Visual Word Recognition in Arabic: Towards a Language Specific Reading Model

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1. Introduction

In the course of the last few decades, reading research, which has traditionally taken English and other Western European languages as its part of departure, has spread to other parts of the world, and researchers with insight into other languages have started to look into reading-related matters from a broader cross-linguistic perspective. At the same time, reading research has been increasingly concerned with word recognition, considering this to be a crucial sub-skill within the reading process, and today reading researchers tend to agree that sub-word entities such as syllables, letters, and even letter segments, play an important role in reading – at least in alphabetic languages.

However, even though reading is definitely thought to be a linguistic process, the core aspects of reading theory and the reading models presented in general literature still seem to consider reading as being a more or less universal process.

This paper is an attempt to view reading theory from a language specific perspective. With Arabic as an example, critical aspects of word recognition are examined and analysed in order to question the universality of the dominating theories about how reading processes proceed at the cognitive level during reading, and based on a review of research considering word recognition in the Semitic languages, a language specific description of word recognition processes in Arabic based on a connectionist reading model is proposed.

After an introduction to the core concepts and language specific features which are central for the further analysis, a connectionist reading model is discussed and adjusted in order to serve the purpose of the paper. Then, the aspects of Arabic script and orthography are treated individually in relation to the proposed reading model, and finally, an attempt is made to make a collective description of how word recognition processes develop in Arabic, with our knowledge of reading in English and other European languages\(^1\) as a comparative framework.

As the paper is believed to be of possible interest to both reading researchers who are not very familiar with Arabic, and to arabists who are not very familiar with reading theory, the text is constructed to serve the needs of both

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\(^1\) Throughout this paper, ‘European languages’ is used as a short term for ‘Indo-European languages which are written in the Roman alphabet’.
groups. Thus, it includes explanations of aspects which might seem trivial to one reader but could be unfamiliar ground to the other and vice versa.

Being a working paper, the text – or at least the copy on the authors hard disk – is being altered and updated continuously, and any criticism, comments and suggestions from readers would be highly appreciated. Please send an email to: g.funder@hist.sdu.dk

I would like to thank my friend and colleague, Kirstine Sinclair, for reading, commenting on and correcting my English in a previous draft of this manuscript.
2. Conceptualisation of language specific features

When approaching the question of possible language specific elements of word recognition processes, we must bear in mind that the concepts we are using do not necessarily take into account whether they describe elements which are general or specific to particular languages.

Below, the concepts of script and orthography are defined, and Arabic script and orthography are briefly described in order to give readers without prior knowledge of Arabic an overview of the language specific elements at stake.

2.1 Script and orthography: Definitions

In the literature there seem to be a lack of consistency in the use of the concepts script, orthography and writing system, and more clearcut definitions of these concepts are indeed necessary in order to address the question of how reading processes in Arabic can be distinguished from reading in the European languages.

In everyday speech, script is often used as to describe a form of writing style, e.g. handwriting or calligraphic script. In an European context, orthography is primarily used (in accordance with its direct translation from Greek) as ‘correct spelling’, while ‘writing system’ is often understood as a glottographic symbol system (a system of graphic forms which reproduce speech acts – in opposition to semasiographics which are language independent, e.g. pictograms) (Elbro 2001). This overlaps with the French researcher Sirat’s definition of ‘l’écriture’:

"L’écriture est le système de signes graphiques utilisés dans les diverses civilisations. Elle est liée à la langue orale qui l’a précédée dans le temps." (Sirat 1990)

Two Israeli researchers who were among the pioneers to research reading across writing systems, Katz & Frost, define script as ‘a set of symbols’ (Katz & Frost 1992), while the German reading researcher Scheerer states:

"A script is defined by the set of characters it uses and by the mapping principle on which it relies. […] when considered with reference to languages using them, scripts become writing systems." (Scheerer 1986:263)
In *The Blackwell Encyclopedia of Writing Systems* (Coulmas 1996:454) script is defined in accordance with this as 'the graphic form of a writing system'. But Coulmas also states:

"The same writing system may be written in a variety of scripts. For example, the Roman, Cyrillic, Greek, Russian and runic scripts are different graphic instantiations of the same writing system, the alphabet." (Coulmas 1996:454)

Here, *writing system* seems to be what Scheerer calls 'the mapping principle' and not a graphical representation. And this implicit definition of *writing system* does not entirely match Coulmas' own definition of this very concept:

"Writing system: A set of visible or tactile signs used to represent units of language in a systematic way, with the purpose of recording messages which can be retrieved by everyone who knows the language in question and the rules by virtue of which the units are encoded in the writing system." (Coulmas 1996:560)

In this definition, *writing system* seems to be the same as *script*.

Furthermore, in a great deal of literature about reading processes published in English, the term *orthography* seems to be used as a meta-designation of it all, thus not only broader but actually entirely different than in the European tradition. Only few authors using these terms have tried to address this conflict. An exception is Scheerer who favours ‘orthography’ to be used unconditionally as ‘correct spelling’ (Scheerer 1986). In contrast to this, especially American authors tend to use the concept as the visual expression of the writing system, e.g. the reading and cognition researchers Carr & Posner who define *orthography* as ‘the visual organization of the writing system’ (Foorman 1994:334) which is in obvious opposition to Scheerer’s definition of *script* og Coulmas’ definition of *writing system*. In reading research, such vague concepts of course have implications, and as Willows & Geva point out:

"[...] it is fairly common in the growing literature on orthographic processing for researchers to refer to orthographic processing as ‘visual/orthographic’ as though these two terms were essentially synonymous" (Willows & Geva 1995:356)

In fact, in recent American literature *orthography* is used to cover all language specific elements of writing. In this sense, orthography is viewed as the way in which a language is written, thus both spelling rules, script and writing system are covered by the term orthography (e.g. Seidenberg 1992:85).
In order to establish useful and well-defined terms for this work, I will merge Elbros, Katz’ and Scheerers definitions (Elbro 2001:56; Katz & Frost 1992:68; Scheeer 1986:263-264) to the following: A writing system is a system for graphic representation of a language, and the script is the set of graphic symbols which the writing system makes use of. Thus, the Roman alphabet, the Arabic alphabet, the Japanese syllabic systems and the Chinese characters are different examples of writing systems wherein the script is the designation of their graphic manifestation. Furthermore, in this paper, orthography is the language specific characteristics of written language, thus both linguistic structure mapped by the writing system and specific spelling rules, e.g. the Korean Hangul’s system of signs symbolising articulation of the phonemes, they represent. In this sense, ‘orthography’ is understood as a complementary rather than overlapping concept in relation to the ‘script’, so that script represents the ‘outer’ dimension, while orthography represents the ‘inner’ dimension of the writing system.

<table>
<thead>
<tr>
<th>WRITING SYSTEM</th>
<th>SCRIPT</th>
<th>ORTHOGRAPHY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graphic dimension</td>
<td>Mapping principle incl. spelling rules</td>
</tr>
<tr>
<td></td>
<td>Not language specific</td>
<td>Language specific dimension</td>
</tr>
</tbody>
</table>

Insert 1  Writing system, script, and orthography

To summarise, the writing system – as illustrated in insert 1 – is the system for graphic representation of a language, where the script is the designation of the graphic dimension which is independent of the language in question, while orthography is the language specific dimension which in principle is independent of the script. The sum of script and orthography is then the writing system. Thus, the Arabic writing system covers both Arabic script – the Arabic alphabet and the remaining graphical signs used in Arabic writing and the root-and-pattern based morphological structure specific to the Semitic languages.

2.2 Script and orthography: Description

Arabic script is written from right to left. The alphabet consists of 28 letters. The script is cursive, and most letters take slightly different forms depending on their position within words (initial, medial, final). Six letters are never connected to the left, thus for these letters the medial and the final forms are
identical. As is the case for the Roman script, borders of words are marked by a space between them. All letters of the Arabic alphabet are consonants. The writing system is consonantal, which is conveyed in the practice of only consonants and long vowels being marked by letters, while short vowels are omitted or marked by diacritics. Besides these, there is an ‘aiding system’ which adds additional phonological information - primarily vocalisation: Three letters, alif, waw and yaa (ا, و, and ی) carry a double function and represent long vowels in some cases. Furthermore, a set of diacritics can be used to mark short vowels, case endings and consonant doublings. These take form of minor strokes or curls, which are placed above or beneath the letters, and compared to the letters their graphical significance is modest (see insert 2). These diacritics are normally omitted, except in some religious and poetic texts and literature for children and beginning readers. In Arab countries, children are slowly introduced to texts without vowels from the third grade, and from around sixth grade the bulk of text material children read in school is without diacritics. In any kind of text, single diacritics can be applied when meaning could otherwise be ambiguous and the ambiguity is not directly clarified by the context.

Arabic morphology is by both Arabic and Western linguists described as a three-consonantal, root-based system which is unique for the Semitic languages. The bulk of Arabic words are constructed by (at least) two morphological entities: a root consisting of three consonants carrying a ‘core meaning’ of action (normally in form of a verb in perfect tense, 3. person, masculine, singular) and a limited number of sets of pre- in- and suffixes, called patterns. In verbs, 10-12 (the number varies according to different

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2 In this paper, the terms ‘voweled’ and ‘vowelisation’ will be used to describe script with diacritics. These terms are disputed, especially among arabists, but used in a number of publications about reading in Arabic - despite the fact that application of diacritics do not only involve short vowels but also consonant doublings, case endings, and additional pronunciation cues. Literature on reading in Hebrew often use the term ‘pointing’ which in principle represent the same thing, but is related to the use of dots in the Hebrew diacritical system which is not the case in Arabic where diacritics are more graphically varied and take the shape of short strokes, curls, circles, etc.
linguistic ‘schools’) patterns provide information about e.g. causal or reflexive aspect. Within the remaining word classes the system is elaborated. Substantives can be independent but are often derived from one of the 10-12 groups of verbs, and adjectives are derived from either verbs or independent substantives. A root is often represented in only a few of all these sets of patterns, and in relation to the semantic value of these morphemic constituents, the system is far from consistent. In some cases, the described relation between the patterns is twisted or not present at all, and in other cases it can be difficult to detect a semantic relationship between words sharing the same root. Such inconsistencies are of course due to linguistic developments through history, and the system is still sufficiently coherent to enable Arabic-speakers to make use of it as a directional tool for retrieving the meaning of an unknown word.

<table>
<thead>
<tr>
<th>الجذر</th>
<th>الفيل</th>
<th>اسم الفاعل</th>
<th>اسم المكان: مفاعل</th>
</tr>
</thead>
<tbody>
<tr>
<td>لد ب</td>
<td>[k-t-b]</td>
<td>كاتب</td>
<td>[kaṭaba]</td>
</tr>
<tr>
<td>ش ه د</td>
<td>[s-h-d]</td>
<td>شهيد</td>
<td>[ṣabīta]</td>
</tr>
<tr>
<td>ح ب خ</td>
<td>[t-b-x]</td>
<td>طبخ</td>
<td>[ṭabaḥasa]</td>
</tr>
</tbody>
</table>

Insert 3  Example of word formation in Arabic: Three roots and three patterns

Insert 4  Example of Arabic homographs
As some patterns only differ in the short vowels, unwoveled text is plentiful in homographs. A simple example of this rather frequent occurrence of Arabic homographs is shown in insert 4. Also, Arabic words are often very information-dense, as articles, prepositions and pronouns are often internalised as affixes while subjects are often implicit in verbal conjugations.

While reading direction and letter architecture are unequivocally graphical aspects, the third dimension is more complex. Besides the fact that words consist of fewer letters, the reduced phonological information and the morphological structure distinguish Arabic from the European languages that are the basis of current reading theories and might be crucial factors in how written words are recognised.

An additional important aspect of Arabic when comparing reading processes in Arabic and in other languages is the diglossic situation, as the distance between spoken and written Arabic is much more pronounced than what is the case in European languages. According to Ferguson’s traditional concept of diglossia, we are dealing with a binary understanding of a ‘high’ language variety (H) versus a ‘low’ (L) language variety, where H is one standardised form of language used in writing and speaking in formal settings, while L is the collective of local dialects used for informal, oral communication (Ferguson 1959). In reality, it would be more appropriate to describe the phenomenon in Arabic as a continuum from the so-called classical language, used in religious texts and traditional forms of poetry, over Modern Standard Arabic (MSA), the modern written language of media and contemporary literature also used in speaking in very formal settings, and different varieties of Formal Spoken Arabic (FSA) which combines the prestigious from the H variety with the informal and structurally simplified from the L variety (El-Hassan 1978; Ennaji 2001; Meiseles 1980; Mitchell 1986; Ryding 1991), to the altogether informal dialect which is used in the family and among people with no or little education — and more or less the complete spectrum is at play in the sociolinguistic behaviour of the educated Arab (Walter 2003).
3. A connectionist word recognition model

In this section, a theoretical model of word recognition applicable to Arabic is outlined and discussed. The traditional dual route model and its shortcomings in general and in relation to Arabic specifically is described, and a connectionist model which take both letter recognition and general word recognition processes into account is developed.

3.1 Shortcomings of the dual route model

For many years, the theoretical discussion about word recognition focused on the extent to which readers rely on phonological vs. lexical ‘routes’ to the mental lexicon. The outset was linguistic descriptions of the correspondence between letters and sounds in English words which were categorised as either ‘regularly’ or ‘irregularly’ spelled. Psychologists argued that significant differences in subjects’ reading speed when decoding regular and irregular words respectively, imply that the two types of words are processed differently (Henderson 1984:3). This did not exactly match the traditional view on word decoding according to which a rule based recoding or ‘translation’ from grapheme to phoneme was applicable to any kind of input. The findings were explained by a ‘dual route model’: Besides the phonological decoding of letters into sounds which leads to recognition of the word and its meaning, there had to be an alternative, more direct route to lexicon, by which words are recognised as lexical entities. While regular words could be recognised through both routes, recognition of irregular words had to be a product of the lexical route, as rule based letter-to-sound correspondences do not apply, and reading of pseudo-words must be a product of the rule-based phonological decoding, as they are not recognisable, lexical units (Henderson 1982:111-169; 1984:3).

The dual route model is supported by experimental research revealing that irregular words are read faster than pseudo-words (supposedly because irregular words are decoded directly, without involving the phonological level of processing) and that regular words are read faster than irregular words (supposedly because regular words are decoded through both routes at the same time), though the difference is very small for high-frequency words but very significant for low-frequency words (supposedly because all words are predominantly decoded through the direct, lexical route when readers have encountered them a sufficient amount of times) (Rayner & Pollatsek 1989:87-93).

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5 Only if a word’s pronunciation follows the rules defined as the most commonly applied phoneme-grapheme correspondence, its spelling is considered to be ‘regular’ (Venezky 1970; Wijk 1966).
Moreover, neurological research revealed isolated phonological dyslexia in brain damaged subjects: They are able to read but cannot decode pseudo-words (apparently because only the phonological route to lexicon has been damaged). Likewise, other patients were found to display ‘surface dyslexia’: They are able to read both regular words and pseudo-words, but they cannot read irregular words and homophones correctly (apparently because only the lexical route to lexicon is damaged) (Coltheart & Coltheart 1997; Miceli et al. 1997; Rapp et al. 1997; Rayner & Pollatsek 1989:393-435).

In recent years, the dual route model and its underlying basis of empiric research supporting the model has been under heavy critique due to new theories of word recognition gaining ground. Among such methodological points of criticism is the extensive use tests employing pseudo-word reading (to ensure phonological decoding, since these words do not exist in the mental lexicon) and lexical decision tasks (in which subjects are to e.g. indicate which of two different but phonetically identical strings of letters is a valid word in order to ensure lexical decoding). However, is has been questioned whether it is in fact possible to view phonological and lexical processes as totally separable from each other and other cognitive processes activated during reading (e.g. Berninger 1994; Geva & Willows 1994; Seidenberg 1992; Vellutino et al. 1995). Furthermore, the neurological support for the dual route model has been questioned as well: Isolated surface dyslexia or phonological dyslexia is most often acquired through brain damage while developmental dyslexics find both phonological and lexical decoding difficult, and according to some critics, this entirely undermines the credibility of the dual route model (e.g. Foorman 1995:397).

Based on such arguments, some researchers are advocating for a modified and more flexible type of word recognition model, in which phonological and orthographic processes are more integrated (Foorman 1994, 1995; Seidenberg 1992; Vellutino et al. 1995), just as other kinds of linguistic competences are also included (Norris 1990; Sharkey 1990).

In relation to reading in Arabic, one might argue that only a phonological and a direct, lexical route to lexicon is a narrow framework. The limited amount of phonological resources provided in unvoweled Arabic text material makes the phonological route appear less efficient, and as we shall see, other kinds of linguistic resources seem to be at play in reading Arabic, even at the isolated word recognition level. In this sense, a reshaped model of word recognition which leaves room for a language specific shaping of its exact characteristics is indeed an interesting development.
3.2 Connectionism: Lots of pros and a few cons

In a broader theoretical context, the basic critique of the dual route model is coherent with the general development in modern cognition research, in which nativism, in linguistics represented by generative linguistics, since the mid 1980’s have been challenged by a new line of thought based on connectionism (or *parallel distributed processing* or *network theory*) (Ramsey 1999; Ravn 1992; Smolensky 1999). Like the development of rationalism, including generative linguistics, was linked to the invention of computers for processing data, network theory is closely linked to the research in and development of artificial intelligence. Connectionist theory strive, like generative linguistics, to internalise language (in opposition to structuralism’s externalisation of and focus on language as system, language is perceived as manifestation of cognitive processes in general). But while Chomsky perceived linguistic competence as an innate set of syntactic structures as an independent module in the brain, connectionists see language as an experience-based competence which operates as part of the general cognition. (Garson 2002; McClelland 1999; Ramsey 1999; Ravn 1992; Smolensky 1999). This difference seems to mirror the difference between the classic computer and the new so-called neuro-computers which are supposed to imitate biological neural networks. While the classic computer runs a programme which is in fact a list of instructions for how various ‘knowledge elements’ in a carefully controlled order are to be combined in order to produce the right output, the neuro-computer is a network of units (similar to the brains’ synapses), typically grouped in input-units and output-units and between these one or several layers of ‘hidden units’. The units are combined in a network of connections, and the information processing happens as a spread of information from the input-units to the rest of the network through a pattern controlled by the weights of the relevant connections. Thus, information (in practice electric power) is weighed against the information which is already stored in the network as different weights within the connections, and the network is ‘trained’ by adjustments of the weights when the output is wrong. This way, the network acquires ‘experience’ which can be used to generalise based on input it has never encountered during its ‘training’ (Garson 2002; McClelland 1999; Ravn 1992).

Connectionism has been used as a theoretical basis for a new word recognition model which thus rejects the mechanism of a dual phonological and/or lexical processing of words. In the connectionist word recognition model, all

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4 However, some do accentuate connectionism as a bridge between nativism and empiricism, as the theory at the same time accepts that our perception depends on a set of innate sensors and that knowledge is based on experience (e.g. Adams 1990:201-204).
resources are applied in one process. All relevant knowledge is stored as weights within the connections, so there is no ‘mental lexicon’ in which we look up words, and thus there is no lexical route to word recognition. Rather, orthographic, phonological and semantic codes are connected within a complete process. Seidenberg, one of the predominant connectionists dealing with word recognition, describes the difference as follows:

"According to this theory, codes are not accessed, they are computed; semantic activation accrues over time, and there can be partial activation from both orthographic and phonological sources. So, for example, whereas in the standard dual-route model, ‘phonological mediation’ required deriving the complete phonological code for a word and using it to search lexical memory, in the present framework there can be partial activation of phonology from orthography, or of meaning from phonology. Thus, the meaning of a word is built up by means of activation from both routes, […] rather than accessed by means of whatever route wins the race." (Seidenberg 1992:105)

So, word recognition is still a matter of processing phonological and lexical material, but rather than running through separate routes to a mental lexicon, the information is gathered in a melting pot, where this – together with other kinds of text relevant experiences – creates meaning: Letter combinations give hints about known phonological patterns, phonological constellations give semantic association, etc. Becoming a proficient reader is a matter of gradually adjusting the connections’ weights based on frequency and consistency in the relations between lexical and phonetic units. Grapheme-to-phoneme correspondences are still essential – however, not as isolated rules but rather as characteristic spelling patterns which are gradually recognised when they have been encountered several times.

This process explains both the effect of word frequency – high-frequency words are recognised faster than low-frequency words (Monsell et al. 1989), the effect of word regularity – words with regular spelling and pronunciation are recognised faster than irregular words (Metsala et al. 1998) – and the interplay between these two phenomena, the effect of neighbour-frequency (Grainger 1992) – the fact that word-frequency for neighbours, that is words with shared letter combinations, influence word recognition speed: If a word and its neighbours are regular (e.g. gave, save and shave) the ‘neighbour-frequency effect’ is positive, and a frequent word increases the speed for recognition of less frequent neighbours. However, for irregular neighbours (e.g. have), the effect can be negative. This is the case for low-frequency words especially, as the effect of highly frequent neighbours slows down their recognition, while frequency effect in highly experienced readers obliterates
the negative effect on high-frequency words (Grainger 1992; Johnson 1992; Massaro et al. 1979; Seidenberg & McClelland 1989). In computer simulations a connectionist word recognition model, Seidenberg & McClelland (1989) were actually able to register ‘frequency-effects’, ‘neighbour-effects’ and ‘neighbour-frequency effects’ which were very similar to results from living subjects.5

Another equally interesting and compelling aspect of the theory is that it explains the complexity of the reading process and handles the processing of different resources in a more integrated way than the traditional interactive reading models are able to do: It embraces a very broadly interpreted version of schema theory, as all sorts of knowledge affect the process, while at the same time it includes the smallest components of phonemes and graphemes – even letter segments. So despite the fact that proficient readers recognise words rapidly without relying on phonological decoding, and despite such readers’ ability to make use of the holistic form of single words in the word recognition process, this does not mean that words are recognised as wholes. And despite the fact that context influences on decoding, it does not mean that reading is based on continuous, context-reliant testing of hypotheses. On the contrary, readers visually process every single letter – but not isolated from its surroundings:

"Even while the individual letters of the text are the basic perceptual data of reading, they are not perceived one by one, independently of each other. Instead, their efficient and productive perception depends additionally on ready knowledge of words – their spellings, meanings, and pronunciations – and on consideration of the context in which they occur. In the mind of the skillful reader, each such type of knowledge is represented by constellations of elementary units, connected in specific, learned relation to each other: Simple patterns are represented by interrelated clusters of units, more complex patterns of clusters of clusters of units, and so on such that the whole of any percept or idea is defined, at core, by the particular relations that hold among its parts." (Adams 1990:14-15)

Hence, meaning is constructed through connections of segments at several levels: Letters are representations of interconnected visual components, just like words are representations of interconnected letter combinations.

5 Additionally, the connectionist reading model represented in insert 5 below accounts for reading aloud as a phenomenon that might involve all elements in the word recognition process without necessarily involving meaning (in opposition to prior reading models in which this aspect is either ignored or illustrated less convincing, e.g. in Rayner & Pollatsek 1989:92&461-473.)
Similarly, the pronunciation of a word corresponds with a complex of phonemes just like its meaning is related to interconnected elements of meaning (Adams 1990:15). Thus, word recognition (and reading comprehension) is a multidimensional puzzle of experience-based elements of knowledge which are put into play and connected to each other.

At the same time, the theory embraces both bottom-up and top-down approaches in a different way than the traditional interactive models: For instance, if a network is fed with letter components and is taught to classify words, pseudo-words and letters, then it learns to identify letters in words better than letters in pseudo-words. So, the model functions bottom-up (is fed with the smallest units) but demonstrates a clear top-down-effect (applies its knowledge of words) (Norris 1990). The reason for this is that information flows back in the network in order to calibrate the weights of connections during ‘learning’. This explains several phenomena in the word recognition process which have been known for a long time, but which have never been accounted for as integrated parts of the traditional reading models, e.g. context-effect (see review in Tabossi 1991). Previously, it has never been possible to determine if context influences word recognition or whether it is not activated until later as part of a full-sentence comprehension process. Similarly, it has not been clear previously whether ambiguous words instantly activate several meanings or only one.

In the connectionist reading model, context-effect is constant as all information affects the weights of the network. In traditional terminology one could say that context is continuously incorporated into the schema and becomes part of the reader’s expectations towards the text (Seidenberg 1990:59; Whitney & Warning 1991). Also, the question of whether one or more meanings are activated during the reading of ambiguous words is eliminated (see review in Seidenberg 1982:490-496 and Simpson, 1984), since we are not dealing with a mental lexicon. Within this framework, semantic values of words are flexible fusions between several kinds of information stored in the connections of the network (Seidenberg 1992:58).

The downside to this model – in its all-embracing universality – is that it is rather unspecific. A relevant point of critique is that the pronounced interactive understanding of the network’s function somehow overrides the fact that complex processes actually seem to take a sequential line of progress, just as the traditional models presume (e.g. Norris 1990).6 For instance, when

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6 Overall, the main criticism of connectionism is that the networks demand a lot of training in order to function properly. They are rather bad at generalising on the basis of fixed rules (in opposition to the traditional computer and human beings) and they are not able to learn from one serious
reading ambiguous words, we can detect a delay of a few ms between lexical decision and word recognition (Whitney & Warning 1991:205). Furthermore, it is rather well documented in neurological research that word recognition does in fact follow a sequential course with recognition of letter forms as an initial process (Miozzo & Caramazza 1998).

This might be one of the reasons why a substantial part of the terminology based on traditional reading models is still used – also by theorists who support connectionism in general. For instance, concepts like orthographic and phonological decoding are used to describe processes involving orthographic or phonological material rather than express that decoding is solely orthographic or phonological (e.g. Seidenberg 1992). So, even though the traditional dual route theory might lose influence, these concepts can still be in play at a more analytical level.

3.3 Language specific features in the connectionist network

In the further analysis of word recognition in Arabic an analytic synthesis of the terminology of the dual route theory and the complexity of connectionism seems useful. However, the sequential aspects of the traditional models should not be ignored. Established connectionist theories of word recognition do not consider the question of possible sub-processes such as initial letter detection (Richman & Simon 1989), since script is simply considered to be an integrated part of the orthography (cf. section 2.1). These aspects are inexpedient for the purpose of this paper, as letter recognition is indeed a critical aspect in a language specific approach concerning Arabic.

A modified model which compensate for these weaknesses is shown in insert 5. In contrast to the original model by Seidenberg & McClelland, which is the primary source of inspiration behind it, this model retains an element of sequential progression with letter recognition as an independent part of the process. As the model demonstrates, word recognition does not necessarily involve phonological processing – thus far it resembles the dual route model. However, as opposed to the linear structure of the dual route model displaying separate routes to a mental lexicon, the output, in this case, is a product of an mistake, as humans are. At a more abstract level, connectionism is criticised for its simplicity, as it has not been possible to include very basic aspects of human cognition. Humanists point at e.g. beliefs, wishes and ethics, while biologists point at neurotransmitters and hormones as examples of aspects which are not included or explained within this model. The counter-argument is that these inadequacies are due to the necessary simplifications of the networks which it has been technically possible to construct at this time, while the living, biological version contains it all (Garson 2002; Ramsey 1999).
interactive process within a network of units which sends signals back and forth among them. Letter detectors, orthography and phonology should not be seen as static elements but as sub-networks within which information is similarly processed in networks of units.

In the following sections we shall investigate further the nature of language specific features stored in this network when reading in Arabic. In order to shed light on the issue from multiple angles, a range of different kinds of research is included in the review. Some sections include research considering reading in Hebrew because the supply of research concerned with Arabic is extremely scarce and the structures of the two languages are in many ways alike.
4. The letter detection network

Connectionist word recognition theory implies that letter recognition relies on a mental network of inter-feature relations which is established through experience. From this perspective, the role of context has been emphasised: Letters are recognised easier when they are presented as part of a word (McClelland & Rumelhart 1981), and mixed fonts are more difficult to process than regular fonts (Sanocki 1987). Actually, connectionist approaches to word recognition seem to represent a rather effective model at the letter recognition level even though this processing level is not explained very explicitly in the theory. In fact, the role of letters within words seems to be an effective analogy to the role of letter segments within letters.

A parallel to the connectionist theory’s rejection of a one-way recognition process and the entire notion of a mental lexicon, as mentioned above, would help us explain the level of flexibility and diversity that characterise our ability to recognise different fonts. According to this analogy, activation of one letter component is not an isolated process. Rather, it is part of a contextual stimulation of letter components that ‘go together’ – according to prior experience with letterforms stored in the network.

Just as word recognition is not a one-way process, the idea of a hierarchical process in letter recognition is - within this framework - replaced by the network’s ability to feed back as well as forward. Similarly, from a connectionist point of view, letter recognition is a completely integrated part of the word recognition process: Letter components are process units within the letter recognition network, just as letters are components in the word recognition network. However, since letters can be recognised without word recognition (a letter can be presented in isolation), while word recognition cannot occur without letter recognition, letter recognition and word recognition can be perceived as two different stages of a modulated process which are both independent and intertwined: They do different things, but they are dependent on each other in a continuous interplay with information flowing in both directions. In this way, letter recognition feeds the word recognition process which again affects and supports the letter recognition process. And just as experience with both whole words’ graphical shapes and with specific letter forms is utilised in the word recognition process, experience with general letter forms and letter component constellations is used in the letter detection process.

Thus, the connectionist framework would reject the idea of a template-matching process, while the feature-detection theory is somewhat easier to
incorporate. The hypothesis of this theory is that each letter is recognised through an analysis of standard letter elements and their interrelation. In this view, we are able to decipher different fonts because letter segments are perceived in terms of their relative positions in relation to other segments and the overall letter shape. Most research within this framework is concerned with Roman majuscules. The segments of these are categorised in terms of line orientation and position of arcs, and it is argued that we recognise the graphic entities of letters through an analysis of these components (Rayner & Pollatsek 1989:11-15), so that we distinguish e.g. E from F or L on the basis of the number of horizontal lines. Regarding minuscules, they are believed to be initially recognised as a general form (Bouma 1971; Massaro et al. 1980; Tinker 1965), by Bouma described as “the smallest enclosing polygon without indentations” (Bouma 1971:460), followed by a process including letters’ sub-components. This process does not only imply recognition but also rejection based on the principle of exclusion.

However, within the connectionist framework, rather than a strictly hierarchical process, we should imagine letter perception as a computation of letter components which creates associations of other components which they match, according to our experience with letters already stored in the network.

When it comes to recognition of Arabic letters specifically, a range of different studies indicate that the graphic characteristics of Arabic script is somewhat problematic in relation to readers’ ability to distinguish between letters: In a study conducted by this author, it was found that Arabic-speakers reading Arabic pseudo-words produced alarmingly high frequencies of letter errors even when possible transfer of dialectal phonology is considered (Hansen 2009). Moreover, Ibrahim et al. (2002) found that Arabic-Israeli subjects were slower in processing Arabic (L1) letters than Hebrew (L2) letters. They concluded that the results were due to the graphic complexity of Arabic script. This is supported by Eviatar et al. (2004). When Arabic letters seem to be more demanding to process than Hebrew letters, it is interesting that Hebrew letters seem to be harder to distinguish than Roman alphabet letters: In a comparative study of subjects’ identification of Roman and Hebrew letters, Shimron & Navon (1981) describe that according to objective measures of ‘distinctiveness’ (how critical the relevant letter segment is for recognition of the letter) and ‘uniqueness’ (how rarely the relevant letter segment occurs in other letters), Hebrew letters are more alike than Roman alphabet letters. And in experiments they find that manipulations of letter segments affect recognition of Hebrew letters more than Roman alphabet letters (Shimron & Navon 1980, 1981). Geva & Siegel (2000) found that English-Hebrew bilingual children make more visual letter recognition errors in Hebrew than
in English. Furthermore, it seems that decoding of both Arabic and Hebrew demands more visuo-spatial awareness or visual attention than decoding in English (Abu-Rabia 2001; Ibrahim et al. 2007; Share & Levin 1999; Shatil & Share 2003), which could be an indicator of the same thing.
5. Reading homographs: the impact of vowels, word-frequency and context

It was not until the early 1980’ies, researchers began to question the universality of the existing reading theories (Henderson 1984:4; Hung & Tzeng 1981; Just & Carpenter 1987:305-). Neurological studies using subjects with acquired dyslexia revealed both universal, cognitive processes and language specific processes, and a range of studies were examining – with the dual route word recognition model as their point of departure – the blend of visual/orthographic and phonological processing in reading different languages (Besner et al. 1984; Coltheart 1984; Just & Carpenter 1987:314; Morton & Sasanuma 1984; Sasanuma 1984).

5.1 The orthographic depth hypothesis

The baseline of the bulk of research exploring differences in reading process in different languages has been the orthographic depth hypothesis (ODH) (Feldman & Turvey 1983; Frost et al. 1987; Katz & Frost 1992). This hypothesis builds on differences in grapheme-to-phoneme correspondence in different alphabetic orthographies: Shallow orthographies have simple and consistent one-to-one correspondences between graphemes and phonemes, while deep orthographies, despite their reliance on the alphabetic principle, have more complex connections between letters and the corresponding sounds. In a continuum between shallow and deep, Serbo-Croatian orthography is shallow, as each letter represents only one phoneme, while each phoneme is only represented by one letter. English orthography, on the other hand, is rather complex because of the phonological differences between words with similar letter constellations (e.g. heal-health) and similar pronunciation for words with different letter constellations (e.g. peel-deal). According to the ODH, reading shallow orthographies initiate phonological decoding, while deep orthographies initiate lexical, or direct, word recognition.

In this sense, the ODH is heavily relying on the traditional dual route word recognition model, but even if the “pure” model, where phonological and orthographic decoding are considered separate and isolated processes, cannot be substantiated, it does not threaten the hypothesis per se (Berninger 1994:13; Katz & Frost 1992:78). Even if reading requires pending connections between both orthographic and phonological cues, it can be argued that when these connections are forged, the reader might rely more
heavily on phonological information when reading shallow orthographies and conversely rely more on orthographic cues when orthographies are deep.

While studies exploring the ODH were initially concerned with Serbo-Croatian and English representing shallow and deep orthographies respectively (e.g. Feldman & Turvey 1983; Katz & Feldman 1981, 1983; Turvey et al. 1984), some researchers began to include non-European languages and other writing systems. Much of the interest focused on Hebrew and Japanese, which each in their own way could contribute with new and interesting dimensions to the field: Hebrew (like Arabic) can be written in two different alphabetic orthographies – one (voweled) highly shallow and one (unvoweled) very deep because of the lacking phonological information when short vowels are omitted. Japanese, on the other hand, use three different writing systems: one logographic (kanji) and two syllabic (hirgana & katagana). While much of this research was primarily focusing on supporting or rejecting the traditional dual route word recognition model (Coltheart 1984:71; Katz & Frost 1992:72; Morton & Sasanuma 1984; Sasanuma 1984; Turvey et al. 1984) it had an important side effect as well: Researchers began to question the general conception of orthographic processing (examples considering the extent of phonological processing in reading Chinese are: Hanley & Huang 1997; Henderson 1982:192; Hung et al. 1994; Jackson et al. 1994). In 1994, Geva & Willows raises this very important issue in the following paragraph:

"[Recent research] highlight[s] the importance of examining carefully in different writing systems what is meant by orthographic knowledge, and the contribution of underlying cognitive and linguistic factors to its development in different orthographic systems. It is clear that theoretical claims regarding the universal role of orthographic and phonological processing in reading and spelling, based on learning to read and spell in English and other Roman-based alphabets, need to be examined carefully." (Geva & Willows 1994:365)

With this exact purpose in mind, Navon & Shimron (1981) were among the first researchers to examine the role of vowels in lexical decision in Hebrew. They found that in tasks involving voweled words and pseudowords – in which subjects were explicitly asked to disregard vowels – lexical decision was slowed down by incorrect vowelisation of words. They concluded, that even

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7 This tendency is expressed in a variant of the ODH called the script dependence hypothesis (e.g. in Geva & Siegel 2000; Gholamain & Geva 1999).

8 Lexical decision is recognition of letter strings as a valid words. In traditional lexical decision tasks, subjects are asked to press a 'yes' or a 'no' button to indicate whether or not they perceive stimulus as being a word. This does not necessarily imply word recognition/lexical access (knowing the meaning of the word).
though proficient readers in Hebrew do not need vowels to achieve rapid lexical decision, they are not able to ignore the vowels, when they are present (Navon & Shimron 1984). Likewise, in an experiment by Frost (1994), subjects who were exposed to unvoweled consonant strings for 300 ms before the vowels appeared, tended to wait for the vowels before reading the words aloud even though vowels were not necessary for decoding. On the other hand, a study by Barnea & Breznitz (1998) indicates that letters are the central input in word recognition of voweled Hebrew. They used pairs of voweled words which were either identical, identical in letters but different in vowelisation, or different in both letters and vowelisation. Subjects were to decide whether the word pairs were identical or not, and reaction times for pairs with different letters were significantly faster than for the other pairs. So even if readers of Hebrew cannot ignore the diacritical vowel marks when present, they undoubtedly play a secondary role compared to letters.

But what is the role of vowels, then? In the following, research concerned with this issue in relation to reading Hebrew and/or Arabic specifically is reviewed. Some of the studies examine reading speed, some naming or lexical decision times, and some are concerned with comprehension, but they share their, direct or indirect, focus on the role of vowels and contribute to explain how orthographic and phonological processing are balanced in the reading of Semitic languages.

5.2 Exploring the ODH

Based on the ODH it seems obvious that word recognition in unvoweled Hebrew, being a deep orthography, is dominated by orthographic processing, and that reading in Hebrew in this regard differs from reading in languages using the Roman alphabet (Bentin et al. 1984; Frost et al. 1987; Koriat 1984). According to Frost & Bentin (1992b:35) the core difference is that pre-lexical phonological processing is not possible when reading unvoweled text. The phonological information available is simply not sufficient, and thus the reader does not gain access to full phonology when he or she has consulted the mental lexicon. On the contrary, decoding of voweled Hebrew, being a shallow orthography, should be predominantly phonological (Frost 1994).

A range of cross-language studies seem to confirm these predictions. An experiment including words in the extremely shallow Serbo-Croatian orthography and the very deep unvoweled Hebrew orthography did not reveal significant differences in lexical decision times (Frost et al. 1987). According to the dual route model, readers of Hebrew were able to make lexical decisions as quickly as readers of Serbo-Croatian because they used the direct, lexical
route to the mental lexicon. Furthermore, in a study of repetition effects for voweled and unvoweled homographs and homophones in Hebrew, Bentin (1989) found that vowels influence subjects’ lexical decision times. He concluded that vowels, when applied, initiate a more phonologically mediated reading process.

More recent studies, however, indicate that decoding unvoweled text is not purely orthographic. These studies are applying an advanced masking technique, where primes are presented for a very short period of time (14-15 ms) followed by targets which resemble the prime phonologically and/or graphically. Such experiments draw on the fact that in Hebrew there are phonemes which are represented by more than one letter. Therefore, the word קפיט /kapit/ (‘tea spoon’), which consist of the letters [kpit] can be masked by the pseudo-words קפיט [kpit], קפיט [kpit], and קפיט [kpit] (all primes phonemically identical with each other and the target but spelled differently with different degrees of graphemic overlap with the target) and pseudowords with varying phonemic resemblance with the target, e.g. קפיז [kpiz] and קפיט [kpitz]. These studies show that the more the prime resembles the target phonologically, the more it helps subjects in rapidly identifying the target. This indicates that even unvoweled text activates phonological processes to some degree (Frost & Yogev 2001; Gronau & Frost 1997).

However, in a comparison between the effect of phonemic and graphemic masking, it appears that graphemic masking had a much larger effect than phonemic masking. These results demonstrate that word recognition in Hebrew is not exclusively orthographic, but they still support the hypothesis that orthographic processes are dominating in decoding unvoweled Semitic orthographies.

Bentin & Ibrahim (1996) investigated this issue empirically by making use of the diglossic situation in Arabic. They exposed their Palestinian subjects to words written in MSA, words in Palestinian Arabic, and pseudo-words in a lexical decision task, e.g. asking them to reject all words which were not MSA. The words were partly voweled in order to avoid homographs. As words belonging to the spoken Palestinian language variety were dismissed even slower than the pseudo-words, the authors concluded that word recognition is predominantly phonological: The subjects did not ignore the phonological structures of the dialectal words, despite the fact that it would have eased their lexical decision to do so. In another experiment, subjects were to dismiss non-words only and to accept all stimuli – whether MSA or dialect – which they perceived to be word-like (with the intention of enforcing phonological processing). As MSA words were accepted slower in the task where dialectal words were to be dismissed than in the task where phonological processing
was enforced, the authors concluded that the subjects were not able to ignore phonology of MSA words either. Despite these rather far-reaching conclusions – especially considering that the authors’ do not delimit them to concern ‘partly voweled Arabic’ alone – the study points in the same direction as the above mentioned conclusions concerning Hebrew: Vowels cannot be ignored when they are present, and vowelisation convey phonological decoding.

5.3 Cross-linguistic studies

A few eye movements and/or reading speed studies have compared reading in Arabic or Hebrew with reading in a European language. Pollatsek et al. (1981) found longer eye fixation latencies and shorter durations of saccades in reading of Hebrew than in reading of English, but similar reading speed in the two languages. Similarly, in a comparison of reading in French and Arabic, Roman & Pavard (1987) found more – but not significantly longer – eye fixations in Arabic than in French. In both cases the authors’ explanation is that words in Hebrew/Arabic are more information-dense than English/French words.

In a later study, Shimron & Sivan (1994) came to a different conclusion. They tested adult Israeli university employees in two separate experiments. The subjects had either Hebrew or English as their L1. In the first experiment, the English L1-subjects read English significantly faster than the Hebrew L1-subjects read Hebrew. Furthermore, the Hebrew L1-subjects read English (L2) faster than Hebrew (L1). However, in the second experiment they found that reading time in English was indeed shorter than in unvoweled Hebrew, but not significantly shorter than in voweled Hebrew.

In addition to this, a range of experiments show that English-Hebrew bilingual children in the first years of school decode voweled Hebrew faster than the deeper English orthography, despite the fact that Hebrew is the children’s L2 (Geva & Siegel 2000; Geva & Wade-Woolley 1998; Geva et al. 1993).

As the studies from the 1980’ies mentioned above are conducted with rather small populations compared to the later experiments, the results seem to indicate that the deeper, or the more complex, the orthography, the slower the reading. In comparison to English, French and voweled Hebrew and Arabic, the unvoweled Semitic orthographies seem to demand more and longer fixations, and thus reading is more time consuming in the unvoweled Hebrew and Arabic orthographies in general.
Furthermore, some researchers have examined simultaneous reading acquisition in bilingual children’s two languages (Geva & Siegel 2000; Geva et al. 1993; Gholamain & Geva 1999; Wade-Woolley & Geva 1998). The results indicate, that reading in different orthographies rely on different kinds of reading related competences: In English-Hebrew bilingual children, phonological awareness seems to be more important in reading English than in reading Hebrew, while rapid word recognition seems to be more important in reading unvoweled Herbrew than in reading English (Geva & Wade-Woolley 1998). This seems to be consistent with the above mentioned results indicating that, compared to reading in European languages, decoding of the very deep unvoweled Semitic orthographies is less reliant on phonological processing.

In general, research in bilingual reading supports both the ODH and the central processing hypothesis: that reading ability in any language is dependent on individual cognitive factors (Geva & Siegel 2000; Geva & Wade-Woolley 1998; Gholamain & Geva 1999). This is in every way compatible with connectionism: General skills and abilities (the central processing) are given, and at the theoretical level they are an indication of how many layers of hidden units the neuro-computer contains (in humans they are contingent on biologically determined preconditions possibly corresponding to the number of synapses in the brain) – while the depth, complexity or informational density of the orthography impact the weights within the connections through training, leading to orthography-specific skills.

5.4 Unvoweled more demanding?

Several researchers have compared reading in Semitic scripts with and without vowelisation in order to determine whether vowels – and thus the possibility of a more phonologically based processing – rend the reading process less cognitively demanding.

Frost, Katz & Bentin (1987) argued on the basis of the above mentioned cross-linguistic studies – which clearly supported the ODH (and hereby also the hypothesis that word recognition in Hebrew is predominantly lexical) – that vowelisation does not ease word recognition. On the other hand, Koriat (1985a) found that vowels did have a slightly positive effect on lexical decision latencies, but mostly for low-frequency words. However, the earlier above-mentioned studies showed ambiguous results, as lexical decision times were almost identical for voweled and unvoweled Hebrew words, while vowels did
have a positive effect on the speed in word naming tasks (Bentin et al. 1984; Koriat 1984; Navon & Shimron 1981; Shimron & Navon 1982).

Bentin, Bargai & Katz (1984) measured times for lexical decision and naming of unvoweled consonant strings of which some were homographs and some were not. The results indicated that phonological ambiguity slowed down naming but did not affect lexical decision. These results are supported by a study of lexical decision in Arabic which show that vowelisation actually makes lexical decision significantly slower (Roman & Pavard 1987) and by another study by Bentin & Frost (1987) who tested lexical decision latencies for reading homographs which could be read as either high-frequency words or low-frequency words, and the same words with vowels. The results show that lexical decision was faster for the unvoweled homographs than for both the voweled (and thus no longer ambiguous) alternatives. Thus, vowelisation did not make lexical decision faster.

Moreover, a test employing repetition priming\(^9\) using homographic primes with both high-frequency and low-frequency meanings followed by targets with or without semantic relation to the prime, showed that a semantically related prime resulted in faster lexical decision of the target regardless of the frequency of the word to which it was semantically related (Frost & Bentin 1992a). This indicates, that the semantic association values of both words were measurable, and on that basis the authors argue that both meanings are activated prior to actual word recognition.

Based on the above mentioned research some have argued that lexical decision does not require detailed phonological analysis despite the fact that readers need vowels to distinguish between homographs when reading aloud. (Frost & Bentin 1992a, b; Frost et al. 1987; Katz & Frost 1992). However, pre-lexical phonological processing may take place during reading of Hebrew homographs. In a test applying amplitude-modulated noise\(^10\) to Hebrew

\(^9\) Repetition priming is a testing procedure developed by Forster & Davis (1984), where subjects are exposed to a 'prime' in form of a word with a particular word pattern (e.g. 'nature') within a very short time span (50-60 ms) before the target word. If the target has the same pattern as the prime (e.g. 'nature'), lexical decision is faster than if the target and the prime do not share the particular pattern. As the subject does not seem to be aware of the relation between the prime and the target, such results are supposed to mirror an unconscious association (Forster & Davis 1984; Frost et al. 1997:832).

\(^10\) Amplitude-modulated noise is a testing method developed by Frost, Repp & Katz (1988), by which an acoustic representation of a word is modulated so that its precise phonemic and syllabic structure is disguised while it is still possible to decipher structures of rhythm and stress as well as groups of consonants (e.g. it is possible to distinguish between a plosive and a fricative but not to determine the exact consonant). This noise is designated the word’s 'acoustic form'. When a word’s acoustic form is presented together with the same word in writing, subjects perceive the noise as a
words, Frost (1991) found that the influence of visual stimuli on the perception of acoustic forms was significant when the two modes of stimuli (visual and auditory) represented the same word, regardless of whether the visual stimuli were voweled or unvoweled words. (Frost 1991). Taking advantage of the same technique, Frost & Kampf (1993) examined whether homographic words activate one or more acoustic forms. They used the same method to test if the correspondence between visual an auditory stimuli perceived by the subjects when they match is established regardless of the frequency of the word used for the auditory stimulus, when the visual stimulus is homographic. They found that the acoustic forms of both high-frequency and low-frequency words are activated. According to the authors, this indicates that word recognition, when reading unvoweled Hebrew homographs, activates all the possible words given by the homographic letter string in the readers mind.

Summarising these results it seems like both semantic and phonological representations of both high-frequency and low-frequency meanings are activated by exposure to Hebrew homographs.

Frost & Bentin further reasoned that vowelisation is not essential for word recognition in Hebrew as the consonants and word structure is sufficient to specify a word (Frost & Bentin 1992b:33). However, several of the above mentioned studies show that vowelisation in Hebrew actually makes word recognition faster despite the fact that more graphical input is to be processed. (Bentin et al. 1984; Bentin & Frost 1987; Koriat 1984, 1985a; Navon & Shimron 1981; Shimron & Navon 1982). It is plausible that this is due to the elimination of the homography. This is consistent with a study by Frost (1995) which shows that reaction times for naming homographs are longer the more ambiguous the words.

Later studies testing reading of text rather than isolated words also show that subjects reading Hebrew read voweled text faster and more correctly than they read unvoweled text. (Abu-Rabia 2001; Shimron 1999; Shimron & Sivan 1994). In Arabic, similar results have been obtained: Roman, Pavard & Asselah studied reading of homographs by letting subjects read Arabic meaningful representation of the given word. On the contrary, if the set of auditory and visual stimuli does not match, the acoustic stimulus is perceived as noise, even when the two are acoustically similar. Such results appear with stimuli being either high- and low-frequency words but not with pseudo-words. This substantiate the hypothesis that a written word creates both an automatic phonological representation of the word and a representation of its acoustic form. Thus, a word’s acoustic form is one of several kinds of information that a listener uses to reach auditory word recognition, just like the graphical shape of a word is believed to be in visual word recognition (Frost 1991; Frost et al. 1988).
sentences which were ambiguous because of an initial verb which could be read as either passive or active mode because it was presented unvoweled. According to the authors, the subjects clarified this ambiguity by establishing hypotheses and testing these according to the context. This being, of course, a time consuming process (Roman et al. 1985). Similar results are present in a number of more elaborated studies conducted by Abu-Rabia in which the effect of vowelisation and context in reading aloud is tested. These studies show that vowelisation as well as context result in a smaller frequency of reading errors and that skilled readers benefit more from vowelisation and context than less skilled readers (Abu-Rabia 1997b, 1998, 2001; Abu-Rabia & Siegel 1995):

In the first study (Abu-Rabia & Siegel 1995), 20 skilled and 20 poor readers were tested for their dependency on context during reading of voweled and unvoweled words respectively. The results show that context plays a significant role for both groups of Arabic readers. The subjects (a group of Canadian 8th graders with Arabic L1 who were all heritage learners of Arabic) were exposed to 10 voweled and 10 unvoweled sentences. All sentences were initiated by a verb (normal sentence structure in formal standard Arabic). The subjects first read the initial verb while the rest of the sentence was hidden. Then the full sentence was presented and subjects had the possibility of rereading and correcting the initial word. When reading the initial verb in isolation, all subjects had a preference for the verbal form with the highest frequency in ordinary text. For instance, all subjects read the word /akkala/ ('fed') as /akala/ ('ate') outside of the context. The initial word was /akkala al-walad kalbahu/ (that is, 'the boy fed his dog' rather than 'the boy ate his dog'). In the same manner, the word /laana/ ('became soft/more understanding') was read /li?anna/ ('because'), which is obviously a much more frequent word. Furthermore, words which both represented the most simple verbal form and carried the most frequent meaning were almost always read correctly in isolation as well as in context. This tendency to favour simplicity and frequency was apparent even in the readings of voweled sentences where the poor readers especially were inclined to ignore the diacritic indicating doubling of a consonant (the shadda). For instance, the word /sallama/ ('greeted') was read as /salima/ ('was healthy/well/safe).

Likewise, later studies in which skilled and poor readers read voweled and unvoweled words and text passages show that vowelisation as well as context result in a reduced frequency of errors in naming and reading aloud, and that skilled readers benefit most from both (Abu-Rabia 1997a, b, 1998).

In yet another study by Abu-Rabia (2001), adult Arabic-Hebrew bilinguals read isolated words and text passages with and without vowels in both
languages. An overview of the results is listed in insert 6. These results support the former studies by Abu-Rabia, as subjects read both kinds of stimuli more accurately with than without vowels in both languages. The results regarding the effect of context is somewhat more complex. In Arabic, accuracy in reading unvoweled words in context is significantly better than reading of unvoweled words in isolation (in accordance with the previous studies), but the same is not the case in Hebrew. This is a surprising result given the documented influence of context in reading of unvoweled Hebrew in the above mentioned studies (Koriat 1984; Koriat 1985b). Additionally, Abu-Rabia's comparisons of the voweled Semitic scripts show that context has an impact on reading of voweled text in Hebrew but not in Arabic. While the result regarding Arabic could be explained by the effect of the shallow, voweled orthography diminishing the impact of context in decoding, it is surprising that the effect of context is apparent in Hebrew in the comparison between the readings of the voweled rather than the unvoweled words and text passages. One would expect the reader to rely more on context when reading unvoweled script where the frequency of homographs is distinct which the results from Arabic seem to indicate.

It is possible that these surprising results are due to the fact that in this study Hebrew is the subjects second language. This weakens the comparability of this study with the other presented research results regarding Hebrew. However, we might have to do with a more profound methodological issue. One possible problematic aspect of the relevant study is that full vowelisation with correct case endings, which is normally used when reading aloud in Arabic, is far from necessary for reading comprehension, and case endings are usually omitted in ordinary writing and speaking (with the exception of the indefinite accusative which is apparent in script and used in a selection of stocked phrases in daily speech). In this study, Abu-Rabia apparently seeks to

| Arabic | Hebrew |
| + vowels | - context | + vowels | - context | + vowels | - context | + vowels | - context |
| + vowels | ns | --- | --- | --- | x | x | --- |
| x | --- | --- | --- |

Insert 6: Correlation matrix of significant differences between reading of isolated words (-context) and text passages (+context) in voweled and unvoweled Arabic and Hebrew. x = significant difference; ** = not significant difference; --- = relation not reported. (Abu-Rabia 2001)
overcome this issue by ignoring errors in or omissions of case endings. However, case endings are traditionally an integrated part of reading aloud in Arabic, and the substantial cognitive load of the continuous syntactic analysis that this requires might influence the process of reading aloud whether or not errors are counted or not. The descriptions of the methodology applied in these experiments do not state if subjects are told that case endings can be ignored, and even so; syntactical considerations while reading aloud might be an automated process which readers cannot easily refrain from, even if they are consciously trying to do so.

Despite these critical points, it seems justified to assume that vowelisation is a resource when settling the ambiguity of homographs in connection with reading aloud in both Arabic and Hebrew. Furthermore, the effect of context is quite convincing for Arabic while somewhat less clear for Hebrew. The effect of context is not significant in the above mentioned study of Abu-Rabia (2001), yet both mentioned studies by Koriat (1984, 1985b) show that context facilitates decoding more so than vowels. In addition, Roman & Pavard (1987) found that vowelisation affects lexical decision more than reading of text passages. This indicates that, to a large extent, readers rely on context if available.

Furthermore, several of the studies reviewed above indicate that word frequency plays a significant role for decoding of homographs. In Koriat’s experiment we see that vowels first and outmost support lexical decision of low frequency words (Koriat 1985b), just like Bentin & Frost (1987) found that word frequency has a significant influence on both lexical decision and naming latencies. In this experiment, low-frequency words, even if vowelled, were recognised significantly slower than both vowelled and unvowelled high-frequency words. The above mentioned studies by Frost & Bentin (1992), Frost & Kampf (1993) and Frost (1995) similarly show that while both high-frequency and low-frequency meanings are activated at exposure for homographic words, the association effects of the high-frequency meanings are stronger than low-frequency alternatives, just as highly frequent phonological representations are stored longer in short-term memory.

Additionally, Bentin & Ibrahim (1996) found a stronger word-frequency effect in lexical decision and naming of partly vowelised Arabic words than what is normally found in European languages. Adding to the result by Abu-Rabia & Siegel (1995) it seems that decoding of low-frequency words is especially demanding but facilitated if other kinds of information like vowelisation or context are available. And, actually, in ‘real life’ we can observe the use of vowelisation applied to single words in otherwise unvowelised text in
both Arabic and Hebrew, when these words are otherwise homographs and infrequent or ambiguous in the relevant contextual setting.

In sum, these studies indicate that both word frequency and vowels as well as context can be used advantageously in the recognition of homographic words. However, context seems to be the most powerful of these three kinds of resources.

One could argue, that the above mentioned experiments are overemphasising the relevance of output measured in naming or reading aloud, as several studies show a lack of significant correlation between fluent reading aloud and reading comprehension in both Arabic and Hebrew. (Abu-Rabia 2001 100; Saiegh-Haddad 2003a). These results are opposite to what is found in studies concerning reading in English: In English, reading aloud seems to be a relevant measure and even a direct indicator for reading competence – including comprehension (Fuchs et al. 2001). Considering the above mentioned research results, this difference is not a mystery: When readers in the Semitic languages need to rely on context because of the frequency of homographs in unvoweled text, it is not surprising if it obstructs the process of reading aloud fluently. As mentioned, matters are complicated further in Arabic by the traditional requirement of applying case endings. On the other hand, because of the shallowness of the Arabic and Hebrew orthographies when voweled, correct and fluent reading aloud of voweled text without reading comprehension is possible in both languages. This can be observed in beginning readers of Hebrew (Geva & Siegel 2000; Gholamain & Geva 1999), in Arabic pre-schoolers and among Muslims who do not know a word of Arabic but are able to read aloud from the Quran without comprehension.

However, a few studies indicate that vowels support reading comprehension as well. In the mentioned study by Shimron & Sivan (1994) they found in both experiments that comprehension was better in readings of voweled than unvoweled texts. Furthermore, in a study of beginning readers of Hebrew, Shimron (1999) found that prose texts were better comprehended and recalled when voweled. Similarly, in a study of reading comprehension among Arabic 2nd and 6th graders, Abu-Rabia (1999) found that children in both grades achieved better comprehension when reading voweled than unvoweled texts. In yet another study by Abu-Rabia (2001) he found similar results for both Hebrew and Arabic with Arab-Israeli high school students.

Regarding reading speed when reading for comprehension one of two experiments in the study by Shimron & Sivan (1994) showed a slightly (but not significantly) improved reading speed in silent reading of voweled
compared to unvoweled Hebrew texts. Likewise, the previously mentioned studies of lexical decision and naming latencies and reading aloud could indicate that vowels improve reading speed during reading for comprehension. Only one study defies these results (a follow-up of the previously mentioned experiment by Roman & Pavard): In a comparison of readings of text passages of about 100 words they observed that vowels reduced reading speed significantly (Roman & Pavard 1987). However, the result of this study seems to be an exception.
6. Mental representation of Semitic morphology and its role in word recognition

When it comes to reading in Semitic languages, the phonology-orthography continuum expressed by the ODH is a rather narrow framework for examining the word recognition process. We should be aware that the consonantal Semitic writing systems reflects the linguistic structure of Arabic and Hebrew and that this specific feature might play a role in word recognition in these languages – distinguishing the process entirely from word recognition processes in the European languages. In other words, we should consider that the specific Semitic word structure may imply a similar mental representation of roots and patterns as separate morphological entities.

In the following section, an outline of the general discussion about the mental representation of Semitic morphology is presented, followed by a review of studies exploring the same issue, but specifically related to word recognition.

6.1 Mental representation of the Semitic root-pattern morphology?

In Semitic linguistics, roots and patterns of Semitic words have traditionally been considered to be a non-linear morphological structure in which patterns as well as roots represent separate morphemes.

In the 1980ies and the beginning of the 1990ies, this concept was challenged by researchers within Arabic and Hebrew linguistics who argued that the root cannot be considered an independent morpheme but rather carries the characteristics of a kind of ‘paradigmatic relation’ between words. One linguistically based argument was that both roots’ and patterns’ relations to word-meanings are not unequivocal (Mahfoudi 2002). On the other hand, some linguistic aspects do point towards a strong root-pattern morphology, e.g. the treatment of some loan-words: Often vowels are extracted from the word and the consonants are treated as roots and inserted in the relevant patterns (Shimron 2002:11). One example is the word قَلْم /film/, which in plural takes the very common Arabic plural pattern with both prefix and infix: أَفَلاَم /aflaam/. Obviously, many loan words consist of more than three consonants, and these are sometimes treated as quadriliterals, 11 leaving four

11 Quadriliterals are words with roots consisting of four consonants. Quadriliterals exist - though few in number – in both Arabic and Hebrew. Quadriliterals take the forms فَقَّيْل /faYYala/ or قَيْل /tafaYYala/ in Arabic, and equivalently حَيْل /pitYaal/ or حِيْل /hitpYaal in Hebrew, where the middle consonant were also originally doubled.
C-slots in the CV-skeleton. An example of this phenomenon is the Hebrew word [תא Tattoon], which applied to the verbal system takes the form [תלפæñ] (‘he telephoned’). On the other hand, there are multiple examples of word formations in which both traditional words and loan words deviate from the morphological structure. For instance the verb [משמש] /mishmish/ ‘computerise’ is derived from the already existing noun [מעמש] /mahmish/ ‘computer’ by applying the prefix [ב], but etymologically it is related to the root [ב-h-s-b] which semantically relates to the concept ‘counting’ (Bolozky 2002:132). A number of linguists use such examples to reject the conception of a specific root-pattern morphology in Semitic linguistics (e.g. Bat-El 2002; Benmamoun 2002; Heath 2002). Heath seems very convinced stating that:

"Once we acknowledge that all of the productive Arabic ablaut processes are directional (i.e. have input stems and output stems), there is no good reason to decompose underived stems into roots, templates, and vocalic melodies, and Arabic lexical structure can be reconciled with those of the great majority of other languages." (Heath 2002:129)

On the other hand, a range of psycholinguistic studies support the hypothesis that roots and patterns in Semitic languages do hold independent mental representations (Bentin & Feldman 1990; Berent & Shimron 1997; Berent & Shimron 2002; Berent et al. 2001; Berg & Abd-El-Jawad 1996; Berman 2002; Borer 2002; Deutsch et al. 1998; Ephratt 1997; Feldman & Bentin 1994; Frisch & Zawaydeh 2001; Frost et al. 2000; Frost et al. 1997; Mahfoudi 2002; Obler 1989; Prunet et al. 2000; Ravid 2002). For instance, a number of studies of metathesis errors12 (e.g. Berg & Abd-El-Jawad 1996; Obler 1989; Prunet et al. 2000), including a study of French-Arabic bilinguals with aphasia, whose metathesis in Arabic only affected consonants, which were part of roots, while patterns – that is, both vowels and consonants in pre- and suffixes – were never affected. In French, the same patients had fewer occurrences of metathesis, and the errors affected both consonants, vowels and syllables (Prunet et al. 2000). Other examples are studies employing repetition priming (Bentin & Feldman 1990; Feldman & Bentin 1994). Within such an experiment, Hebrew speaking subjects were presented to primes followed by targets carrying semantic and/or morphologic association to the prime, e.g. the prime [疟מ] /migdal/ (‘tower’), and the targets [גזרה] /tzeriah/ (‘canon tower’) (semantically related), [גריד] /gidul/ (‘tumor’) (morphologically related) and [גדיר] /gadol/ (‘big’) (both semantically and morphologically related to the prime). If the target followed immediately after the prime, lexical decision latencies were

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12 Metathesis is the transposition of letters, syllables or sounds within words, e.g. historically as the name Andreas becoming Anders or as in this case as speech errors as a consequence of brain damage.
improved regardless of the associative relation. But if 15 words without any relation to either the prime or the target were shown in between, lexical decision was only faster when primes and targets were morphologically related. Furthermore, targets with both semantic and morphologic relation to primes never resulted in faster lexical decision than targets which were only morphologically related. These studies seem to indicate that associations involving roots are stored in memory longer than associations involving semantic information, and they imply that, at least at some level of word processing, the root is distinguished from the pattern (Bentin & Feldman 1990:704). Other examples are studies of subjects’ reactions to initial and final doubling of root consonants. These studies rely on phonotactic constraints in both Hebrew and Arabic stemming from the fact that roots with final doubled consonants (e.g. bdd) are rather normal, while roots with initial doubled consonants (e.g. bbd) are extremely rare (Berent & Shimron 1997; Berent et al. 2001; Frisch & Zawaydeh 2001). In experiments involving lexical decision tasks, pseudowords with initial doubled consonant roots are rejected significantly faster than pseudowords with final doubled consonant roots, and this sensitivity to root constructions appears regardless of the position of the root consonants within the word (Berent & Shimron 1997; Berent et al. 2001). Furthermore, it seems documented that the phenomenon cannot be explained solely by the statistical possible occurrence of the different structures (Berent & Shimron 2002).

Moreover, it has been shown that Arabic-Hebrew bilinguals are able to extract meaning from roots and create words based on the root-pattern structure, and this goes for even pre-readers who have not yet been formally introduced to the linguistic tradition of describing Semitic morphology as root-based (e.g. Berman 2002; Clark & Berman 1984; Ravid 2002). For instance, 3-7 year old Hebrew-speaking children were exposed to a verb connected to a question, e.g. the use of a certain instrument was described, and when the children lacked vocabulary for the relevant instrument, they applied the morphological pattern implying ‘instrument for the action’ in connection with the root given by the verb of the question. In this way they invented words which were morphologically sound and semantically comprehensible but non-existent in the Hebrew vocabulary. In a corresponding comprehension test, the same children were asked to describe the semantic value of pseudo-words constructed the same way by the authors. Such words were comprehended in 59% of the cases among the 3-year-olds and among 87% among the 5-year-olds, while the control group of adult subject comprehended 100% of these invalid words (Clark & Berman 1984). Another study of Hebrew-speaking children’s linguistic development found that two-year-olds produce speech errors by mixing roots and patterns into invalid words exactly the same way
(Borer 2002). Furthermore, Badry (1983) found that Moroccan schoolchildren’s knowledge of roots – compared to other types of linguistic resources – was the predominant positive factor for their production of verbs in writing. And Berman put forward a statement just as categorical as the one by Heath cited above, but reflecting the opposite point of view:

"[...] for speakers of Hebrew, the consonantal root has definite psychological reality as both the structural and the semantic basis for new-word formation." (Berman 2002:245)

Viewing the question in a historical perspective, it can be argued that the root-pattern-morphology originate from the Proto-Semitic language which is the origin of the presently living Semitic languages which have since developed in different directions. This is why we can observe linguistic phenomena and new word formations violating the root-based structure. On the other hand, one could say that many of the linguistic examples given with the purpose of rejecting the root-pattern morphology – especially in Hebrew – are based on loans from other languages importing the structure of these at the expense of the rules linked to Semitic language structures and inflexional patterns. This does not seem to differ from what sometimes happens to loan words in other languages.

In any case, linguistic arguments do not change the fact that psycholinguistic research in the area as reviewed above makes it hard to ignore that the traditional portrayal of Semitic morphology as based on roots and patterns actually mirrors a mental reality of roots and patterns carrying separate cognitive representations in native speakers of Arabic and Hebrew.

6.2 The role of roots and patterns in word recognition

A range of studies deal with the possible role of the root-pattern morphology in word recognition in Hebrew and Arabic specifically. The bulk of these studies take the dual route model as their point of departure, and in this sense the ultimate aim of such experiments has been to determine whether or not word processing in the Semitic languages rely on roots and patterns as independent entries in the mental lexicon.

Frost, Forster & Deutsch (1997) performed a series of tests with repetition priming of Hebrew nouns. In order to test the lexical status of roots and patterns, they examined how roots and patterns respectively influence lexical decision and recognition of words and pseudo-words: Subjects were exposed to primes which were either identical with the target, had the same root as the
target, had the same pattern as the target or had no root- or pattern-relation to the target. When exposed to the target, lexical decision or naming latencies were measured. All primes and targets in all the different scenarios consisted of the same number of letters, and all words were voweled high-frequency words which were not homographs. Each pseudo-word was constructed by a pseudo-root and a valid pattern. The experiment showed that when the prime and the target shared the same pattern, there was no significant effect on the prime. However, when they shared the same root, lexical decision and naming were significantly faster than in the control situation where there was no relation between prime and target. Real word targets which were identical with the primes were always recognised fastest, whereas identical primes and targets did not result in reduced naming latencies of pseudo-words compared to the other situations. This seems to confirm that the measured effect of the primes reflect lexical associations. The authors concluded that the roots of Hebrew nouns hold an independent lexical status in Hebrew readers, while the same is not the case for patterns.

In a follow-up, Deutsch, Frost & Forster (1998) made the same kind of tests using Hebrew verbs. Besides constructing stimuli similar to those used in the prior experiment, only using verbal patterns, they added a pattern repetition priming task in which all targets were pseudo-words, but while half of these were constructed of valid patterns and pseudo-roots, just like in the previous experiment, the other half had both valid roots and valid patterns which in combination gave an invalid word. In the lexical decision task subjects were to reject only pseudo-words with pseudo-roots. The results showed a clearly significant effect of all three priming conditions on both lexical decision and naming and the difference between results in the two pattern-tasks were marginal. The authors concluded that for Hebrew verbs, both roots and patterns are lexical units, and the fact that morphological decomposition of verbs occurs even when a word consist of an invalid root-pattern combination strengthens the hypothesis that verbal patterns are processed independently during word recognition.

Abu-Rabia & Awwad (2004) replicated the first of the two above mentioned studies (Frost et al. 1997), only in Arabic. They reported to have found slightly but not significantly reduced lexical decision and naming latencies when primes and targets were pattern-related – similar to the results found in Hebrew. Regarding accuracy, pattern-relation between primes and targets significantly influenced subjects’ ability to correctly reject pseudo-words in the lexical decision task (when primes and targets shared the same pattern, error percentage was half of what was the case in the condition with no relation between prime and target) Opposite to the Hebrew results, root-relations between primes and targets did not have a positive effect on latencies, and
error percentages in rejections of words were – opposite to the pattern condition – higher when the prime and the target were root-related. Based on this, Abu-Rabia & Awwad concluded:

"The conclusion of this study is that the nominal derivational morphology of Arabic words is represented in the mental lexicon as separate whole words, and the nature of the morphology exerts no influence on the process of word recognition." (Abu-Rabia & Awwad 2004:332).

<table>
<thead>
<tr>
<th>Patterns</th>
<th>Hebrew</th>
<th>Arabic</th>
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<tbody>
<tr>
<td></td>
<td>Lexical decision</td>
<td>Error %</td>
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<td>5.2</td>
</tr>
<tr>
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<td>9.1</td>
</tr>
<tr>
<td>Not related</td>
<td>579</td>
<td>8.2</td>
</tr>
<tr>
<td>Identical</td>
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<td>8.4</td>
</tr>
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<tr>
<td>Not related</td>
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<td>9.6</td>
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<td>6.2</td>
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<tr>
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<tr>
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<td>8.9</td>
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<tr>
<td>Root-related</td>
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<td>9.8</td>
</tr>
<tr>
<td>Not related</td>
<td>639</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Insert 7  Reaction times for lexical decision and word recognition (ms) and error frequencies in lexical decision in Hebrew (Frost, Forster & Deutsch 1997) and Arabic (Abu-Rabia & Awwad 2004) when primes and targets were identical, pattern-/root-related or not related.

<table>
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<th>Arabic</th>
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<tbody>
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<td>Naming</td>
</tr>
<tr>
<td>Words</td>
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<td>3 (0.5 %)</td>
</tr>
<tr>
<td>Pseudo-words</td>
<td>-3 (-0.5 %)</td>
<td>1 (0.2 %)</td>
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<tr>
<th>Roots</th>
<th>Hebrew</th>
<th>Arabic</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Lexical decision</td>
<td>Naming</td>
</tr>
<tr>
<td>Words</td>
<td>13 (2.2 %)</td>
<td>13 (2.1 %)</td>
</tr>
<tr>
<td>Pseudo-words</td>
<td>-3 (-0.5 %)</td>
<td>-2 (-0.3 %)</td>
</tr>
</tbody>
</table>

Insert 8  Differences in reaction times between not related and pattern/root related primes and targets in ms and % in Hebrew (Frost, Forster & Deutsch 1997) and Arabic (Abu-Rabia & Awwad 2004). Significant differences are marked by bold numbers on white background.
However, a closer comparison of the two studies reveals a marked discrepancy between the results which are listed in insert 7. In insert 8 the differences between the two studies are listed as deviations in ms and percentages between reaction times with and without pattern or root relation between primes and targets. While a latency reduction of just 13 ms, corresponding to a little more than 2%, in the condition of root-related word primes is statistical significant in the Hebrew experiment, a latency reduction of 78 ms, corresponding to about 13%, in the conditions of pattern-related word and pseudo-word primes in the Arabic test is not enough to constitute a significant difference. This is probably due to larger standard deviations in the Arabic results, and in insert 8 we see that mean values are much more uniform in the Hebrew than in the Arabic experiment. In the Arabic study, all differences in reaction times between identical and not related primes and targets are significant for words, so the value of association from the identical primes were obviously measurable, but while the effect of identical primes and targets in the root-task was significant for pseudo-words, this was not the case in the pattern-task. In short, the results obtained in the Arabic experiments are somewhat less convincing than the results in the Hebrew experiment which seem more homogenous and thus presumably more valid. However, this would not be particularly problematic without the rather far-fetched conclusion by Abu-Rabia & Awwads cited above: The fact that they do not find a statistical significant value of association between primes and targets does not necessarily imply that morphology does not exert any influence on the word recognition process. A criterion for the selection of stimuli was that words were highly frequent, and – as the authors themselves point out – it is often presumed that high-frequency words are predominantly orthographically decoded. This entails that they – to a larger extent than less frequent words – are recognised as whole lexical units, while other resources such as phonology and morphology are mainly activated when such a direct, lexical word recognition is not established (Abu-Rabia & Awwad 2004:334). Furthermore, the analysis of the marked differences in results between the Hebrew experiment and their own – despite the fact that the former functions as a model for the chosen test design – is limited to the following:

"The letters in Arabic are connected to one another, except for five letters that are not connected from the left; such a writing system seems to be cognitively demanding so that readers overlook morphological decomposition of words. Such an orthographic characteristic makes the Arabic language different even from Hebrew." (Abu-Rabia & Awwad 2004:333)

It is possible of course that the discrepancy in the results of the two studies are actually due to qualitative differences between Hebrew and Arabic script –
especially considering the review presented in section 4 – but one could imagine other possible reasons, e.g. a rather disparate sample or a lack of decoding abilities among the subjects in the Arabic experiment. The somewhat irregular results and not least the large error frequencies in the Arabic results could indicate that these exact issues are part of the explanation. And, unfortunately, the authors do not make a great effort in analysing the differences which prove to be significant: Why did the pattern-related primes result in lesser lexical decision errors in the pseudo-word targets than primes with no relation to the target? And why did root-related primes result in more lexical decision errors for words in the same category? One explanation could be that the root actually does play a significant role in whether or not the stimulus is perceived as a word: When the prime shares pattern with the target, the difference between the two is obviously the root. If we imagine that the subjects in the experiment perceive the pattern as a ‘word template’, it would explain that pattern-related primes leave more cognitive surplus to focus on the root and correctly reject it as a pseudo-root. In the condition of root-related primes and targets (in which the prime per definition is the pseudo-root used to construct the pseudo-word target), one could imagine that the prior activation of the pseudo-root in combination with the valid pattern of the pseudo-word target results in the large tendency to perceive pseudo-word stimuli to be valid words, resulting in the high error frequency. In any case it seems somewhat hasty to reject roots and patterns entirely as being relevant for lexical processing of Arabic nouns based on this single study.

At least for Hebrew, it seems that the morphological structure has a say in word recognition. When the effect of pattern priming is only significant in verbal forms, it might be due to the fact that there are lesser different verbal patterns and that they are more phonologically regular than nominal patterns. Whether the morphological structure plays the same role in Arabic cannot be determined on the basis of the study by Abu-Rabia & Awwad (2004) alone. A replication of Abu-Rabia & Awwad’s experiment and a study employing repetition priming of verbal forms in Arabic similar to the study by Deutsch et al. (1998) would be of great interest in this regard.

However, a very different study by Ryan & Meara (1991) indicates that consonant structures are important for decoding in Arabic after all. In this experiment the subjects were Arabic-speaking English-learners. Their reading errors in English were compared to reading errors made by English learners of other L1’s. The results show that Arabic-L1 learners – unlike European-L1 learners – had a clear tendency towards ignoring vowels and overemphasising the importance of consonants when reading in English, so that they often
confused English words sharing the same consonants. For instance, 'biscuit' was decoded as 'basket', 'spread' as 'separate', 'pulls' as 'plus' and 'moments' som 'mountains'. Thus, they apparently constructed phonological representations of the words primarily based on their consonantal structure. Seemingly, this kind of misreading is due to a transfer of a decoding strategy based on root consonants.

Related to the reviewed research from tests employing repetition priming, this leads to the conclusion that the consonantal root is given at least some level of separate attention in the decoding of both Arabic and Hebrew.

6.3 Studies of dyslexia

Most studies of dyslexia in adult speakers of Semitic languages are comparisons of their reading errors in a Semitic and a European language respectively, e.g. Arabic-French (Berg & Abd-El-Jawad 1996; Prunet et al. 2000) and Hebrew-English (Obler 1989). As mentioned in section 6.1, these studies show that dyslexics’ reading errors in the Semitic languages involve word’s roots exclusively while patterns are not affected.

When it comes to children’s reading difficulties, a few studies aim at examining the specific characteristics of dyslexia in these languages. Reading disorders in children with European L1’s have been investigated thoroughly, and it is documented that, in most cases, reading disabilities cannot be explained by either low intelligence or visual dysfunction. Rather, they are due to a lack of different kinds of specific linguistic competences (Dalby et al. 1992:107-113), and a deficit in phonological awareness seems to be the primary reason for developmental dyslexia (Frost & Bentin 1992a). With this fact as a point of departure, it has been investigated which forms of inadequate linguistic competences result in reading disabilities in Arabic and Hebrew. After all, the unvoweled Semitic orthographies are – in opposition to e.g. the deep English orthography – deep because of a lack of phonological information. Thus, we should expect that phonological awareness play a less significant role for reading ability than is the case in the European languages.

Ben-Dror, Bentin & Frost (1995) compared a group of reading disabled children with two groups of children without such difficulties. One of these last groups matched the reading disabled group in age, while the other matched it in vocabulary (as a result, this group consisted of younger children than the rest). The children, who were all Hebrew-speakers, were tested in both perception and production of a range of different linguistic competences
including ability to categorise words semantically, identify phonemes, and determine the morphological relation between words based on roots and patterns and across inflexions. In the perceptive tasks involving the mentioned parameters no significant differences between the normal reading groups of children were found, while the reading disabled children mastered all the tasks significantly worse. The most prominent difference between the groups appeared in the morphological task. Here, the difference between the reading disabled children and their age-matched peers were about three times bigger than in the remaining tasks. In the productive tasks the reading disabled and the vocabulary-matched children performed more evenly, while the normal reading, age-matched children performed significantly better. Still, the group of reading disabled children had the poorest performance, except in the semantic test where the group of younger children performed worse. The difference between the reading disabled and their normal reading age-matched peers was again most prominent in the morphological task. In both the perceptive and the productive morphological tasks, it was the relation between root and pattern that created the major difficulties for the reading disabled children, while their ability to determine the morphological relation across inflexional patterns was roughly as good as the other groups’ and in the perceptional condition the differences between the groups were not statistically significant.

Abu-Rabia, Share & Mansour (2003) conducted a similar study with three groups of Arabic-speaking children, only the control group of younger children was matched on reading proficiency in stead of vocabulary and the testing parameters were phonology, syntax, orthography, morphology, verbal memory and visual processing. While the group of reading disabled children did not display poorer competences than the other groups regarding orthography and syntax in speech, they did perform poorer in written syntax, verbal memory and visual processing. The result of the visual task shows that shortage in visual processing seems to be a significant factor for Arabic-speakers. This conclusion is backed by a study of reading development in Hebrew-speaking children showing that visual short term memory is a critical parameter for reading proficiency in Hebrew (Meyler & Breznitz 1998). Such results contradict what we know about reading proficiency in European languages where a large number of experiments have eliminated deficient visual processing as a valid indicator for ordinary, developmental dyslexia in children (Dalby et al. 1992:107-113). As in the study of Ben-Dror et al., the reading disabled children in the study by Abu-Rabia et al. (2003) displayed markedly poorer morphological competences than their peers. However, in contrast to Ben-Dror et al. they found that the reading disabled children did poorly in the phonological task as well. This difference between the results of
the two studies might be due to differences in testing methods: In the perceptual tasks, Ben-Dror et al. asked the children to answer ‘yes’ or ‘no’ to a question of whether or not a word was initiated by a certain phoneme, and in the productive task they were asked to name a word initiated by a pre-defined phoneme. In the study by Abu-Rabia et al. the phonology task was far more complex: The children were asked to delete initial or final phonemes from words or pseudo-words and to pronounce the rest of the word. This task demands a very different level of abstraction whereby other cognitive competences, e.g. memory, which in the same study proves to be weaker in this group, might affect the outcome of the experiment. In a study of Arabic-English bilingual children in Canada, Abu-Rabia & Siegel (2002) also found phonological deficits in reading disabled children, but to a lesser extent when compared to monolingual peers. However, in this study the phonology task was based on decision of whether or not the sound of a pseudo-word was ‘word-like’ – a test which makes sense in English but seems questionable in Arabic, partly because of the narrow framework of how different words can appear in Arabic, partly because of the barriers that the differences between spoken and written language represent (Abu-Rabia & Siegel 2002:666).

Moreover, Abu-Rabia & Taha (2004) compared dyslexic, Arabic-speaking children with normal reading age-matched peers and younger children matched on reading proficiency. In this study reading and spelling errors among the three groups were compared. The results show that dyslexic children produce the same frequencies and types of errors as the reading proficiency-matched younger children do, and compared to the errors produced by their age-matched peers, the errors of the dyslexic children reflect more phonological decoding difficulties as they tend to ignore short vowels. Interestingly, morphologically determined reading errors where the children keep the root of the word while applying a false pattern was the most common type of error in all three groups.

These studies document that Arabic- and Hebrew-speaking reading disabled children, just like reading disabled children who speak European languages, demonstrate a lack of several different forms of linguistic competences. However, when it comes to determining the weight of the different types of competences as indicators of reading disability, it seems that deficiency in morphological competences is of greater importance for the missing formation of age-equivalent reading proficiency in Arabic and Hebrew compared to what is the case in the European languages. Furthermore, it seems that reading in Arabic and Hebrew places heavy demands on visuo-spatial processing which probably does not merely affect letter processing (c.f. section 4) but the processing of whole words, too, because of the non-linear morphological
structure and for beginning readers the position of diacritics in a separate graphical level compared to the letters (Abu-Rabia et al. 2003:439).

In addition to this, Shatil & Share (2003) conducted a study examining how different cognitive competences affect reading acquisition in Hebrew-speaking beginning readers at as early a stage that dyslexia would not yet be diagnosable. The authors found that early reading, visual-orthographic memory and phonological memory in pre-schoolers were significant predictors of the same children’s word recognition skills at the end of first grade. As opposed to what is found in the same sort of studies of children who speak European languages (Adams 1990:65), phonological awareness was not a statistically significant predictor compared to the remaining competences examined (Shatil & Share 2003:18).

To sum up, these studies point towards the conclusion that successful reading acquisition in the Semitic languages puts more demands on visual, orthographic and morphological competences than does reading acquisition in the European languages.

6.4 A note on the possible influence of Arabic diglossia

A very important aspect of the whole complex of the influence of vowels, which the previously reviewed research does not touch on very explicitly, is that vowels seem to have a secondary function compared to consonants, not only in writing but in general. (Barnea & Breznitz 1998; Ryan & Meara 1991; Shimron & Navon 1981). This is especially apparent in Arabic where a substantial part of the variation between the spoken varieties and Modern Standard Arabic (MSA) appear as differences between vowels.

In Abu-Rabia’s study from 1998 he tested 17 year-old high-school students’ proficiency in reading aloud. The experiments show that reading aloud in Arabic is a complex task for both skilled and poor readers regardless of text genre and whether the texts are voweled. The error frequency during reading of unvoweled text – which is the form of practically all texts presented to the ordinary reader in daily life – was very high for both the skilled and the less skilled subjects. The highly skilled readers made errors in 64% of all words in the informative text genre. For the poor readers, error frequency in the same genre was 86%. The cognitive load of disambiguating homographs and the previously mentioned traditional way of applying case endings is undoubtedly among the reasons for this alarming error rate (Abu-Rabia 1998:116-117). However, the same study reveals that even during readings of correctly voweled informative texts (the genre both groups read most correctly), skilled
readers made errors in 22% of all words while the error frequency produced by the poor readers was wholly 79%. According to the author, these results indicate that the diacritics – not only vowels but also other diacritics such as shadda (consonant doubling) and hamza (glottal stop) – demand many eye fixations which are very cognitively demanding. In general, this could be an indicator supporting the conclusion of section 4 about letter recognition in Arabic: The Arabic script itself might be an important obstacle because graphic complexity and similar letter forms makes it difficult to distinguish between letters.

Other explanations are possible of course. The mentioned poor reading results correspond well with studies from the 1980’ies showing that 30-50% of Arabic primary school pupils struggle with serious reading problems (Bashi et al. 1981; Habib-Allah 1985). In the discussions presented in these studies the discouraging results are explained by aspects like poor teaching methods, inadequate teaching materials and a lack of clear curricular objectives.

However, the aspect of diglossia is probably also relevant in explaining the modest result that Arabic-speaking pupils seem to deliver when it comes to reading. Because of the distance between spoken and written Arabic, readers are not to the same extent as speakers of e.g. English or Hebrew able to rely on word identification based on word knowledge from the spoken language. Furthermore, during reading they need to activate syntactical knowledge which is not used in the spoken varieties. In recent years, several research projects have contributed to enlighten this issue. For instance, Saiegh-Haddad (2003b) tested phonological awareness and decoding skills in Palestinian preschoolers and 1st graders. She found that the distance between the children’s spoken language variety and MSA constitutes a barrier for acquisition of basic reading skills in MSA (Saiegh-Haddad 2003b:445). Saiegh-Haddad points out the phonological differences between the two language varieties as the central problem:

“[…] though the first grade children seemed to have benefited from the increased exposure and experience with MSA structures that formal literacy instruction allows, they were still facing particular difficulty when confronted with the task of isolating standard phonological structures. This finding demonstrates one of the unique complexities present in learning to read in MSA. Whereas in other linguistic contexts, beginning readers come to the reading task with sufficient knowledge and experience with the phonological structures that they are taught to decode, Arabic native children are required to simultaneously master the oral representation of a set of diglossic structures that are not
This conclusion is supported by several studies showing that exposure to MSA in the pre-school years affect children’s later reading acquisition positively. Abu-Rabia (2000) examined reading comprehension in two groups of Palestinian children in 1st and 2nd grade. During the last year of pre-schooling, one group had stories read aloud and did special activities in MSA 3 x 30 minutes daily. The other group was told stories and did the same activities in their spoken language variety. The children who had been exposed to MSA achieved significantly better reading comprehension in both 1st and 2nd grade than the other group. Jenkins (2001) examined reading proficiency in Syrian primary school children who had been enrolled in a specific kindergarten where the staff communicated with both children and parents in MSA only. Children who had attended this kindergarten during all three years of pre-schooling were able to speak MSA fluently and almost flawless and achieved significantly better reading skills than the control group of children who attended an ordinary modern pre-schooling program or did not attend preschool at all. Children who attend quranic pre-schooling also achieve better reading skills during the first years in schooling than children who receive no pre-schooling or who attend pre-schooling without focus on any written language variety (Wagner & Spratt 1987). However, the effect of quranic school seems to be much weaker than exposure to MSA, and other factors like e.g. growing up in an urban setting rather than a rural affects reading acquisition more significantly than quranic education during the pre-schooling years (Wagner & Spratt 1987:1218).

In an attempt to determine whether MSA can be said to be a second language to Arabic speakers, Ibrahim & Aharon-Peretz (2005) compared semantic priming effects in auditory lexical decision in spoken (Israeli) Arabic, MSA and Hebrew (L2 to all participants). Primes were either in MSA or in Hebrew and the targets were in spoken Arabic and vice-versa. The priming effect was three times as large when both prime and target were spoken Arabic than between languages and no difference between Hebrew and MSA was found. According to the authors, this indicates that despite Arabs’ intensive daily use of MSA when dealing with written language and oral language in formal

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13 Pre-schooling is very common in the Arabic world. The vast majority of children attending preschool are enrolled in qurainc schools where they learn to decode and recite religious texts, that is, classical Arabic. However, today it becomes increasingly popular among the urban populations to send their children to modern, privately owned ‘kindergartens’ where the focus on learning rather than playing might still be prominent, but where all spoken communication is normally in the local language variety.
settings and the relative proximity between MSA and spoken Arabic, spoken Arabic and MSA entertains two distinct lexica, and in this regard MSA seems to qualify as a second language.

During the last 10-15 years, we have witnessed a trend towards an acceptance of the hypothesis that diglossia constitutes an actual problem in linguistic and educational matters in the Arab world. (e.g. Abu-Rabia 2002; Ayari 1996; Maamouri 1998). This is exemplified by the citation below which is taken from an official report to the World Bank on human development in the Arab world:

"A [...] question relates to whether Arabic diglossia really constitutes a critical variable for the spread of literacy and the quality of basic education in the Arab region or whether socioeconomic factors override most of the elements that relate for the general impact of the Arabic language on educational attainment and achievement. This author's claim is that even though it cannot by itself bear all the blame for the crisis in Arab education, Arabic diglossia is a definite aggravating factor in the low results of schooling and non-formal instruction and taking care of it, if at all possible, would greatly improve the quality of education in the region." (Maamouri 1998:68)

In sum, it seems quite clear that besides the specific skills related to reading unvoweled Semitic scripts – skills which are cognitively demanding it seems – the distance between the spoken and the written language has a negative impact on reading acquisition in Arabic.
7. An attempt to make sense of it all

So what does it all tell us about how the decoding system works for Arabic? To sum up, reading of unvoweled Semitic orthographies – compared to European orthographies – demands longer fixations and is more time-consuming. This is probably due to the more dense level of information within words in form of e.g. articles, prepositions and pronouns which are internalised as affixes and subjects which are implicit in verbal conjugations. It is likely that the mental split-up of these different kinds of morphemes demand more cognitive capacity.

Furthermore, it seems that the reading process takes different courses for voweled and unvoweled texts. Decoding of unvoweled script is predominantly orthographic while in voweled script information is complete, and this prompts a more phonological process of decoding which seems to be faster, at least for low-frequency words. Multiple studies concerned with reading of European languages show that phonological decoding is slower than orthographic, or lexical, decoding. From a dual route perspective this is explained by the ‘direct’ access to lexicon which does not involve an ‘extra’ level of phonological processing. However, even if the nature of the dual route mechanism is rejected, this is somewhat surprising, since decoding of voweled text involves more graphic input to be processed (the diacritics).\footnote{A study of foreign language learners’ reading of Arabic reveals that, for beginning and intermediate learners, voweled text is in fact less rapidly processed than unvoweled text (Hansen 2008). This indicates that vowelisation is in fact a cognitively demanding factor during the reading process. However, in highly proficient L2-learners and native speakers the resource of information that vowels provide overrules the issue of graphical complexity.}

Similarly, when it comes to context, the results from research concerned with reading of Semitic languages collide with traditional reading theory. Not only does context play a much more dominant role in the decoding of both Arabic and Hebrew than in European languages; highly proficient readers also seem to be better at tapping the resources of contextual information in Arabic than less proficient readers. This contrasts Stanovich’ interactive-compensatory theory which is empirically well documented and broadly accepted in reading theory in general (Adams 1990; Just & Carpenter 1987; Rayner & Pollatsek 1989; Stanovich 1980, 1986, 2000). According to this theory, only less proficient readers need to rely on context in order to compensate for their less efficient decoding skills (Stanovich 1980).

These mismatches between reading theory based on European languages and reading research involving Semitic languages can be explained with the higher
level of redundancy in the European scripts. In English, it would definitely be possible to decode script even if vowels were omitted:

txt s stll mr r lss lgble whn vowls hv bn rmvd (example from Adams 1990:119)

Or – even better:

•n th• S•m•t•c l•n••g•s w• m•r• r l•ss kn•w th• n•mb•r •nd th• p•s•t••ns •f th• •w•ls w• n•d th•s m•k•s th••se sc•r•pts s•m•wh•t m•r• •cc•ss•ble.

The above examples illustrate that vowel information added to the consonants in the Roman alphabet is to some degree redundant. On the other hand, we should expect that even with practice of reading such a writing system, we are able to obtain more reading speed when vowels are specified. In that sense, it is not surprising that vowels support rather than burden word recognition in Semitic languages. This argument is strengthened by the fact that the positive effect of vowels on reading speed diminish when words are presented in context.

Furthermore, the role of context can be explained by this ‘missing redundancy’ in the unvoweled Semitic orthographies: Only less proficient readers in English need to rely on context because the phonological information necessary for decoding is often available. This is not entirely the case in the Semitic languages where a large proportion of words, because of the lack of vowels, are homographs, and this makes decoding heavily context dependent. For instance, it is often necessary to gain an overview of the entire sentence in order to determine the form of an initial verb. In voweled Semitic texts sufficient phonological redundancy is available, so that context becomes an additional resource that skilled readers do not need, but it can be used as a back-up source of information if decoding skills are inadequate. Thus, the consequence of Semitic script most often being unvoweled is that context plays a quite different and more important role than in the European languages: When reading in languages which use the Roman script, less skilled readers can rely on context as a compensatory resource, while highly proficient readers do not need to do so. When reading in Semitic languages, highly proficient readers are highly proficient because they rely on context.

Even though millions of native speakers of Semitic languages are able to decode unvoweled Semitic orthographies in an uncomplicated, fluent process, it seems clear that it is of great importance for the reading process that the
reader – because of the lack of phonological information compared to what is the case in Roman-written orthographies – have less resources at their disposal during reading. And it seems there is reason to assume that as a result, readers of these languages make use of other kinds of resources than those utilised in the European languages, and that the decoding process demands more cognitive capacity. When vowelisation – independently of decoding speed and word recognition accuracy – improves reading comprehension, it is at least an indication that reading without vowels is so cognitively demanding that it absorbs capacity which – when vowels are present – is more readily available for comprehension processes.

When determining how these different resources affect the decoding process in Semitic languages, we should bear in mind that practically all these research projects examining lexical decision and word recognition were carried out with the dual route model as their point of departure. This has influenced both research designs and the way the data was interpreted. When studies show that vowelisation does not improve lexical decision latencies for homographs, and that homographic primes seem to activate more meanings, it was reasoned that lexical decision takes place before the exact vowel pattern is applied and thus before the reader has decided on which word among the different possibilities he is dealing with. Based on this assumption, an expanded reading model for unvoweled Semitic orthographies was launched. This included an extra level of processing on the route towards the mental lexicon. This ‘extra lexicon’ consists of valid consonant strings, and since lexical decision does not necessarily involve phonological processing, all entries are possibly solely orthographic. In any case, a word’s full phonological representation is a result of – rather than a means to – word recognition. (Frost & Bentin 1992a; Frost et al. 1987; Katz & Frost 1992). Along with the knowledge about the influence of context and word frequency, these researchers ended up with a reading model in which word recognition in Semitic languages go through root based entries to the mental lexicon: The reader meets an ambiguous word, detracts the root and then considers which vowel pattern it makes sense to match it with according to the context; and – if context is either ambiguous or not available – he weights the options according to a frequency-determined hierarchy of possible words. On many occasions, this frequency-based hierarchical procedure would of course by its very nature lead him directly to the correct meaning.

However, the more recent data documenting pre-lexical phonological processing contradict this word recognition model, while they match the proposed reading model in insert 5 perfectly. In accordance with connectionism, this model contends a continuous interplay between
orthographic and phonological processes - within which all kinds of relevant resources established by the reader through previous exposure to text are activated. In this model, all the previous documentation on how the different forms of relevant resources (context, word frequency, and vowels if available) are activated, can easily be incorporated. At the same time, the connectionist model explains how the system of roots and patterns influences the reading process – not only as part of the broad linguistic competence (at the top of the model) but also at the level of word recognition where the morphological structure probably plays a crucial role as a compensatory source of information in the case of missing vowels. This does not necessarily function as a splitting of roots and patterns into independent morphemes (despite the fact that this seems to be the case, at least in Hebrew), but as a result of frequency: The limited number of possible patterns leaves the reader with a limited number of possible word structures stored in the hidden units ready to guide the decoding process.

Based on these issues it is possible to come a step closer in the determination of how information processing in word recognition in Semitic languages differ from equivalent processing in the European languages:

In general it seems that phonological processing during reading of unvoweled script is more modest. This is reflected in the research exploring the ODH and those data concerning dyslexia as reviewed above. While phonological processes are crucial in word recognition in English just as phonological awareness is "inescapably required" (Adams 1990:305) in order to achieve good reading skills, this is only to a lesser extent the case in Semitic languages, where, on the contrary, orthographic and morphological processes play a more prominent role in establishing good reading skills than is the case in the European languages. According to the ODH this is due to the limited amount of phonological information given by the orthography in question, and as a result the reader has to rely on other available resources. This explains why – in opposition to what is the case in the European languages – correct reading aloud and reading comprehension do not correlate in Arabic and Hebrew (Abu-Rabia 2001; Saiegh-Haddad 2003a): While phonological processing is of course a prerequisite for reading aloud, reading comprehension does not necessarily require an identification of words’ exact phonological identities, since word recognition to a large extent makes use of other kinds of resources. Furthermore, Arabic diglossia might have a say in this matter: When written and spoken language are so far apart, the possibilities of phonological association processes are reduced and this might contribute to a word recognition processing which to a large extent rely on other resources than phonology.
If these issues are viewed within the illustration in insert 5, we could say that during reading of Semitic languages the information flow is – to a larger extent than in European languages – more distinctly guided towards the left of the model, both at the word recognition level and at the top level, where context is more significantly utilized. A possible articulated output could be illustrated as an external connection from the ‘phonology’ box towards the speech organs, but a substantial part of the information flow evades this part of the model, which explains the weak connection between comprehension and reading aloud mentioned earlier.

If we look more closely at the role of morphology which is not explicit in the model but is internalised in the hidden units, in particular between orthography and phonology, we should suspect that the process at this location within the model is indeed language specific, since the reader’s experience with linguistic structures is stored in the hidden units (as described in section 3.2 & 3.3) In European languages, high-frequency and low-frequency letter constellations are essential in this context, because of the ‘neighbour-frequency-effect’ as mentioned in the review above, or as Adams (1990) puts it:

"The nature of the stimulation passed along from a donating to a receiving letter depends on the frequency with which the two letters have occurred together in the reader’s lifetime of reading experience. Letters that have often been seen with the donating letter will receive positive excitation; the more often they have been seen together, the stronger this positive excitation will be. Conversely letters that have rarely been seen with the donating letter will receive negative excitation, or inhibition, that is proportionate to the rareness of their co-occurrence." (Adams 1990:109)

These processes implicitly entail that we have a perceptual tendency to split long words into syllables automatically. If, for instance, the first letter of a word is a ‘d’, it is more probable that it is followed by a ‘r’ than by a ‘n’, thus ‘dr’ represent a well-known letter constellation while ‘dn’ would be less expected. And while less frequent letter constellations often occur in the connection of two syllables, as in ‘midnight’, the reader would – based on experience – be inclined to split the word at this very spot, if he fails to deal with the word as a whole (Adams 1990:116). This is of course very expedient when each syllable represent independent unities of meaning, and the strategy therefore represents yet another resource in the reading process. In other words, neighbour-frequency effect is a result of storage of syllabic and morphological information in the hidden units, where both orthographic and
phonological elements play their part and result in different degrees of ortho-
and phonotactic incentives or constraints.

In addition to this linear processing, we rely on a more holistic visual
perception of each word. As exemplified in insert 9, we are able to retrieve
word recognition fairly quickly based on word length and a few letters in the
right position, despite the fact that the text triggers notable feedback of several
uncommon or even unacceptable letter constellations.

Hence, automatic word recognition, which is essential for good reading skills,
relies very much on the perception of single words as wholes. However, the
linear letter analysis is still activated (Adams 1990:111). Seidenberg &
McClelland have shown that at least monosyllabic words are processed
through a ‘triple-letter-analysis’ in which words are treated as a series of
trigrams. For instance, the word ‘drum’ is processed as [ dr], [dru], [rum], [um ].
This continuous processing functions as a ‘auxiliary engine’ which supports
the process by confirming the reader’s perception of the holistic input, settle
the question in matters of doubt and ‘cobble the pieces together’ when needed
during the process. All this put together enables the reader to obtain fluency
and increase reading speed.

In the Semitic languages it is a totally different matter, as the phonological
information is more scarce, and the morphological structure different: Since
short vowels are not present, the reader does not have the same possibility of
establishing a reaction to well-known and unaccustomed letter constellations,
and thus it is not possible to establish positive or negative feedback based on
combinations like ‘dr’ and ‘dn’. First of all, ‘dr’ could represent either /dar/,
/dur/, /dit/ or /dr/. Second, the orthographic recognisability depends very
much on the third consonant of the relevant root. Furthermore, letters which
are part of a word’s pattern hold fixed positions within the word, and there is
no restrictions upon which consonant such a pattern-letter can be combined
with. And when it comes to the holistic word processing, the information

This example shows that linear letter analysis is not
necessary for word recognition (at least not when words are fairly
frequent).

Insert 9 An example demonstrating that linear letter analysis is not
necessary for word recognition (at least not when words are fairly
frequent).
available is similarly scarce, as the limited number of patterns results in a graphically more uniform vocabulary. In short, Semitic words do not look as diverse as European words. Large groups of words are only distinguishable by the three consonants that make up the root, and thus there is no basis for establishment of the mentioned positive and negative types of feedback based on letter constellations.

In return, the tight morphological structure in the Semitic languages provides other kinds of resources: Some pre- in- and suffixes can – like word length – give feedback on which patterns are applicable to a given word. Actually, a prefix will sometimes reduce the number of possible pattern combinations to very few or even a single one. And when the pattern is given, the vowels are, too. Recognition of a pattern is in other words essential, when a letter constellation like ‘dr’ is to be decoded, as it determines whether the reader is dealing with /dar/, /dur/, /dir/ or /dr/. Moreover, recognition of the root might be crucial as well, since this recognition will reduce the number of applicable patterns.

Another example of the different kinds of morphological structures stored in the hidden units in European and Semitic languages respectively is that in European languages we are readily able to distinguish between pseudo-words (which are word-like), e.g. ‘kvir’ or ‘flas’ and non-words (which are not word-like), e.g. ‘ikvr’ or ‘lfas’: Pesudo-words consist of well-known letter constellations and represent an acceptable phonological structure, and the linear letter analysis gives positive feedback though they have no semantic value. The non-words, on the other hand, give negative feedback because the unfamiliar letter constellations collide with the grapho- and phonotactic constraints that have been established within the word recognition system. In the Semitic languages the difference between pseudo-words and non-words will not depend on letter constellations but on valid or invalid patterns. If the pattern is valid, the ‘word’ will be perceived as word-like, and the difference between words and pseudo-words thus depends solely on whether or not the three root consonants construct a valid word in combination with the given pattern. Construction of a non-word would demand a non-existent pattern. Likewise, it would be impossible to construct a Semitic version of the example in insert 9 (which demonstrates our ability to read English – at least high-frequency words – even if only the first and last letters are in the right positions). A corresponding manipulation of Semitic words would have a totally different result. With three root consonants and e.g. an infix, it would

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15 Note that in both European and Semitic languages there are in fact words – especially loan-words – which are valid despite the fact that they collide with established grapho- and phonotactic constraints, e.g. in Arabic ‘ديمقراطية’ (‘democracy’) and in English ‘phthalates’.
sometimes be possible to create a range of valid words, since interchange of root consonants would often result in another valid root, just like an infix in another position would sometimes result in another valid pattern.

In other words, the Semitic languages' morphological structure must lead us to conclude that during reading in these languages, processes like triple-letter analysis and neighbour frequency effect are not essential elements as is the case in the European languages. On the other hand, the presented review and the differences between morphological structures in European and Semitic languages should lead us to assume that roots and patterns receive some level of separate attention in the word recognition process in Arabic and Hebrew, whereby knowledge of possible patterns play a substantial role in word recognition. Based on connectionist theory it is plausible that some kind of ‘pattern-frequency effect’ is stored in the hidden units of the word recognition system where it is used to obtain rapid word recognition. The primary argument for this assumption is that the selection of available resources provided by the writing system is rather scarce, and recognition of valid word patterns seems to be the essential source to vowel information, at least during reading of low-frequency words.
8. Conclusions

The purpose of this analysis has been to bring forward a collective overview of what we know about how word recognition processes function in Arabic compared to similar processes in English and other European languages which have traditionally been the outset for reading research in general.

As a theoretical framework for this analysis, the common connectionist word recognition model is adjusted in order to accommodate the need for regarding letter recognition as a separate process. This part of the analysis is not very elaborated so far – research in this field is very scarce and as a result, we do not come this issue any closer than a rather general, comparative description of Arabic letters being more difficult to decipher and distinguish than letters in the Roman alphabet. The reason for this is most likely found in the cursive writing and the rather similar letterforms characterising Arabic script.

When it comes to the ‘next level’ of word recognition – the integration of phonological and orthographic information in the decoding process – research concerned with Hebrew provides a valuable resource. Assuming that the similarities in the morphological structures of Arabic and Hebrew entail that decoding processes in these two languages, beyond the letter recognition stage, are equally similar, the collective of research dealing with reading in these two languages offer a range of guidelines for assuming that reading in Semitic languages does in fact progress rather differently than is the case in the European languages: The fact that short vowels are normally omitted in Semitic writing makes decoding more reliant on other kinds of information than phonology. In relation to the orthographic depth hypothesis, decoding is predominantly orthographic, and the vast amount of homographs makes the reader heavily dependent on context in the quest for the meaning of words, and within this context-dependent searching for meaningful output, word-frequency seems to be a guideline for prioritising the possible meanings.

Furthermore, several psycho-linguistic studies seem to indicate that the root-pattern morphology in Arabic and Hebrew is embedded rather deeply in the linguistic cognitive system of native speakers of these languages, and knowledge of roots and patterns and their possible combinations might play a significant role as pieces in a word-constructive puzzle within the decoding process, thus acting as yet another resource.
Adding a few more analytically based comparative considerations based on differences between the European and the Semitic writing systems brings us a step further: the linear features of word recognition processes in European languages like triple-letter analysis, neighbour-frequency effects and splitting of words into syllables do not make much sense in Arabic, just as grapho- and phonotactical constraints established in connection to such processes cannot exist in the Arabic word recognition network the way they do in the word decoding system in skilled readers of European languages. Rather, readers of Arabic establish other kinds of decoding resources, and in this respect some kind of a pattern-frequency effect build into the network of the skilled reader of Arabic is a probable outcome of knowledge of word patterns being a crucial source of vowel information.

However, despite the fact that such substitutions for the lacking phonological information are thus available, reading in Arabic generally seems to be a more complex matter than reading in European languages. The script issue mentioned above might be part of the explanation, but furthermore, Arabic words are often more dense on information than words in European languages generally are, since more morphological entities are often included as parts of words, which then are to be crystallised as separate entities during decoding. Though not scientifically proved, this aspect could be of importance.

In addition to these issues linked to normative aspects concerning the Arabic writing system, socio-linguistic aspects may be relevant in explaining that Arabic readers tend to process text material less accurately and at a slower pace than readers processing texts in European languages. Besides socio-economic difficulties and tradition-bound teaching methods limiting the educational standards in vast parts of the Arab world, the diglossic situation in Arabic is probably relevant in this respect. It can be argued, that the written language variety in Arabic is a second language to children entering school. However, the conclusion is not very important in relation to this question, because, obviously, when a child is only taught how to read in a language that he or she does not speak, it is not a perfect start of a literacy career.

The final remarks of this paper are as controversial and sensitive as the one just mentioned (at least when brought forward in the Arab world). One conclusion of this study is that more research in this field is necessary in order to shed more light on the nature of reading processes in Arabic. However, in the broader picture of this topic, a another conclusion could be that Arabic language policies need to address the problems revealed throughout this review. All the different cognitive complexities posed on reading processes in Arabic by the nature of the script, the writing system, the languages within the
language and the way reading is taught – and not least the combination of these issues – could very well be among the most important obstacles to human development in the Arab world. Tradition, religion and aesthetics are of course important values, but in relation to Arabic written language they might have been overemphasised for too long.
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