identify than when the family is smaller.

3.5.3 Discussion

While the results of this experiment are not easy to interpret, novel coinage words do produce priming in their related forms. It is not clear, however, if this root priming is distinct from phonological priming, since nonwords are known to produce repetition effects in auditory priming tasks (Goldinger, 1996).

We also see the significant effects of prime lexicality and morphological family size. When a word lacks one of its most likely morphological relatives (e.g. its form II relative, the word is slower to identify. These results could be taken to mean that the root's representation is strengthened based on the number of words it surfaces in (i.e., morphological family size), and that the access route based on the root is active when words are not controlled for frequency (a task which remains, at this time, impossible).

Furthermore, real word primes and nonword primes show no prime lexicality effect here, since there was no detectable difference when only the root condition was examined for effects of prime lexicality. So nonwords or novel coinages which share a root show morphological priming as the root in real words. For these novel coinages, we see that the root alone is enough to prime words, however, the effect sizes are quite different between real-word primes and novel coinages. This may suggest that there are different mechanisms behind these two effects.

I turn now to an investigation of these factors with the subliminal speech priming technique to see how they may differ when the primes are not consciously audible. Since the subliminal speech priming technique is not sensitive to phonological form effects, the morphological nature of the effects described here can be established or rejected.

3.6 Experiment 4b: Subliminal Prime Lexicality and Morphological Family Size

This experiment uses the same real-word prime-target pairs as experiment 4a with the subliminal speech priming technique. Following the overt auditory technique in experiment 4a, an effect is detected for new coinages from existing roots. Since phonological effects do not obtain with the subliminal speech priming effect (neither above in experiment 3b nor in Kouider and Dupoux, 2005), morphological effects from nonword primes would entail an independent lexical representation of these morphemes. The priming for novel coinages suggests that root representations are automatically extracted early in the word recognition process.

3.6.1 Methods

The same methods as Experiment 2 were employed.

Participants

Participants were recruited in the same way as experiments 3a and 3b. The target recruitment was set at 60 to get the target of 48 participants. Data was excluded from participants who reported being non-native speakers of Arabic (4), abnormal hearing (1), who had less then 70% accuracy (18), or a combination of these qualities. This left 38 subjects in the analysis.

Materials

As in experiment 3b, nonwords with poor performance (< 70% accuracy in experiment 3a) were replaced with new nonwords; otherwise the items were the same as experiment 3a. Eight of the real-word targets (/ʕrək/, /krəf/, /nfəd/, /nhəq/, /nkəd/, /qṛəṭ/, /ṛḍəx/, and /xrəz/) did not reach 70% accuracy and were eliminated from the analysis along with 21 nonwords.

Procedure

The procedure was the same as in experiment 3b.

3.6.2 Results

2.4% of the data was trimmed as outliers. The means appear in Table 3.9. No interaction between the experimental factors was detected ($pMCMC = .0986$), regardless of whether the point of measurement was target onset or offset, and if quasiexperimental factors were included or not. There was no effect of Form II neighbors ($p > .5$) but the identity ($Estimate = -77ms, SE = 16.42, t = -4.700, p < .0001$) and root conditions ($Estimate = -57ms, SE = 17.03, t = -3.325, p < .001$) and target duration ($Estimate = -652ms, SE = 99.54, t = -6.550, p < .0001$) were significant. This suggests that a nonword prime can activate a real word. There was no effect of nonword filler repetition priming ($p > .05$).

The lack of effect of an existing form II neighbor is striking, particularly compared with experiment 4a in which the identity and control conditions see an effect of the form II family member (where a form II family member indicates a larger morphological family size). This null effect motivates a post-hoc analysis, in which the targets with real form II family members and those without are analyzed separately. If there is no effect of an existing or non-existant form II neighbor, identical results with a post-hoc analysis should confirm this fact.

When only the targets with real form II family members are analyzed, there are indeed significant effects for the Identity ($Estimate = -93ms, SE = 23.71, t = -3.920, p < .0001$) and Root conditions ($Estimate = -78ms, SE = 26.80, t = -2.912, p < .005$) as well as target duration ($Estimate = -610ms, SE = 140.43, t = -4.341, p < .0001$) with the experimental condition as a random slope. For the targets without extant form II family members, however, we see a different pattern. The identity condition is significant ($Estimate = -56ms, SE = 18.2287, t =$

Table 3.9: Experiment 4b – Means

	Onset		Offset		Percent Error	
	Nonce	Real	Nonce	Real	Nonce	Real
Control	979	979	519	535	2.1	2.6
ID	935	898	471	453	1.6	1.7
Root	958	911	491	463	1.9	1.8

$-3.097, p < .003$) as well as target duration ($Estimate = -731ms, SE = 149.5967, t = -4.884, p < .0001$) and order of presentation ($Estimate = -0.39ms, SE = 0.1781, t = -2.164, p < .04$), but not the root related condition ($Estimate = -33ms, SE = 17.8590, t = -1.857, p > .05$).

This post-hoc analysis suggests that words with larger morphological family sizes are quicker to be identified than those with smaller morphological families, and that nonce words may not activate their real-word family members.

Furthermore, the lack of priming for novel coinage primes in the post-hoc analysis also shows that subjects distinguish compressed form II verbs (with gemination) from their compressed form I counterparts. While these two forms may sound similar when compressed, subjects this experiment detects a difference between the two prime types. If subjects were unable to distinguish geminated (form II) verbs from nongeminated (form I) verbs, we would expect subjects to show facilitation in the Form II condition, as the near phonetic match would be mapped to its closest lexical item. The lack of an effect in the Form II - Nonce condition, however, leaves no doubt that subjects heard these two forms as distinct.

3.6.3 Discussion

In contrast to supraliminal auditory priming in experiment 3a, the subliminal technique suggests one of two things. Either a) that morphological family size does not play a role lexical access with the subliminal speech priming technique and the root is an independent entity with phonological content, or b) that that only real-word primes facilitate their related targets. Given the lack of significance for form II relatives in the main analysis, it is reasonable to assume that an analysis such as that of Frost et al. (1997) is correct, and that roots do have phonological content which can be activated from nonce words.

These contrasting results show a need to use a variety of techniques to investigate auditory word recognition. Since the subliminal technique avoids the confound of non-lexical processes–shown by the absence of nonword repetition effects–it should be given priority in examining the structure of the lexicon: nonword repetition, by definition, must reflect a non-lexical process (e.g. memory, pure phonology, etc).

One additional result of this experiment is the differential effects of form II priming with real words and nonce words, compared to identity priming in the post-hoc analysis. Form II nonce words did not prime their related form I real words, but those same real words showed repetition priming. Subjects can, indeed, distinguish between the compressed form I and form II primes. Of course, the two verb forms differ not only in gemination, but also in syllable structure. But these differences, to the non-native speaker, might seem rather slight when words are uniformly compressed to 240ms. Nonetheless, this experiment shows repetition–but not form II priming for form I real words when the related form II prime is not a real word.

The results of this experiment suggest that either morphological family size does not play a role lexical access with the subliminal speech priming technique and the root is an independent entity with phonological content, or that that only real-word primes facilitate their related targets. I assume that a root-based analysis–such as Frost et al. (1997)–is correct, and that roots do have phonological content which can be activated from nonce words. If this interpretation is correct, we expect that any root-related word should demonstrate priming. I turn next to test this hypothesis.

3.7 Experiment 5

3.7.1 Methods

The same methods as Experiment 2 were employed.

Participants

Participants were recruited in the same way as experiment 2. 86 subjects were recruited in an attempt to get 48 total subjects. Data was eliminated from subjects who were nonnative speakers (4), reported a history of hearing problems (1), reported not using headphones (2), responded to demographic questions with less than 500ms median reaction time (1), achieved greater than 70% on a post-test of prime awareness, did not achieve 70% accuracy (42), or a combination of these factors leaving data from 34 participants.

Materials

53 roots were selected which each appear in the three fundamental patterns in Moroccan Arabic: Form 1 (CCəC), Form 2 (CəCCəC), and Form 3 (CaCəC). Each root was tested with the target as its Form 1 family member or the form 2 family member. This target form factor was crossed with the experimental condition. Each root was tested in four experimental conditions. The first of which is the identity condition, where the prime is a repetition of the target. The second is the common relative: when the target is the form 1 family member the prime is form 2, and vice versa. Forms 1 and 2 are the most commonly occurring forms in the lexicon. The

Table 3.10: Experiment 5 – Conditions

	Form 1 Target		Form 2 Target	
	Prime	Target	Prime	Target
Identity	fhəm ‘understand’	fhəm	fəhhəm	fəhhəm
Control	7rek ‘go away to war’	fhəm	7rek	hfəhhəm
Close Relative	fəhhəm ‘make understand’	fhəm	fhəm	fəhhəm
Distant Relative	tfahəm ‘understand one another ’	fhəm	tfahəm	fəhhəm

third is the less common relative, where the form 3 family member is the prime. Finally there is an unrelated control to serve as the baseline. Primes and targets may include a /t-/ prefix which, in general, reduces the number of arguments by one (i.e., distinguishing passives from actives, reflexives from reciprocals, or inchoatives from causatives). Whenever a forms without the prefix was available, that was chosen. The real word stimuli are presented in Appendix E.

Eleven of the roots had targets which did not attain 70% accuracy and all target items from those roots (ʕyn, ʕda, ʕwd, lqa, lzm, myl, nwb, qyl, ṛwn, hda, and xwa) were excluded from the analysis.

Procedure

The procedure was the same as in experiment 3b.

3.7.2 Results

2.4% of the data was trimmed as outliers. The means appear in Table 3.11. An interaction was detected between the target form factor and the subjects' reported socioeconomic status (SES) was detected. When the 12 low SES subjects (who reported that neither they nor their parents attended university) are analyzed, there is no effect of the experimental condition ($p > .05$) or the target form fac-

Table 3.11: Experiment 5 – Means

	Onset		Offset		Percent Error	
	F1 Target	F2 Target	F1 Target	F2 Target	F1 Target	F2 Target
Control	847	993	396	427	2.0	3.1
ID	796	921	341	359	2.3	2.8
R1/2	802	895	351	327	2.2	2.8
R3	836	911	391	349	1.7	2.6

tor ($p > .05$), though the means suggest that there may be a further interaction of these two factors.

When the high SES subjects were analyzed, an interaction between the experimental condition and the target form was detected. When only the form 1 targets are analyzed, there is a significant effect of the identity ($Estimate = -79ms, SE = 25.73, t = -3.088, pMCMC = 0.0020$) and near related (i.e., form 2 relative, $Estimate = -56ms, SE = 24.80, t = -2.275, pMCMC = 0.0258$) conditions, as well as target duration ($Estimate = -496ms, SE = 163.36, t = -3.038, pMCMC = 0.0010$) but not the distantly related condition (i.e., form 3 relative, $Estimate = -10ms, SE = 24.69, t = -0.416, pMCMC = 0.6452$). This indicates that Form 3 verbs do not prime their form 1 counterparts for high SES subjects. When the form 2 targets were analyzed, however, a different pattern of results is seen. Identity ($Estimate = -89ms, SE = 28.23, t = -3.160, pMCMC = 0.0024$), the Form 1 near relation ($Estimate = -124ms, SE = 27.81, t = -4.453, pMCMC = 0.0001$), the form 3 distant relation ($Estimate = -116ms, SE = 29.09, t = -3.989, pMCMC = 0.0004$), and target duration ($Estimate = -447ms, SE = 169.92, t = -2.633, pMCMC = 0.0050$) were all significant. There was no effect of repetition for nonword filler items ($p > .05$) with condition as a random slope for subjects).

A post-hoc analysis coded the primes for number of syllables and the inclusion of the *t*- prefix but neither of these were significant ($p > .05$ in both cases).

These results indicate that, rather than simply accessing a root representation directly from a full word form, subjects seem to access related family members through distinct routes, but not all the routes are equal. Form 2 targets are readily accessed from hearing any family member, but form 1 targets are not accessed after hearing a form 3 family member. It is also interesting to note the effect sizes differ dramatically between the two forms. While target duration is present in the model, the two verb forms are inherently of different lengths.

Furthermore, the interpretation of the results of experiment 4b cannot be correct, if every morphologically related form does not activate a root representation. The prediction of a theory with a root element is that the root links to each family member equally, regardless of which form activates the root. The alternate theory, that nonwords are mapped to their nearest phonological neighbor is appealing, despite the lack of phonological priming in experiment 3b. Alternately, a network model may prove fruitful, with differently weighted connections between each member of the paradigm. In order to account for the facilitation of nonce words in experiment 4b, a network could have a root element with phonological content that is a weak route to access.

It is also interesting to note that the results of this experiment show that form II verbs primed by form I are faster to identify than form I verbs primed by form II and also faster than repetition priming for either form I or form II verbs. This contrasts the similar results in experiments 3a and 3b where form II verbs primed form I verbs to a greater extend than repetition priming.

Nothing can be said currently of the low SES subjects, since no effects obtained for them. It is interesting to note, however, that some aspect of education may influence the processing of morphologically related forms like this. (though see

Table 3.12: Summary of Experiments 1, 3a, 3b, 3a, and 4b

Experiment	Effect Tested	Methodology	Facilitation?
1	Semantics	Regular	No
3a	Phonology	Regular	Yes
3b	Phonology	Subliminal	No
3a	Novel Coinages	Regular	Yes
4b	Novel Coinages	Subliminal	Yes
5	Pattern Types	Subliminal	Mixed

experiment 6b in chapter 4)

3.8 General Discussion

The results of all six experiments are summarized in Table 3.12. Semantic effects do not obtain with the overt priming technique. Phonological effects obtain with the over technique, but not the subliminal technique. Novel coinages do show root priming effects. Each pattern, however, does not show the same effects of root priming.

While evidence from linguistic performance cannot directly show evidence for linguistic competence, we can use the results of psycholinguistic experiments to help refine linguistic theories since the process of auditory word recognition and lexical access must reflect some aspects of lexical representation and organization. The results of these experiments argue for a morphological family organization in Moroccan Arabic, but not a root as an independent lexical entity speech-perceptionwise.

First, these priming experiments show that morphological relations are detectable in Moroccan Arabic when subjects are not aware of the prime, at least among the most productive forms. Semantic or phonological relations, however, do not show facilitation in the subliminal speech priming technique. The fact that the semantics of a word is not activated in the lexical decision task is, perhaps, unsurprising. Even in visual lexical decision, semantics are not activated, though the semantic categorization task does show effects with visual masked priming(Forster, 2004). This suggests the possibility of a similar task effect, where the meaning of a word is irrelevant for identifying it. Phonological effects, at least in terms two-thirds overlap in root consonants, likewise do not obtain with the subliminal technique whereas they do obtain with the overt technique.

The major conflict in these results, is the results of experiment 4b and experiment 5. Experiment 4b shows that novel coinage primes can activate their real-word morphological relatives, which suggests a phonologically contentful root element in the system. Experiment 5 shows that form 3 verbs (of the CaCeC type) do not prime their form 1 (CCeC) counterparts, which is not predicted by a root theory. If the interpretation of experiment 4b is correct, we expect that roots should be accessed from hearing any word in a morphological family. This does not appear to be the case, however. If the results of experiment 5 are correct, we expect a word-based hypothesis may be correct, such that a network of words (i.e., a morphological paradigm) may have different, direction-specific, connection weights between words. The word-based theory, however, would predict no facilitation from non-existant forms since they are not well established in the speaker's lexicon of phonological forms. Nonetheless, the root theory's predictions are clear and it seems more likely that the morphological cluster theory may prove fruitful.

The post-hoc analysis of experiment 4b revealed no statistical evidence of novel coinages priming their real-word counterparts, but this fact may have be due to the reduced power. There was a 33ms non-significant effect which suggests that novel coinages do facilitate reaction to their root-related family members. There was not, however, any evidence of an effect of morphological family size in experiment

4b, as there was in experiment 4a, which is surprising. Since there are strong morphological family size effects in non-priming visual lexical decision tasks in Hebrew (Moscoso del Prado Martín et al., 2005) and the supraliminal task in experiment 4a, it seems odd that there would be no effect in experiment 4b. This experiment, then, deserves replication in a laboratory environment to see if the results hold.

Sociolinguistic factors also affect the reaction time for the lexical decision, but the target and prime durations appear more influential by and large. Some aspect of family education seems to interact. These inconsistent sociolinguistic effects may be because the sociolinguistic factors have been added in post-hoc, rather than being controlled and manipulated. It is also important to remember that both prime and target duration not only represent the time it takes to pronounce the word in question, but also a number of other lexical factors–e.g. frequency (Gahl, 2008), neighborhood density, or morphological family size–or even sociolinguistic factors related to an individual's dialect. Further research is needed to see exactly how these lexical factors are related to the word's duration, and future research that can quantify these attributes may refine the models presented above. See the next chapter for a further discussion on this matter.

A model of morphological priming, however, must take all of these factors into account. Abstracting away from sociolinguistic factors, we need a model that allows for non-words to activate real words and also for words in a family to differentially activate their family members. The basic model of root priming is developed by Frost et al. (1997) and shown in Figure 3.2. Each word in a morphological family can activate the root, and each root then activates the rest of the family members. This model appears untennable, however, given the results of experiment 5. As shown in Figure 3.3, there is no reason to suspect that a root would differentially allow access to any forms. Thus, in Figure 3.3 the form 2 /ketteb/ has a route to form 1 /kteb/ but form 3/kateb/ has no access to form 1 /kteb/.

Figure 3.2: The Root Access Route (Frost et al., 1997) – Upon hearing the segments /k/, /t/, and /b/, the root representation becomes activated, which activates the word family containing ktəb, kəttəb, kateb, ktab, etc.

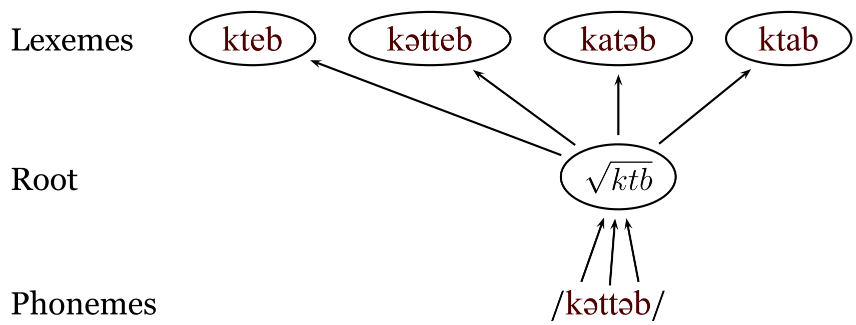


Figure 3.3: The problem with the root access route is the two pathways below are predicted to be identical, whereas experiment 5 shows there is no route to /katəb from /ktəb on the right.

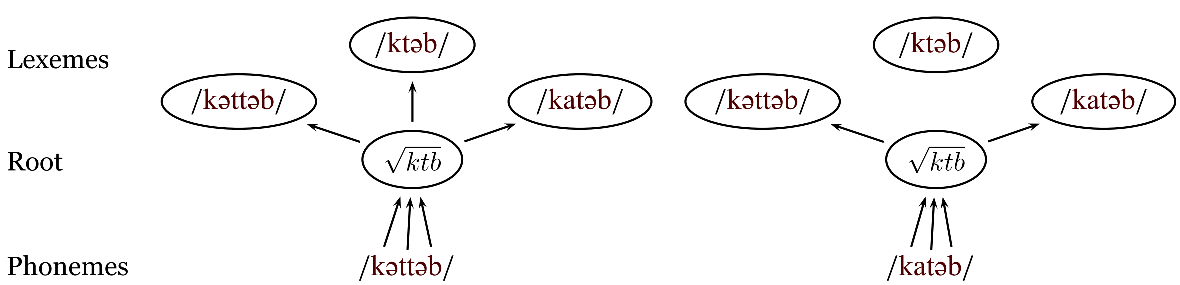
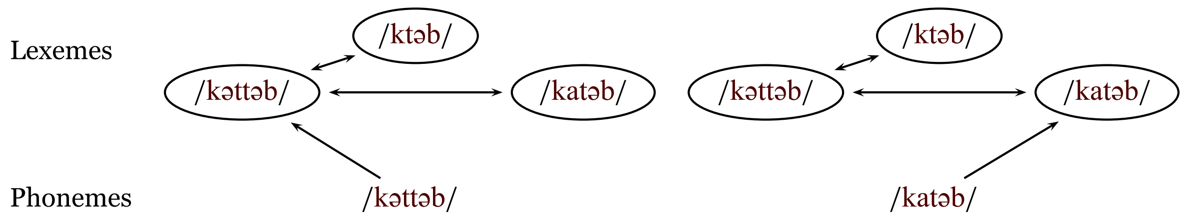


Figure 3.4: The phonological lexicon is organized in a network, where connections need not be bidirectional. The form 3 prime /katəb/ is not immediately linked to the form 1 target /ktəb/.



The lack of root access to each form is a major problem for a root theory of access. Instead, a word-based theory of access can allow for this, shown in Figure 3.4. In a morphological-cluster theory there are no connections between the form 1 and form 3 family members. Thus, the input activates its exact match and up to one connected family member in the network in the phonological lexicon. This allows from 2 to activate form 3, but form 1 will not activate form 3.

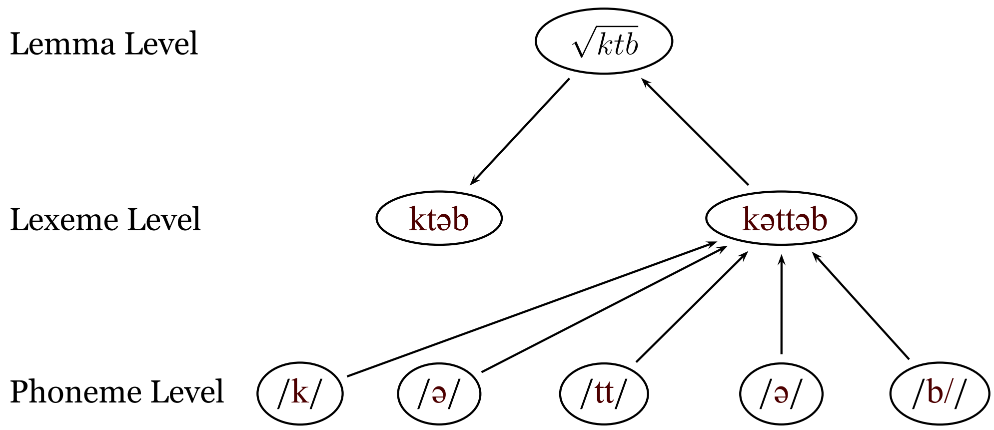
The problem with a word-based model, of course, is that it cannot account for nonce forms activating real words. Experiment 3b showed that near phonological matches do not facilitate one another with the subliminal priming technique, but perhaps a much closer phonological relationship would allow nonwords to activate real words. Thus, the nonword */hetter/ may activate the existing word /hter/ because the unrecognized phonological form is mapped to its nearest match. Real words, having an exact match, as in experiment 3a and 3b, would not have this property because an exact match does exist. The difference in priming between existing and nonce words in the post-hoc analysis of experiment 4b supports this conjecture. It is worth noting that all of the primes in experiments 3a and 3b were existing words, and the lexical system's primary function is to identify established words of the lexicon. It may not be surprising if unattested phonological forms are mapped to their closest match, but this remains to be tested.

An alternative to a morphological cluster model would be the inclusion of a root element which includes phonological content, but is only activated by novel coinages. This is not entirely implausible since the lexical system must identify novel words or words used in novel ways, such as puns or novel coinages. It does, however, seem odd that a root morpheme would be accessible only by novel coinages and not existing words like /kateb/ which should be linked to its root $\sqrt{ktb}$. Additionaly, lower facilitation levels of experiment 4a for the novel coinage condition seems to indicate that regular phonological processes may be sufficient for this sort of mapping, as in experiment 3a. Thus, a phonological near match is a more plausible solution to this problem.

Another alternative to the morphological cluster model is the supraliminal root theory, shown in Figure 3.5. This model is directly opposed to strictly feed-forward theories like MERGE (Norris et al., 2000), but allowing for the existence of a root-representation above the word-level is appealing on other grounds. A supralexical theory of the root allows for root effects. This theory, however, suffers the same problems as Frost et al. (1997)'s root access route, which does not predict the lack of priming between form 1 and form 3 as in experiment 5.

A morphological cluster or word-based system is also suggested by Frost et al. (1997). Such a system, shown in Figure 3.4, lacks an explicit root representation. Instead, morphologically related words are represented in the same strata. Activation of one word in the morphological cluster (e.g. /kəttəb/) spreads activation within the level to related items (e.g. /ktəb/) with little inhibition between family members. Frost and colleagues discard this theory based on bare root activation. While they find no priming for novel coinage roots in a derived verbal pattern (Hebrew הפעיל /hiCCiC/), they do find it with the presentation of three root consonants in isolation, whether or not those consonants represent an existing word

Figure 3.5: The Supralexical Root Access Route – The phonemes /k/, /ə, /tː/, /ə, and /b/ activate the word form /kəttəb/, which activates the root $\sqrt{ktb}$. The root, in turn, sends top-down feedback to related words ktəb, kateb, ktab, etc.



of the lexicon. Auditorily, however, a bare root consisting of three consonants is impossible to pronounce. If the root consonants are syllabified and given a neutral vowel (i.e., /ə/) we arrive at the Moroccan Arabic forms /ktəb/ or /kəttəb, which are as close to bare roots as auditorily possible. Furthermore, the current experiment presents only the root consonants, there could be no confusion for a root extraction system about which consonants belong to the root and which may belong to a prefix or suffix as in the Hebrew form הכתיב [hixtiv] (from the root $\sqrt{ktb}$ with spirantization of coda consonants).

The cluster analysis is still tenable from the perspective of activation and inhibition. In activation-based models, the neuropsychological currency is activation and inhibition, where activation flows between levels and inhibition flows within levels. Since there appear to be no phonological effects with the subliminal speech priming technique (cf. experiment 3b and Kouider and Dupoux, 2005, for French), activation would presumably flow from one phonological word-form to another. Inhibition must flow primarily between morphological families, rather than within, though some forms within a morphological family (i.e., form 1 and form 3) may still inhibit one another. It may be unexpected, from the lexical access point of view, for entire morphological families to be activated at once. Given that each family member fits a very specific morphosyntactic context (noun, transitive verb, intransitive verb, reflexive verb, etc.), entire family activation may fit well with a syntactic processing account.

Next, it is important to note that the lack of priming between phonologically related forms with the subliminal speech priming technique may be unexpected given current theories of speech perception. The COHORT model (Marslen-Wilson and Tyler, 1980) and later Neighborhood Activation model (Luce and Pisoni, 1998) is based on the phonological neighborhood effects, where all (or most) of a target word's phonological neighbors are activated. Additionally, there is evidence that a phonetic and phonological similarity may have inhibitory effects, as well as facilitatory effects (Slowiaczek and Hamburger, 1992; McQueen et al., 1995, among others). Facilitatory or inhibitory phonological effects appear to hold at the supraliminal level, but not the subliminal level. This represents another dramatic divergence of the vision and audition system, since orthographic form priming is ubiquitous in visual masked priming. Auditorily we see repetition and morphological effects without phonological form effects. It may be that the one-segment different relationship (see experiments 3a and 3b) is too coarse for Moroccan Arabic speakers, but the French data (Kouider and Dupoux, 2005) with one-segment added did not show effects either. The lack of a phonological neighbor effect indicates a quick exact match process, and a much slower phonological activation process. This slower phonological search may function as a back-up system which helps speakers parse mispronunciations, word errors, or jokes. This swift exact-matching process should also be investigated in typologically different languages, particularly agglutinative and polysynthetic languages with a high morpheme-to-word ratio to see if those languages show differential effects. The need for a phoneme-recognition level in models of speech perception (See the model in chapter 1) is also questioned by the lack of a cohort effect. Further investigation of the time-course of auditory lexical activation, both with behavioral data from compressed speech and neurophysiological measurements may clarify the cohort effect and what role it should play in theories of speech perception.

Finally, it is odd to note that root effects may be stronger than repetition effects. These models lack data on word and root frequency, neighborhood density, and morphological family size, all of which may contribute to a word's reaction time. We might expect the inclusion of one or more of these qualities in the model to adjust the measure of effect size. If they do not, the model must then account for the odd fact of morphological priming exceeding repetition priming.

3.9 Conclusion

This chapter presented evidence from a series of six experiments that question a root-based theory of the lexicon in Moroccan Arabic: morphological priming effects are strong and not equivalent to semantic or phonological effects, but they are not uniform as predicted by a root-based theory. Thus, a word-network or morphological cluster theory is more appealing, despite suffering from a potentially problematic account of nonce word priming. While morphological effects are strong, they may not be best interpreted as root effects, which involve the triconsonantal root taken from linguistic theory. We must assume that a root does not exist as a strong phonological entity. If a root has phonological content, it is only immediately activated by novel coinages, whereas existing words do not use the root as an access route.

These facts suggest a type of multiple route theory of lexical access. Exact matches in phonological form are quickly processed, and these words activate (or fail to inhibit) all of their morphological family members. This route is quite rapid. A second, slower route, can be accessed via the phonological form alone–a near match. This route is detectable with supraliminal auditory priming, but not subliminal auditory priming.

The question of phonological content in the root is worth further exploration. Can closer phonological relationships activate root representations? And are root representations the triconsonantal entities suggested by philologists? The next chapter addresses this question by examining the priming effects of the so-called "weak" roots which do not display precisely three surface consonants in all their forms.

CHAPTER 4

MORPHOPHONOLOGY *SANS* PHONOLOGY

4.1 Introduction

While chapter 3 marshaled evidence showing that the root plays an early and vital role in speech perception for speakers of Moroccan Arabic, the root may not exist independently of the words it is incarnated in. Experiment 5 in chapter 3 shows that form I, II, and III verbal patterns do not produce equal priming effects for each other. Because we expect a root representation to prime all of its related forms equally, we are lead to the conclusion that there is not a root representation that is accessed directly from phonological input. That is to say, there may be decomposition in terms of analysis–words are recognized as words and then their morphemes are recognized–but not the synthesis or interdigitation of root and pattern. The primary unit of speech perception in Moroccan Arabic is not the root, but the word. While this is not predicted from item-and-arrangement theories of morphology (e.g., McCarthy, 1981; Hudson, 1985, among others), it is still in-line with realizational theories of morphology (Anderson, 1992; Beard, 1995; Blevins, 2006).

There remains the question of the content–whether semantic or phonological–of the root. How are morphological families defined? There is a paradox here, because phonological effects seem to be absent with the subliminal speech priming technique, but morphological families are defined by phonological and semantic regularities. Phonology seems to play a role in developing morphological representations, but the root relationship appears to be dissociated from any phonological content. In chapter 3, I tested strong roots, showing that the traditional description of the consonantal root fares well in terms of auditory word recognition, but only for more frequent forms. In this chapter, I test the representation of the root with weak roots, to investigate how morphological families are defined. These weak roots all deviate from the strong, triconsonantal type of root which was used each experiment in chapter 3. Five experiments test relationships between weak roots to determine whether or not phonological similarity of consonants alone is enough to cause facilitation, or if there is some underlying morphological or phonological structure to the root relationship. These weak roots are important for demonstrating the phonological form of the root, because each member of the morphological family may not display a consistent phonological shape.

Weak roots in Semitic languages are those associated with stems which do not consistently display three surface root consonants. A lack of three surface consonants is most common when one of the consonants appears in some stems as a glide or vowel: historically, constraints against a variety of vowel and glide sequences may have resulted in elision or contraction of the sounds in some forms. Etymologically, hollow verbs like /mat/ 'he died' may derive from */mawit/ (Watson, 2002; Holes, 2004), though many consider the glide to be an insertion from an originally biconsonantal form */mat/ (cf. Huehnergard, 2004; Lipiński, 2001; Agmon, 2010, among others). Weak verbs in Moroccan Arabic only deviate from strong roots by including glides or vocalic elements, or in terms of gemination of a root consonant in some forms. Hebrew, on the other hand, shows assimilation of /n/ and a following adjacent consonant (e.g., Hebrew נפל /nafal/ 'he fell' and יפל /yipal/ 'he will fall' (< */yippal/ < */yinpal/) with lenition of /p/ to [f] in the former and but not in the latter). Many Semitic languages–Hebrew and Amharic included–also show weaknesses in the so-called guttural consonants, where Amharic ጻፈ /s'af-ə/ 'he wrote' is historically related to መጽሐፍ /məs'haf/ 'book' (and Arabic

صحافة /ṣaħaafa/ 'journalism'). These are the alternations that call into question the root as a synchronic construct. Here, I use the terms *etymological root* to indicate the root whose surface consonants are not consistent, where etymology (among other factors) suggests a vocalic or abstract semi-vocalic segment as part of the root. I contrast the etymological root with the *synchronic root*, which is a root representation which focuses just on the consonants and phonological surface form (cf. Davis and Zawaydeh, 2001). Thus, the synchronic root is a root theory that ignores the possibility of abstract or variable root segments, taking the root of the hollow verb /mat/ as $\sqrt{mt}$ rather than the etymological $\sqrt{mwt}$. To what extent does the history of a morpheme influence its synchronic representation? Is there enough synchronic evidence for speakers to develop a root representation based on abstract segments? In Moroccan Arabic, roots are constructed despite vicissitudes in the surface forms of words.

Moroccan Arabic shows three broad classes of weak roots: hollow roots with vocalic or semi-vocalic segments medially (i.e., /ban/ $\sqrt{byn}$ 'it appeared'), lame roots with vocalic or semi-vocalic segments finally (i.e., /bna/ $\sqrt{bny}$'he built'), and geminate roots whose final segment is doubled (i.e., /səbb/ $\sqrt{sb}$ 'he insulted'). A fourth type of non-canonical root is the quadriconsonantal roots (i.e., /bəsməl/ 'he said "in the name of God" '), which follow the CəCCəC template with four root segments. Priming effects between these classes of root illuminate the degree to which morphological relations are abstract. While the results of experiments 3a and 3b (see Chapter 3) suggest that phonological similarity alone is not enough to cause priming, the phonological relationships tested in this chapter are much closer than the relationship tested in experiment 3a and b.

Synchronically, one need not assume that a root contains any elements other than consonants. Take, for example, a verb displaying a hollow root like /mal/ 'it rocked'. In the imperfect the stem changes /i-mil/ 'it is rocking' to include a high vowel. Furthermore, related forms, such as the form II transitive verb /məyyəl/ 'he rocked (something), tilted (something)' show a semivowel /y/ as the medial root segment. It is not clear, on synchronic analysis, why the stem should include the vowel /a/ in the perfective third person, /i/ in the first or second person perfective, and /y/ in the geminated form. From an etymological or historical perspective, we may say that the original or inserted semi-vowel becomes a vowel on the surface because forms like *[myəl] violate phonological or phonotactic constraints relating to semivowels: either prohibiting consonant-glide clusters in verb forms, or glides in a non-geminated word-medial onset. An abstract interpretation is that the stem may have a semi-vowel as a root segment. Alternately, it is well known in Arabic that some roots take certain theme vowels (Holes, 2004). In Classical Arabic, form I (CvCvC-) verbs may take the /_a_a_/ A-pattern, the /_a_i_/ I-pattern, or the /_a_u_/ U-pattern. The U-pattern is often seen in stative verbs, but not all stative verbs show the U-pattern. While the I-pattern often is used with verbs of psychological state, motion, or bodily functions, membership in the I-pattern class of verbs is likewise not guaranteed based on semantics, as /xaraj-a/ 'he exited' and /daxal-a/ 'he entered', verbs of motion in the A-pattern, show. Likewise, /xaṭif-a/ 'he grabbed' does not seem to fit the generalization for the I-pattern. A synchronic analysis might take the consonants of /mal/ as the root $\sqrt{ml}$ and assume an associated theme vowel or theme glide as needed. This hypothesis has a different level of abstraction, because the semi-vowel is not considered phonological content *per se*. In the experiments reported in this chapter, I will contrast root relations based on the etymological root (e.g., $\sqrt{myl}$)–which includes an abstract vowel or glide–with the synchronic or consonant-only root $\sqrt{ml}$. Distinct weak root types might show a similar synchronic root (e.g., /ban/ and /bna/ share the surface consonants /bn/ but do they share one root $\sqrt{bn}$ or display two distinct roots ($\sqrt{byn}$ and $\sqrt{bny}$)?

Weak roots are often called *biliteral* roots, emphasizing the spelling with two consonantal graphemes. There is some evidence that suggests these weak roots may not be triconsonantal, in so far as vocalic elements must be assumed to be underlying or consonants missing. The lame verbs, those which do not display a third root consonant, have been analyzed as including a vocalic element. Watson (2002) gives three reasons that lame roots are, at best, historically related to glide-final roots in San'ani and Cairene Arabic: 1) while glide-final roots are said to contain both /w/ and /y/, only /y/ ever surfaces, 2) the long vowel resulting from historical contraction is now used in other morphophonological contexts, and 3) monophthongization of diphthongs may no longer be a synchronic process. These arguments also appear to apply to Moroccan Arabic. There are no words where a purported underlying final root glide surfaces. The full vowel of /qra/ 'he studied, read' changes to /i/ in /qrit 'I studied, read' but the suffix is also /-it/ in geminated verbs like /ħəbbit/ 'I loved' $\sqrt{hb}$ rather than the normal /-t/ suffix in /ktəb/ 'he wrote' and /ktəbt/ 'I wrote'. If the suffix were simply /-t/ we would expect schwa epenthesis as in */ħəbbət/ for 'I loved'[1]. The /-it/ suffix for first person singular has been extended from lame verbs (CCa) to geminate verbs (CəCː). And diphthongs occur in some forms like /kayn/ 'there is'. Thus, it is worthwhile to contrast consonantally identical weak roots (e.g., the /ban/ and /bna/ types share their consonants). These roots may share a morphological family based on surface root consonants alone, or not if speakers consider vocalic or semi-vocalic elements as part of the root.

I continue to assume here, for the convenience of discussion, that roots may be phonologically identified and the etymological theory of the root tells us the phonological shape of the root. This is in line with theories like Arad (2005) and McCarthy (1981). Thus, the root for related forms /ktəb/ and /ktab/ and /kəttəb/ is $\sqrt{ktb}$ and the root of /mal/, /i-mil/, and /məyyəl/ is $\sqrt{myl}$. Roots could be equally

[1] This is actually the feminine form for 'she loved' where the suffix is /-t/.

well identified numerically, with each root assigned a unique number (e.g., $\sqrt{\#532}$) or a description based on the general semantic meaning of the family (e.g., $\sqrt{write}$). The consonantal description is standard among Semiticists and clear. Nothing else is.

I focus first on hollow roots, since these are the most prevalent of the weak root types in Moroccan Arabic. These experiments answer the question: "Is the etymological definition of the root accurate to describe morphological families?" The answer, with a few caveats, is affirmative. Experiments 6a and 6b show that derived forms of hollow roots (the causative, denominal, or intensive Form II which is universally in the CəCCəC pattern for strong and hollow roots) prime their non-derived weak family member (Form I in the CCəC pattern for strong or CaC for weak roots) for most, but not all, speakers. Next, Experiment 7 shows that Moroccan hollow verbs do not have a null or empty "slot" in their medial position which can be filled by any consonant: vowels and semi-vowels are integral to defining morphological families. Experiments 8a and 8b test biconsonantal identity and shows that root consonants are encoded or represented in linear order with semi-vocalic elements. Thus morphological families are not defined by surface consonants alone since /ban/ and /bna/ fail to prime one another. Experiment 9 further tests biconsonantal identity, showing that roots do not simply contain underspecified morae, since consonantally identical verbs with a reduced vowel and gemination (e.g., /səbb/ 'he insulted') and verbs with full vowels but no gemination (e.g., /sab/ 'he rebelled') do not prime one another. Experiment 10 shows that, contrary to conventional thinking, roots with three consonants (e.g., /t-bənned/ 'he was somewhat of a show-off' $\sqrt{bnd}$) have a morphological relationship with words that contain four consonants (e.g., /bəndər/ 'he played the *bendir*' $\sqrt{bndr}$).

4.2 Experiment 6a: Root Strength

To what extent does the phonological form of the root interact with the morphology of the word? Do the "weak" roots, which do not consistently display three surface root consonants, behave like strong verbs which do display all their root consonants? Velan et al. (2005) showed that weak roots induce facilitation among family members visually in Hebrew for most cases (as in נפל /nafal/ 'he fell' or the bare consonantal root $\sqrt{npl}$ priming מפולת /mapolet/ 'landslide') . Experiment 6a tests a similar relation in Moroccan Arabic with hollow roots. The so-called hollow roots do not consistently display their medial root consonant. This means that Moroccan Arabic forms, like /ṭal/ 'last, stay' are phonologically quite divergent from related forms like /ṭəwwəl/ 'prolong'. In experiments 3a and 3b we saw that near phonological matches did not produce priming effects, but that is not the case with these divergent forms. This experiment tests the experimental condition factor with three levels: Identity, Control, and Root related crossed with the two-level factor root strength (strong, weak). The design is thus 2×3.

This experiment will show whether or not weak roots, which do not consistently display three surface consonants, induce facilitation effects like strong roots do. If both strong and weak verbs pattern identically with the same significance in the morphological condition, we can conclude that the root representation for weak verbs includes a hidden consonant. If they do not show the same patterning, they must be stored differently.

4.2.1 Methods

The same methods as experiment 3a were employed.

Table 4.1: Experiment 6a – Conditions

	Strong		Weak	
	Prime	Target	Prime	Target
Identity	sqəṭ ‘be quiet’	sqəṭ	ṭal ‘last, stay’	ṭal
Control	ḍeḷḷem ‘make dark’	sqəṭ	ʃəbbəh ‘mistake s.o. for s.o.’	ṭal
Root	səqqəṭ ‘make quiet’	sqəṭ	ṭəwwəl ‘lengthen, prolong’	ṭal

Participants

Participants were recruited in the same way as experiment 3a with 40 participants recruited for this experiment. Data was excluded from participants who reported being non-native speakers of Arabic (4), abnormal hearing (1), whose median reaction time to demographic questions was less than 500ms (5), or who had less than 70% accuracy (12). Some subjects were excluded on multiple grounds. Data from 21 subjects was used in the analysis.

Materials

60 target words were selected to appear in six counterbalanced conditions. The identity condition is an exact repetition of the target. The morphological root condition is a word related via the root. The control condition is unrelated to the target. Crossed with this factor is root strength, so an equal number of weak verbs and strong verbs occur in each condition. Root strength, however, is a between-items factor, as a verb cannot have both a strong and weak root. In each case it is the form II verb (i.e., CəCCəC pattern) priming the form I (i.e., CCəC or CaC) verb. The manipulated conditions can be seen for the verbs /sqəṭ/ ‘be quiet’ (strong) and /ṭal/ ‘last, stay’ (weak) in Table 4.1. The real word stimuli are presented in Appendix F.

Table 4.2: Experiment 6a – Means

Mean	RT Onset			RT Offset			Percent Error		
	Cont	ID	Root	Cont	ID	Root	Cont	ID	Root
Strong	1006	846	865	577	414	434	3.9	1.1	0.7
Weak	1056	862	842	533	329	314	3.5	0.9	1.1

Nonword filler items were constructed in the same way as experiment 2.

Procedure

The procedure was identical to the one used in experiment 2.

4.2.2 Results

The statistics were carried out just as in experiment 2 (see Chapter 3). Five real words (/ħal/, /ʒr̩əd/, /lan/, /ṣaṭ/, and /tʕəm/) and 23 nonwords did not achieve the 70% accuracy mark after excluding subjects for accuracy and were excluded from the analysis. 3.4% of the data was excluded as outliers. The mean reaction times can be seen in Table 4.2.

No interaction of root strength and the experimental condition was detected ($p > .05$). Root strength ($Estimate = -82ms, SE = 21.83, t = -3.75, pMCMC = .0001$) was significant–with the strong level as the baseline–along with the repetition ($Estimate = -184ms, SE = 16.22, t = -11.36, pMCMC = .0001$) and root related ($Estiamte = -182ms, SE = 16.24, t = -11.21, pMCMC = .0001$) conditions. Therefore both strong and weak verbs show the same patterns of priming for the identity and morphologically related conditions: words with roots which do not consistently show three surface consonants behave like words with roots that do. Furthermore, subjects access weak root verbs quicker than strong root verbs.

4.2.3 Discussion

Velan et al. (2005) found morphological effects for weak roots in Hebrew visual processing, but a different type of weak verbs was investigated: those with a weak initial consonant, rather than a weak medial consonant. This experiment confirms weak-verb results with auditory effects for hollow verbs in Moroccan Arabic. Here weak root priming is not only significant, but of the same magnitude as strong roots, unlike the visual analog. That is to say, hollow verbs prime their related forms just as strong verbs do, in supraliminal auditory priming. We can assume that morphological families for weak verbs are structured similarly to strong verbs. Thus, weak roots may have root morphemes in the same way as strong verbs.

4.3 Experiment 6b: Subliminal Root Strength

Experiment 6a showed that hollow verbs function like strong verbs in a supraliminal lexical decision task. This experiment is the subliminal speech priming variant of experiment 6a. If the priming in experiment 6a is purely phonological in nature, we would expect the effect to vanish with the subliminal technique (see experiments 3a and 3b). If the two words are, in fact, morphologically related, we expect to see priming in this experiment.

4.3.1 Methods

The same methods as experiment 6a were employed.

Participants

Participants were recruited in the same way as experiment 2. 60 participants were recruited. Data from 38 subjects was used in the analysis. One recruiter provided most of the excluded data (14 subjects of 20) and low accuracy was the main reason for rejection.

Materials

The materials are the same as experimt 6b with the exception of the nonword filler items. The only difference in items is that some poorly performing nonwords (which did not receive 70% or higher correct responses) were swapped for new nonwords.

Procedure

The procedure was identical to the one used in experiment 3a (see chapter 3).

4.3.2 Results

Eleven words (/ʃaʕ/, /faṛ/, /lan/, /lqəf/, /mkən/, /naħ/, /qam/, /ṛam/, /sas/, /ṣaṭ/, and /ṭaʕ/) and eighteen nonwords did no achieve the 70% accuracy mark and were excluded from the analysis. 2.0% of the data was discarded as outliers. The mean reaction times can be seen in Table 4.3, Interactions were detected between the related condition and root strength ($Estimate = -67ms, SE = 24.795, t = -2.712, p < .01$), root strength and dialect ($Estiamte = 64ms, SE = 30.666, t = 2.090, p < .05$), root strength and socioeconomic status (SES, $Estimate = 85ms, SE = 26.267, t = 3.255, p < .005$), and target duration and socioeconomic status ($Estimate = -292.749, SE = 131.323, t = -2.229, p < .05$). Because socioeconomic status shows multiple interactions here, showed an interaction previously, and has a less extreme division of subjects (26 high, 12 low) compared to dialect (32 Rabat/Casablanca, 6 other) SES was selected for detailed analysis.[2]

[2]The basic models which do not consider quasi-experimental factors find interactions between root strength and both the identity ($Estimate = -58ms, SE = 25.15, t = -2.294, pMCMC =$

Table 4.3: Experiment 6b – Means

	RT Onset			RT Offset			Percent Error		
	Cont	ID	Root	Cont	ID	Root	Cont	ID	Root
Strong	931	891	921	500	457	487	2.6	3.5	3.0
Weak	1017	915	930	477	378	397	2.8	2.6	2.6

There was no effect of nonword repetition with only the condition (ID, Control) was considered ($p > .05$) nor when root strength (weak, strong) was considered ($p > .05$ for both factors with no interaction).

For the 26 high SES subjects, the means (Table 4.4) and patterns of significance are similar to experiment 6a. Identity priming ($Effect = -88ms, SE = 15.3571, t = -5.752, p < .0001$) and root priming ($Estimate = -62ms, SE = 15.3637, t = -4.061, p < .0001$) effects obtain, but there is no effect of verb strength ($p > .05$) with trial number as a random slope for subjects. There was an interaction of target duration and trial number ($estimate = -4ms, SE = 1.9786, t = -2.089, p < .05$). Hollow verbs behave the same with respect to both subliminal and supraliminal techniques, at least for most participants.

For the 12 low SES subjects, however, a different pattern emerges. The means are presented in Table 4.5. Neither root strength ($p > .05$) nor the experimen-

.0246) and root related ($Estimate = -66ms, SE = 25.24, t = -2.602, pMCMC = .0070$) conditions. When only strong verbs are considered and target offset is the measurement point, there are significant effects of both the identity ($Estimate = -71ms, SE = 18.83, t = -3.750, pMCMC = .0002$) and the root related ($Estimate = -57ms, SE = 19.95, t - 2.847, pMCMC = .0054$) conditions. When only the weak verbs are considered measuring from target offset, there is a significant effect of the identity condition ($Estimate = -84ms, SE = 23.43, t = -3.580, pMCMC = .0002$) but not the root related condition ($Estimate = -44ms, SE = 23.95, t = -1.838, pMCMC = .0640$). Thus, related priming only obtains for strong verbs, though there is a trend for the weak verbs as well. When these models measure from target onset, however, the pattern is reversed and strong verbs show repetition ($Estimate = -49ms, SE = 18.77, t = -2.63, pMCMC = .0134$) but not root related ($Estimate = -36ms, SE = 19.86, t = -1.79, pMCMC = .1008$) effects, and weak verbs show both repetition ($Estimate = -117ms, SE = 22.33, t = -5.23, pMCMC = .0001$) and root ($Estimate = -81ms, SE = 22.57, t = -3.59, pMCMC = .0002$) effects.

Table 4.4: Experiment 6b – High SES Means

	RT Onset			RT Offset		
	Cont	ID	Root	Cont	ID	Root
Strong	892	850	863	460	415	433
Weak	1007	869	895	467	334	366

Table 4.5: Experiment 6b – Low SES Means

	RT Onset			RT Offset		
	Cont	ID	Root	Cont	ID	Root
Strong	1022	983	1053	591	551	613
Weak	1037	1006	966	498	467	457

tal condition ($p > .05$) obtain with the full model measuring from target offset, though the basic offset model detects effects of root strength ($Estimate = -116ms, SE = 21.71, t = -5.338, pMCMC = .0001$). Likewise the full onset model detects effects of root strength ($Estimate = -78ms, SE = 24.048, t = -3.237, pMCMC = .0018$)[3]. The basic onset model detects repetition priming ($Estimate = -46ms, SE = 20.793, t = -2.234, pMCMC = .0310$) but not the related condition ($p > .05$). Trusting the full model measuring from target onset, the effects for low SES subjects are too muddled to make any claims.

Nonetheless, the congruence between the majority of subjects (High SES) in experiment 6b and the subjects in experiment 6a suggests that the shape of hollow roots does involve some form of abstract medial segment, at least for most speakers, and the root relationship is defined in terms of the root phonology. I turn now to determine if this is simply an abstract slot that can be filled with any consonant (suggested by the results presented by Deutsch et al. (1998)), or if the

[3]Along with effects of uncompressed prime duration ($Estimate = 312ms, SE = 103.219, t = 3.026, pMCMC = .0026$) and an interaction of age and target duration ($Estimate = -22ms, SE = 9.733, t = -2.276, pMCMC = .0248$)

abstract segment has specific phonological content.

4.4 Experiment 7: The middle of Hollow Roots

In visual studies of Hebrew, hollow roots did not show pattern priming unless a 'dummy' consonant was added into the middle (Deutsch et al., 1998). That is, words which do not display three surface root consonants do not produce pattern priming, but nonwords with three root consonants do, though the visual results in Hebrew are not always consistent on this point Frost et al. (1997); Deutsch et al. (1998); Velan et al. (2005). Experiment 7 similarly tests whether roots have an abstract "hollow" medial segment or if it is specified to be a particular segment. Pairs of words like /dab/ 'it dissolved' $\sqrt{dwb}$ and /dərrəb/ 'he trained' $\sqrt{drb}$ are tested, where the initial and final consonants are identical, but the medial root segment differs and one member of the pair is hollow. The experimental condition factor (ID, Related, Control) was crossed with Priming Direction (Weak-Strong, Strong-Weak) for a 3×2 design.

4.4.1 Methods

The methods employed are identical to experiment 3b.

Participants

Participants were recruited in the same way as experiment 3b. 60 participants were recruited. Data was excluded from participants who reported being non-native speakers (6), unable to give consent (1), failing to achieve the 70% accuracy mark (28), or achieving greater than 70% accuracy on the post test of prime awareness (6), or a combination of these reasons. Data from 28 of the participants was included for analysis.

Table 4.6: Experiment 7 - Conditions

	Weak-Strong		Strong-Weak	
	Prime	Target	Prime	Target
Identity	dab ‘it dissolved’	dab	dərrəb	dərrəb
Control	sməʕ ‘he heard’	dab	sməʕ	dərrəb
Related	dərrəb ‘he trained’	dab	dab	dərrəb

Table 4.7: Experiment 7 – Means

	Onset		Offset		Percent Error	
	Hollow Target	Strong Target	Hollow Target	Strong Target	Hollow Target	Strong Target
Control	947	968	446	507	1.8	1.6
Identity	874	891	369	430	1.9	1.8
Related	917	972	411	502	1.4	1.5

Materials

72 prime-target pairs were constructed, and 72 nonword prime target pairs were used as filler. Examples of the pairings are shown in Table 4.6. The real word stimuli are presented in **??**.

Procedure

The procedure was identical as the one used in experiment 3b.

4.4.2 Results

Sixteen real word targets (/ɣab/, /ħad/, /ħar/, /bxəs/, /fəggəd/, /fərrəz/, /ʒfəl/, /lam/, /lan/, /ləqqəħ/, /maʒ/, /naħ/, /qas/, /ṛʃəm/, /ṣqəl/, and /xʃan/) and 15 nonword targets did not achieve 70% accuracy and were excluded from the model. 2% of the data was discarded as outliers. The mean reaction times can be seen in Table 4.7. No interactions were detected. The experimental condition is only significant for the identity condition ($Estimate = -74ms, SE = 14.74, t = -5.004, pMCMC = .0001$) but not the related condition ($Estimate = -17ms, SE = 14.60, t = -1.194, pMCMC = .2224$). The direction of priming was not significant ($p > .05$) for any model. Target duration ($Estimate = 518ms, SE = 109.75, t = 4.716, pMCMC = .0001$) and original prime duration ($Estimate = 1017ms, SE = 85.75, t = 11.854, pMCMC = .0001$) were also significant. The means suggest there may be a related priming effect when only hollow verbs are considered as targets, but this is not born out by a post hoc test ($p > .05$).

There is an effect of nonword repetition ($Estimate = -39ms, SE = 19.72, t = -1.964, p < .05$).

4.4.3 Discussion

First, there is no priming between hollow verbs and strong verbs which share their first and last consonants. The subliminal speech priming technique appears to be insensitive to phonological relations, but sensitive to morphological ones. Thus, the word pairs in the related condition do not appear to be morphological related. Deutsch et al. (1998) tested this effect for pattern priming, not root priming. That is, do weak roots in the basic pattern like /mal/ prime strong roots in the basic pattern like /ktəb/, or Hebrew /katav/)? In Hebrew, pattern priming was not seen between strong and weak roots of the same pattern (modulo the fact that the patterns were not identical on the surface since the weak consonants alter the graphic similarities between forms). Further visual results in Hebrew suggest that weak roots can (but do not always) produce root priming Velan et al. (2005). The lack of phonological form priming is not entirely unexpected in light of experiment 3b (see Chapter 3), where phonological form effects do not obtain though they did with the overt priming technique in experiment 3a. There is no root extraction process during lexical retrieval that simply targets the first and last segments of hollow roots. Hollow roots without three consistent consonantal segments are not "hollow" in this sense. We can conclude there is something in the middle of hollow roots, which supports a representation with a vocalic or semi-vocalic medial segment. This could be a glide segment, as is commonly assumed (e.g., McCarthy, 1981), or a set of possible segments as in Hudson (1985, 1986).

It is also interesting that prime's original duration is significant since each prime was compressed to 240ms. Here, the prime duration factor must represent a lexical factor akin to word frequency, neighborhood density, or morphological family size. It is well known that lexical factors such as these may correlate with a word's pronunciation, where less frequent words (for example) may be pronounced slower or more carefully than more frequent words (e.g., Gahl, 2008).

Since hollow roots are not related to strong roots, I turn now to test whether different pairs of weak roots can be related purely by their regularly occurring surface consonants.

4.5 Experiment 8a: Biconsonantal Roots

Do weak verbs privilege their consonants? That is to say, are the so-called hollow verbs and the so-called lame verbs represented in terms of their consonants, or does the root's glide or vowel also play a role? Word pairs like /ban/ 'it appeared' ($\sqrt{byn}$) and /bna/ 'he built' ($\sqrt{bny}$) show a close phonological relationship: these words are consonantally identical but they differ in the location of their vowel akin to methathesis or a transposed segment. Transposed letter effects have been studied recently with visual masked priming (e.g., Andrews, 1996; Perea and Lupker, 2003; Perea et al., 2003; Grainger and Van Heuven, 2003; Schoonbaert and Grainger, 2004, among others), so it makes sense to test root-consonant transposition as a near phonological or root relationship. Experiment 7 uses the supraliminal auditory technique and tests the factor *Phonological Form* with three levels: Identical, Unrelated, and Related. The design is thus 1 × 3. The related condition, like that tested above in Experiment 7, represents a potential root relationship. If the relationship is similar to identity priming, it is likely to be a morphological relationship. If it is about half the size of the identity relationship, the related condition is likely to be just a phonological relationship.

This experiment supports the results of the previous experiments (3a, 3b, 6a, 6b, and 6) by testing a different phonological relationship. Weak verbs are often represented with a vowel or semivowel as a root segment; this experiment tests the primacy of the consonants over vowels and the order of vocalic root segments. Verbs like /ban/ ($\sqrt{byn}$) and /bna/ ($\sqrt{bny}$) are tested for phonological priming, since their phonological relationship is much closer than that tested by experiments 3a and 3b.

4.5.1 Methods

This experiment uses the supraliminal auditory priming technique. The same methods as experiment 3a were employed. Items from experiments 3a were used as filler items for experiment 7a and vice versa.

Participants

Participants were recruited in the same way as experiment 2. 86 subjects were recruited. Data was eliminated from subjects who reported being nonnative speakers (7), a history of hearing problems (3), not using headphones (2), with a median RT to demographic questions less than 500ms (10), low accuracy (13), or some combination thereof leaving 66 subjects in the study.

Table 4.8: Experiment 8a - Conditions

	Prime	Target
Identity	ban 'seem'	ban
Control	ħḍəṛ 'show up'	ban
Related	bna 'build'	ban

Materials

36 target words were selected to appear in three counterbalanced conditions. The identity condition is an exact repetition of the target. The control is unrelated, and the phonological condition shares the consonants of the theoretical weak root, but not their order. Thus /ban/ has the root $\sqrt{bVn}$ where the medial segment of the root is vocalic or semivocalic, and /bna/ has the root $\sqrt{bnV}$, so they share the consonants [b] and [n] but not a root. Phonologically speaking, these verbs differ by metathesis of the (semi-)vocalic root segment. The real word stimuli are presented in Appendix H.

Four real word items (/ħma/, /naħ/, /ṛam/, and /sba/) and 15 nonword targets did not reach the 70% accuracy mark and were excluded from the analysis.

Nonword filler was constructed in the same way as experiment 2.

Procedure

The procedure was identical as the one used in experiment 2 with the supraliminal auditory technique.

4.5.2 Results

2.3% of the data was trimmed as outliers. The means are shown in Table 4.9. Significant effects of the identity ($Estimate = -153ms, SE = 11.90067, t =$

Table 4.9: Experiment 8a – Means

Mean RTs	Control	Identity	Related
RT Onset	994	782	854
RT Offset	465	330	405
Percent Error	3.9	2.6	2.1

$-12.841, pMCMC = .0001$), related ($Estimate = -85ms, SE = 11.95510, t = -7.089, pMCMC = .0001$), as well as prime duration (measured in seconds, $estimate = -877ms, SE = 66.50232, t = -13.190, pMCMC = .0001$) obtain. An interaction between age and trial number was detected, but is orthogonal to the effects of interest ($Estimate = -0.1ms, SE = 0.01929, t = -5.084, pMCMC = .0001$). Models considering only the experimental condition or measuring from the target onset show the same pattern of significance in the experimental condition.

4.5.3 Discussion

Form priming obtains, but the effect size is much lower than for identity priming. Morphological effects (even for the same types of words as in experiments 3a and 3b in chapter 3) are similar in significance and magnitude to identity priming, whereas phonological priming is about half the size of identity priming in experiment 3a (see chapter 3). Because of the difference in magnitude of the effects, we may conclude that the representations of /ban/ and /bna/ are suitably different at the morphological level that there is only phonological priming for similar sounds. Thus, /ban/ and /bna/ do not instantiate biconsonantal roots as such (e.g., $\sqrt{bn}$), but a vocalic or semivocalic element shapes the root (e.g., $\sqrt{byn}$ and $\sqrt{bny}$). If there is no priming effect between these forms with the subliminal technique (see experiment 8b), then this interpretation will be confirmed.

4.6 Experiment 8b: Subliminal Biconsonantal Roots

This experiment is the subliminal speech priming version of 7a. If the there is no priming in the related condition, we can conclude that the reduced priming effects of experiment 7a are purely based on phonological form. If not, these etymologically distinct roots will be shown to be synchronically related.

4.6.1 Methods

The same methods as experiment 6a were employed.

Participants

Participants were recruited in the same way as experiment 3b. 50 subjects were recruited. Data was excluded from subjects who reported being non-native speakers (7) or did not achieve the 70% accuracy mark (12) with some overlap between the two. Data was analyzed from 33 participants.

Materials

As experiment 7a. Nonwords which did not have 70% accuracy in Experiment 7a were replaced with other nonwords.

Procedure

The procedure was identical to the one used in experiment 7a.

4.6.2 Results

Seven words (/ħaf/, /fda/, /ʒal/, /naħ/, /ṛam/, /saħ/, and /sba/) and 14 nonwords did not achieve the 70% accuracy mark and were excluded from the anal-

Table 4.10: Experiment 8b – Means

Mean RTs	Control	Identity	Related
RT Onset	974	924	9768
RT Offset	536	482	527
Percent Error	7.1	5.7	6.9

ysis. 2.4% of the data was discarded as outliers. The means are shown in Table 4.10. The experimental condition was significant, but only the identity condition differed significantly from the control ($Estimate = -52ms, SE = 19.349, t = -2.685, pMCMC = .0070$). There was no effect of for the related condition (p>.05), suggesting the effect in experiment 7a is purely phonological. Target duration (measured in seconds, $estimate = -867ms, SE = 107.853t = -8.036, pMCMC = .0001$) was also significant. There was no effect of repetition for nonwords ($p > .05$).

4.6.3 Discussion

Just as the phonological condition from experiment 3a is absent in experiment 3b, we see here that the phonological effect vanishes with the use of the subliminal speech priming technique. Morphological root effects do obtain with the subliminal speech priming technique, which suggests that there is no structural relation between /ban/ and /bna/. While transposed letter effects are common visually, transposed segments in auditory word recognition can show phonological form effects (see Experiment 7a), but only at later stages.

Nonword repetition at the 240ms level suggests that this compression rate is near the limit of human perception. It is not clear what factors may affect nonword repetition, not why nonword repetition effects obtain without phonological effects. Further research may distinguish whether these effects are phonological or related to episodic memory. Perhaps nonwords show phonological effects because there is no word-level interference, or these nonwords are easier to encode in episodic memory because they have fewer surface segments.

4.7 Experiment 9: Hollow and Geminate Roots

Some roots with only two surface consonants show gemination in the basic Form I pattern (i.e., /səbb/ 'he insulted') rather than a full vowel as in /ban/ 'it seemed' and /bna/ 'he built'. McCarthy (1981) argues that these roots are truly biconsonantal, with the second consonant showing gemination when needed to fill out the prosodic template. Like experiments 7a and 8b, experiment 8 tests consonantal and vocalic representations to see if the etymological definition of the root is instantiated in the mind. This experiment tests pairs like /sab/ 'he rebelled' ($\sqrt{syb}$) $\sim$ /səbb/ ($\sqrt{sb}$), which differ minimally on the surface (i.e., a full vowel versus a geminated consonant) but greatly in terms of their roots. Experiment 8 uses the subliminal speech priming technique to test the factor *experimental condition* with three levels Identity, Control, Related in a 1×3 design. As with experiments 6, 7a, and 8b the related condition may represent phonological form or a morphological relation. If there are priming effects for the related condition, we expect it is a morphological relation. If there are no effects for the related condition, it must represent phonological form since the subliminal speech priming technique is not sensitive to these phonological form effects. Since experiments 3a/b, 4a/b, 6a/b, 6, and 7a/b have shown there are not phonological form effects and given the limitations of time and money, this experiment only uses the subliminal speech priming technique and was not tested with the supraliminal technique.

Table 4.11: Experiment 9 - Conditions

	Prime	Target
Identity	sab ‘he rebelled’	sab
Control	ħrək ‘he went to war’	sab
Related	səbb ‘he insulted’	sab

4.7.1 Methods

This experiment uses the subliminal speech priming technique with the same methods as experiment 3b. Experiments 9 and 10 were run concurrently, thus the items in this experiment were used as distractors in Experiment 10.

Participants

Participants were recruited in the same way as experiment 3b. 65 subjects were recruited. Data was excluded from subjects who reported being non-native speakers (4), did not achieve the 70% accuracy mark (36), or achieved 70% or higher on the post-test of prime awareness. 28 subjects were used in the analysis.

Materials

21 prime-target pairs were created in which the surface consonants were identical between related prime and target but differed in terms of consonant gemination or full [a] vowel. This is shown in Table 4.11. The real word stimuli are presented in **??**.

Procedure

The procedure was identical to the one used in Experiment 7b.

Table 4.12: Experiment 9 – Means

	Control	Related	Identity
Onset	952	933	873
Offset	399	382	325
Percent Error	10.6	11.8	5.9

4.7.2 Results

Five real word targets (/guwwəd/, /huwwəl/, /muwwən/, /sab/, and /ṣaṛ/) did not achieve 70% accuracy and were excluded from the analysis. 3.2% of the observations were excluded as outliers. The mean reaction times can be seen in Table 4.12. No interactions were detected. The experimental condition was significant, but only for the identity condition ($Estimate - 76ms, SE = 21.29, t = -3.575, pMCMC = .0010$). The phonological condition did not obtain ($Estimate = -18ms, SE = 20.71, t = -0.863, pMCMC = .4002$). Target duration (measured in seconds, $estimate = -568ms, SE = 205.62, t = -2.761, pMCMC = .0094$) was also significant. There was also a significant effect of repetition for non-words ($Estimate = -53ms, SE = 23.67, t = -2.245, p < .05$).

4.7.3 Discussion

These results are not unexpected, given the results of lack of phonological form priming with the subliminal speech priming technique. In this experiment there is no priming between geminate and hollow verbs. This indicates that the relation tested here is one of phonological form, not morphology. This further indicates that the etymological definition of the root appears to be synchronically instantiated in the mind, and that subtle differences between word-forms are distinguishable with the subliminal speech priming technique.

One last pair of relations to test is between words with four root consonants and those with only three.

4.8 Experiment 10: Quadraconsonantal Roots

While most roots of the language contain three (or sometimes two) consonants, other roots display four consonants. These words provide a natural way to test extreme phonological similarity between words: a triconsonantal root may be wholly contained within a quadriconsonantal root. Such extreme phonological similarity should show whether word relations might be purely phonological. This experiment tests whether words with four root consonants prime words with only three root consonants. The experimental factor has three levels: Control, Identity, and Related. The related condition tests the potential relationship between roots of three and four consonants. If priming obtains, it should be a morphological relationship. If there is no priming, we can assume the overlap in consonants is just a relation of phonological form.

4.8.1 Methods

This experiment uses the subliminal speech priming technique and uses the same methods as experiment 3b. Experiment 10 was run concurrently with experiment 8, thus the items in experiment 8 served as distractors for this experiment.

Participants

Participants were recruited in the same way as experiment 3b. 65 subjects were recruited, data was excluded from subjects who reported being non-native speakers (4), subjects who did not achieve 70% accuracy (36), and subjects who achieved

Table 4.13: Experiment 10 - Conditions

	Prime	Target
Identity	bəssəm ‘he made someone smile’	bəssəm
Control	ɣṭəṣ ‘to submerge, disappear’	bəssəm
Related	bəsməl ‘he said “in the name of God” ’	bəssəm

greater than 70% accuracy on a post-test of prime awareness. This left data from 28 subjects in the analysis.

Materials

44 prime-target pairs were selected to appear in three conditions: identity, control, and related. Related prime words were chosen to display four root consonants. Three of the root consonants in the target words overlap with the prime's consonants, in linear order. Thus, a word with four consonants $\sqrt{C_1C_2C_3C_4}$ primed words with root consonants $\sqrt{C_1C_2C_3}$ or $\sqrt{C_2C_3C_4}$. This is shown in Table 4.13 with the target /bəssəm/ $\sqrt{bsm}$. Verbal form was not controlled for. The real word stimuli are presented in Appendix J.

Procedure

The procedure was identical to the one used in experiment 3b.

4.8.2 Results

Seven real words (/bəssəm/, /bʒeɣ/, /hənnəd/, /nəggəṛ/, /rəbbəd/, /rəggəb/, and /rfəd/) and two nonwords did not achieve the 70% accuracy level. 2.3% of the data was excluded as outliers. The experimental condition was significant for both the

Table 4.14: Experiment 10 – Means

	Control	Related	Identity
Onset	966	891	930
Offset	491	423	458
Percent Error	3.0	3.5	3.5

identity ($Estimate = -72ms, SE = 14.87, t = -4.831, pMCMC = .0001$) and related ($Estimate = -32ms, SE = 14.92, t = -2.176, pMCMC = .0296$) conditions. The mean reaction times can be seen in Table 4.14. In addition, target duration (measured in seconds, $estimate = -412ms, SE = 123.91, t = -3.326, pMCMC = .0001$) is significant. This suggests that there is a close relationship between verbs with four root consonants and those which share three of those consonants.

A post-hoc test examined the overlap between the quadriconsonantal prime and the triconsonantal target, to see if there was a difference between prime-target pairs whose prime shared the initial three consonants versus the final three consonants. There was no effect ($p > .05$) of which consonants overlap; the first three and last three consonants primed equally.

There was an effect of nonword repetition ($Estimate = -68ms, SE = 13.06, t = -5.212, p < .0001$) with condition as a random slope for subjects. Because of the number of distinct target patterns in this experiment, a post-hoc analysis including nonword form (F1, F2, F3, F9), number of phonemes in target (numeric), full vowel in target (yes, no), and number of syllables (monosyllabic, bisyllabic) were conducted. There was no interaction with the experimental condition for the first three factors ($p > .05$ in each case), but number of syllables did interact with the experimental condition ($Estimate = -47ms, SE = 20.50, t = -2.305, p < .05$) with condition as a random slope for subjects. Analyzing the monosyllabic words (forms I and IX), there are significant effects of repetition

($Estimate = -45ms, SE = 14.43, t = -3.142, pMCMC = .0018$) and target duration ($Estimate = -384ms, SE = 182.34, t = -2.107, pMCMC = .0322$). Analyzing only the bisyllabic words (forms II and III), there are significant effects of repetition ($Estimate = -97ms, SE = 14.62, t = -6.647, pMCM = .0001$), SES ($Estiamte = -99ms, SE = 47.57, t = -2.075, pMCMC = .0250$), and target duration ($Estimate = -607ms, SE = 208.28, t = -2.916, pMCMC = .0036$). While there is facilitation in both cases, there is a stronger facilitation effect of forms II and III, which are also faster for high SES subjects to recognize.

4.8.3 Discussion

Compared to the previous results, these results are quite odd. This subliminal experiment suggests that quadriconsonantal roots prime triconsonantal roots which are wholly contained within the quadriconsonantal root. What we have here is an exact consonantal match, though the prime root has an additional consonant in it. This holds when the target root overlaps with the first three consonants of the prime or the last three. Quadriconsonantal roots, then, are organized in the same lexical space or via the same root morpheme as triconsonantal roots. Note that these are root similarities, not just phonological form since words were not controlled for the morphological pattern (i.e., basic form I–CCəC, geminated form II–CəCCəC , or full voweled form III–CaCəC). The meaning of the roots likewise seems to play no role here (cf. Experiment 2 in chapter 3).

A purely phonological explanation for this result seems implausible. Recall that all the primes in these experiments were compressed to 240ms, so quadriconsonantal and triconsonantal prime words are equal in terms of duration. No other phonological effects were detected in these experiments with the subliminal speech priming technique (which is used for this experiment) for real words, despite strong phonological similarity. Likewise, semantic effects were not found with the supraliminal technique. One might suspect, however, that if the quadriconsonantal primes are either not established in the lexicon or only weakly established, they may show a type of phonological priming similar to novel coinages as in experiment 4b (see chapter 3). It is unlikely that quadriconsonantal to triconsonantal root priming is an effect of speech segmentation. Phonological effects of one-added phoneme did not obtain in Kouider and Dupoux (2005) with prime-target pairs like *devis* [dəvi] 'cost estimate' ∼ *divise* [dəviz] 'motto; currency; cash'.

The alternative explanation is that quadriconsonantal roots are stored in the same morphological space or via the same root morpheme as triconsonantal roots, which refutes the etymological theory of the root for these forms. A structural relationship between quadriconsonantal roots and triconsonantal roots is not predicted by formal theories, and this merits further investigation.

The nonword repetition results suggest that some difference between the clearly bisyllabic forms (II and III) and the others (forms I and IX), results in a nonword being processed by the system. There may be some aspect of these derived templatic forms which makes them more easily recognizeable as word-like, or an earlier stage of phonological processing at work for these forms.

4.9 General Discussion

The etymological definition of the root fares quite well in behavioral tests. Morphological families of weak verbs seem to be based on the presence of vowels and semivowels, not simply the stable surface consonants. Furthermore, linear order of the segments are important. Simply sharing consonants between phonological word-forms is not enough to produce priming (except in Experiment 10); it is the morphological structure itself that seems to do it. As seen in the previous chapter, however, real words are required to produce this morphological priming. As such, these roots, while important for lexical access, have phonological content but no independent sublexlical representation.

There are two caveats to the etymological definition of the root. First, the etymological root does not define morphological families for all subjects. In experiment 6b, the low SES subjects did not show root priming effects. For these subjects, the etymological definition of the root did not predict their behavior with derived hollow root pairs (e.g., /ban/ and /bəyyən/). This disparity indicates that, while subjects may speak the same language, they might not process it in the same way. A morphological cluster theory becomes appealing in light of these results, as all subjects could simply develop different morphological clusters for each word family based on factors like frequency, neighborhood density, semantics, etc. This disparity may be the result of the subject's sociolinguistic environment but further research is needed to determine what factors influence these cognitive and behavioral differences.

The second caveat is the results from quadriliteral primes in Experiment 10. Since none of the other experiments detected phonological effects with the subliminal technique for real words, it would be surprising if quadriliteral primes produced phonological priming in words whose root consonants are contained within the quadriliteral prime. This suggests that the morphological organization of the lexicon has a triconsonantal basis (both for linguistic and psycholinguistic models), and quadriconsonantal roots are organized with their triconsonantal neighbors. That is to say, any given quadriconsonantal root $\sqrt{C_1C_2C_3C_4}$ is really organized with the morphological families $\sqrt{C_1C_2C_3}$ and $\sqrt{C_2C_3C_4}$. It is implausible that this is an artifact of the technique and the segmentation of the speech stream; Kouider and Dupoux (2005) tested the one-phoneme-added phonological relationship and found no effects. Participants are likely expecting already-segmented phonological lexemes in the experiment, since the stimuli that subjects hear are all complete phonological word-forms. Furthermore, the stimuli were controlled at the level of root consonants, not for prefixes or medial gemination. Therefore, there is less phonological overlap between these form (e.g., /bəsməl/ and /bəssəm/ differ in terms of gemination of the /s/ and inclusion of the /l/).

The fact that the etymological definition of the root is so successful at predicting facilitation effects suggests that morphological families are constructed with some phonological component, though phonological similarity alone (see experiment 3b in chapter 3) is not enough to account for the facilitation shown here. How can we make sense of the facts that phonology alone does not activate root representations, yet morphological families seem to be defined based on very abstract triconsonantal representations?

One unexpected results of the experiments presented here is that three of the five subliminal speech priming experiments found an effect of nonword repetition priming when primes were compressed to 240ms (experiments 7, 9, and 10). We expect that chance should produce significant nonword priming effects occasionally, but there may be some hidden factors that influence nonword repetition. The post-hoc analysis of experiment 10 suggests that the clearly bisyllabic forms (II and III) show more facilitation than the others (forms I and IX). This difference in facilitation, along with the socioeconomic status of the subjects, hint that there may be lexical factors (i.e., form frequency) and sociolinguistic factors that influence the early and automatic processing of phonological word forms.

The consistent morphological effects discovered here argue in favor of phonologically-defined morphological families, but not necessarily for a phonological component for a root representation, or even a root representation at all. First, if there was a phonological component to a root representation, we should still see root priming from any given word in a family to any other word. This does not obtain (see experiment 5 in chapter 3). Second, a phonological component to a root representation seems somewhat redundant for a model of speech perception. If phonological word-forms are stored, morphemes may be intermediate representations linked to those phonological word-forms without any individual phonological content *per se*. There is no behavioral evidence with the subliminal speech priming technique, which appears to be sensitive to the earliest stages of word recognition, that supports a direct link between phoneme representations and the root. Even some formal theories, such as Distributed Morphology (Halle and Marantz, 1994) or A-morphous Morphology (Anderson, 1992) do not require morphemes with phonological content at all. Realizational theories of morphology take morphemes to be abstract elements which can be manipulated apart from their phonological realization.

In a morphological cluster theory (see chapter 3), where there are no root representations, there cannot be any phonological content to the root because there are no root representations, merely root relationships. Sound-meaning correspondences may be used by children while acquiring the language. While phonology may influence the shape of the lexicon (i.e., developing root representations or morphological clusters), the adult grammar need not be identical to the child's developing grammar. Thus, phonological similarity may be discarded as unnecessary once morphological families are established by the learner. If the language system learns to identify things such as medial gemination (a causative, intensive, or denominalizing morpheme), it must do so in such a way that it knows the related forms, which are only consonantal. The observation that Semitic languages use strict prosodic templates (Bat-El, 1994, 2003; Ussishkin, 1999, 2005), gives us a clue as to the statistical regularities that children may notice while acquiring root representation. Thus the system bins /ban/ with /bəyyən/ together, just as it bins /ktəb/ and /kəttəb/. There is no need to explicitly store additional phonological forms, but rather to link existing ones somehow.

Linguists have long known that Modern Hebrew novel coinages are word and consonant-based (Ravid, 1990; Bat-El, 1994; Ussishkin, 1999), with novel coinages being largely based on the existing consonants (and sometimes vowels) of base words. The consonants are fitted to the Hebrew templatic pattern, so this may appear to be a type of 'root extraction', but we need to clearly distinguish between roots as historical vs. synchronic entities, and roots which have phonological content. Principled listing of historical forms provides a clear explanation for the preservation of formerly productive systems (Blevins, 2004). Novel forms in Hebrew, however, violate spirantization and preserve consonant clusters which show clear links to base words (Ravid, 1990; Bat-El, 1994). Furthermore, the presence of semi-vowels or reduplication is predictable from the base form as well (Ussishkin, 1999). Theorists who argue for consonantal roots are those who assume a 1:1 correspondence between phonological and morphological elements or have a desire to derive existing words from roots (e.g., McCarthy, 1981; Arad, 2005; Faust and Hever, 2010). If roots do not have phonological content, the argument against the root (Bat-El, 1994, 2003; Farwaneh, 2007; Ratcliffe, 1997; Schluter, 2007; Ussishkin, 1999, 2005, 2003) is avoided. Unlike the generative mixed position, suggesting that some words are derived from other words while others are derived from roots Arad (2005); Faust and Hever (2010), we can simply assume historical forms are preserved in the lexicon Blevins (2004) and novel forms are generated from new words.

Without phonological content for roots, the adult grammar would need to make use of existing phonological word-forms in the coinage of new words. This is a testable prediction, which Ussishkin (1999) and Bat-El (1994) explored. Borrowings into Modern Hebrew are fitted to the templatic morphological system based not upon extracted root consonants, but the phonological form of the borrowing: productive forms are built from existing words, not roots. This is similarly testable with native vocabulary from polysemous roots. If speakers are presented with novel coinages (of the type used in experiment 4b in chapter 3), a root theory would predict subjects could assign any meaning within the semantic domain of the entire morphological family. If the word theory is correct, speakers would base the meaning of the novel coinage on existing forms, probably the most frequently occurring member of the family or perhaps the form heard most recently (a form of semantic priming). Causatives or reciprocals would be based on the meaning(s) available to the base verb used, as denominals are based on the original meaning. What is predicted not to exist is novel coinages that are based on an abstract root meaning.

So what is a root? Roots are abstract relationships that links similar phonological lexemes with semantic forms, but are not themselves phonological or semantic entities or even morphological entities. This notion is opposed to recent theories of morphology, including Distributed Morphology (DM; Halle and Marantz, 1994) and word-and-paradigm morphology (Blevins, 2006). Harley (2012), following Pfau (2009) and Acquaviva (2008), argues that roots cannot be identified on the basis of semantics or phonological form alone, which is in accordance with the results presented in chapter 3. DM holds that the lexicon is distributed in three components: morphosyntactic representations, vocabulary items, and encyclopedic knowledge. Of these, roots are of the morphosyntactic type. Roots are not vocabulary items (i.e., phonological lexemes) like /ktb/, nor are they semantic or conceptual entities like WRITE. The root is an element of morphosyntactic computation, which links the conceptual information such as WRITE with the phonological word forms /ktəb/, /kəttəb/, /katəb/, /ktab/, etc. What is incompatable with DM here is that roots do seem to be etymologically defined, yet there is no evidence that they are processing units *per se*.

Other morphological frameworks, such as Blevins (2006)'s word-and-paradigm approach, might suggest that the root is akin to the paradigm's address in the lexicon, or is the paradigm itself. According to Blevins (2006) the word is the basic unit of the lexicon, because full phonological word-forms can predict the parts better than the parts can predict the word form. Words are arranged into a network, called a paradigm. Presumably the syntax can call for the third person, imperfective, Do-verb form from paradigm #256 and the word-form /iktəb/ is retrieved. Even amongst word-based theories of morphology and the lexicon, there is need for an abstract notion of the morpheme (Bauer, 1999). However, a paradigm theory cannot account for the results here without weighting the connections between cells in a paradigm, and also, it seems, allowing for individual differences in the number of cells in a paradigm and their relationships.

Do we need this additional abstract morpheme level? Caramazza (1997), for example, suggests this level is unnecessary, directly linking semantic and phonological levels of representation. Completely isolating languages might not make use of these intermediate root forms, as they could directly link the invariant phonological forms to semantic forms. Whether or not an isolating language needs abstract roots, linguists have recognized the inadequacy of simple item-and-arrangement theories of morphology for a long time (cf. Hockett, 1954, among others), and that there is a need for "morphology by itself" (Aronoff, 1994). Most modern theories of morphology incorporate some insight from lexeme-based realizational approaches to morphology (Aronoff, 2007; Matthews, 1972; Mathews, 1974; Anderson, 1992). The abstract morpheme, realized by lexemes, is a compelling theoretical perspective, though there is no evidence here for the root as a processing node, rather than as a relationship between words. It is interesting to note that isolating languages like Chinese may link an abstract root position with the orthographic form, even if an abstract root may seem unnecessary when dealing with phonological word-forms. And even Hebrew or standard Arabic may link orthographic form to root representations, but there is no evidence from audition to support the root as a unique processing node.

Another question is, should we expect formal theories of language and theories of language behavior to converge? The results here suggest that formal and behavioral models will converge, though unifying these two approaches may result in models unfamiliar to either linguistic or psycholinguistic theory. Nonetheless, without formal models of language, behavioral scientists have little to test. While the previous chapter suggests that the root may not be an independent entity used in spoken word recognition, the root relationship clearly plays a role in speech perception. Furthermore, it is not a simple matter of consonantal overlap, or even stem-consonant overlap. The root relationship takes into account abstract phonological material. Though more work is required to develop a complete unified theory of Semitic roots and morphological families, the concepts from formal theories of language are testable with psycholingustic techniques, and this will results in a more complete model of morphology, the structure of the lexicon, and lexical access.

What the root-as-relationship does not predict is aphasia errors (Prunet et al., 2000; Idrissi et al., 2008). There remain a number of possible explanations which can make sense of the conflicting evidence. If children develop root representations based on phonological and semantic regularities, aphasic patients may either do the same or tap into latent phonological information associated with root creation. Alternately, an aphasic may instead re-develop those links in the brain. It is also possible that literacy strongly influences morphological representations and the observation that certain forms share letters in the orthography drives the observation that some word-forms are related.

The lack of a COHORT or neighbor effect (noted in Chapter 3) with the subliminal speech priming technique can also be revisited in light of these experiments. It is interesting to note that all of these phonologically related conditions presented here have small and consistent, but non-significant, facilitation effects. Experiments with more power might find that phonological similarity results in 10-15ms facilitations. Other experimental tasks or techniques may be able to shed light on this. Such research may show that there may, in fact, be a cohort effect based on phonological form, it is just much smaller and later than one would expect from overt priming techniques.

4.10 Conclusion

Morphological families play a major role in speech perception, and the traditional definition of the root as a triconsonantal element–complete with abstract "consonantal" segments–fairs well with behavioral testing. The evidence from chapter 3, however, makes the claim that roots have phonological content themselves dubious. Instead, it is more likely that children acquiring the language make use of phonological and semantic regularities to build morphological families. The fact that not all speakers develop these families identically further suggests that there is no phonological root constructed, but rather roots, if they exist, are completely abstract morphosyntactic elements without conceptual or phonological content. For symbolic theories of language, those which include full word-forms in the lexicon *and* abstract, phonology-free root morphemes are supported.

CHAPTER 5

IMPLICATIONS AND CONCLUSION

5.1 Introduction and Summary of Experimental Results

This dissertation has sought to define what the root appears to be in terms of psycholinguistic theory, so that the results can constrain our linguistic theories. In order to do this, I have modified the subliminal speech priming technique, tested for semantic and phonological effects apart from morphology, tested predictions of the root hypothesis, and tested the etymological theory of the root.

The subliminal speech priming technique is the most promising technique for investigating dialectal differences, studying pre-literate or illiterate populations, or investigating unwritten languages and dialects (chapter 2). Experiment 1 refined the subliminal speech priming technique, so that an all-auditory, unconscious priming technique would be available to deploy in the Moroccan Arabic context. This experiment shows that primes should be compressed to 240ms in English, and the prime duration largely holds for Moroccan Arabic as well.

The six experiments in chapter 3 show that roots do not have their own, independent, lexical representation. First, experiments 2, 3a and 3b detangle the influence of semantics and phonology from morphology. Experiment 2 tested semantic effects in Moroccan Arabic with supraliminal priming. This experiment found evidence of morphological effects, but not semantic effects. Synonyms did not prime one another, and there was no difference in the morphological condition between those words judged close or distant in meaning. Experiments 3a and 3b tested a root phonology with prime-target pairs that differed in their medial root consonant. While phonological priming obtained in experiment 3a with the supraliminal priming technique, there was no effect of phonology with the subliminal technique. This suggests that phonology similarity may have late effects, but it is not relevant at the earliest stages of lexical access. Experiment 4a and 4b tested the hypothesis that nonwords built from real words should prime real words. This was borne out by both the supraliminal (4a) and subliminal (4b) techniques. Novel coinages–built from real roots and patterns but the form is not established in the lexicon–do prime real-word relatives. Finally experiment 5 tests the hypothesis that a root representation must activate all its related words. This is not born out, as there was no effect of form III (CCeC) priming form I (CaCeC) relatives while form II (CeCCeC) did. This lack of symmetry drives the idea that roots cannot be independent entities, and the priming from novel coinages in experiment 4b may be itself a prime lexicality effect.

The seven experiments in chapter 4 tested the etymological definition of the root. The results show that the triconsonantal root of formal linguists is a good definition for morphological families in Moroccan Arabic, with two exceptions. Experiment 6a and 6b shows that hollow roots (only displaying two surface consonants, where the third is an abstract glide) show morphological priming effects as strong triconsonantal roots do. Experiment 7 shows that morphological effects of hollow roots cannot be reduced to the importance of the first and last phonemes, but that the middle of the word-form is also important. Experiment 8a and 8b show that different types of biconsonantal roots (hollow and lame) do prime one another with the supraliminal technique, but not the subliminal technique. This indicates again that it is not simply consonants that produce morphological effects in the subliminal speech priming technique, but a more abstract definition of the form. Experiment 9 replicates this finding with hollow and geminate roots, which are also biconsonantal on the surface. Finally experiment 10 shows an exception to the etymological root definition: there are unexpected priming effects from quadriconsontal roots to triconsonantal roots which overlap in root consonants. The second exception is shown by experiments 6b and 4b, where socioeconomic status moderates priming effects, indicating that there may be important individual differences in the organization of the Semitic lexicon.

Taken as a whole, the results of this dissertation suggest that the subliminal speech priming technique can reveal the organization of the lexicon, and the organization it reveals is one of etymologically defined morphological relationships, but not root representations. Individuals, however, may not all develop the same set of morphological relations. In this chapter, I review the implications for speech perception, formal morphological theories, and psycholinguistic theories. I turn first to the implications for speech perception and the subliminal speech priming technique.

5.2 Subliminal Speech Priming and Speech Perception

The subliminal speech priming technique is a fruitful method for investigating morphological relations in Semitic. While Kouider and Dupoux (2005) did not find morphological effects in French with masculine-feminine pairs, the effects are robustly detectable in Semitic. This may be a result of a robust morphological system in Semitic or an effect of the specific templatic system in Semitic. Other morphologically rich or templatic languages are good candidates for future research with the technique to see if the Semitic results generalize or are language (or language-family) specific.

The subliminal speech priming technique appears to be very insensitive to phonological relations. Phonological neighbors show no effects in Moroccan Arabic with the subliminal speech priming technique. Quadriliteral roots showed any potential deviation from this generalization, and it may be a true morphological generalization. It is worth investigating quadriliteral priming further in additional Semitic languages. The lack of phonological priming in general also contradicts models of word recognition which rely on cohort or neighbor activation (Marslen-Wilson, 1987; Luce and Pisoni, 1998), and does not show inhibition which is also found with phonetic or phonological similarity (Slowiaczek and Hamburger, 1992). It is worth noting that there is a consistent non-significant facilitation effect in each experiment where the priming between phonologically similar forms. Individually these effects may not be important, but taken as a whole, the consistent facilitatory effect (opposed to a mix of non-significant inhibition and facilitation) suggests that there may be weak facilitatory effects. We may expect closer relationships between words (e.g., English *mad* ∼ *matt*) to show effects, or effects to obtain if lexical factors (e.g., frequency, neighborhood density, morphological family size, etc.) can be controlled more carefully. The general lack of phonological effects suggests that words are heard first, then phonological neighborhood is activated. This word-first, phonology-second system may serve as a second pass system for detecting speech errors or puns.

I turn now to the implications for formal morphological theory.

5.3 Morphological theory

The main morphological conclusions gathered here are based on Experiment 5, which shows that, of all the words in a morphological family, some words do not prime their relatives. Word-based theories of morphology, where there is no root, are supported by the lack of a root processing unit. This experiment should be replicated, not only in Moroccan Arabic but with other Semitic dialects and in the visual modality as well. Replication will show whether or not all Semitic languages, from Akkadian to Zway, do function similarly.

The prime lexicality effects of experiment 4b also warrant repetition. While the results of experiment 4 do support the notion of an independent root morpheme, they conflict with the results of experiment 5. The interpretation that nonwords are mapped to their closest relative is testable, in Semitic and beyond. Moreover, this effect may be peculiar to roots (in any language). Languages with a higher morpheme-to-word ratio (e.g., Tamil, Japanese, Greenlandic, Quechua, etc.) may show similar root effects.

The lack of morphological effects in experiment 5 could alternately be an interaction with close phonological relationships (Ussishkin, p.c.). Incredibly close phonological relations (i.e., /ktəb/ and /kəttəb) might show inhibition (i.e., competition) in phonological form but facilitation from the morphological effect. In essence, the two would cancel out.

Theoretically the lack of phonological effects from each word in a morphological family supports a notion that, during speech perception there is no phonological content to the root because any relative should activate the root morpheme. In speech production, roots would be accessed before form. Evidence from lesion-deficit studies (Prunet et al., 2000; Idrissi et al., 2008) seems to contradict this analysis (see below), unless they are so slow that they are constructed via phonological routes or roots are not required elements to get root effects (Bat-El, 1994; Ussishkin, 1999, 2005).

The lack of priming effects for low socioeconomic status subjects is also troubling for linguistic theory. Linguistic theory has a tendency to utilize an ideal speaker-hearer and ignore performance issues, but these subjects did not show morphological effects when others did. This evidence needs to be investigated, because it is a different class of performance-competence issue than differences in syntactic judgments. That is to say, two dialects may differ in terms how a copula or negation works in the syntax or use different systems of agreement or negation, but we don't expect two dialects with the same set of words to display different morphological organizations. We have no reason to believe that low socioeconomic status individuals have abnormal speech, but other differences such as vocabulary size or degree of bilingualism may be responsible. Further research into individual and socioeconomic differences is required (cf. Andrews and Hersch, 2010; Andrews and Lo, 2012; Yu, 2010).

Quadriconsonantal roots represent one other deviation for morphological theory. Triconsonantal and quadriconsonantal roots are not theorized to be mentally related. This should be investigated further. While triconsonantal (experiment 3b) and biconsonantal roots (experiments 7, 8b, and 9) do not prime one another if they do not share the etymological root, here quadriconsonantal roots primed surface-related triconsonantal roots. This fact is unexpected given the etymological definition of the root, and bears further investigation. Including frequency information for the quadriconsonantal primes may alter the model, and the experiment should be replicated with triconsonantal roots priming their quadriconsonantal relatives. Also of interest are the roots with more than five consonants, such as loan-verbs in Hebrew (Bat-El, 1994), which may shed light on this situation and would show if this effect generalizes to other varieties of Semitic.

I turn now to psycholinguistic theory and the conflict between disfluent speech and lexical access studies.

5.4 Disfluent Speech vs. Lexical Access

The errors in aphasic speech are the largest challenge to the analysis presented here, because the data appears contradictory. In spontaneous speech situations the patient ZT produced a series of unusual errors involving the metathesis of root consonants in Arabic but not French. Prunet et al. (2000) and (Idrissi et al., 2008) conclude that this is evidence for a root morpheme with phonological content. However, the speech error analog they rely on was not replicated in Hamrouni

(2010). It is also unclear if Prunet et al. (2000); Idrissi et al. (2008) argue for a theory in which no full words are stored, or one in which lexemes simply can be (re)created from roots and patterns. This conflict between the data presented here and the aphasic data could be resolved in a few different ways.

First, the results here may have another explanation. If experiments 4b and 5 do not replicate in Moroccan and other Semitic languages (though note that these results are similar to Frost et al. (1997)'s experiment 6 which is a visual study on novel coinage priming), then perhaps this was just a rolling a 20 on a twenty-sided die. Another, more nuanced, explanation might be that there is a conflict between incredibly close phonological neighbors and morphological family members, such that phonological competition might mediate or moderate the effects of morphological relatedness with the subliminal speech priming technique. Alternately, phonological content for roots may be a fact of speech production, but not perception. That is, the production system may rely on the synthesis of words from roots and patterns, but the perception system need not analyze words into their component parts.

Second, roots may have phonologically contentful representations that are weak or late. Nonwords might be able to access these root representations while real words do not activate them immediately. This analysis, however, must contend with the failure of form III to prime form I while it did prime form II in experiment 5, however. What would it mean if some word-pairs require more time to prime one another than other word pairs?This raises an important question: what does it mean for a linguistic theory if morphemes are gradiently activated (cf. Hay, 2001; Hay and Baayen, 2002; Hay, 2002; Hay and Baayen, 2003; Hay and Plag, 2004; Hay and Baayen, 2005; Plag and Baayen, 2009, among others)? Furthermore, what is the architecture of the lexicon which would allow this? A conscious or lengthier computation process may be involved in reaching morphemes and their phonological content.

Finally, there are linguistic theories which predict "root consonant" effects without a structural unit called the root (Bat-El, 1994; Ussishkin, 1999, 2005, among others). These theories suggest that universal units such as stem and vocalic infixes, along with a preference for bisyllabic stems and faithfulness to consonants, may give rise to an epiphenomenonal root.

I think this is in there, but not all right here. It would, of course, be exciting if analogous experiments could be conducted with aphasic patients similar to ZT. Ideally, these should be run in all major varieties of modern Semitic including Hebrew, Maltese, various Arabic and Aramaic dialects, Amharic, Tigrinya, and one or more of the Mahrian language of Yemen and Oman. Another interesting comparision would involve doing the study with subjects proficient at reading Semitic but not speaking it: professional linguists, philologists, and other scholars who, for example, read Akkadian or another ancient Semitic language. These subjects would primarly have orthographic representations, which are often primarily consonantal and written in Roman transcription. It would also be especiallyintersting to know how halting the spontaneous speech of ZT is. It is possible that ZT, when failing to retrieve a stored phonological lexeme, restorts to constructing novel coinages during these speech errorts. In this case, we might expect to see a temporal difference in his production of root metathesis words which are lexical items (selecting the wrong root or wrong paradigm member) against nonword utterances (attempting to build a suitable word from its component parts or via analogy with existing lexemes). Furthermore, following Velan and Frost (2011), we may see differences in ZT's root errors based on the morphological family size of the word. If Velan and Frost (2011) are correct, there should be no root exchange errors for orphan words with no morphological relatives. If there are effects for orphan words or nonwords, we may hypothesize that ZT's root errors may relate to stems and affixes more than root representations.

Following McCarthy (1981) many others argue that the consonantal tier is not unique to Semitic and Yokuts, the languages for which it was first proposed, but that phenomena such as vowel and consonant harmony can find explanations in the nonlinear notions, such as consonants and vowels occurring on distinct tiers (McCarthy, 1981, 1982). Rose (2000), among others, notes that constraints affecting consonants may ignore intervening vowels. Phenomena such as vowel and consonant harmony rely on long-distance dependencies, which have been argued to be due to consonants and vowels occurring on distinct tiers. Whatever mental phemonema are captured by the notion of consonantal and vocalic tiers may be found in other languages beyond Semitic. Nonetheless, there is something special about root consonants in Semitic, whether it is due to phonologically-contentful roots or some other property of the language. Because nonlinear phonology is not unique to Semitic, we expect to see speech errors in healthy and aphasic people conforming to other aspects of nonlinear phonology.

Finally, word based theorists may pick up the gauntlet thrown down by Idrissi et al. (2008, et seq.,). A closer analysis of the aphasia data might show a link between root consonants and the orthography. The scripts of India, for example, are consonant-heavy like Semitic, though their morphologies are not consonant-heavy. If consonant transposition effects are found there, we may still be able to ascribe the Prunet et al. (2000); Idrissi et al. (2008) results to effects of literacy. More distantly related languages, for example Hausa or Tashylhit might also show consonant heavy morphologies, and evidence from these languages might be martialed in lesion-deficit studies, language game studies, or slip of the tongue studies. Furthermore, given the results of Moscoso del Prado Martín et al. (2005) and Boudelaa and Marslen-Wilson (2011) orphan roots should not be prone to root exchanges, and the data can be examined in light of this.

It is important to note, as well, the agreement between Prunet et al. (2000), Idrissi et al. (2008), and the current study. There is something to the root, and the etymological definition of the root. Not only do we see evidence for the form-concept links in aphasic speech and speech perception. Consonants alone do not account for morphological families, but vocalic and semi-vocalic elements appear to be instrumental to roots as well.

5.5 Conclusion of Conclusions

Through over a dozen experiments, this dissertation sought to answer whether or not there is evidence from audition for the root as a morpheme. The results are, predictably, somewhat mixed. The results suggest that real-words do not prime one another in Moroccan unless they share a root, with the one exception of quadriconsonantal words priming triconsonantal words sharing a surface root. Nonwords built from real roots and patterns (i.e, novel coinages) do prime their related forms which suggests that roots can be activated independently. However, form III words did not facilitate response latencies to their form I relatives, which is not predicted from a root theory. This suggests that the effects of novel coinages are a prime lexicality effect rather than a root effect. So roots are not independent processing units. However, the etymological definition of the root, rather than one based on the surface consonants, appears to be the correct definition of morphological families, *modulo* quadriconsonantal roots priming triconsonantal roots. This suggests that linguistic theory might fruitfully explore notions of the paradigm and morphological families. The root appears to be not an entity, but a property of words which defines the relationship between various historically related forms.

APPENDIX A

STIMULI FOR EXPERIMENT 1

Words				Nonwords			
Target	Prime	Target	Prime	Target	Prime	Target	Prime
act	knock	leg	rich	ɑɹnd	θɪts	pʌd	lajns
age	dare	meant	food	bæntʃ	sɪʃ	pɹæs	tɑɹk
art	save	neck	hall	blɪd	ʃɪs	pɹoʊd	tʃæst
bank	beach	park	shoot	tʃʌt	lɪdʒd	pɹoʊs	fɹæs
beg	board	past	card	tʃɛnd	tɑɹs	ɹaʊnt	pɛntʃ
blow	caught	plane	wind [waɪnd]	tʃɪd	nɑnz	ɹeɪns	ʃaʊnt
brain	known	poor	date	tʃɪs	θænz	sʌɹ	flʌs
camp	wake	pull	ship	daʊns	gɛns	ʃɑnd	dɹeɪt
catch	white	quit	hide	dɛndʒ	laʊnt	ʃænz	pɹeɪs
class	fall	reach	pal	ɛlts	gækt	ʃɪd	geɪs
clean	kiss	round	boss	fɛntʃ	tʃɑɹs	ʃɪz	baʊnt
clock	box	sense	team	foʊst	hæntʃ	spɹoʊ	θænt
cost	whose	shop	six	gæks	jænz	tɑɹn	lɑɹs
court	bomb	slow	news	gæns	θʌts	taʊnt	fɹɪt
cup	shall	sold	fit	gʌkt	leɪnt	θɑnt	zænz
deep	seem	song	share	gaʊnt	ɹɪv	θæst	gɑɹt
doubt	gas	sort	field	gajnd	tɛndʒ	θɔɹt	plʌd
earth	state	sound	fact	gɹɛd	bɑɹm	ðɪk	dʒʌk
fast	bear	spot	grow	hɑnd	lajnt	ðɪn	sweɪt
felt	ought	star	book	hist	mæntʃ	θɹɪs	ðæns
fish	fight	steal	half	dʒæst	pɑɹp	θɹɪt	ʃɑɹs
fix	less	stick	suit	kleɪs	ðɛnd	tɪb	pɪktʃ
flight	near	stole	dude	kweɪt	daʊnt	tɪvt	pɛnθ
fly	feet	stuck	top	lɑns	teɪs	vɔɹt	kʌz
fool	cold	tape	fair	lændʒ	sɪdʒ	vaʊnt	tɪv
force	sent	taste	send	lʌmd	wæst	wɑɹt	vɪz
gold	rest	teach	nine	lʌɹ	loʊst	wɑst	ɹʌɹ
green	born	test	note	mændʒ	jɑɹt	waʊnt	tʌms
guard	wear	tough	though	mɪv	tʃɑnd	jɑnt	ðɪkt
horse	list	train	piece	nɛns	θɑnd	jʌt	ajɹts

ice	dog	tree	hair	nɛɹt	θæns	jɛnd	kɑɹʤ
join	band	type	jail	nɪd	nɪz	jɪk	jɪd
joke	lots	weird	mess	nist	pɹid	jɪkt	θɪs
land	none	wild	king	noʊst	ʃɑnt	jɪs	toʊnt
laugh	law	wind /wɪnd/	soul	pæntʃ	ʤajnd	jɪt	nʌks
learn	cash	worse	fear	pænʤ	tʃɔɹt	zɪd	dɪdz

APPENDIX B

REAL-WORD STIMULI FOR EXPERIMENT 2

Distant Morph				Close Morph			
Target	Semantic	Root	Control	Target	Semantic	Root	Control
ʕbəṛ	qṭəʕ	ʕəbbəṛ	ʃəbbəʕ	ʕḍa	məṛṛəḍ	ʕəḍḍa	ḍfəḷ
ʕəḍḍəḷ	ṣawəb	ʕḍəḷ	ʃfəʕ	ʕfa	ṣməħ	ʕafa	ḍxəḷ
ʕqəḍ	ẓəyyəṛ	ʕəqqəḍ	wṛəṭ	ʕṣa	ṭməṛṛəḍ	ʕəṣṣa	bəṭṭəḷ
ʃṛəṭ	fəṣṣəṛ	ʃəṛṛəṭ	ṣəxxəf	ʃhəṛ	fḍəħ	ʃəhhəṛ	bxəḷ
ɣənna	nʃəḍ	ɣna	ħṣəḍ	ħəbbəṣ	wəqqəf	ħbəṣ	bḷəẓ
ħəṣṣən	qəṛṛəʕ	ħṣən	fxəṛ	ħəṣṣəḷ	ʃəḍḍ	ħṣəḷ	ḍəkkəṛ
ħẓəm	ṛbəṭ	ṭħəẓẓəm	bʒəɣ	bəṣṣəḷ	ḍṣəṛ	bṣaḷ	ḍməṛ
bəḷḷəɣ	ḷəħħəq	bḷəɣ	ħəffəḍ	ḍhən	ṣbəʕ	ḍəhhən	kəḍḍəb
bṣəṭ	fṛəħ	bəṣṣəṭ	fəkkəṛ	ḍmən	ṭkəḷḷəf	ḍḍamən	kṛəf
ḍḷəm	qhəṛ	ḍəḷḷəm	bəṛṛəẓ	gʕəḍ	gḷəṣ	gəʕʕəḍ	qṣəʕ
fṭəħ	ħəḷḷ	fəṭṭəħ	ʃbəħ	hbəṭ	nẓəḷ	həbbəṭ	fṭəq
ʒṛəḍ	ħṣəb	ʒəṛṛəḍ	qənnəʕ	hḍəm	həṛṛəṣ	həḍḍəm	ħḷəm
kṛəm	yəbbəṣ	kəṛṛəm	ɣḍəb	kʃəf	ḍbaḷ	kəʃʃəf	bẓəq
qḍam	bḷa	qəḍḍəm	bṛəq	ḷẓəm	wqəf	ḷəẓẓəm	nkəḍ
qəḍḍəṛ	xəmməm	qḍəṛ	kfəṛ	qṭəḷ	məwwəṭ	qaṭəḷ	bəṛṛəq
ṛʃa	ḍuwwəṛ	ṛəʃʃa	ṣxəf	ṛgəḍ	nʕəṣ	ṛəggəḍ	ħkəm
ṛfəq	ħənn	ṛafəq	ħfəḍ	ṣbəṛ	ṭṣənna	ṣəbbəṛ	kḍəb
ṛkəẓ	ḍəṛḍəq	ṛəkkəẓ	ḍfən	ṣfa	wḍaħ	ṣəffa	fgəṣ
ṣəḍḍəq	ʕṭa	ṣḍəq	fṭəṛ	ṣxəṛ	ḍħək	ṣəxxəṛ	ḍkəṛ
ṣḷəm	ʕamən	ṣəḷḷəm	hḍəṛ	ṭʕəb	ʕya	ṭəʕʕəb	fəḷḷəṣ
ṣṛəħ	ṛʕa	ṣəṛṛəħ	nəqqəḷ	ṭḷəq	ṛxa	ṭəḷḷəq	ʃəʕʃəʕ
ṭɣafəṛ	ḍẓawəṛ	ɣfəṛ	ḍəxxəḷ	ṭṛəʃ	ṣəṛfəq	ṭəṛṛəʃ	fəṭṭəṛ
ṭəbbəq	ʒəṛṛəb	ṭabəq	ħəkkəm	wəqqəʕ	ṣina	wqəʕ	həḍḍəṛ
ṭəṛṛəħ	ɣəḷḷəb	ṭṛəħ	ṛfəḍ	wəṣṣəḷ	ḍḍa	wṣəḷ	ħʒəb
wəḷḷa	ṭħəwwəḷ	waḷa	ɣəḍḍəb	wḷəḍ	xḷəq	wəḷḷəḍ	mxəḍ
wfa	ṣaḷa	wəffa	bṛəẓ	xṣəṛ	ṭkəṛfəṣ	xəṣṣəṛ	bṭəḷ
wʒəḍ	ḷqa	wəʒʒəḍ	hʒəṛ	ẓʕəm	ẓṭəm	ẓəʕʕəm	kbəṛ
xḷəʕ	xəwwəf	xəḷḷəʕ	kṣəb	bʕiḍ			
xḷəf	ʕəwwəḍ	xəḷḷəf	hṛəm	bʕiḍ			

APPENDIX C

REAL-WORD STIMULI FOR EXPERIMENTS 3A & 3B

Target	Root	Ph. Form	Control	Target	Root	Ph. Form	Control
bləɣ	bəlləɣ	bʒəɣ	ḍṣəṛ	nkəd	nəkkəd	nʃəd	ħṣəḷ
bṭəl	bəṭṭəl	bxəl	zʕəm	nqəl	nəqqəl	nzəl	ʒṛəd
bṛəq	bəṛṛəq	bzəq	ʕda	qḍəṛ	qəḍḍəṛ	qhəṛ	ḍləm
brəz	bərrəz	bləz	qsəm	qnəʕ	qənnəʕ	qṣəʕ	sləm
dxəl	dəxxəl	dfəl	lħəs	rgəd	rəggəd	rfəd	lzəm
dhən	dəhhən	dfən	shət	sxəf	səxxəf	skəf	frəħ
dkər	dəkkər	dmər	wʒəd	ʃṛəħ	ʃəṛṛəħ	ʃbəħ	xləq
fṛəq	fəṛṛəq	ftəq	qṭəʕ	sxən	səxxən	skən	ħəll
fṭəṛ	fəṭṭəṛ	fxəṛ	xləʕ	sbəq	səbbəq	sṛəq	ʕṭa
fləs	fəlləs	fgəs	zṭəm	skər	səkkər	stər	ʕfa
ɣḍəb	ɣəḍḍəb	ɣṣəb	nʕəs	ṣbəṛ	ṣəbbəṛ	ṣhəṛ	wala
ħʒəb	ħəʒʒəb	ħsəb	wrət	skət	səkkət	slət	lʕəq
ħfəḍ	ħəffəḍ	ħṣəḍ	ftəħ	ʃṛəṭ	ʃəṛṛəṭ	ʃbəṭ	ʃkəṛ
hdəm	həddəm	hrəm	bsal	ʃbəʕ	ʃəbbəʕ	ʃfəʕ	hmaq
ħkəm	ħəkkəm	ħləm	qdam	tʕəb	təʕʕəb	tqəb	ṭṛəʃ
ħsən	ħəssən	ħḍən	ksəd	wṣəl	wəṣṣəl	wħəl	msəx
hḍəṛ	həḍḍəṛ	hʒəṛ	ɣna	xləf	xəlləf	xṛəf	ṛħəl
ħḍəṛ	ħəḍḍəṛ	ħfəṛ	qtəl	xdəm	xəddəm	xtəm	ḍmən
ħnət	ħənnət	ħdət	ṭṛəħ	xtər	xəttər	xmər	mrəʒ
kdəb	kəddəb	ksəb	gʕəd	ʕqəd	ʕəqqəd	ʕbəd	ħṛəq
kʃəf	kəʃʃəf	krəf	ħsəd	ʕṛəf	ʕəṛṛəf	ʕzəf	ṛfəq
krəm	kərrəm	ktəm	sala	ʕdəl	ʕəddəl	ʕməl	sməħ
kbər	kəbbər	kfər	gləs	ʕṛəq	ʕəṛṛəq	ʕtəq	ʃhər
mṛəḍ	məṛṛəḍ	mxəḍ	rʃa	ʕbəṛ	ʕəbbəṛ	ʕdəṛ	ṭḷəq

APPENDIX D

REAL-WORD STIMULI FOR EXPERIMENTS 4A & 4B

Real Form II				Nonword Form II		
Target	Real Relative	Control		Target	Nonce Relative	Control
ṭṛəḍ	ṭəṛṛəḍ	lhət		xmər	xəmmər	ħəḍḍən
kħob	kəħħəb	ʕbəṛ		bṛəq	bəṛṛəq	xəbbəʃ
ṛməq	ṛəmməq	hdəm		rkəz	rəkkəz	ʕəṣṣəṛ
nħəṛ	nəħħəṛ	ʕṛəʒ		ʃhəd	ʃəhhəd	bərrəd
ħsəd	ħəssəd	xtər		sməʕ	səmməʕ	ʕəṭṭəs
msəx	məssəx	ʃfəʕ		mṛəḍ	məṛṛəḍ	wərrəd
nsəx	nəssəx	sxəṛ		ħrək	ħərrək	ʃəṛṛəṭ
ʃṭən	ʃəṭṭən	ṣbəṛ		hṛəb	həṛṛəb	ṭəṛṛəħ
qhəṛ	qəhhəṛ	skən		kʃəf	kəʃʃəf	ʕəddəl
nhəḍ	nəhhəḍ	ʃhəṛ		ħməd	ħəmməd	ləʕʕəb
mḍəɣ	məḍḍəɣ	skər		wləd	wəlləd	təlləf
ʃnət	ʃənnət	mnəʕ		sʕəd	səʕʕəd	səbbəq
krəf	kərrəf	wħəl		qḍəṛ	qəḍḍəṛ	həddən
ṛʃəq	ṛəʃʃəq	fhəm		xrəz	xərrəz	səlləħ
ṭḷəb	ṭəḷḷəb	fzəg		nkəd	nəkkəd	fəllət
nhəq	nəhhəq	ʕṛəḍ		zħəf	zəħħəf	səllək
hrəd	hərrəd	ɣfəl		ɣṭəṣ	ɣəṭṭəṣ	bərrəz
xbəz	xəbbəz	ẓhəṛ		ħfəḍ	ħəffəḍ	ḍəḷḷəm
htər	həttər	bləɣ		hbəl	həbbəl	nəʕʕəs
sləx	səlləx	bṣəṭ		fṭəṛ	fəṭṭəṛ	ṭəbbəʕ
nʒəṛ	nəʒʒəṛ	kbər		xləf	xəlləf	wəʒʒəd
hʒəm	həʒʒəm	kməl		ʕməṛ	ʕəmməṛ	ħəṣṣəḷ
ṛḍəx	ṛəḍḍəx	ħəddər		ɣṛəm	ɣəṛṛəm	znəd
hlək	həllək	ʃəbbəh		qfəl	qəffəl	wqəʕ
rsəl	rəssəl	ɣəḷḷəṭ		tʕəb	təʕʕəb	gʕəd
ntəʒ	nəttəʒ	qənnəṭ		nfəd	nəffəd	kṛəh
ʃxəṛ	ʃəxxəṛ	ʒəṛṛəd		ħṛəm	ħəṛṛəm	ʒdəb
ʃfəq	ʃəffəq	dəxxəl		ktəṛ	kəttəṛ	ħzəq
ʕfəs	ʕəffəs	ħəlləf		fʒəṛ	fəʒʒəṛ	ʃɣəl
qṛəṭ	qəṛṛəṭ	nəʃʃəf		fkəṛ	fəkkəṛ	wʒəb

ʕrək	ʕərrək	ṭəḷḷəq	qdəm	qəddəm	qbəl
ħdət	ħəddət	nəzzəl	brəm	bərrəm	ħzən
sʕəl	səʕʕəl	ṭəʕʕəm	ḍħək	ḍəħħək	sqəṭ
ʃrək	ʃərrək	qəṭṭəʕ	nbət	nəbbət	ṣṛəṭ
ʕṭəb	ʕəṭṭəb	ləmməʕ	sləm	səlləm	nsəl
nqəd	nəqqəd	nəffəx	fṛəɣ	fəṛṛəɣ	lzəm

APPENDIX E

FORM 1, 2, & 3 STIMULI FOR EXPERIMENT 5 (ORGANIZED BY ROOT)

Root	F1	F2	F3	Root	F1	F2	F3
bka	bka	bəkka	tbaka	qwm	qam	qəwwəm	qawəm
brk	brək	bərrək	barək	qyl	qal	qiyyəl	tqayəl
dwm	dam	duwwəm	dawəm	ṛwm	ṛam	ṛuwwəm	tṛawəm
dxl	dxəl	dəxxəl	daxəl	sb	səbb	səbbəb	tsabb
fhm	fhəm	fəhhəm	tfahəm	sbq	sbəq	səbbəq	sabəq
fṛq	fṛəq	fəṛṛəq	faṛəq	ṣfa	ṣfa	ṣəffa	tṣafa
fṣl	fṣəl	fəṣṣəl	faṣəl	ṣlħ	ṣləħ	ṣəlləħ	ṣaləħ
ħb	ħəbb	ħəbbəb	tħabb	slm	sləm	səlləm	tsaləm
hda	hda	thədda	thada	ʃnq	ʃnəq	ʃənnəq	tʃanəq
ħfḍ	ħfəḍ	ħəffəḍ	ħafəḍ	sqṭ	sqəṭ	səqqəṭ	tsaqəṭ
ħkm	ħkəm	ħəkkəm	tħakəm	ṣṛf	srəf	ṣəṛṛəf	tsarəf
ħlf	ħləf	ħəlləf	tħaləf	ʃṛṭ	ʃṛəṭ	ʃəṛṛəṭ	tʃaṛəṭ
ħml	ħməl	ħəmməl	tħaməl	sʕd	sʕəd	saʕʕəd	saʕəd
ħsn	ħsən	ħəssən	ħasən	wjb	wjəb	wəjjəb	wajəb
ħwl	ħal	ħəwwəl	ħawəl	xla	xla	xəlla	txala
kbr	kbər	kəbbər	kabər	xlf	xləf	xəlləf	xaləf
kdb	kdəb	kəddəb	tkadəb	xṭa	xṭa	xəṭṭa	txaṭa
lqa	lqa	ləqqa	laqa	xwa	xwa	xəwwa	txawa
lṭf	lṭəf	tləṭṭəf	laṭəf	ʕda	ʕda	ʕədda	ʕada
lzm	lzəm	ləzzəm	lazəm	ʕdl	ʕdəl	ʕəddəl	ʕadəl
mwt	mat	muwwət	tmawət	ʕqd	ʕqəd	ʕəqqəd	tʕaqəd
myl	mal	miyyəl	tmayəl	ʕṛḍ	ʕṛəḍ	ʕəṛṛəḍ	ʕaṛəḍ
nwb	nab	nuwwəb	tnawəb	ʕṛf	ʕṛəf	ʕəṛṛəf	tʕaṛəf
qbl	qbəl	qəbbəl	qabəl	ʕwd	ʕad	ʕəwwəd	ʕawəd
qd	qədd	qəddəd	qadd	ʕwm	ʕam	ʕəwwəm	ʕawən
qtʕ	qtəʕ	qəṭṭəʕ	tqaṭəʕ	ʕyn	ʕan	ʕəyyən	ʕayən

APPENDIX F

REAL-WORD STIMULI FOR EXPERIMENTS 6A & 6B

Weak Roots			Strong Roots		
Target	Root	Control	Target	Root	Control
naḍ	nuwwəḍ	ʃəffəʕ	ɣḍəb	ɣəḍḍəb	ẓəhhəṛ
ṭal	ṭuwwəl	ʃəbbəh	sqəṭ	səqqəṭ	ḍəḷḷəm
daz	duwwəz	ʕəmməṛ	qbəl	qəbbəl	ləzzəm
ṣaṛ	siyyəṛ	kəmməl	lqəf	ləqqəf	zəʕʕəf
ʃat	ʃiyyəṭ	xəddəm	wʒəb	wəʒʒəb	ʒəbbəd
ṭaf	ṭuwwəf	fəzzəg	ʃhəṛ	ʃəhhəṛ	ɣəssəl
dam	duwwəm	həḍḍəṛ	sxəṛ	səxxəṛ	məṛṛəḍ
ħal	ħəwwəl	qəffəl	ɣḷəṭ	ɣəḷḷəṭ	fərrəz
sas	suwwəs	ḍəṣṣəṛ	nʃəf	nəʃʃəf	ħəṣṣəḷ
ṭaṛ	ṭiyyəṛ	fəʒʒəṛ	wrəd	wərrəd	bərrəz
daʕ	diyyəʕ	ʃəɣɣəl	sxən	səxxən	kəttəṛ
xaf	xəwwəf	wəqqəf	qləʕ	qəlləʕ	ħəmməd
faṛ	fuwwəṛ	bərrəm	bləɣ	bəlləɣ	həṛṛəb
ṭaʃ	ṭiyyəʃ	bəṛṛəq	mkən	məkkən	nəkkəd
dab	duwwəb	qənnəʕ	xləf	xəlləf	sərrəd
ʃaʕ	ʃiyyəʕ	ħəmməl	wləd	wəlləd	həddən
lan	luwwən	nəqqəl	ḍħək	ḍəħħək	ləmməʕ
ṭaħ	ṭiyyəħ	ʕəṭṭəs	ħzən	ħəzzən	dəffən
ṣam	ṣuwwəm	gəlləs	ħṛəm	ħəṛṛəm	səxxəf
ṣaṭ	ṣuwwəṭ	ʕəṛṛəḍ	hbəṭ	həbbəṭ	ṭəbbəʕ
naħ	nuwwəħ	nəbbət	fṛəq	fəṛṛəq	ħənnət
qam	qəwwəm	qəddəm	ktəb	kəttəb	qəḍḍəṛ
ʒaf	ʒiyyəf	ʃəṛṛəħ	dhən	dəhhən	fəhhəm
saq	siyyəq	xənnət	ʕqəd	ʕəqqəd	ləʕʕəb
ʒaʕ	ʒuwwəʕ	wərrət	ʒṛəd	ʒəṛṛəd	sələk
ṣaṛ	siyyəṛ	kəbbəṛ	skət	səkkət	rəʕʕəd
dax	duwwəx	ṣəḷḷəħ	ʃṛəṭ	ʃəṛṛəṭ	ṣəṛṛəf
zad	ziyyəd	ləbbəs	ɣṛəm	ɣəṛṛəm	ʕəlləf
ṛam	ṛuwwəm	ħəssən	ṛhəb	ṛəhhəb	xərrəz
ṭab	ṭiyyəb	kərrəm	ṭʕəm	ṭəʕʕəm	xəttəṛ

APPENDIX G

REAL-WORD STIMULI FOR EXPERIMENT 7

Target	Related	Control	Target	Related	Control
ḷan	ḷʕən	ħṛəm	ʒməʕ	ʒaʕ	ṣab
kan	kəhhən	ħẓən	xʃan	xan	ḍaṛ
ħaṛ	ħəḍḍəṛ	ʕqəḍ	ṣəbbən	ṣan	maṭ
ḍab	ḍəṛṛəb	ṣməʕ	ṛʃəm	ṛam	ṣaḷ
ẓaḍ	ẓənnəḍ	wʒəb	ḍəmməʕ	ḍaʕ	ʒab
naħ	nbəħ	ṣaṣ	ʃṛəf	ʃaf	ɣṭəṣ
ʃaṛ	ʃxəṛ	faṭ	bxəṣ	baṣ	ṣaṭ
faḍ	fṛəḍ	fkəṛ	ṣməħ	ṣaħ	ʃaṭ
ħaḍ	ħqəḍ	ʕməṛ	nəqqəḷ	naḷ	bḷəɣ
ṭab	ṭəṛṛəb	xḷəf	ʃəṛṛəṭ	ʃaṭ	ṣxən
ḍaẓ	ḍbəẓ	ʕfəṣ	ṛʃəħ	ṛaħ	ṛab
ḷam	ḷəṭṭəm	ḍax	fəggəḍ	faḍ	ʒaf
bʕəṭ	baṭ	ṣab	qaḷ	qbəḷ	ħṛəm
ṣḷəb	ṣab	ḍaṛ	ṭaħ	ṭṛəħ	ħẓən
fəṛṛəẓ	faẓ	maṭ	baḍ	bɣəḍ	ʕqəḍ
ʒfəḷ	ʒaḷ	ṣaḷ	ṣaħ	ṣəbbəħ	ṣməʕ
ʒħəḍ	ʒaḍ	ʒab	ɣab	ɣəḷḷəb	wʒəb
ṛgəḍ	ṛaḍ	ɣṭəṣ	ʒaṛ	ʒbəṛ	ṣaṣ
ħəmməḷ	ħaḷ	ṣaṭ	ṣam	ṣḍəm	faṭ
ḷəqqəħ	ḷaħ	ʃaṭ	maʒ	mṛəʒ	fkəṛ
ṣqəḷ	ṣaḷ	bḷəɣ	qaṣ	qəḍḍəṣ	ʕməṛ
ṛəṭṭəb	ṛab	ṣxən	ḍaʕ	ḍḍəṛṛəʕ	xḷəf
ṭəbbəq	ṭaq	ṛab	xaf	xəṛṛəf	ʕfəṣ
fṛəq	faq	ʒaf	ban	bəṭṭən	ḍax
ḍaṛ	ḍəṣṣəṛ	ħṛəm	bəṛṛəħ	baħ	ṣab
ṭaṛ	ṭəmməṛ	ħẓən	ḍəṛṛəm	ḍam	ḍaṛ
ṣaṛ	ṣməṛ	ʕqəḍ	fʒəṛ	faṛ	maṭ
ṣaq	ṣḷəq	ṣməʕ	naṣəb	nab	ṣaḷ
baḷ	bəṣṣəḷ	wʒəb	nbəḍ	naḍ	ʒab
ʃab	ʃəṭṭəb	ṣaṣ	bḍəʕ	baʕ	ɣṭəṣ
ʃaʕ	ʃəbbəʕ	faṭ	ɣəṭṭəṣ	ɣaṣ	ṣaṭ

ṭaf	ṭəṛṛəf	fkəṛ	ħəḷḷəf	ħaf	ʃaṭ
ṭab	ṭqəb	ʕməṛ	nəʒʒəm	nam	bḷəɣ
ṭaʕ	ṭḷəʕ	xḷəf	fṭəħ	faħ	ṣxən
ṭaʃ	ṭṛəʃ	ʕfəṣ	məṭṭəḷ	maḷ	ṛab
ṭaḷ	ṭəbbəḷ	ḍax	qṣəm	qam	ʒaf

APPENDIX H

REAL-WORD STIMULI FOR EXPERIMENTS 8A & 8B

Target	Related	Control	Target	Related	Control
dar	derra	rdem	daʕ	dʕa	nṣeħ
ṣal	sella	ħṛen	fda	fad	ṛʕeʃ
ṣaṭ	ṣeṭṭa	nkes	fad̢	fd̢a	ṭḷeb
kan	kenna	ʕʃeq	fat	fta	hlek
naħ	neħħa	ʕfes	ħaf	ħfa	hter
ṛab	ṛebba	hḍeṛ	ħla	ħal	zber
ʃaf	tʃeffa	nṣeħ	mal	mla	rdem
zga	zuwweg	ṛʕeʃ	qla	qal	ħṛen
hda	huwwed	ṭḷeb	ṛam	ṛma	nkes
ħma	ħewwem	hlek	ṛeʒ	ṛʒa	ʕʃeq
hna	huwwen	hter	sba	sab	ʕfes
qṛa	qewweṛ	zber	saħ	sħa	hḍeṛ
ṛḍa	ṛeyyeḍ	rdem	ṣḷa	ṣal	nṣeħ
ṛʕa	ṛuwweʕ	ħṛen	saq	sqa	ṛʕeʃ
ṣfa	ṣuwwef	nkes	sra	sar	ṭḷeb
ʒṛa	ʒiyyer	ʕʃeq	ṭaf	ṭfa	hlek
bla	bal	ʕfes	xfa	xaf	hter
ban	bna	hḍeṛ	ʒal	ʒla	zber

APPENDIX I

REAL-WORD STIMULI FOR EXPERIMENT 9

Target	Related	Control
fuwwəʒ	fəʒʒəʒ	ṛʃəq
qal	qəlləl	tʕəb
sal	səll	ʕṭəb
huwwəl	həlləl	ħfəḍ
faḍ	fəḍḍəḍ	ħrək
muwwən	mənn	ktəṛ
ẓuwwəq	ẓəqq	mṛəḍ
daq	dəqq	tʕəb
ʒaf	ʒəff	ʕṭəb
daz	dəzz	ħfəḍ
kuwwəṛ	kəṛṛəṛ	ħrək
sawəm	səmməm	ktəṛ
tʕəwwəʒ	ʕəʒʒəʒ	mṛəḍ
ṣaṛ	ṣəṛṛ	nqəd
qəwwəd	qədd	ṛʃəq
huwwəd	hədd	tʕəb
ʒiyyər	ʒərr	ʕṭəb
bal	bəlləl	ħfəḍ
sab	səbb	ħrək
guwwəd	gəddəd	ktəṛ
ʒaṛ	ʒəṛṛ	mṛəḍ

APPENDIX J

REAL-WORD STIMULI FOR EXPERIMENT 10

$\sqrt{123}$ Overlap		$\sqrt{234}$ Overlap	
Target	Related	Target	Related
ʕəṛṛəb	ʕaṛbən	ṛbəṭ	ʕaṛbəṭ
ħməd	ħəmdəl	nəggəṛ	ʕəngəṛ
ħṛəq	ħəṛqəṣ	rəggəb	ʕərgəb
bʒəɣ	bəʒɣəṭ	qləb	ʃəqləb
tbənnəd	bəndər	rəbbəl	ɣərbəl
bəssəm	bəsməl	rdəʕ	bərdəʕ
fəṛṛəʃ	fəṛʃəx	zgəl	bəzgəl
ṛgəʕ	fərgəʕ	rkəl	fərkəl
hrəm	hərməʃ	rdəʕ	gərdəʕ
htər	hətrəf	ʕəwwəṛ	kəʕwəṛ
kəlləf	kəlfəṭ	rəkkəb	kərkəb
məṛṛəħ	məṛħəb	rfəd	qərfəd
mərrən	mərnəz	ṛaqəb	qəṛqəb
tnagər	nəgrəz	nsəl	sənsəl
nʒəṛ	nəʒṛəz	ṛfəq	ṣəṛfəq
qṛəṭ	qəṛṭəṣ	rəttəl	sərtəl
tṣəḷḷəṭ	ṣəḷṭən	səffəl	təsfal
sənnəd	səndəf	nəffəs	xənfəs
xṛəb	xəṛbəq	nʒəṛ	zənʒəṛ
zələg	zəlgəf	ṛʃəm	bəṛʃəm
kəbbər	kəbrət	rəbbəl	kərbəl
bəṛṛəq	bəṛqəq	ħfəṛ	kəħfəṛ
hənnəd	həndəz		
hdər	hədrəf		

REFERENCES

Abd-El-Jawad, H. and I. Abu-Salim (1987). Slips of the tongue in Arabic and their theoretical implications. *Language Sciences*, **9**(2), pp. 145–171.

Acquaviva, P. (2008). Roots and lexicality in Distributed Morphology. In Galani, A., D. Redinger, and N. Yeo (eds.) *Fifth York-Essex Morphology Meeting*, volume 5, pp. 1–21.

Agmon, N. (2010). Materials and Language: Pre-Semitic Root Structure Change Concomitant with Transition to Agriculture. *Brill's Annual of Afroasiatic Languages and Linguistics*, **2**(1), pp. 23–79.

Andersen, T. (1995). Morphological stratification in Dinka: On the alternations of voice quality, vowel length and tone in the morphology of transitive verbal roots in a monosyllabic language. *Studies in African Linguistics*, **23**(1), pp. 1992–1994.

Anderson, S. R. (1992). *A-morphous morphology*, volume 62 of *Cambridge Studies in Linguistics*. Cambridge University Press, Cambridge.

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

Andrews, S. and J. Hersch (2010). Lexical precision in skilled readers: Individual differences in masked neighbor priming. *Journal of Experimental Psychology: General*, **139**(2), pp. 299–318.

Andrews, S. and S. Lo (2012). Not all skilled readers have cracked the code: Individual differences in masked form priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **38**(1), pp. 152–163.

Arad, M. (2005). *Roots and patterns: Hebrew morpho-syntax*, volume 63. Springer, Dordrecht.

Aronoff, M. (1976). *Word formation in generative grammar*, volume 1 of *Linguistic Inquiry Monographs*. The MIT Press, Cambridge.

Aronoff, M. (1994). *Morphology by itself: Stems and inflectional classes*, volume 22 of *Linguistic Inquiry Monographs*. The MIT Press, Cambridge.

Aronoff, M. (2007). In the beginning was the word. *Language*, **83**(4), pp. 803–830.

Baayen, R. (2008). *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge University Press, Cambridge.

Bachra, B. (2001). *The phonological structure of the verbal roots in Arabic and Hebrew*, volume 34. Brill, Leiden.

Barkai, M. (1980). Aphasic evidence for lexical and phonological representation. *Afroasiatic Linguistics*, **7**, pp. 163–187.

Barr, D. J., R. Levy, C. Scheepers, and H. J. Tily (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, **68**(3), pp. 255–278.

Bat-El, O. (1994). Stem modification and cluster transfer in Modern Hebrew. *Natural Language & Linguistic Theory*, **12**(4), pp. 571–596.

Bat-El, O. (2003). Semitic verb structure within a universal perspective. In Shimron, J. (ed.) *Language processing and language acquisition in a root-based morphology*, volume 28 of *Language Acquisition & Language Disorders*, pp. 29–59. John Benjamins, Amsterdam.

Bauer, L. (1999). Is the morpheme dead? *Acta Linguistica Hafniensia*, **31**(1), pp. 7–25.

Beard, R. (1995). *Lexeme-Morpheme Based Morphology: A General Theory of Inflection and Word Formation*. State University of New York Press, Albany.

Bender, M. and H. Fulass (1978). *Amharic verb morphology: A generative approach*. African Studies Center, Michigan State University, East Lansing.

Blevins, J. (2004). *Evolutionary phonology: The emergence of sound patterns*. Cambridge University Press, Cambridge.

Blevins, J. P. (2006). Word-based morphology. *Journal of Linguistics*, **42**, pp. 531–573.

Booij, G. (1998). Phonological output constraints in morphology. In Kehrein, W. and R. Wiese (eds.) *Phonology and morphology of the Germanic languages*, pp. 143–163. Niemeyer, Tübigen.

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

Boudelaa, S. and W. Marslen-Wilson (2001b). The time-course of morphological, phonological and semantic processes in reading Modern Standard Arabic. In *Proceedings of the Twenty-third Annual Conference of the Cognitive Science Society*, pp. 138–143. Edinburgh. ISBN 0805841520.

Boudelaa, S. and W. Marslen-Wilson (2004a). Abstract morphemes and lexical representation: the CV-skeleton in Arabic. *Cognition*, **92**(3), pp. 271–303.

Boudelaa, S. and W. Marslen-Wilson (2004b). Allomorphic variation in Arabic: Implications for lexical processing and representation. *Brain and Language*, **90**(1-3), pp. 106–116.

Boudelaa, S. and W. Marslen-Wilson (2005). Discontinuous morphology in time: Incremental masked priming in Arabic. *Language and Cognitive Processes*, **20**(1), pp. 207–260.

Boudelaa, S. and W. Marslen-Wilson (2011). Productivity and priming: Morphemic decomposition in Arabic. *Language and Cognitive Processes*, **26**, pp. 624–652.

Boudelaa, S., F. Pulvermüller, O. Hauk, Y. Shryrov, and W. Marslen-Wilson (2010). Arabic Morphology in the Neural Language System. *Journal of Cognitive Neuroscience*, **22**(5), pp. 998–1010.

Boudlal, A. (2009). *The prosody and morphology of a Morocan Arabic dialect*. Verlag Dr. Müller, Saarbrücken.

Broadwell, G. A. (2006). *A Choctaw reference grammar*. University of Nebraska Press, Lincoln.

Brysbaert, M. and B. New (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, **41**(4), pp. 977–990.

Bybee, J. L. (1985). *Morphology: A study of the relation between meaning and form*, volume 9 of *Typological studies in language*. John Benjamins Publishing, Amsterdam.

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive neuropsychology*, **14**(1), pp. 177–208.

Chomsky, N. (1965). *Aspects of the Theory of Syntax*. The MIT press, Cambridge.

Chomsky, N. (1995). *The minimalist program*. Cambridge University Press, Cambridge.

Chomsky, N. (2000). Linguistics and brain science. In *Image, language, brain: Papers from the first mind articulation symposium*, pp. 13–28.

Davis, C., J. Kim, and A. Barbaro (2010). Masked speech priming: Neighborhood size matters. *The Journal of the Acoustical Society of America*, **127**(4), pp. 2110–2113.

Davis, S. and B. A. Zawaydeh (2001). Arabic hypocoristics and the status of the consonantal root. *Linguistic Inquiry*, **32**(3), pp. 512–520.

Dell, F. and M. Elmedlaoui (2002). *Syllables in Tashlhiyt Berber and in Moroccan Arabic*. Kluwer Academic Publishers, Boston. ISBN 1402010761.

Dell, G. S., M. F. Schwartz, N. Martin, E. M. Saffran, and D. A. Gagnon (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological review*, **104**(4), p. 801.

Deutsch, A., R. Frost, and K. I. Forster (1998). Verbs and nouns are organized and accessed differently in the mental lexicon: Evidence from Hebrew. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **24**(5), pp. 1238–1255.

Deutsch, A., R. Frost, S. Pelleg, A. Pollatsek, and K. Rayner (2003). Early morphological effects in reading: Evidence from parafoveal preview benefit in Hebrew. *Psychonomic Bulletin & Review*, **10**(2), p. 415.

Duñabeitia, J., S. Kinoshita, M. Carreiras, and D. Norris (2011). Is morpho-orthographic decomposition purely orthographic? Evidence from masked priming in the same–different task. *Language and Cognitive Processes*, **26**(4-6), pp. 509–529.

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

Elihay, J. (2007). *The olive tree dictionary: a transliterated dictionary of conversational Eastern Arabic (Palestinian).* Minerva Publishing, Jerusalem.

Emmorey, K. (1989). Auditory morphological priming in the lexicon. *Language and Cognitive Processes*, **4**(2), pp. 73–92.

Farwaneh, S. (2007). Hypocoristics Revisited: Challenging the primacy of the consonantal root. In Mughazy, M. A. (ed.) *Perspectives on Arabic linguistics XX*, volume 290 of *Current Issues in Linguistic Theory*, pp. 25–50. John Benjamins, Amsterdam.

Faust, N. and Y. Hever (2010). Empirical and Theoretical Arguments in Favor of the Discontinuous Root in Semitic Languages. *Brill's Annual of Afroasiatic Languages and Linguistics*, **2**(1), pp. 80–118.

Fitzgerald, C. M. (1997). *O'odham Rhythms*. Ph.D. thesis.

Forster, K. and J. Forster (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods*, **35**(1), pp. 116–124.

Forster, K. I. (1998). The pros and cons of masked priming. *Journal of psycholinguistic research*, **27**(2), pp. 203–233.

Forster, K. I. (2004). Category size effects revisited: Frequency and masked priming effects in semantic categorization. *Brain and Language*, **90**(1), pp. 276–286.

Forster, K. I. and C. Davis (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **10**(4), pp. 680–698.

Fountain, A. V. (1998). *An optimality theoretic account of Navajo prefixal syllables*. Ph.D. thesis, University of Arizona, Tucson.

Frost, R., A. Deutsch, and K. I. Forster (2000). Decomposing morphologically complex words in a nonlinear morphology. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **26**(3), pp. 751–765.

Frost, R., K. I. Forster, and A. Deutsch (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), pp. 829–856.

Frost, R., T. Kugler, A. Deutsch, and K. I. Forster (2005). Orthographic structure versus morphological structure: Principles of lexical organization in a given language. *Journal of Experimental Psychology: Learning, Memory, and Cognition Learning, memory, and cognition*, **31**(6), pp. 1293–1326.

Gafos, A., P. Hoole, D. Roon, and C. Zeroual (2010). Variation in overlap and phonological grammar in Moroccan Arabic clusters. *Laboratory Phonology X, Mouton de Gruyter, Berlin/New York*, pp. 657–698.

Gahl, S. (2008). *Time* and *thyme* Are not Homophones: The Effect of Lemma Frequency on Word Durations in Spontaneous Speech. *Language*, **84**(3), pp. 474–496.

Goldinger, S. (1996). Auditory lexical decision. *Language and Cognitive Processes*, **11**(6), pp. 559–568.

Goldsmith, J. A. (1976). *Autosegmental phonology*. Ph.D. thesis, Massachussets Institute of Technology, Cambridge.

Grainger, J. and W. Van Heuven (2003). Modeling letter position coding in printed word perception. In Bonin, P. (ed.) *The Mental Lexicon*, pp. 1–24. Nova Science, New York.

Halle, M. and A. Marantz (1994). Some key features of Distributed Morphology. *MIT Working Papers in Linguistics*, **21**(275), p. 88.

Hamrouni, N. (2010). *Structure and Processing in Tunisian Arabic: Speech Error Data*. Ph.D. thesis.

Harley, H. (2012). On the identity of roots. *Manuscript, University of Arizona*.

Harrell, R. (1962). *A short reference grammar of Moroccan Arabic*. Georgetown University Press, Washington, D.C.

Harrell, R. (2004). *A short reference grammar of Moroccan Arabic*. Georgetown classics in Arabic language and lintuistics. Georgetown University Press, Washington, D.C.

Harrell, R., H. Sobelman, and T. Fox (2004). *A Dictionary of Moroccan Arabic: Moroccan-English*. Georgetown University Press, Washington, D.C.

Hay, J. (2001). Lexical frequency in morphology: is everything relative? *Linguistics*, **39**(6), pp. 1041–1070.

Hay, J. (2002). From speech perception to morphology: Affix ordering revisited. *Language*, **78**(3), pp. 527–555.

Hay, J. (2003). *Causes and consequences of word structure*. Routledge, New York and London.

Hay, J. and H. Baayen (2002). Parsing and productivity. In Booij, G. and J. van Marle (eds.) *Yearbook of Morphology 2001*, volume 35, pp. 203–235. Kluwer Academic Publishers, Dordrecht.

Hay, J. and H. Baayen (2003). Phonotactics, parsing and productivity. *Italian Journal of Linguistics*, **15**, pp. 99–130.

Hay, J. and R. Baayen (2005). Shifting paradigms: gradient structure in morphology. *Trends in Cognitive Sciences*, **9**(7), pp. 342–348.

Hay, J. and I. Plag (2004). What constrains possible suffix combinations? On the interaction of grammatical and processing restrictions in derivational morphology. *Natural Language & Linguistic Theory*, **22**(3), pp. 565–596.

Hill, J. H. and O. Zepeda (1992). Derived words in Tohono O'odham. *International Journal of American Linguistics*, **58**(4), pp. 355–404.

Hockett, C. (1958). A course in modern linguistics. *Language Learning*, **8**(3-4), pp. 73–75.

Hockett, C. F. (1954). Two models of grammatical description. *Morphology: Critical Concepts in Linguistics*, **1**, pp. 110–138.

Holcomb, P. J. and H. J. Neville (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. *Language and Cognitive Processes*, **5**(4), pp. 281–312.

Holes, C. (2004). *Modern Arabic: Structures, functions, and varieties*. Georgetown University Press, Washington, D.C.

Hudson, G. (1985). The Principled Grammar of Amharic Verb Stems. *Journal of African languages and linguistics*, **7**(1), pp. 39–58.

Hudson, G. (1986). Arabic root and pattern morphology without tiers. *Journal of Linguistics*, **22**(01), pp. 85–122.

Hudson, G. (1991). On a defence of autosegmentalism. *Journal of linguistics*, **27**(1), pp. 163–177.

Huehnergard, J. (2004). Afro-Asiatic. *A The Cambridge Encyclopedia of the World's Ancient Languages*, pp. 138–159.

Hyman, L. M. (2006). Affixation by place of articulation: Rare and mysterious. *UC Berkeley Phonology Lab annual report (2006)*.

Hyman, L. M. and S. Inkelas (1997). Emergent templates: The unusual case of Tiene. *University of Maryland Working Papers in Linguistics*, **5**, pp. 92–116.

Idrissi, A., J.-F. Prunet, and R. Béland (2008). On the mental representation of Arabic roots. *Linguistic Inquiry*, **39**(2), pp. 221–259.

Ingham, B. (2003). *Lakota*. Number 426 in Languages of the World/Materials. Lincom Europa, Munich.

Inkelas, S. and C. O. Orgun (1995). Level ordering and economy in the lexical phonology of Turkish. *Language*, pp. 763–793.

Kolan, L., M. Leikin, and P. Zwitserlood (2011). Morphological processing and lexical access in speech production in Hebrew: Evidence from picture–word interference. *Journal of Memory and Language*, **65**(3), pp. 286–298.

Kouider, S., S. Dehaene, A. Jobert, and D. Le Bihan (2007). Cerebral bases of subliminal and supraliminal priming during reading. *Cerebral Cortex*, **17**(9), pp. 2019–2029.

Kouider, S. and E. Dupoux (2005). Subliminal speech priming. *Psychological Science*, **16**(8), pp. 617–625.

Laks, L. (2009). How to choose a prosodic template. On verb innovation and variation in Hebrew. *STUF-Language Typology and Universals*, **62**(4), pp. 307–324.

Lipiński, E. (2001). *Semitic languages: outline of a comparative grammar*, volume 80 of *Orientalia Lovaniesnsia Analecta*. Peeters, Leuven.

Luce, P. A. and D. B. Pisoni (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing*, **19**(1), pp. 1–36.

Marslen-Wilson, W. (1987). Functional parallelism in spoken word-recognition. *Cognition*, **25**(1), pp. 71–102.

Marslen-Wilson, W. and L. K. Tyler (1980). The temporal structure of spoken language understanding. *Cognition*, **8**(1), pp. 1–71.

Mathews, P. (1974). Morphology: an introduction to the theory of word-structure.

Matthews, P. H. (1972). *Inflectional morphology: A theoretical study based on aspects of Latin verb conjugation*. Cambridge University Press, Cambridge.

McCarthy, J. (1979). *Formal problems in Semitic phonology and morphology*. Ph.D. thesis, MIT.

McCarthy, J. (1981). A prosodic theory of nonconcatenative morphology. *Linguistic Inquiry*, **12**, pp. 373–418.

McCarthy, J. (1982). Prosodic templates, morphemic templates, and morphemic tiers. In Smith, N. and H. van der Hulst (eds.) *The Structure of Phonological Representations I*. Foris, Dordrecht.

McCarthy, J. (1983). A prosodic account of Arabic broken plurals. In Dihoff, I. (ed.) *Current Trends in African Linguistics I*. Foris, Dordrecht.

McCarthy, J. and A. Prince (1990). Foot and word in prosodic morphology: The Arabic broken plural. *Natural Language & Linguistic Theory*, **8**(2), pp. 209–283.

McCarthy, J. J. and A. Prince (1995). Faithfulness and reduplicative identity.

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

McQueen, J. M., A. Cutler, T. Briscoe, and D. Norris (1995). Models of continuous speech recognition and the contents of the vocabulary. *Language and Cognitive Processes*, **10**(3-4), pp. 309–331.

Moscoso del Prado Martín, F., A. Deutsch, R. Frost, R. Schreuder, N. H. De Jong, and R. H. Baayen (2005). Changing places: A cross-language perspective on frequency and family size in Dutch and Hebrew. *Journal of Memory and Language*, **53**(4), pp. 496–512.

Newman, P. (2000). *The Hausa language: An encyclopedic reference grammar*. Yale University Press, New Haven.

Norris, D., J. McQueen, and A. Cutler (2000). Merging information in speech recognition: Feedback is never necessary. *Behavioral and Brain Sciences*, **23**(03), pp. 299–325.

Perea, E. . G. C., Manuel & Rose (2002). Is the go/no-go lexical decision task an alernative to the yes/no lesical decision task? *Memory & Cognition*, **30(1)**, pp. 34–45.

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

Perea, M., S. J. Lupker, S. Kinoshita, and S. Lupker (2003). Transposed-letter confusability effects in masked form priming. In Kinoshita, S. and S. J. Lupker (eds.) *Masked priming: State of the art*, Macquarie Monographs in Cognitive Science, pp. 97–120. Psychology Press, New York.

Pfau, R. (2009). *Grammar as processor: a distributed morphology account of spontaneous speech errors*, volume 137 of *Linguistik actuell*. John Benjamins Publishing Company, Amsterdam.

Plag, I. and H. Baayen (2009). Suffix ordering and morphological processing. *Language*, **85**(1), pp. 109–152.

Poeppel, D. and G. Hickok (2004). Towards a new functional anatomy of language. *Cognition*, **92**(1), pp. 1–12.

Prince, A. and P. Smolensky (1993/2004). *Optimality Theory: Constraint interaction in generative grammar*. Blackwell, Oxford.

Prunet, J.-F. (2006). External evidence and the Semitic root. *Morphology*, **16**(1), pp. 41–67.

Prunet, J.-F., R. Béland, and A. Idrissi (2000). The mental representation of Semitic words. *Linguistic Inquiry*, **31**(4), pp. 609–648.

Qafisheh, H. A. (1997). *NTC's Gulf Arabic-English dictionary*. NTC Publishing Group, Lincolnwood.

Radeau, M. (1983). Semantic priming between spoken words in adults and children. *Canadian Journal of Psychology/Revue canadienne de psychologie; Canadian Journal of Psychology/Revue canadienne de psychologie*, **37**(4), p. 547.

Radeau, M., M. Besson, E. Fonteneau, and S. L. Castro (1998). Semantic, repetition and rime priming between spoken words: behavioral and electrophysiological evidence. *Biological Psychology*, **48**(2), pp. 183–204.

Radeau, M., P. Mousty, and P. Bertelson (1989). The effect of the uniqueness point in spoken-word recognition. *Psychological Research*, **51**(3), pp. 123–128.

Ratcliffe, R. (1997). Prosodic templates in a word-based morphological analysis of Arabic. In Eid, M. and R. R. Ratcliffe (eds.) *Perspectives on Arabic Linguistics X, Papers from the tenth annual symposium on Arabic linguistics*, pp. 147–172. John Benjamins, Amsterdam.

Ravid, D. (1990). Internal structure constraints on new-word formation devices in Modern Hebrew. *Folia Linguistica*, **24**(3-4), pp. 289–347.

Rose, S. (2003). The formation of Ethiopian Semitic internal reduplication. In Shimron, J. (ed.) *Language processing and acquisition in languages of Semitic, root-based, morphology*, volume 28 of *Language Acquisition & Language Disorders*, pp. 79–97. John Benjamins, Amsterdam.

Schluter, K. (2007). Amharic Internal Reduplication and Foot Structure: A Word-Based Approach. *Kansas Working Papers in Linguistics*, **30**, pp. 287–301.

Schoonbaert, S. and J. Grainger (2004). Letter position coding in printed word perception: Effects of repeated and transposed letters. *Language and Cognitive Processes*, **19**(3), pp. 333–367.

Shaw, J., A. Gafos, P. Hoole, and C. Zeroual (2009). Syllabification in Moroccan Arabic: Evidence from patterns of temporal stability in articulation. *Phonology*, **26**(01), pp. 187–215.

Simmons, J. P., L. D. Nelson, and U. Simonsohn (2011). False-Positive Psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science*, **22**(11), pp. 1359–1366.

Slowiaczek, L. M. and M. Hamburger (1992). Prelexical facilitation and lexical interference in auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **18**(6), p. 1239.

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

Stump, G. T. (2001). *Inflectional morphology: a theory of paradigm structure*, volume 93 of *Cambridge Studies in Linguistics*. Cambridge University Press, Cambridge.

Taft, M., A. Castles, C. Davis, G. Lazendic, and M. Nguyen-Hoan (2008). Automatic activation of orthography in spoken word recognition: Pseudohomograph priming. *Journal of Memory and Language*, **58**(2), pp. 366–379.

Tucker, M. (2010). Roots and prosody: The Iraqi Arabic derivational verb. *Recherches linguistiques de Vincennes*, pp. 31–68.

Twist, A. E. (2006). *A psycholinguistic investigation of the verbal morphology of Maltese*. Ph.D. thesis, University of Arizona.

Ullrich, J. F. (2008). *New lakota dictionary: Lak□ótiyapi-English, English-Lak□ótiyapi & incorporating the Dakota dialects of Yankton-Yanktonai & Santee-Sisseton*. Lakota Language Consortium Inc, Bloomington, IN.

Ussishkin, A. (1999). The inadequacy of the consonantal root: Modern Hebrew denominal verbs and output–output correspondence. *Phonology*, **16**(03), pp. 401–442.

Ussishkin, A. (2000). *The emergence of fixed prosody*. Ph.D. thesis, University of California at Santa Cruz.

Ussishkin, A. (2003). Templatic effects as fixed prosody: The verbal system in Semitic. *Amsterdam studies in the theory and history of linguistic science series*, **4**, pp. 511–530.

Ussishkin, A. (2005). A Fixed Prosodic Theory of Nonconcatenative Templatic Morphology. *Natural Language & Linguistic Theory*, **23**(1), pp. 169–218.

Ussishkin, A. and A. Twist (2009). Auditory and visual lexical decision in Maltese. In *Introducing Maltese linguistics: Selected papers from the 1st International Conference on Maltese Linguistics*, pp. 233–249. John Benjamins Publishing Company, Bremen. ISBN 9027205809.

Ussishkin, A., A. Wedel, K. Schluter, and C. Dawson (2013). Auditory masked priming in Maltese spoken word recognition.

Vaden, K., G. Hickok, and H. Halpin (2009). Irvine phonotactic online dictionary. *URL http://lcbr. ss. uci. edu/iphod/index. html*.

Velan, H. and R. Frost (2011). Words with and without internal structure: What determines the nature of orthographic and morphological processing? *Cognition*, **118**(2), pp. 141–156.

Velan, H., R. Frost, A. Deutsch, and D. C. Plaut (2005). The processing of root morphemes in Hebrew: Contrasting localist and distributed accounts. *Language and Cognitive Processes*, **20**(1), pp. 169–206.

Watson, J. (2002). *Phonology and morphology of Arabic*. The phonology of the world's languages. Oxford University Press, Oxford.

Wehr, H. and J. M. Cowan (1979). *A dictionary of Modern Written Arabic:(Arab.-Engl.)*. Wiesbaden: O. Harrassowitz.

Yip, M. (1988). Template morphology and the direction of association. *Natural Language & Linguistic Theory*, **6**(4), pp. 551–577.

Yu, A. (2007). *A natural history of infixation*, volume 15. Oxford University Press, USA.

Yu, A. (2010). Perceptual Compensation Is Correlated with Individuals'"Autistic" Traits: Implications for Models of Sound Change. *PloS one*, **5**(8), p. e11950.

Zepeda, O. (1983). *A Papago grammar*. University of Arizona Press, Tucson.