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Chapter 6

Arabic Language and Reading

The reading process is an interaction between the brain, the eyes, and a visual stimulus, which, for Arab readers, is Arabic language text on a page or a screen. The Arabic text in turn presents both visual and linguistic content. The first few chapters dealt with the nature of the visual presentation i.e. the Arabic script with its characteristics, components, and its evolution to its present day status. The previous chapter looked at the process of reading, and the marks of legibility in typeface design. This chapter deals with the linguistic content, the way it interacts with the visual stimulus, and the few studies that have been done to investigate the reading of Arabic. This chapter is the field where Arabic design and language interplay. As will be argued later on, the orthography and morphology of the Arabic language have a strong influence on reading. With that in mind, the chapter starts with a short introduction to the Arabic language that will turn out to be very handy once we get into the details of how it is all affecting reading.

Whether by design or twist of fate, Arabic text presents a rather puzzling combination of elements. To put it shortly, many Arabic words are formed as derivatives of a consonantal root. These derivatives are formed by changing vowel signs and the occasional addition of a few consonants. However, these same vowels are usually dropped out in written Arabic. As a result, a significant portion of a word's phonology is lost. Vital information is left out. So how does one read Arabic then? In short, it is mostly educated guesswork. And that is what this chapter is all about.

The Morphology and Orthography of the Arabic Language

There is a popular Arabic saying amongst linguists and it goes as: In order to read Arabic, you need to know what you are reading. Some sayings are exaggerated or sometimes even false. This one is not. It sums up in one sentence the hard truth about reading Arabic. Why is it so? It all comes down to how words are formed, i.e. morphology, and the fact that short vowels are dropped out of everyday texts. Excluding foreign words and transliterations, the majority of the Arabic lexicon of Modern Standard Arabic is built via two forms of structures: derivational morphology and inflectional morphology.

Derivational Morphology: Root + Pattern Model

Derivational morphology is the structure through which verbs and nouns are formed. These are based on triliteral or quadriliteral roots, also referred to as three or four consonantal roots respectively. The first term is more accurate as it is possible to have a root that includes consonants and a long vowel such as the root /qwl/ (related to saying). Words are formed when a phonological pattern is applied on a root. There are three types of patterns:

The first is a series of short vowels that are interspersed with the root consonants/vowels (Abu-Rabia & Awwad, 2004). For example, take the pattern /a-a-a/ which indicates the action of doing for the past tense of third person male singular and apply it on the root /ktb/ which is the semantic field of writing. This yields the verb *kataba* كَتَبَ, which means, "he wrote." This morphological structure and the resulting phonology do not break the orthographic order of the root since the short vowels are usually not indicated (In everyday texts it would be كتب instead of كَتَبَ).

The second type of pattern is a combination of short and long vowels inserted within the root (Abu-Rabia & Awwad, 2004). One example is the pattern is */ā-i/* (with a long a) meaning the person who did the action. When applied on /ktb/ it gives *kātib* كاتِب meaning writer. This type of pattern breaks the orthographic order of the root consonants just as in this example the Alif is inserted in between the first and second consonant.

The third type of pattern is a combination of short vowels with long vowels and/or certain consonants that are inserted between, in front of or after the root (Abu-Rabia & Awwad, 2004). One example is the pattern */ma-a/* indicating the place of action which when applied on /ktb/ gives *maktab* مَكْتَب meaning office or desk. This type of pattern also breaks the orthographic order of the root consonants. Derivational morphology in Arabic is then called non-concatenative[1] since the morphemic units are interweaved into one another.

These patterns can be alternatively categorized as verbal vs. nominal patterns. There are fifteen frequently used verbal word patterns and nine nominal ones; while nominal patterns retain semantic consistency, different verbal patterns applied on the same root could convey different semantics (Abd El-Minem, 1987). For example, nouns based on the root /ktb/ such as *kātib* كاتِب (writer), *maktūb* مَكْتوب (letter), *maktab* مَكْتَب (desk), *kitāb* كِتاب (book), *kutayyib* كُتَيِّب (small book), are all semantically consistent. On the other hand, verb patterns can form transitive (*kataba* كَتَبَ – he wrote), intransitive (*inkataba* إنْكَتَبَ – something was written), active, and passive (*kutiba* كُتِبَ – it was written) verbs from the same root (Abu-Rabia & Awwad, 2004).

Luckily, patterns are consistent in the meanings they generate whether it is an action, an event, a place, an object, or a person. Similarly, roots have embedded semantics in them. /ktb/ is always related to writing, /hms/ to whispering, /ksr/ to breaking, and /drs/ to studying etc. This is the key to learning Arabic. **Even dictionaries are organized via roots**. Once students learn the meanings implied within roots and patterns, they are then able to extrapolate that knowledge and apply it to learn new words. Thus, **the root communicates more semantic information than the phonological pattern, and this points to the basic meaning of any given word; the actual pattern applied points to a word class as described earlier** (Abu-Rabia & Awwad, 2004).

As for roots, there are strong and weak ones, the latter accounting for 10% of total number of Arabic roots (Mrayati, 1987). Weak roots usually have a long vowel

1 Also referred to as non-linear or discontinuous morphology (Boudelaa & Marslen-Wilson, 2004a)

(Waw و or Yeh ي) as one of the components. These would act as a consonant in the basic root form (eg. /wfq/ meaning agreeing) but could disappear when some patterns are applied (eg. *Ittafaqa* إتّفق) (Boudelaa & Marslen-Wilson, 2004b). This fusion of one of letters of the root and the letters of the pattern is referred to as gliding, which is part of an allomorphic instance of several morphemes combining together to make more complex ones (Boudelaa & Marslen-Wilson, 2004b). The effect of such morphological play on lexical access and reading will be discussed later in the chapter.

Inflectional Morphology

The second way words are formed is through inflectional morphology. Instead of roots and patterns, this is a process of attaching prefixes and suffixes to existing words. This can be applied to both verbs and nouns. In verbs, the system is dependent on person, number, gender, and time (Abu-Rabia & Awwad, 2004). For example, the verb *kataba* كتب (he wrote) becomes *katabat* كتبت (she wrote) once you add the unvocalized t that denotes both the female gender and a singular number. Contrary to Latin, verbs and pronouns in Arabic also include a case for pairs. So, to conjugate the verb *kataba* in the past tense one adds a series of suffixes (colored here in grey) to the past tense of the third person masculine singular version of the verb:

Third Person Masculine:
Kataba – he wrote كتب
Katabā (long a, Alif) – the pair wrote كتبا
Kātabū – they wrote كتبوا

Third Person Feminine:
Katabat – she wrote كتبت
Katbatā – the pair wrote كتبتا
Katabna – they wrote كتبن

First person:
Katabtu – I wrote كتبت
Katabnaa – we wrote كتبنا

In the present and future tense, verbs take on both prefixes and suffixes:

Third Person Masculine:
Yaktubu – he writes يكتب
Yaktubān (long a, Alif) – the pair writes يكتبان
Yaktubūn – they write يكتبون

Third Person Feminine:
Taktubu – she writes تكتب
Taktubān – the pair write تكتبان
Taktubna – they write تكتبن

First person:
Aktubu – I write أكتب
Naktubu – we write نكتب

This delineation of gender and number is also indicated in the addition of pronouns to nouns. Pronouns are usually added as suffixes and usually follow a similar conjugation to that of verbs. For example, if one takes the noun *kitāb* (book):

Third Person Masculine:
Kitābuhu – his book كتابه
Kitābuhumā – the pair's book كتابهما
Kitābuhum – their book كتابهم

Third Person Feminine:
Kitābuhā – her book كتابها
Kitābuhumā – the pair's book كتابهما
Kitābuhunna – their book كتابهن

First person:
Kitābī – my book كتابي
Kitābunā – our book كتابنا

These are some examples of inflectional morphology in Arabic verbs and nouns. Going back to the first paragraph in this section, one is now able to see how readers of the Arabic language are able to deduce the meaning of a word even though the vowels are not indicated. This is possible once one is familiar with the verbal and nominal patterns. This identification process kicks off once the context clarifies if the word is a verb or a noun, and one is then able to guess which pattern best fits the written consonants and vowels. This is why it is said that one needs to know what one is reading in order to be able to understand the meaning. The role of the root and pattern in lexical access, and their subsequent effect on reading and word recognition will be discussed later on in this chapter.

Etymons

Though the general consensus amongst linguists bears that the smallest morphological unit in the Arabic language is the triliteral root, a few authors have argued that the smallest unit, called etymon, is actually comprised of only two unordered consonants. The argument for the etymon points to the existence of a similar semantic reference in different roots that share two of their three consonants. Examples cited include *baṭṭa* بطّ (cut off), *baṭara* بطر (sever), *balaṭa* بلط (sever), *baṭaka* بطك (separate), *sabata* سبط (cut down) [Boudelaa, 2001]. These words have only two consonants (/t/ and /b/) in common and the root+pattern theory would classify these as being based on five different roots (/btt/, /btr/, /blt/, /btk/, /sbt/), even though it is obvious that they share a phonological and semantic reference.

Bohas (1997) argues that this is a commonly occurring paradigm in the Arabic lexicon and the root+pattern as the smallest morphological unit fails to explain this regular occurrence. Boudelaa and Marslen-Wilson (2001, p. 68) expand on how the process forms:

> "In order to have a surface form the bi-consonantal etymon morpheme is morphologically expanded by the addition of an epenthetic segment (i.e. a segment inserted as a result of a phonological process) specified as non-syllabic, which covers the 27 consonants of the language."

Furthermore, the authors claim that the etymon theory manages to explain a feature of the Arabic language where two semantically similar roots share two of their three consonants but in a different order. This allomorphic variation occurs in examples such as *māta* مات (perish) and *tamma* تمّ (come to an end). The respective roots are /mwt/ and /tmm/ and the suggestion is that the etymon /tm/ is common to both and that the reverse order does not change the basic meaning of the etymon (Boudelaa & Marslen-Wilson, 2001). This, it is argued, holds true for 135 of the possible 235 etymons in Modern Standard Arabic (G. Bohas & Darfouf, 1993). Though this might seem logical at first glance, further arguments start to border on being somehow farfetched:

> "A second instance of allomorphy is in cases where the segmental structure of the surface form is different across the realizations of a family of related forms, argued to be linked back to the same underlying etymon morpheme. An example is the set of forms [**S**a**b**ara] (bind), [**D**a**b**ba] (keep under lock), [ra**b**a**T**a] (tie up), [**'A**aqa**d**a] (knot), [Ha**b**asa] (hold back), [Ha**b**aka] (bind), [Ha**b**lun] (a rope), ['**A**a**f**fa] (refrain), where the etymon consonants are in bold, and where they all share a core meaning related to notions such as (restraint) and (tying up). The underlying phonological commonality between these forms is that they all consist of a featural combination of a [+labial] consonant and a [+pharyngeal or +pharyngealized] consonant, suggesting that the abstract specification of the form of the etymon is in featural rather than segmental terms." (Boudelaa & Marslen-Wilson, 2001, p. 68)

The above argument seems to try too hard to find supporting arguments for the existence of the etymon. Indeed, the etymon is no longer composed of two common consonants but of two phonetically related consonants. The authors give an example of how this system works:

> "Thus, in the forms [sabata] (cut down), [batara] (cut off) the etymon is /bt/ rather than /st/ or /br/, because the meaning (cutting) recurs in other forms containing the two consonants /b,t/ as in [tabba] (cut) and because this is consistent with the featural specification of the etymon as [+labial] and [+dental]. By the same token, the forms [Sabara] (tie) and [rabaTa] (bind) are morphologically related because they share the consonant /b/ and their respective /S/ and /T/ consonants are homorganic in that that they are both pharyngealized." (Boudelaa & Marslen-Wilson, 2001, p. 68)

Opponents of the etymon theory point to the fact that the above paper by Boudelaa, and the study that it carried, is only concerned with the psychological reality of the existence of the etymon but does not offer any theoretical framework in which the etymon could be isolated or identified (Bentin & Frost, 2001). Indeed, it turns out that the identification of the etymon in any given word is a quite complicated and difficult task, which is in strong contrast to the ease and simplicity with which the trilateral root can be identified.

Bentin and Frost's argument goes on to say that the "there are no a priori and clearly defined rules for morphological decomposition that would result in the unequivocal stripping or isolation of the etymon letters or phonemes" (Bentin & Frost, 2001, p. 114). Given that, the alternative approach was to test if native speakers were sensitive to the etymon and able to extract it. Benton and Frost (2001) put this to the test and the result was that only 68% of the subjects were able to identify the etymon. This was considered to be a low figure especially given the fact that there are only three possible two-letter combinations in a three-letter root. Bentin goes on:

> "The weakness of this performance is even more conspicuous considering that native speakers of Semitic languages can easily report without error what letters of the word belong to the root, even at the first grades of primary school" (Bentin & Frost, 2001).

Boudelaa's study does offer interesting evidence to support the existence of the etymon. The study found that when testing word pairs, the lexical decision performance was significantly faster when the target and the prime shared a common etymon. Bentin acknowledges these results but offers an alternative theory that "these effects reflected knowledge accumulated implicitly by exposure to the statistical regularity that exists between orthographic and phonological sublexical units and semantic features" (Bentin & Frost, 2001, p. 115). Given the lack of a supporting theoretical construct, or wide ranging and supporting field data, the question of the etymon and its role as a morphological unit remains to be confirmed. The trilateral root remains as the widely accepted smallest morphological unit in Arabic.

Homographs

As mentioned in previous sections, Arabic texts in every day situations are usually un-vocalized. It has also been demonstrated how any given root can be expanded into many different words depending on the pattern that is applied on it. The pattern, as already shown, is a sequence of vowels, as well as possible consonants that are added onto the root. There are several patters that affect the consonants of the root similarly, and only differ in the vowels they deploy. Once these vowels are dropped out of everyday text, the effect is that Arabic texts have a large number of homographs: words that look similar, but are vocalized and therefore pronounced differently.

Some example patterns that do not add any consonants to the root are:
/a-a-a/: he did an action
/u-i-a/: an action was done
/i–u/: an action
/a-a-u/: noun resulting from the action

Indeed, one can find many examples of this sort, more than there is space for here. A good example of homographs related to the root /mlk/: *malikun* مَلِكٌ (king), *milkun* مِلْكٌ (property), *malaka* مَلَكَ (he owns), *mallaka* مَلَّكَ (he gave property to someone), *mulika* مُلِكَ (it was owned), *mullika* مُلِّكَ (he was given property). Without any vocalization, all these words are written as: ملك.

In the previous examples, two of the patterns actually do affect as the consonants as they double (stress) the middle consonant. However, the doubling of the consonant is noted as a mark above the character. This is part of the vocalization system. Though it is linguistically incorrect not to show it, this is often the case.

Orthography

The Arabic script is partially connected, and as mentioned already, the vowels are of 2 kinds: short and long. Short vowels are usually dropped out in everyday texts and are included in texts for children, beginning readers, poetry and liturgical texts.

Long vowels, of which there are three, are usually pronounced as long vowel sounds though they do on occasion function as consonants as well. Every consonant corresponds to one sound only (though that sound can vary across regional accents) and, with the exception of the "Teh marbuta" and the "Lam" in the "Alif-Lam" article with certain nouns, these consonants are always sounded out, and the relation of grapheme to phoneme in the Arabic language is consistent. The Arabic language, then, employs shallow orthography when fully vocalized and deep orthography when it is not.

Another important aspect of Arabic orthography is related to the shape of the script itself, and that is the abundant use of dots and the reliance on very few basic shapes in the script make-up. This makes the Arabic script quite challenging to read for beginning readers. However, this is an aspect of the script that cannot be tested or so easily changed. It would not be possible to set up an experiment where one typeface is dotted and the other is not. Because of that, the issue of the dots does not come up in psycholinguistics research and is absent from the following pages.

Literature Review of Findings Related to the Reading of Arabic

The Nature of the Arabic Spoken and Written Language

As mentioned in chapter 1, spoken Arabic differs significantly from the formal written version. Dialects across different regions are so different that it is sometimes very difficult to understand what another Arab might be saying. However, the written Arabic language, Modern Standard Arabic (MSA), is the same across the entire Arabic speaking region. Therefore, while it might be difficult for a Lebanese to understand what an Algerian is saying, they will both read the same books and the same newspapers. MSA is used for written communication as well as formal occasions such as political speeches and the news on TV and radio.

The spoken Arabic dialects are different from one another and very different from MSA. A study that looked at the ability of MSA and spoken Arabic to prime one another found that these two are functioning as two separate languages (Ibrahim & Aharon-Peretz, 2005). Children going into school would have been exposed to spoken Arabic at home and in daily activities and, as such, it is their first language. In preschool years, they are exposed to MSA through TV programs or books read aloud to them, but the first language they learn is the local dialect of Arabic. In fact, in the study cited above which was done with Arab Israeli readers, MSA and Hebrew had the same priming effects for spoken Arabic leading to the conclusion that MSA is retained as a second language in their cognitive system (Ibrahim & Aharon-Peretz, 2005). Furthermore, MSA and spoken Arabic are stored as distinct lexica, as was shown in a naming study, though there exists strong connections between the two languages due to the perception that they are different forms of the same language (Ibrahim, 2006).

Given this situation, Arabic is then a case of diglossia due to the differing nature of the spoken and written forms and because the specific "socio-functional" situations in which these two forms are used (Saiegh-Haddad, 2005, p. 562). Not only are these two forms different in their lexicon, but also in their phonetic make-up: spoken Arabic has fewer consonants and more vowels (Saiegh-Haddad, 2005). The nature of syllables is also different: in spoken Arabic, words can start with a silent consonant or can have two silent consonants in a row, both of which are not allowed in MSA. As to the difficulties facing a child learning to read what is practically a new language, Saiegh-Haddad explains:

> "In order to identify a word, the beginning reader must be able to discover the linguistic relatedness between the two forms of the word and to recover the linguistic distance between them. This is a formidable task, especially given the fact that phonological distance is usually compounded by morpho-syntactic distance. Also, because almost all function words and many of the high frequency content words that (s)he encounters have a phonological form in MSA that is completely different from their form in the child's spoken vernacular" (Saiegh-Haddad, 2005, p. 563)

This leads to a situation where a child is reading in a shallow orthography (fully vocalized Arabic) that nevertheless contains uncommon phonemes, which lead the author to hypothesize that "phonological processing for MSA phonemes would be more difficult for children than that for SAV[2] phonemes, and that this would be related to their reading fluency" (Saiegh-Haddad, 2005, p. 564). The author also points out that the new sounds that a young child encounters in MSA makes vocalized Arabic less of a shallow orthography than what one initially expects.

As it turns out, "the strongest predictor of reading fluency in vowelized Arabic was letter recoding speed. Letter recoding speed was predicted by memory, rapid naming, and phoneme isolation" (Saiegh-Haddad, 2005, p. 559). In other words, even though Arabic is a case of diglossia, the most reliable factor that influences reading, is the ability to connect the letter to its sound. Luckily for young Arab children, studies have shown that exposure to MSA in pre-school years can yield to better reading comprehension once they start school (Abu-Rabia, 2000). It is fortunate, then, that with parental support at home, young children will have an easier job once confronted with the task of reading what is a new language to them.

Another study that tested Arabic and Hebrew monolingual readers vs. Hebrew/Russian bilinguals found that Arabic readers had similar reading abilities to bilingual readers which is further support for the argument that MSA is at the level of a second language to Arabic speakers (Ibrahim, Eviatar, & Aharon-Peretz, 2007). In fact, the authors argue that exposure to literary Arabic (MSA) requires the same levels of linguistic analysis as the exposure to two languages that are as different from one another as Hebrew and Russian. Furthermore, in another study, Arab children showed similar linguistic abilities like the Hebrew-Russian bilinguals: better phonological skills, but lower on vocabulary scores (Eviatar & Ibrahim, 2000).

Learning to Read

In spite of all the odds, and the pessimism one feels when faced with the idea that one's native reading language is still a foreign language, Arab children still manage to learn to read and write. As to how they manage to do that, one study looked at whether the dual route approach to reading is also applicable to Arabic. The results showed that Arab children go through a similar process as other children do in learning how to read English (Taouka & Coltheart, 2004):

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2 SAV stands for Spoken Arabic Vernacular

- Discrimination-net phase: This is the stage where children know a certain number of sight words that they recognize via specific visual features (Taouka & Coltheart, 2004).

- Phonological-recoding phase: In this stage the children have a much larger vocabulary that they can actually read so they will read words letter by letter, using their knowledge of grapheme-to-phoneme conversion to arrive to the correct pronunciation that will help them recognize the word itself (Taouka & Coltheart, 2004).

- Orthographic phase: By this stage, children will have arrived to the point in time where they are able to directly rely on orthography in order to read (Taouka & Coltheart, 2004).

The study also showed that the ability to use the correct contextual form of a letter[3] is a skill that is learned late in the reading stages, but once learned this knowledge becomes so "deeply engrained" that it is difficult for adult readers to read Arabic text that does not employ the correct contextual forms (Taouka & Coltheart, 2004).

In terms of difficulties for beginner readers, it seems that there are certain types of misreadings and misspellings that are consistent through the early years of education. In effect, errors are often caused by misreading the short vowels, by writing the inappropriate contextual form of a letter, and by omitting or adding extra letters in writing exercises (Azzam, 1993). The frequency of the errors diminishes as children grow, but the types of errors remain (Azzam, 1993). Other studies have also found that at least 50% of spelling errors are phonological in nature (Abu-Rabia & Taha, 2006).

As to bilinguals, a study found a "cross-linguistic relationship between phonological awareness" in bilingual Canadians who spoke both Arabic and English, even though these languages are written in completely different script systems (Saiegh-Haddad & Geva, 2008). The same study did not find a relationship between morphological awareness between Arabic and English leading to the conclusion that "morphological awareness is primarily a language-specific linguistic skill that emerges as a function of language proficiency, and is therefore relatively independent in the two languages of bilingual children" (Saiegh-Haddad & Geva, 2008, p. 15).

Effect of Morphology on Reading

Are words recognized as whole entities or via the root? As mentioned in chapter 5, the role of morphology in lexical access is dependent on language itself and that it is often the case that there is a race between whole-word access and decomposition into the route. If words are stored in the mental lexicon as whole entities, then there should be no difference in the identification of morphologically simple or complex words (Abu-Rabia & Awwad, 2004). Abu-Rabia and Awwad tried to see if the root would act as a prime for other words derived from the same root, or if the word pattern would prime other words derived from the same pattern and used the naming of **high frequency** words and non-words as procedure. It found that neither the root nor the word pattern acted as a prime for their derived nouns leading to the conclusion that "the nominal derivational morphology of Arabic words is represented in the

3 For example using the final form in the initial position is a mistake to be avoided.

mental lexicon as separate whole words, and the nature of the morphology exerts no influence on the process of word recognition" (Abu-Rabia & Awwad, 2004, p. 332).

As to why this is a different case from Hebrew, the authors note that the partially connected nature of the Arabic script makes it different from Hebrew and a complex cognitive task to perform and so readers overlook the decomposition of a word into its root (Abu-Rabia & Awwad, 2004). However, as discussed in chapter 5, highly frequent words are accessed as whole even in languages that are not as reliant on morphology as Arabic, and this study used high frequency words in its set-up. In such a case, their statement that "The main conclusion of this study on the morphology of Arabic is that roots and word patterns have no essential role in word organization in the mental lexicon" (Abu-Rabia & Awwad, 2004) would only be applicable for the recognition of high frequency words. This is an issue that will be further elaborated on in the next paragraphs.

But before we do that, there is another element of morphology in Arabic that is the less commonly discussed which is the CV-structure, where C and V refer to consonants and vowels respectively. The CV-structure is the specific pattern of consonants and vowels that result from the application of a pattern on a root (McCarthy, 1981). McCarthy lists an inventory of the possible canonical forms in Arabic:

1.	C	V	C	V	C			
2.	C	V	C	C	V	C		
3.	C	V	V	C	V	C		
4.	C	V	C	V	C	C	V	C
5.	C	V	C	V	V	C	V	C
6.	C	C	V	C	V	C		
7.	C	C	V	C	C	V	C	
8.	C	C	V	V	C	V	C	

A study (Boudelaa & Marslen-Wilson, 2004a) investigated the priming of words that share the same vowels (as dictated by different patterns), words that share the same CV-skeleton, and words that share both (in essence the same word pattern). It found that the priming by words that share the same CV-skeleton was stronger than that by words that shared the same vowels, and had the same strength as that induced by the word pattern. The authors point to the fact that this CV-skeleton priming was done by words that did not share the same consonants or had any semantic relationship (Boudelaa & Marslen-Wilson, 2004a).

The same authors further investigated the changing role of morphological priming over time of display (Boudelaa & Marslen-Wilson, 2005). With the use of masked priming with display durations (Stimulus Onset Asynchronies or SOA) of 32, 48, 64, and 80 ms, the study found reliable root priming at all SOAs. They also found priming effects for the word pattern but only at 48 and 64 ms for nouns, and 48 for verbs. This led the authors to conclude that there is a likely difference in the time needed to extract word pattern vs. root information. The reasons proposed are very interesting to note:

> "In other words, while the visual event presents fully specified information about the consonantal root, it presents only partial information about the word pattern. This means that while accessing the meaning of an orthographically presented root can be direct, the mapping of a visually presented word pattern onto its morpho-syntactic meaning is indirect and may require mediation through access to phonology. If this is correct, then it is phonological mediation that results in word pattern priming kicking in after root priming. Another factor underlying the differential priming onsets of word patterns and roots may be simply the nature of information conveyed by the two units.

> In particular, the meaning conveyed by the root is arguably more constraining than that conveyed by the word pattern. Surface forms sharing a root make up a more coherent morphological family than those sharing a word pattern, and this may also facilitate access" (Boudelaa & Marslen-Wilson, 2005, p. 231).

In other words, the root is always a prime because its letters are almost always preserved in Arabic orthography. On the other hand, the pattern is often a combination of short vowels, and a few long vowels and consonants. Since the short vowels are usually not indicated in normal texts, the reader will often need to rely on these long vowels and consonants to guess what pattern is applied and therefore how to correctly read the word. If the pattern is composed of only short vowels, then it is only the sentence context that will clarify which pattern is applied.

As to orthographic and semantic priming, the authors found evidence of that from only 80 ms onwards, which again further supports their conclusion that "morphological effects in Semitic languages represent distinct structural characteristics of the language"(Boudelaa & Marslen-Wilson, 2005, p. 207).

As mentioned earlier in this chapter, Arabic roots can be either weak or strong depending if one of its letters undergoes allomorphic changes or not (/wfq/ is a weak root because the Waw و changes to a Teh ت in *ittifaqa* إتّفق). Interestingly, weak roots have the same priming capabilities as strong ones, and roots show priming abilities even when the semantic relationship between prime and target is not very obvious (Boudelaa & Marslen-Wilson, 2004b). Patterns are also able to act as primes, with the exception of the cases when they induce allomorphic variations that change their underlying CV-skeleton (Boudelaa & Marslen-Wilson, 2004b). The same study also found that Arabic words that are neither semantically related nor modeled in the same pattern but are phonetically similar nevertheless do not have priming effects (Boudelaa & Marslen-Wilson, 2004b).

An interesting study by the same authors looked at priming effects of roots and patterns in terms of their productivity[4] (or family size), both of which are used to indicate the number of possible words this root or pattern will produce. As part of the experiment description, the authors list some interesting statistics of Arabic roots and patterns. There are around 6000 roots in Arabic and the average productivity is quite low (12 derived words for the most frequent 1000 roots) and the highest productivity ranging between 30 and 40 derived words. As for patterns, there are 155 nominal patterns (in the sample selected by the authors), but their productivity is much higher and is on average around 60, but can go up to 434 (Boudelaa & Marslen-Wilson, 2011). They tested the ability of the word pattern to prime, and tested that against the productivity of both roots and patterns.

What they found was that there were strong priming effects for less productive word patterns that were applied on productive roots. Also, if the root is not productive, then the word pattern would not prime, irrespective if that pattern was productive or not (Boudelaa & Marslen-Wilson, 2011). In other words, if a word is derived from a root that has a large set of possible derivatives, and its pattern is infrequent, then its priming power is stronger. Also, if it is part of a small set of possible derivatives, its priming power is weak, and the productivity of its pattern is not relevant. As to why this is so, it is possible that a more productive root is simply more frequent as it is the entry point for so many words in the Arabic lexicon.

Furthermore, the results show that the amount of pattern priming is dependent on the family size of the priming root, but not of that of the target root (Boudelaa

4 Roots that have a large number of word derivatives would be highly productive and vice versa.

& Marslen-Wilson, 2011). This led the authors to conclude that the processing of the word pattern is dependent on the processing of the root and a delay in root processing will delay the processing of the pattern. This is also supported by their previous investigations as to the SOA time frames of when the root and pattern are able to prime.

Going back to the issue of the root frequency, is the root, which is an abstract string of consonants with a specific semantic reference, stored as a lexical unit, or is the Arabic lexicon made up of only whole words? Evidence for the first came from an Arabic-French bilingual who suffered a stroke that resulted in a language deficit where the subject's comprehension and ability to read aloud were impaired (Prunet, Béland, & Idrissi, 2000). A study of the errors that this subject made led to some very interesting observations. His impairment was characterized as deep dyslexia, and his language tests showed a consistent consonant metathesis error: two consecutive consonants of the 3 consonants found in the root would be switched around, but the pattern applied remains unchanged. These errors occurred at 25 times the rate of errors while reading French. The interesting aspect of these errors in Arabic is that the consonants that are added in via the word pattern were never switched around and that the CV skeleton remained unchanged. This led the authors to conclude that the metathesis is happening only with the root which means that the root is stored as an independent unit in his lexicon (Prunet et al., 2000).

Another support for the role of the root in Arabic morphology came through a study that looked at name shortening or hypocoristics, such as the name Hassan being turned to Hassoun (Davis & Zawaydeh, 2001). The study points to the prevalence of the consonantal root in these formations, at the time that the extra consonants added by the word pattern do not surface. An example of that is *Salman* (root is /slm/) being shortened to *Sallūm* where the n added in by the pattern does not appear in the hypocoristic (Davis & Zawaydeh, 2001). Moreover, the ability to correctly identify which words share a common root (morphological identification), and the ability to name more words that share the same root (morphological production) have been shown to be reliable indicators of reading comprehension (Abu-Rabia, 2006).

Looking again at bilinguals, Arabic and English bilingual children who had high proficiency in decomposing morphologically complex Arabic words had higher oral reading proficiency in Arabic, while this relationship was not present in the reading of English (Saiegh-Haddad & Geva, 2008). Bilingual children who had poor skills in reading English and Arabic still showed better spelling and pseudoword reading skills than monolingual children who only read English (Abu-Rabia & Siegel, 2002).

Given the limited amount of research regarding Arabic morphology, it was interesting to review research done for Hebrew. The similarities between the two are many: they are both Semitic languages with similar root and pattern based morphology (Deutsch, Frost, Pollatsek, & Rayner, 2000), both written from right to left, and both drop out vowels in every day texts. There are of course obvious differences: the Hebrew script is not attached, and the gap between spoken and written is not as wide as in Arabic.

The findings related to Hebrew are also similar to those in Arabic: The root, or any word derived from it, has a strong priming effect in both naming and lexical decision tasks of words derived from that same root (Deutsch, Frost, & Forster, 1998). The word pattern is also able to act as a prime, though only for verbs and not for nouns (Deutsch et al., 1998). These results led to the conclusion that that the Hebrew lexicon includes:

> "... a multiple system of connections between a whole-word level (nouns and verbs) and a sub-word morphological level, which consists of root and

> verbal-pattern morphemes. By this view, all word units, whether nouns or verbs, are connected to root morphemic units. In addition, verbal forms are also connected to verbal pattern units. This organisation is independent of semantic factors" (Deutsch et al., 2000, p. 491).

Moreover, if the root was shown in the parafovea, it is able to give a preview benefit for the target word n+1 (Deutsch et al., 2000). When readers were fixating on word n, the following word would be the root. However, once the readers move their eyes towards that word, the display changes, and they will see the target word, which in this case is derived from the root shown before. This is the typical boundary technique and is a good test of the priming abilities of the root in Hebrew[5]. Even when the readers did not move their eyes, and the word currently fixated was replaced by a word derived from a root previewed in the parafovea, the root facilitated lexical decision making (Deutsch et al., 2000). The authors also hit on a very important note: the root gave a preview benefit, even when its letters were interspersed all over the target word (Deutsch et al., 2000). In essence, this is not about two words that start with the same letters and thus act as primes for one another; this is a unit in a non-concatenated morphology demonstrating its role in lexical access.

This key role was further demonstrated in a later study by the same authors. Using a similar experimental set-up and using eye tracking to measure the amount of preview benefit, the study investigated the ability of the root to act as a prime, though this time in a sentence context (Deutsch, Frost, Pelleg, Pollatsek, & Rayner, 2003). Also different in this experiment was that the priming word was not the root, but rather another word derived from it. In effect, the test was looking to see if two words derived from the same root can prime one another, and the results were positive (Deutsch et al., 2003). Another interesting aspect that the authors point to is that the priming effect of the derived word happens early on in lexical access. The preview benefit, as discussed in chapter 5, happens in the pre-attentive phase of sentence reading. That is to say, this parafoveal preview is taking place before the eyes actually fixate on the target word. As such, and as the authors have concluded, morphological effects are very early in the Hebrew word encoding process (Deutsch et al., 2003).

However, further investigation into the type of derivational morphology that is able to give a preview benefit showed that words derived from the same pattern are able to facilitate the processing of one another, though only in the case of verbs but not nouns (Deutsch, Frost, Pollatsek, & Rayner, 2005). The sensitivity to the word pattern extends to the syntactic role that the derived word fits into. In a sentence context that requires a noun, a verbal preview delayed the reading times of a noun derived from the same root, thus demonstrating that the morphological information gained in the preview is modulated by the sentence context expectations (Deutsch et al., 2005).

While comparing the results of parafoveal previews of roots and verbal patterns, the authors arrive to the conclusion that the root is analyzed at an earlier time frame than the verbal word pattern (Deutsch et al., 2005), a result which is similar to that found for Arabic and discussed in previous paragraphs.

Morphology, then, is a big player in the process of reading semitic languages such as Arabic and Hebrew. The role of roots and patterns is very clear in terms of their ability to prime, in the time frames they operate in, and the extent with which they define the Arabic lexicon. This is not to say that all questions have been answered or that all issues are clearly settled. However, within the field of study of Arabic reading, the influence of morphology is the one that has been most thoroughly tested.

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5 The study took into consideration word length and the first 3 letters of the target word (Deutsch et al., 2000) as both of these factors are known to affect the preview benefit as discussed in the previous chapter.

Frequency Effects

With regards to the process of reading Arabic, studies have found very high frequency effect in naming Arabic words (Bentin & Ibrahim, 1996). This could be due to the easier access to a frequent word's phonology. Because vowels are dropped out, phonological processing is taking place during word recognition. When subjects were presented with naming and lexical decision tasks of transliterated words (that made illegal orthographic structures), the reaction times slowed down and naming was also slower (Bentin & Ibrahim, 1996). Word frequency, then, has a large effect on "phonological encoding and lexical access" in the reading of Arabic texts (Bentin & Ibrahim, 1996, p. 320). As is the case with Latin-based languages such as English, French, and German, words in Arabic are named faster than both pseudowords and illegal nonwords (Jordan, Paterson, & Almabruk, 2010).

Mental Representation of Arabic Words

When we read in English, concepts, stories, and football games all develop from the left to the right. When this is the one language one reads, and given how frequent reading is, this script direction might very well color the way one orders events in the real world. It is also the case in Arabic, but in the other direction. It is often that foreigners when faced with Arabic will claim that it reads in the "wrong" direction, but there is no right or wrong in reading directions. There are only conventions. So how strongly do these conventions affect the way we view the world?

Researchers have discovered a spatial bias in the ordering of agents in a visual and in the processing of events that is dependent on the primary language spoken by the subject; Israeli readers had a preference for an order of events that went from right to left, and German readers had an opposite preference (Dobel, Diesendruck, & Bölte, 2007). However, this preference was not found with Israeli and German preschool age children leading to them to conclude that this bias is brought about by the reading directions of the two script systems.

This is in line with a similar study with Italian and Arab subjects that was conducted a few years earlier. It turns out that Italians imagine the actions of a sentence happening from left to right, and the Arabs imagine it in the other direction (Maass & Russo, 2003). In other words, readers of the Latin script place the subject on the left of the object in a drawn illustration of the sentence, and this position is reversed for Arab readers. The study had an interesting element as it tested with Arabs living in Italy and in the Middle East, and those in Italy responded in either Arabic or Italian. The right to left bias was seen in the Arabs living in the Middle East, but no bias was found for Arabs living in Italy. The study did find that there is a small influence for left hemisphere specialization (the tendency to order events from left to right independent of language), but that effect is a third in strength of that of the writing system bias (Maass & Russo, 2003).

Indeed, there seems to be a language based bias in the inhibition of return of eye movement (Spalek & Hammad, 2005). In other words, once a person has moved their eyes from one position to another, there is a tendency to continue in that direction and a bias against going back to the initial position. This study found evidence that Arab readers have a bias for right to left orientation while English readers have the bias in the opposite direction (Spalek & Hammad, 2005).

On the other hand, when it comes to illustrating passive and active verbs in English and Arabic sentences, one study found no orthographic bias in terms direction of action, and the subjects in general preferred motions that moved from left to right (Altmann, Saleem, Kendall, Heilman, & Rothi, 2006). This seems contradictory to the results listed above, and is mentioned as a surprise result for the authors themselves; they recommend further studies using eye tracking in order to get a more detailed view of the subjects' preferences (Altmann et al., 2006) which would certainly be an interesting avenue to follow. It is important to note here that the English speakers in this study were monolingual, but there is no mention regarding the ability of the Arabic speakers to read English. As seen in the Maass and Russo study (2003), it is possible for Arabic speakers to lose that bias when they are interacting heavily with another language. This could explain the lack of right to left bias in this particular case.

Lastly, the issue of direction bias seems to be an issue of training, through the act of reading, of the parts of the retina involved in the direction of scanning, and so is an actual physical phenomenon. Reading and the reading direction result in an adaptation of the visual pathways and early visual processing system that helps to speed up word recognition (Nazir, Ben-Boutayab, Decoppet, Deutsch, & Frost, 2004). This training, however, is stimulus specific and only comes into effect with words, and not with unfamiliar non-words (Nazir et al., 2004). This might very well also explain the frequency effect.

Effect of Orthography on Reading

It would be difficult to test for the effect of orthography on reading measures within one script system. Unlike vocalization, the orthography of the Arabic language is not one that you can turn on or off. Arabic readers expect that Arabic letters are attached, and any attempt to test against this would have serious familiarity flaws. To that end, testing against Hebrew is the best possible option. Both languages are Semitic and written from right to left with the option to either include or drop out the short vowels. One such test compared the oral recitation of Arabic and Hebrew alphabets by bilingual subjects for whom Arabic is the first language; their performance was the same for both (Ibrahim, Eviatar, & Aharon-Peretz, 2002). However, when the alphabets were to be visually processed, their performance with Hebrew was better than with Arabic (Ibrahim et al., 2002). The similarity in performance results in the phonological task, and the differing results in the orthographic task, led the authors to conclude that it is the visual complexity of Arabic letters that slows down their processing. At this point one wonders if it is the actual form of letters that is increasing this complexity, or the fact that the Arabic script is connected. Most likely, it is both. The results of the previous test showed that reaction times for Arabic were significantly[6] higher than Hebrew whether the Arabic letters were connected or not though the difference was most pronounced in the connected form (Ibrahim et al., 2002). In other words, even when Arabic letters are in their isolated form, they require more time to be processed. This perceptual load increases when they are in the connected form.

A later study further supports this argument. Though Arab monolinguals showed the same level of phonological skills as Hebrew/Russian bilinguals, their performance while reading Arabic texts was poorer than the performance of these same bilinguals when they were reading Hebrew (Ibrahim et al., 2007). Analysis of the types of errors made in this study led the authors to conclude that the extra demands imposed by the visual complexity of Arabic orthography created a heavier

6 The effect reached statistical significance.

perceptual load, and therefore there was less attentional resources left for higher level processes related to syntax and comprehension (Ibrahim et al., 2007). Note here that both written Arabic and Hebrew share the status of a second language due to the diglossia present in the region. Also paramount to keep in mind, these subjects could presumably speak Hebrew as part of their life in Israel, but MSA is a language that one rarely speaks and as such is possibly farther away from the reality of daily life than Hebrew. This is not to say that the results do not stand, but simply that the situation is more complex and nuanced than one might at firsthand think.

Another chance to attest to the complexity of the Arabic script came through the comparison of naming tasks in Hindi and Urdu. The spoken languages are very similar, but Urdu uses the Arabic script (Rao, Vaid, Srinivasan, & Chen, 2011) usually in the Nasta'liq style of calligraphy. Comparison between the results showed that naming Urdu words was slower and less accurate than in Hindi, even though Urdu is the first script that the test subjects learned (Rao et al., 2011).

Another recent study also looked at the effect of the complexity of the Arabic script in comparison to Hebrew. Bilingual subjects were better able to detect a vowel symbol when it was set amongst Hebrew words than in the context of either connected or disconnected Arabic words and non-words (Abdelhadi, Ibrahim, & Eviatar, 2011). The study did not find a word superiority effect in Arabic, or an effect of lexical frequency as the reaction times in words and non-words were similar. The study did not show the visual samples presented, but did mention that the typefaces used were Times New Roman for the Arabic and Tahoma for Hebrew. These results can be attributed to one of two factors. If the samples were visually balanced so that the optical size for both scripts is the same, then the increased complexity of Arabic letterforms is to blame. If the two samples were not visually balanced, then the results can possibly be attributed to the relatively small body size of Arabic typefaces with regards to point sizes[7]. A small apparent size would make the detection of vocalization marks a harder task.

Still, one does not doubt the complexity of the Arabic script system as any reader of the script can testify. In fact, even students of Arabic as a foreign language face the same difficulty in decoding Arabic words and the writing system "major obstacle to the establishment of automatic word recognition, which is a prerequisite for skilled reading" (Hansen, 2010).

The Role of Vowels and Typeface Legibility

This section deals with the studies directly related to the experiment to be conducted and that can help answer the thesis questions regarding typeface legibility and the role of vowels. The section starts with the role of vowels in reading, and then moves on to eye tracking, brain imaging, and legibility studies.

Effect of Vowels on Reading Speed and Comprehension

Perhaps the first study on the effect of vowels on reading speed was carried out in France in 1987 (Roman & Pavard). It compared vocalized to un-vocalized Arabic

7 A 12 pt. Arabic typeface often appears much smaller than a 12pt. Latin one.

texts and found that the presence of vocalization reduced reading speed, increased fixation durations, and the total number of fixations. They found that gaze duration was 75 ms longer in vocalized texts. The authors attribute this to the vowels acting as either an extra "perceptual noise" or an extra layer of information processing to be done:

> "We must hypothesize that the presence of vowels, either constitutes a kind of perceptual noise (due for example for masking effect between lines), or induces an information processing process (syntaxic and semantic) carried by the vocalic morpheme. In either case, however, vowels delay access to the meaning of text" (Roman & Pavard, 1987, p. 436).

The authors conclude that Arabic words are accessed via a "consonantal lexical representation" (Roman & Pavard, 1987, p. 436). This extra time cost was present in both continuous reading as well as naming tests, and even when the task was naming a simple vocalized root (Roman & Pavard, 1987). Subjects were presented with double lexical decision task for words and non-words. The stimuli presented were either vocalized or not. The findings revealed that the vowels increased the lexical decision latency, even when the task was to identify the root only. The delay was on average 300 ms, though the authors attribute that amount of delay to the quality of screen display that the lexical tests were done on.

Bentin and Frost (1987) report on a series of studies in English where homographs are named faster than non-homographs, and homographs that had only one pronunciation were the fastest to be named. When they investigated lexical decisions and naming in Hebrew, they found that the inclusion of vowels delayed the lexical decision (deciding whether if it is a word or non-word status) of ambiguous words. This led the authors to conclude "that, in Hebrew, the information provided by the vowels is not absolutely necessary for lexical decisions" (Bentin & Frost, 1987, p. 20). They also found that the naming of homographs was highly in favor of the most frequent meaning of that homograph.

With regards to the reading of homographs, a study found that homographs take longer time to read (Gottlob, Goldinger, Stone, & Orden, April 1999). In a study related to homographs in Arabic, the results showed that vowels did not improve performance in reading comprehension and reading duration whether the sentence started with a homograph or not (Seraye, 2004). The author concludes that an adult Arab reader is able to fully comprehend text without the aid of the short vowels. In fact, reading time increased when vocalization was added which led to the conclusion that vowels were being processed during reading and not ignored (Seraye, 2004). This study had other relevant results: The addition of vowels (correct or not) increased reading times for both homographs and non-homographs, with the exception of high frequency homographs that were correctly vocalized. It also showed that the role of the context only comes into effect for homographs (Seraye, 2004).

With regards to reading accuracy, Abu-Rabia's research had shown that the addition of vowels, especially in the context of paragraphs, had increased reading accuracy for highly skilled Arabic readers (Abu-Rabia, 1996). The analysis of the types of errors encountered in such texts revealed that these problems were of two kinds: vowels processing and context matching leading to the conclusion that processing all of the vowels is a difficult task, even for highly skilled readers (Abu-Rabia, 1996).

Another study by Abu-Rabia looked at the effect of vowels on reading accuracy and naming ability of target words. The subjects were required to name the first word in a sentence, after which the rest of the sentence would be revealed to them. They were allowed to correct themselves once they started reading the sentence.

The beginning word was often a homograph and was usually read in its most frequent form. Skilled readers were better able to correct themselves once they recognized that the target word was actually another. The highest number of mistakes was in the un-vocalized condition where the target word was presented alone first (Abu-Rabia, 1997a). Skilled readers were better able to recognize their mistakes and to back track. However, one needs to be careful with labeling what "mistakes" are. From the errors presented in the paper, it is possible to see that skilled readers were mostly reading the homograph in one of its forms that just happens to not be the one needed in the sentence. In such a case, it is not a mistake in reading as much as a failure to predict which version is required. The conclusion that one can draw from this study is that predicting the intended pronunciation of a homograph without knowledge of the intended context or vowel assignment is simply a matter of probability based on the frequency of the intended meaning.

This conclusion is actually supported by another study by the same author which showed that the number of errors decrease when a word is presented in a sentence context or is vocalized (Abu-Rabia, 1997b). The subjects were presented with several tasks related to full texts and word lists and the vocalized conditions were being presented first (Abu-Rabia, 1997c). Because one has to take into account the learning effect and the effects of fatigue in a test environment, it is advisable to present the material in a balanced design and to offer the vocalized conditions first for half the subjects, and the un-vocalized first for the other half. This is something that the author corrected in later experiments and studies. The results here, though, are still in line with other tests on this subject.

In another study, Abu-Rabia (1998) modified the experiment set-up to present a balanced design and to include wrongly vocalized texts as well as to increase the age group and the kinds of texts being read aloud. The study showed again that accuracy was higher in vocalized conditions in all types of texts and for both poor and skilled readers. In the cases of wrong vocalization, these were not ignored but rather they resulted in mispronunciations (Abu-Rabia, 1998). Still, and in spite of added accuracy provided by the vocalization, the author had interesting observations:

> "Further, skilled readers did not find reading Arabic in any of the reading conditions to be an easy task. These results suggest that reading vowelized Arabic is not just a letter-sound correspondence, but it is distinguished by additional Arabic characteristics and factors that skilled readers have to master in order to read Arabic correctly. The Arabic reader has to process short vowels posted above and under the letters and other diacritics such as shadda and hamza. This is cognitively highly demanding even for skilled readers. Processing all the diacritics may demand more attention for eye fixation; in principle, this might result in extra demands on the reader and substantial fatigue. The reader has to bring to the text prior knowledge of literary Arabic in order to be able to process automatically all diacritics, especially those on ends of words. Vowelization of ends of words changes owing to the grammatical function of these words in the sentence. As mentioned above, the same word may be vowelized and pronounced differently in four sentences owing to its grammatical function in the sentence. Thus, reading this word in its four syntactic positions is linguistically highly demanding even for skilled readers." (Abu-Rabia, 1998, p. 116)

In a later study, Abu-Rabia tested the effect of vocalization on reading comprehension and again found evidence for improved comprehension results in the vocalized conditions for both beginning and advanced readers (Abu-Rabia, 1999).

When Arabic/Hebrew bilinguals read Arabic and Hebrew texts in vocalized and un-vocalized conditions, the results were consistent: Vocalized texts were read more accurately (Abu-Rabia, 2001). The subjects were also given the task to silently read vocalized/un-vocalized texts and were tested on reading comprehension. The results again showed improved comprehension results for vocalized texts (Abu-Rabia, 2001). The author explains the improved comprehension results with the argument that fully vocalized text is shallow orthography and therefore requires less cognitive efforts. This in turn has positive implications for reading comprehension. As to the context, it did not improve reading accuracy in vocalized conditions, but it did have an effect in un-vocalized ones (Abu-Rabia, 2001).

An interesting aspect of this study was the finding that the reading accuracy results could not predict the subject's comprehension results (Abu-Rabia, 2001). The author proposes that different processes are at play during silent vs. loud reading. This is possible but there is a much simpler explanation. Several of the word patterns that result in the same CV-skeleton are very similar in meaning and typically only one of these would be used to generate the various derivatives of a certain root. So, it is often the case that the general meaning of a word is understood at the time when it is not a hundred percent clear which pattern is being applied. For example, the simplest and most frequent noun derived from the root /qrd/, which implies the loaning of something, is *qurud̩* قُرُض which mean loans. However, it is a common mistake to say *qard̩* قَرْض which also follows a legal pattern. It sounds correct and reasonable except if one knows that this pattern is not the one to be applied. Such a mistake is spotted in reading aloud, but goes undetected in silent reading. It is not an issue of comprehension, since the meaning is perfectly understood, but rather having a wrong mental representation of what pattern that word follows. It is simply the case that it is very possible for a native speaker to use wrongly vocalized words, not because of lack of familiarity, but simply for not knowing any better.

That also goes for the vocalization on word endings. It is perfectly possible for the reader to fully understand what the text is saying and still be unable to deploy the correct mark. This is mainly due to the complex grammatical rules that the Arabic language has. This type of mistake is very frequent in public speaking occasions, as can be seen very often on TV. It is typically a source of derision when the public speaker is unable to properly vocalize his speech, but both the speaker and the listeners are able to fully comprehend what the words mean.

If anything, short vowels are almost a second-class citizen in the world of Arabic. Though a single short vowel can change the meaning of "kill" *qatala* قَتَلَ to "be killed" *qutila* قُتِلَ, that does not seem to reduce from the fact that the entire Arab nation reads its news and books with very few vowels inserted. Neither does it take away from how difficult it is to encounter an adult Arab reader who is able to correctly vocalize Arabic texts[8] without making any errors. So, in reality, accurately vocalizing Arabic texts is fortunately divorced from the ability to comprehend written Arabic. The second-class status of vowels is an attitude that native Arabic speakers seem to have imported into the reading of English as well. Studies looking at the difficulties Arabic natives face while studying English as a second language have found that these readers were less aware of English vowels than the control group (Hayes-Harb, 2006).

In later studies by Abu-Rabia, adding vowels to Arabic texts failed to be a reliable indicator of reading accuracy in naming exercises, or of reading comprehension in reading tests (Abu-Rabia, 2006). Indeed, the author concludes that "knowledge of the structure of the word was the best facilitator of reading rather than *active use of*

8 At least this is the case in Lebanon.

short vowelization" (Abu-Rabia, 2006, p. 103). These results are in apparent contradiction to earlier findings by the same author, who offers the following explanation for the different results:

> "All the Abu-Rabia studies used short vowelization of texts in experiments in passive conditions where readers had to recognize the posted short vowelization either for reading accuracy or for reading comprehension. The use of the available short vowelization on words or sentences facilitated reading accuracy and reading comprehension. In the present study, I used reading conditions in which the readers had to be more creative and decide where to post short vowelization. This demanding skill requires readers to possess knowledge of grammar and syntax. This maybe affected the power to predict reading and reading comprehension among both normal and dyslexic readers across all grades in this study" (Abu-Rabia, 2006, p. 103).

In other words, earlier studies were testing the effectiveness of adding vocalization to texts that the subject would then read. In this study, the test was the ability of the subjects themselves to correctly identify the short vowels to be added to a three-word sentence. That is the active use that was referred to earlier. The reasoning still is open to questioning as the ability to accurately read aloud unvocalized Arabic text (as in the earlier tests) is similar to the task being described in this study. The test of vocalization is in reality a test of grammar, vocabulary, syntax, and even comprehension. It is therefore a complex situation to navigate.

Still, the fact that this ability to post the correct vowels, or rather the lack of it, does not impede reading comprehension is very interesting to note, and is as mentioned earlier. It is further evidence that, once the reader has mastered Arabic morphology, short vowels form a superfluous level of information that is only really needed to clarify homographs that the sentence context leaves ambiguous. The vowels improve reading accuracy, might or might not improve comprehension—there are contradicting results there—but they reduce reading speed. The question then is which is more important, accuracy or speed? There is a trade-off between the two and one expects that for younger readers, accuracy and comprehension are the most important, and speed becomes more important once the reader has fully mastered the language.

Results of Eye Tracking Studies

The first use of eye tracking in the study of Arabic was by Gray in 1956. In it he found that Arab readers made more regressions than readers of English (Gray, 1956). His data showed that in silent reading, Arab readers read 1.4 words per fixation, while they read 1.3 words per fixation in oral reading.

The second eye tracking study was the commonly cited one by Roman and Pavard (1987) which further expanded the use of eye movement in the study of Arabic language. The set up was simple: compare the reading of French and Arabic texts that are direct translations of one another. The number of words used in French is 1.5 times that of Arabic, which is typical of Arabic linguistic density as one can pack propositions and articles into verbs or nouns to make word phrases. The findings of this study are very important since this is the only study to have linked eye movement to the linguistic content being read. So, the metrics of eye movement are no longer abstract numbers but rather the units of measurement of comparable but different linguistic entities. The average fixation duration in Arabic was 342 ms, and 215 ms in French, also a ratio of 1.5 times. The authors argue that the total reading time is almost the same, though the number of fixations and fixation durations differ, and that the reading speed (of words per minute) is the same (Roman & Pavard, 1987).

Another comparison of French and Arabic came a few years later though this time in relation to fixation positions. As mentioned in chapter 5, the fixation positions while reading in Latin script are usually biased to the left of the word center. The question when addressing this issue in Arabic was: is this bias also present, or would one see a reverse direction? Farid and Grainger (1996, pp. 352–354) proposed 3 possible scenarios as to what one can expect in fixation positions in Arabic:

. "Hemispheric specialization": There is a tendency to place more text in the right visual field as it is easier to be recognized there. Therefore, fixations will fall towards the left of center in order to maximize that benefit. They do not fall too far off in order not to keep most of the word in the fovea.

. "Reading habits and the perceptual span": The perceptual span is asymmetric and is biased in the direction of reading and attention. Therefore, the same logic will produce a reverse if the directionality in Arabic. The fixations will fall to the right of center.

. "Lexical constraints": The beginnings of words in English and French have higher lexical constraint, and research had shown that the fixation positions move to the right when the end of words holds more relevant lexical information. Therefore, they propose that the fixation positions would not be governed by writing direction but rather by the "distribution of critical constraining information in the stimulus word."

By manipulating the morphological structure of the target words, Farid and Grainger found that the distribution of fixation is not shifted in either direction, is actually symmetrical, and is in fact biased by the morphological constraints of the target word. The fixations moved to the left when the word ends were more informative, and to the right when the beginnings had more lexical constraint. Moreover, these results were not found in French, and the knowledge of French did not bias the results when the subjects were reading Arabic (Farid & Grainger, 1996). Rephrase: knowledge of French did not affect eye movement behavior.

The authors offer very interesting reasoning behind the difference in results: the omission of short vowels in Arabic heightens the importance of the morphology in lexical access since the reader must analyze the consonantal structure in order to deduce the phonology of the words presented (Farid & Grainger, 1996). This information is clustered around the root morpheme and so the fixations follow where the root goes. It is also likely that the reader gravitates towards the root as it provides the entry point to lexical access. Later studies cited in the previous sections have gone on to show the importance of morphology in reading Arabic, and so it stands to reason that this critical role has an effect on eye movement during reading.

Another explanation to the symmetrical distribution of the optimal viewing position in Arabic could be the learning effect that parts of the retina are conditioned to via the continuous reading process (Brysbaert & Nazir, 2005). The authors offer the following arguments: continuous exposure of stimuli on a specific location within the retina trains that area for better word processing, and because of that words are processed faster when the fixation is at the beginning of the word rather at the end. This is because fixations often undershoot their target at the center and end up landing more towards the beginning. This explains the leftward bias in left-to-right languages. As to the right-to-left languages, the hemispheric specialization argument calls for having a larger portion of the word to occur in the right visual field. So, the visual training offsets the OVP (optimal viewing position) towards the right, and the hemispheric specialization pushes it towards the left resulting in a symmetrical distribution (Brysbaert & Nazir, 2005). This might seem as a valid line of argument, though it does not explain the morphological effect, nor does it take into account the hemispheric activation levels during the reading of Arabic. This will be further discussed in the next section.

Given the morphological similarity between Arabic and Hebrew, it is interesting to see what sort of eye movement information has been gleaned regarding the reading of Hebrew text. Deutsch and Rayner (1999) compared target words with different lengths and inflectional morphological construction. For example, they compared the preferred viewing position in 5-letter nouns, and 3-letter nouns in the plural (adding 2 letters for that). The results showed that preferred viewing location is usually on the 3rd letters of the word and on average is to the right of the center (opposite to English), and this position was unbiased by morphology (Deutsch & Rayner, 1999).

However, the study has also found that the optimal viewing position is actually affected by morphology (Deutsch & Rayner, 1999). If the root was at the center of the word, performance was better when the fixation was on the left side of the word. When the root was at the beginning, there were better performances when the fixation was on the right (beginning) of the word. When the root was spread out, the performance was the same for fixations on either side (Deutsch & Rayner, 1999). Comparison between the morphological structures in the set of experiments showed that inflectional did not affect fixation positions but derivational morphology did. The authors argue that this is most likely due to the role that the root morpheme plays in lexical access.

Hemispheric Specialization

The studies of eye movement in reading Arabic tend to develop into the discussions regarding hemispheric specialization and the different roles they play in reading. Stimuli presented in the left visual field are processed by the right hemisphere in the early stages of processing, and similarly those presented in the right visual field are process by the left hemisphere. Language processing is primarily taken on by the left cerebral hemisphere (Al-Hamouri et al., 2005) though it seems that this is not the full picture when it comes to Arabic.

Medical records have shown that an Arabic reader, one who has sustained brain damage to the left hemisphere and consequently suffered language impairment, had managed a quick recovery in reading and writing, which lends support to the argument that the right hemisphere is involved in Arabic reading and writing (El Alaoui-Faris et al., 1994). The authors postulate that this recovery is most likely due to the particulars of the Arabic writing system.

When brain scans[9] of Arab readers were done, these were the results:

> "Brain magnetic activity sources associated with language function were found in four broad regions for both hemispheres for Arab as well as for Spanish participants: the temporoparietal cortex (including the posterior part

9 Using magnetoencephalography (MEG), which records magnetic fields generated by the electric currents in the brain. It also gives direct information regarding neural activity in the brain as well as their location (Hämäläinen, 2007).

> of the middle and superior temporal gyri and the angular and supramarginal gyri), the mesial temporal cortex (hippocampus and parahippocampal gyrus), the inferior temporal areas and the inferior frontal and insular regions, all of them reported in previous studies as areas associated with language processing." (Al-Hamouri et al., 2005, p. 1862)

However, a time analysis of the results showed that in the early timeframes after exposure to the stimulus (200–500 ms), both Spanish and Arabic readers showed equally higher levels of activation in the left hemisphere. However, in the 500–700 ms timeframe, the Arabic readers showed levels of activation in the right hemisphere that was almost equal to that of the left, while the Spanish readers maintained the same level of lateralization (Al-Hamouri et al., 2005).

As to why this is observed, the author offers a very intriguing explanation: the left hemisphere has been shown to be able to quickly assign the most frequent meaning to ambiguous words (like homographs) while inhibiting others. The right hemisphere, on the other hand, is able to hold all possible meanings of a word for a longer period of time. This, the author argues, is an essential quality needed for the reading of un-vocalized Arabic (Al-Hamouri et al., 2005).

More clarity for the involvement of the right hemisphere in reading Arabic also came from traditional psycholinguistic studies. A CVC (consonant vowel consonant) grapheme-to-phoneme conversion test was presented to the subjects with the stimuli falling either in the left visual field, the right visual field, or both. Results showed that, compared to Hebrew or English readers, Arabic readers needed more exposure time to the stimuli in order to achieve a 50% error rate (Eviatar & Ibrahim, 2004). This is most likely because Arabic letters were presented separated, and so reading the 3 letters as one syllable takes more effort (Taouka & Coltheart, 2004) than in scripts where this is not an issue. The authors have made the same argument as well.

The study also showed better performance when the stimuli were presented in the right visual field, and when they were presented to both hemispheres. It was also the case that the error rates showed that reading Hebrew and Arabic was not done serially, most likely due to the need of the reader to apply a pattern in order to arrive at the phonological information, and for that words need to be read as a whole (Eviatar & Ibrahim, 2004). Also interesting was the finding that readers of Arabic made the most mistakes when stimuli were presented in the left visual field. In such a case, the right hemisphere is not assisting word processing in a visual stimulus capacity. This is in line with the low activation of right hemisphere in the first 500 ms after stimulus exposure. It is logical then to follow Al-Hamouri et al.'s argument that the right hemisphere is assisting in higher-level processes like the prolonged activation of word meanings.

Tests of letter matching showed that for subjects who were fluent in both these languages, the processing of their native Arabic letters was more difficult that the processing of Hebrew ones (Eviatar, Ibrahim, & Ganayim, 2004). This was attributed to the higher level of visual complexity within the Arabic script (Eviatar et al., 2004), but not to the fact that it is partially connected as the letters were presented in their isolated form. This difficulty was even more pronounced when the stimulus was presented in the left visual field (Eviatar et al., 2004). Indeed, it seems that the right hemisphere struggles with the encoding of Arabic letters. Within the same study, the subjects were given a letter-distinguishing task with sets of various Arabic letters, and the results were quite important to note: The right hemisphere is unable to distinguish between letters that look similar such as letters that share the same structure but are differentiated by the position and number of dots (Eviatar et al., 2004). This difficulty is limited to Arabic letters and not to Hebrew and English (Ibrahim &

Eviatar, 2009). Luckily for Arabic readers, the left hemisphere is able to distinguish between Arabic letters (Eviatar et al., 2004).

The inability of the right hemisphere to distinguish between similar letters has actually also been demonstrated in an inability to recognize words (Ibrahim & Eviatar, 2012). This study presented native speakers of Arabic, Hebrew, and English with unilateral or bilateral[10] samples of words and non-words in order to gouge the extent to which the two hemispheres interact in lexical decisions. The results showed that there was integration between the 2 hemispheres for both Hebrew and English. In the bilateral presentation for Arabic, when the left hemisphere was distracted by another stimulus, the right hemisphere was unable to perform lexical decisions at above chance level (Ibrahim & Eviatar, 2012). The right hemisphere then is unable to recognize words on its own and needs the support of the left hemisphere in order for word processing to proceed (Ibrahim & Eviatar, 2012).

So, the emerging view of the involvement of the right hemisphere in reading Arabic is less of a visual analysis and more of a linguistic one. As it turns out, lexical decision tasks were faster when the roots was apparent within the word structure and can be readily extracted (kudos to morphological effects again), and this effect was more pronounced in the left visual field (Eviatar & Ibrahim, 2007). The right hemisphere is thus more sensitive to the root, and the left hemisphere, it also appears, is more sensitive to the structure of the word and all in all word processing is a bilateral task (Eviatar & Ibrahim, 2007). The sensitivity of the right hemisphere of Arabic readers to morphology and the overall reading strategy are extended to their second languages as well (Ibrahim & Eviatar, 2009), and this recalls the finding that native Arab speakers have problems with vowels while reading English, as mentioned earlier in this chapter. The right hemisphere is also able to unilaterally reject non-words in a lexical decision task but word processing in Arabic requires a significant amount of coordination of both hemispheres (Ibrahim & Eviatar, 2009).

Recent studies have shown that the left fronto-temporal brain network, which is usually associated with the processing of linguistically complex text, is activated during the processing of all Arabic words that have complex morphology (Boudelaa, Bozic, & Marslen-Wilson, 2010). There is still much to learn regarding the two hemisphere's involvement in the reading of Arabic and so this field of study is still very much open for further investigation.

Some of the results of tests with the Arabic language are also consistent with results from other languages using the Arabic script. When Urdu text, which uses the Arabic script but is a very different language, was presented to native speakers, fewer errors were made when the words were presented in the right visual field (Adamson & Hellige, 2006). Moreover, it seems that letters are processed more serially than words and non-words, and more so in the right visual field than the left one (Adamson & Hellige, 2006). Therefore, the inability of the right hemisphere to identify Arabic letters is true to different languages using the Arabic script.

Legibility Studies for Arabic

The review of Arabic legibility studies is unfortunately very short as there are only a handful of studies to go over. One study compared the relative legibility of the Arabic versions of Times New Roman and Courier in 3 different sizes, and with subjects of normal and simulated low vision (Alotaibi, 2007). The subjects were asked

10 The visuals were presented in either one of the two visual fields or in both.

to read a sentence aloud and reading speed and reading rates were calculated. The results showed that the reading performance improved with the largest of the 3 sizes tested (8, 10, and 12 pts.) and that this improvement was greater for Times New Roman (Alotaibi, 2007). As with many of the legibility studies for the Latin script, this experiment encounters a few problems. Courier Arabic has seriously deformed proportions as the letters have been stretched into a mono-spaced grid and so the actual word shapes are sometimes so misshapen that it is no wonder that the reading speed decreased. The spacing is much wider than in Times New Roman, the weight obviously lighter, and the optical size also bigger. These are differences that might very well have affected the reading speed. However, the main issue is that Courier is not a typeface that one often uses for Arabic, and so even when the conclusions are formed, it is not a finding that one can take into real life applications. Still, it is good to have evidence for the detrimental effect of small sizes on reading in Arabic.

Similar to the effect of small sizes is the effect of low resolution in dot-matrix displays. Another study researched various low resolutions and pixel shape (square or round) and color on the legibility of Arabic letterforms (Al-Harkan & Zaki Ramadan, 2005). The results showed better performance with higher pixel density, square rather than round pixels, and density ratios that were squarish rather than rectangular in format (as in 8x8 instead of 7x9) (Al-Harkan & Zaki Ramadan, 2005). Green text was rated as more comfortable than red (Al-Harkan & Zaki Ramadan, 2005), but that is very likely due to the nature of these colors and not related to Arabic specifically. Green on black has more contrast than red on black, and the eye shows much higher sensitivity to the color green (NDT, 2012). This is not to discount the psychological associations of the 2 colors.

As to the use of eye tracking in Arabic legibility studies, one study published in 2010 looked at the relative legibility of 6 different Arabic typefaces (Al-Dosary, Al-Salloom, & Al-Rashid, 2010). The typefaces are presented at 14 pts. and legibility is measured via the total reading time needed to read aloud short paragraphs as well as the accuracy and gaze intensity[11] (Al-Dosary et al., 2010). The results showed that Arial has the fastest reading time and highest level of accuracy. It was also judged by two thirds of the participants as the most legible of the 6 typefaces presented. These were: Andalus, Traditional Arabic, Simplified Arabic, MS Serif, Courier New, and Arial Unicode. Andalus had the lowest scores as well as the most number of fixations as presented in the visualization of the eye movements.

With regards to the typefaces tested, Arial and MS Serif appear much bigger than the other 4 when they are all used at the same point size as was the case here. Therefore, it is not surprising that they get the highest scores. To avoid such pitfalls the design of the materials used could have adjusted the typefaces used in order to appear visually equal in size.

The use of eye tracking within the method gives a lot of detailed information with regards the reading process, and the visualizations presented offer a glimpse of that. The findings would be better supported if this data were to be analyzed, and if inferential statistics were reported so that one can be certain that the results are statistically significant and are not due to chance. One can argue, also, that reading out loud is not the most suitable test procedure to be coupled with eye tracking. Reading out loud is slower than silent reading and the pattern of eye movement is somehow different as the eyes cannot proceed smoothly but need to wait for the reading aloud to catch up.

11 The authors do not define the measure for gaze intensity.

In terms of information collected with eye tracking, the number of fixations and other measures of fixation durations would have shed further light on the relative legibility of these typefaces, and so the visualizations alone are not enough. The only evidence of eye tracking presented is in the comparison of the visualizations of eye movement while reading in Arial and Andalus. However, this is a qualitative comparison with Andalus showing higher density and longer fixations. One expects this is what the authors refer to as gaze intensity. Still, this is unmeasured and, as such, one cannot confirm the statistical reliability of the results.

Another experiment using eye tracking, also in 2010, studied the effect of size on legibility. Subjects read aloud 6 different paragraphs set in Simplified Fixed Arabic and Traditional Arabic at 12, 14, and 16 pts. (Al-Wabil & George, 2010). The results showed faster reading speed and lower fixation durations the larger the size, and Simplified Fixed Arabic also had faster reading speed and less fixations than Traditional Arabic (Al-Wabil & George, 2010). Similar to the previous study, there is no reporting of inferential statistics so one cannot know if these results are statistically significant, though the numbers shown do exhibit a strong trend.

There are not any other Arabic legibility studies, at least none that this research could uncover. It is, therefore, a field wide open for further exploration. Though one might be discouraged by the lack of research, it is certainly exciting to know that so much more still needs to be discovered.

Conclusions

The Arabic language, the Arabic script, and Arabic typographic norms are very intricately intertwined. The study of reading Arabic necessitates the research of the exact way in which the visual presentation of text affects word processing. It is as much about typeface design, as it is about the writing system and the way it interacts with the Arabic language.

Though the studies related to Arabic reading and legibility are relatively few, one can start to see a picture taking shape. On the one hand, you have a language that is very orderly formed on a system of roots on which word patterns are applied to form the Arabic lexicon. These word patterns provide the vocalization of the resulting words and so are essential for proper pronunciation. On the other hand, you have a writing system that is visually very complex and, to make things worse, usually makes away with the visual representation of vowels resulting in many distinct words that look the same but are pronounced differently. The resulting conundrum is further complicated by the fact that the written version of Arabic is practically a new language for Arab children. It is a language that has less consonants and more vowels, and yet, against all these odds, they do learn how to read. That process, though, is one that so shapes their entire reading strategy that they will take it over into the reading of other languages, and even into the way they see the world.

As to how they manage to read, it all seems to go back to the root. It is, though some might argue, the most basic lexical unit in Arabic, one that it is so strong and ubiquitous that it serves as the lexical entry point for Arabic words. The root has strong priming abilities, and its effect is so magnetic that it pulls the optimal fixation position towards it, wherever it might be distributed in the word.

The words themselves are no easy visuals to process either. The script is connected and even when the letters are isolated, they are still more complex to their native readers than other scripts like Hebrew and Latin. In fact, they are so complex that the right hemisphere sometimes cannot even tell them apart. This is not to say that the right hemisphere is not engaged in the process of reading Arabic. Quite the contrary, brain scans have shown much higher levels of right hemisphere activation levels than what one sees in other languages.

And it is not just brain activity that is different in Arabic, eye movement is also particular. The fixation averages are longer, and the fixation positions are also exhibiting different patterns. As to the effect of typeface design on eye movement and reading in general, very little information is there. This is where this research comes to play.