Chapter 4
Why is it Hard to Read Arabic?

Zohar Eviatar and Raphiq Ibrahim

Abstract Previous research has shown that reading in Arabic is a slower process than reading in other languages, even among skilled native Arabic speakers. In addition, the process of reading acquisition by beginning readers is slower than in other languages. We present three possible sources of these phenomena from both a psycholinguistic and a neuropsychological perspective. We examine the effects of diglossia (the fact that children learn to read a language in which they are not fluent), and the visual characteristics of Arabic orthography on reading acquisition, and suggest that the particular combination of grapheme-phoneme relations and visual characteristics of Arabic orthography result in a specific reading strategy among skilled readers that involves the cerebral hemispheres differently in Arabic than in Hebrew or English.

Keywords Arabic · Cognitive system · Cognitive processing · Diacritics · Diglossia · Unvoweled script · Voweled script · Word reading

4.1 Introduction

Previous research has shown that both reading single words and reading acquisition in Arabic is slower than in other languages, even among skilled native Arabic speakers (Azzam 1984; Eviatar and Ibrahim 2004; Abu-Rabia 2001). In addition, the process of reading acquisition by beginning readers seems to be more challenging than in other languages (Saiegh-Haddad 2003). This chapter explores three possible sources for these phenomena, from both a psycholinguistic and a neuropsychological perspective. We examine the effects of diglossia (one manifestation of which is the fact that children learn to read a language in which they are not orally fluent) (for a detailed discussion see Saiegh-Haddad and Henkin-Roitfarb, in this volume), and the visual characteristics of Arabic orthography on reading

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acquisition, and suggest that the particular combination of grapheme-phoneme relations and visual characteristics of Arabic orthography result in a specific reading strategy among skilled readers that involves the cerebral hemispheres differently in Arabic than in Hebrew or English.

4.1.1 Diglossia

Arabic has two forms: the *spoken* form (*ʔa:mmiyya*—the spoken vernacular, one of a set of colloquial dialects that share certain syntactic and morphological features and lexicon and differ in others) is used by speakers of the language in a specified geographic area for daily verbal communication, and is the native language of virtually all Arabic speakers. The *literary* form (*fusħa*) is the language in which all speakers of Arabic, from all over the world, read and write. This form of Arabic is universally used in the Arab world for formal communication and is known as "Modern Standard Arabic" (hereafter, StA). Spoken Arabic (hereafter, SpA) is a colloquial dialect and has no formal written form. Everyday life requires a mixing of SpA and StA. This can be seen on television, where characters in shows speak SpA, but announcers speak StA. On news programs, interviewees often mix the two forms of Arabic, whereas interviewers speak StA exclusively. Recently, the advent of the internet and of texting on cellular phones has resulted in a grass-roots development of a written form of *ʔa:mmiya*(SpA) using Latin letters and numbers, known as 'Arabizi' (a combination of 'Arabic' and 'Inglizi' (English) (Bashraheel 2009). To our knowledge, this phenomenon is only beginning to be studied.

The differences between *ʔa:mmiyya* and *fusħa* served as part of the background to the introduction of the term 'diglossia' by Ferguson in 1959, and have generated a long debate over the distinction between diglossia and bilingualism(e.g., Eid 1990). Several psycholinguistic studies have addressed this issue directly. Ibrahim (Ibrahim and Aharon-Peretz 2005; Ibrahim 2009) examined the relationship between the two forms of Arabic in adults, by comparing auditory semantic priming and repetition effects on lexical decisions within the native language (L1 (SpA)) with the effects obtained when the primes were either in StA or in Hebrew (the participant's second language (L2)) and the targets were in Spoken Arabic, and vice-versa. These studies showed that facilitation patterns were more similar between StA and Hebrew than between either of these languages and SpA. Ibrahim suggested that despite the intensive every day use and psychological proximity of SpA and StA, they are represented in two different lexica in the cognitive system of the native Arabic speaker. However, the statistical differences indicate a closer relationship between the two forms of Arabic than between Hebrew and SpA (Ibrahim 2006).

Eviatar and Ibrahim (2000)examined this question in children, by exploring the effects of the relationship between a bilingual's languages and the emergence of metalinguistic skills in childhood. The following hypothesis was addressed: given that bilingual children reveal heightened metalinguistic abilities as a result of acquiring two linguistic systems rather than one, do preliterate and newly literate Arab children evince this effect, before they have been exposed to any other language? The study tested samples of monolinguals (Hebrew), bilinguals (Hebrew and Russian), and Arabic-speaking kindergarten and 1st grade children. The Arabic speakers' first acquired language was Spoken Arabic and they were exposed to StA via story book reading, television, and formal instruction in literacy-related activities in kindergarten and 1st grade. The Russian-Hebrew bilingual children came from immigrant families to Israel from the former USSR. They are growing up in Russian-speaking homes, but attend Hebrew-speaking schools. The Russian-Hebrew bilinguals showed the classic pattern resulting from exposure to two languages: higher performance levels in metalinguistic tests, and lower performance levels in the vocabulary measure as compared to monolinguals. The Arab children's performance levels were similar to those of the bilingual children for the most part, and suggested that exposure to StA in early childhood promotes metalinguistic skills to the same degree observed among bilingual children exposed to two different languages. This implies that Arabic-speaking children raised with SpA and StA behave linguistically and metalinguistically like bilinguals.

Effects of Diglossia On Readings

Diglossia is a complex phenomenon that can have several effects on the acquisition of reading (see Saiegh-Haddad and Henkin-Roitfarb, in this collection). One effect has been demonstrated by Saiegh-Haddad (2003, 2004), where kindergarten children showed particular difficulty when asked to access StA as against SpA phonological structures in metalinguistic awareness tasks. This difficulty has been demonstrated in explicit as well as implicit phonological awareness tasks (Saiegh-Haddad et al. 2011). Further, formalized as the *Linguistic Affiliation Constraint*, this effect has been shown to have a cross-dialectal validity and to persist across the early elementary grades (Saiegh-Haddad 2007). Saiegh-Haddad has also shown that the recoding of letters representing StA phonemes was correlated with awareness of these phonemes and that letter recoding speed is the best predictor of pseudo-word decoding fluency in the 1st grade. These results were interpreted as indicating that Arabic-speaking children fail to construct accurate phonological and lexical representations for StA words. In convergence with these findings, recent results from our lab (Asaad 2011) reveal that even adult speakers of Arabic are slower in accessing the names of letters representing phonemes that do not exist in their specific spoken dialect. In this study, children and university students were given two versions of the RAN (Rapid Automatized Naming–in which they must name a series of letters as quickly as they can). In one version, the letters represented sounds that occurred in the participants' dialect and in the other, the letters represented sounds that did not occur in their dialect. It was found that although naming time decreased as children grew older and had more experience with StA, letters representing phonemes that only occured in StA were always named more slowly, at all ages (Fig. 4.1).

It is well known that metalinguistic ability, specifically, phonological awareness, is positively related to the acquisition of reading (e.g., Share et al. 1984). As

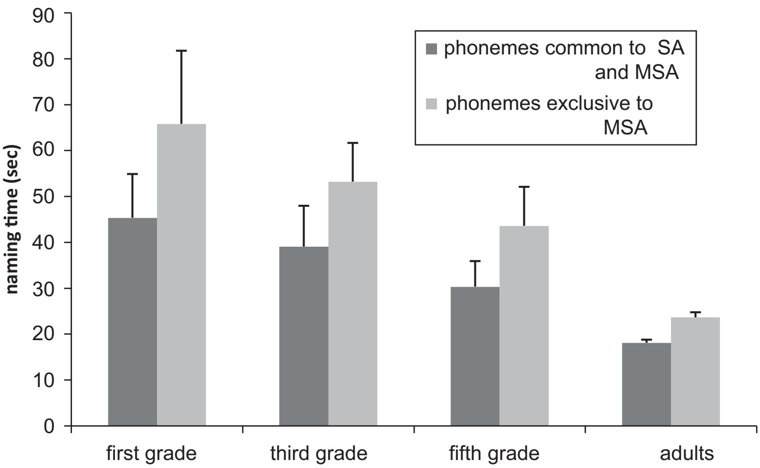

Fig. 4.1 Response times on the RAN. Error bars are standard errors. SA = the stimuli were letters representing sounds common to both the dialect spoken by the participants (Spoken Arabic) and Modern Standard Arabic; MSA = the stimuli were letters representing sounds that are not part of the dialect spoken by the participants

described above, we have previously shown that children exposed to both forms of Arabic function as bilinguals, as they show higher levels of phonological awareness than age matched monolingual Hebrew-speakers. This would predict that they should show an advantage in reading acquisition. However, the opposite finding has been reported. In addition, we measured the relationship between phonological abilities and various reading measures in the 1st grade in children learning to read either Hebrew or Arabic as L1(Ibrahim et al. 2007). The children were given a series of tests of phonological awareness, a vocabulary test, and grade level texts to read. The correlations between the metalinguistic measures and text reading speed and accuracy are shown in Table 4.1.

It can be seen that out of 8 possible correlations, 7 are significant among the monolingual group, and 6 are significant for the Russian-Hebrew bilingual group. Both of these groups are learning to read Hebrew. For the Arabic-speaking children who are learning to read Arabic, only 3 of the correlations are significant. This implies that there is a weaker relationship beween phonological abilities and reading in Arabic than in Hebrew. Table 4.1 also shows that the children reading Arabic read more slowly and make more errors than the children reading Hebrew. Thus, although the Arab children evince higher levels of phonological awareness-than monolingual Hebrew-speakers, this phonological awareness advantage does not translate into an advantage in reading acquisition. What could be the reason for this? StA has an alphabetic orthography, like English and Hebrew, and in both these languages, phonological awareness is a very good predictor of success in reading acquisition. One possible answer might be related to the effect of the diglossia—the two groups who were reading Hebrew were fluent in Hebrew, while Arab children were learning to read a language in which they are not fluent. This may weaken the

Table 4.1 Correlations between measures of phonological ability and vocabulary and mean text reading time (RT) and errors (ERR) in 1st grade children. The monolinguals and Russian-Hebrew bilinguals are learning to read Hebrew. The Arabic speakers are learning to read Arabic. Negative correlations reflect the relationship between high scores on the phonological and vocabulary tests, and faster reading rates and fewer errors in text reading. Only significant correlations are shown ($p < 0.05$)

	Hebrew monolinguals *N*=20		Russian-Hebrew bilinguals *N*=19		Arabic readers *N*=20	
Text reading	*RT*	*ERR*	*RT*	*ERR*	*RT*	*ERR*
Phonological tests						
Initial phoneme	−0.46	ns	−0.51	−0.47	ns	ns
Final phoneme	−0.59	−0.48	−0.48	Ns	ns	ns
Deletion	−0.80	−0.82	−0.56	−0.61	−0.46	−0.55
Vocabulary	−0.55	−0.52	ns	ns	−0.54	ns
Mean	127 s	5.6	112 s	3.1	190 s	8.6
SD	69.2	6.4	55.7	4.1	74.1	5.0

relationship between phonological awareness, word decoding, and reading acquisition (Saiegh-Haddad 2005; Saiegh-Haddad et al. 2011).However, it has been shown that skilled adult readers of Arabic also read more slowly than skilled adult readers of other languages (Azzam 1993). Therefore, diglossia cannot be the only reason for this pattern. What could be blocking the facilititative effect of phonological awareness? We hypothesized that the visual complexity of Arabic orthography may be this factor, an aspect to which we now turn.

4.1.2 Arabic Orthography

For a comprehensive presentation of the Arabic language and alphabet, see Chapter 1 of this volume by Saiegh-Haddad and Henkin-Roitfarb. We will focus on two separate aspects of Arabic orthography, which may or may not be related. The first aspect is orthographic depth. This concept has to do with the relationship between letters and the sounds they represent (Katz and Frost 1992). Orthographies in which this relationship is straight-forward (such as Spanish) are considered ’shallow’, whereas orthographies in which it is not (such as English), are considered ‘deep’. The second aspect of the orthographic system that can affect reading processes is the visual complexity of the letters themselves. Recently, a study by Rao et al. (2011) examined the effects of both orthographic depth and visual complexity in Urdu and Hindi. They measured speed and accuracy of reading single words in Urdu (in which the deep orthography is based upon a modification of Perso-Arabic script), and in Hindi (which uses a shallower, and less visually complex orthography), in Urdu-Hindi adult bilinguals. They reported that despite the fact that Urdu was the participant’s native language and the language in which most of their schooling took place, responses to Urdu were consistently slower and more error prone than for Hindi. The authors suggested that this is due not only to the differences in orthographic depth in the two languages, but also because Urdu is visually more complex than Hindi.

In Arabic all verbs and most nouns are written primarily as roots that are differently affixed and voweled to form the words of the lexicon (Prunet et al. 2000). This root-pattern morphological structure has psychological reality (see Boudelaa , in this collection). Most written texts do not mark short vowels. When vowels are included in the text (in poetry, children's books and liturgical texts), they are signified by diacritical marks above or below the letters within words. Inclusion of these diacritical marks completely specifies the phonological form of the orthographic string, making it completely transparent in terms of orthography/phonology relations. Thus, voweled Arabic words are orthographically shallow, in the sense that all of the phonological information necessary for identification is represented. Unvoweled Arabic texts are orthographically deep, because information about vowels must be inferred from the morphological, the contextual and the lexical cues present in the text.

An additional source of complexity arises from the role of dots in Arabic orthography. Dots comprise an integral part of many letters, and there are many sets of letters that have a similar or even identical structure, and are distinguished only on the basis of the existence, location and number of dots (e.g. the Arabic letters representing /t/ /*n*/, /θ/ and /*b*/ are represented by the following graphemes: ت, ن, ث, ب; the graphemes representing/r/ and/z/ are represented by the graphemes ر and ز)

In addition, 23 of the 29 letters in the alphabet have four shapes each (word initial, medial, final, and when they follow a non-connecting letter, for example, the phoneme/*h*/ is represented by the graphemes: (ﻪ ـﻬـ ﻫ), and six letters have two shapes each, final and separate. Thus, the grapheme phoneme relations are quite complex in Arabic, with similar graphemes representing quite different phonemes, and different graphemes representing the same phoneme.

Another characteristic of the Arabic orthography is that the majority of letters must be connected to their neighbors mostly from both sides (right and left), except for six letters (ادـذـرـزـو). The unique aspect of these six letters is the fact that they can only be connected from their left side. Thus, most words in the language are comprised of completely connected letters, or contain at least some connected letters, with letter strings composed of separate letters being very infrequent (for a detailed discussion of the linguistic and orthographic features above, see Saiegh-Haddad and Henkin-Roitfarb, in this collection).

We hypothesized that the visual complexity of Arabic orthography may interfere with the acquisition of automatic grapheme-phoneme relations, and in the automatization of reading.

The Effects of Orthographic Complexity on Letter and Diacritic Vowel Identification

Orthographic complexity has been shown to affect letter and vowel perception and identification in both beginning and skilled readers. In three studies with skilled readers, we showed that the identification and manipulation of Arabic letters is slower than that of both Hebrew and Latin letters. In the first study (Ibrahim et al. 2002), we asked 10th grade students who were native Arabic-speakers and were studying in Arabic to complete the Trails Test with Hebrew and with Arabic letters. Arab schools begin teaching Hebrew as a foreign language in 2nd grade, and English in 3rd grade, such that these students are multilingual. We used oral and visual variants of the trail making test (Reitan 1971) in Arabic and Hebrew. Both versions have two levels of complexity: the oral version of Level A requires the declamation of numbers (up to 20) and letters, in order. The visual version requires connecting numbers *or* letters, which are randomly positioned on a page, in the right order. Level B in the two modalities requires alternation between letters and numbers. The oral version of Level B involves declamation of the alternation (A 1, B, 2, etc.). The visual version requires alternation on the page, which has both letters and numbers. Performance time was the dependent variable. At the low level of complexity (Level A) there were no differences between performance in Hebrew and in Arabic in either the oral or the visual versions. In the more complex version (Level B), language (Hebrew or Arabic) did not affect speed in the oral version, but in the visual version, the test in Arabic was performed significantly more slowly than the test in Hebrew. Thus, among these skilled readers, when the task required more attention, the recognition of written letters in Arabic took longer than in Hebrew.

In the second study we showed Arabic, Hebrew, and English speaking university students consonant-vowel-consonant (CVC) nonsense trigrams in their native language, and asked them to name the letters making up the trigram (Eviatar and Ibrahim 2004). We titrated the time that the stimuli were shown individually for each participant, in order to achieve an error rate of 50 %. The top panel of Fig. 4.2 shows the mean exposure duration necessary for each language group to make 50 % errors. It can be seen that English-speakers only reach this error rate when the stimuli are presented extremely quickly, Hebrew-speakers make errors when the stimuli are exposed for almost twice as long, and Arabic-speakers already make 50 % errors in letter identification with much longer exposure durations.

In the third study with university students, we used an even simpler task (Eviatar et al. 2004). We presented pairs of letters in Hebrew and in Arabic, and asked the participants to decide if the two letters were physically identical or not. The Arab students were bilinguals, and could read both Arabic and Hebrew;the Hebrew-speakers could not read Arabic. The response times and error rates from this study are shown in the bottom panels of Fig. 4.2. It can be seen that for both groups—those who know how to read Arabic, and those who do not—responses to pairs of letters from the Arabic alphabet are slower than to pairs of letters from the Hebrew alphabet.

In our next study (Abdulhadi et al. 2011), we used an even simpler task. We hypothesized that voweled text may result in perceptual overload, making simple detection of letters and vowels more difficult. In this study we asked children in 3rd and 6th grade, who were identified by their teachers as good readers, to detect a vowel diacritic in a three-letter stimulus in Hebrew and in Arabic. In both languages, the target was the diacritic for the vowel ‘a’, which is a small horizontal line that appears above the letter in Arabic and below the letter in Hebrew. The stimuli were of the type illustrated in Table 4.2, such that children saw both words,

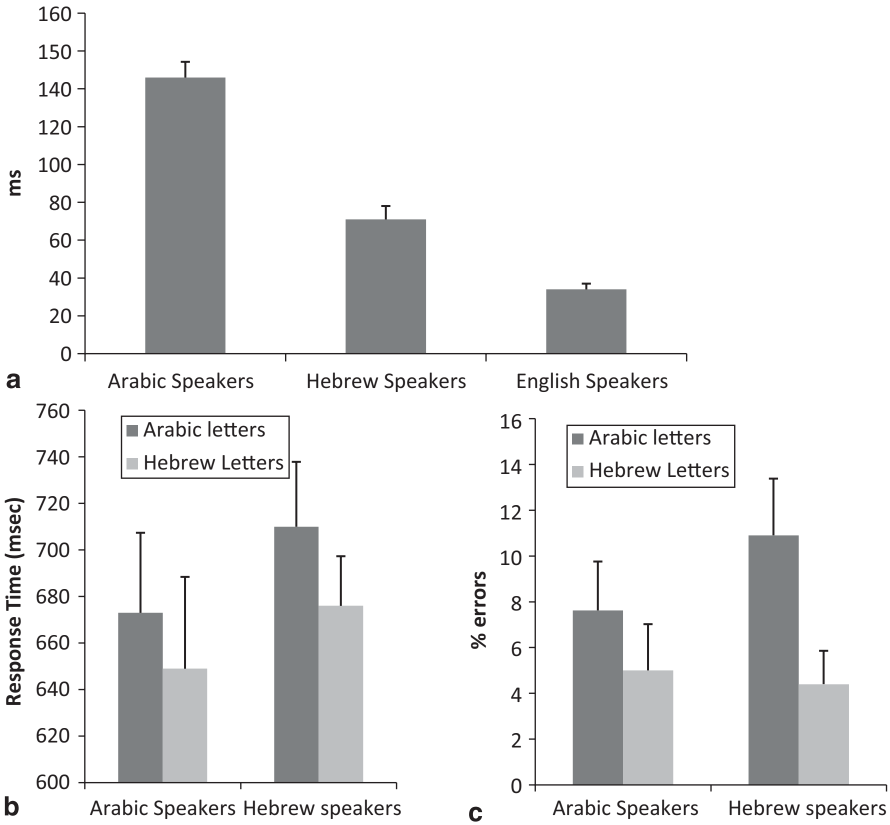

Fig. 4.2 Letter processing in adult skilled Arabic readers. *Panel a*: mean exposure duration to achieve a 50 % error rate in letter identification of nonsense trigrams in native readers of Arabic, Hebrew, and English. *Panels b and c*: response times and error rates for a letter matching task in Arabic and Hebrew using a physical identity criterion. Error bars are standard errors

nonsense trigrams, and non-letter stimuli. In Arabic we categorized the stimuli as *simple*, if they were comprised of letters that do not connect, *connected*, if they were comprised of connecting letters that do not utilize dots, and *complex*, when they were comprised of connecting letters that include dots.

The results of this experiment are illustrated in Fig. 4.3. There are three important findings here: the first is that again, and as shown in the top panel, detection of a diacritic vowel target was faster in Hebrew (their L2) than in Arabic. We believe that this pattern results from the fact that the Hebrew stimuli are visually less complex than the Arabic stimuli. The remaining findings are new, and we will now examine each one separately.

Second, the children did not show a word superiority effect in either response latency or sensitivity. The word superiority effect is the consistent finding that among literate participants, letters are detected faster and more accurately in the context of real words than in pseudo-words (Cattell 1886).The usual explanation for this effect is that real words are recognized quickly via their global features, such that

Table 4.2 Stimuli in the target detection task

Arabic stimuli: Lexicality levels	Orthography groups	◌َ Target present	Target absent
Real words	1) Simple	دُرَرٌ	إرْمِ◌
	2) Connected	مَطرٌ	مُعْدٍ
	3) Complex	نَتَجَ	خُبزٌ
Pseudo-words	4) Simple	وَرَحٌ	وِدْمٌ
	5) Connected	عَسْمٌ	لُكدٌ
	6) Complex	بَشيَ	فُخِض
Non-letters	7) Simple	[illegible]	[illegible]
	8) Connected	[illegible]	[illegible]
	9) Complex	[illegible]	[illegible]
Hebrew stimuli		◌َ *Target present*	*Target absent*
Real words		שִׁיחַ	עֶרֶב
Pseudo-words		צַדַב	דֶרֶר
Non-letters		[illegible]	[illegible]

their constituents (the letters) can be inferred quickly, whereas non-words, being novel stimuli, require sequential letter-by-letter processing. The fact that even the 6th graders did not detect the vowel diacritic faster or more accurately in the context of a real word than in the context of a nonsense word, suggests that the readers were not using a global word-form strategy. If words, non-words, and non-letter stimuli are processed similarly, this may indicate a low level of automatization of the reading process.

The third interesting finding from this experiment somewhat mitigates the conclusion in the previous paragraph. This is that among the responses to Arabic stimuli, we found a difference between words and non-words on the one hand, and non-letter stimuli on the other hand. That is, when the stimuli were composed of real letters, the fastest and most accurate responses were obtained on the connected stimuli. We believe that this reflects a frequency effect—recall that the majority of words in Arabic are comprised mostly of completely connected letters, such that words comprised of three unconnected letters are very rare. The finding that the children can detect the fatha more accurately and more quickly when the stimuli are comprised of connected rather than unconnected letters suggests that we may be tapping a perceptual strategy that is specific to text, and is affected by their previous experience with texts, even though it is not sufficiently developed to distinguish between words and non-words.

4.1.3 Strategies of Reading

The results reported above suggest that 3rd and 6th graders used a different perceptual strategy when the stimuli were more word-like (e.g., comprised of connected letters) than when they were less word-like (e.g., comprised of separate letters). Thus, it

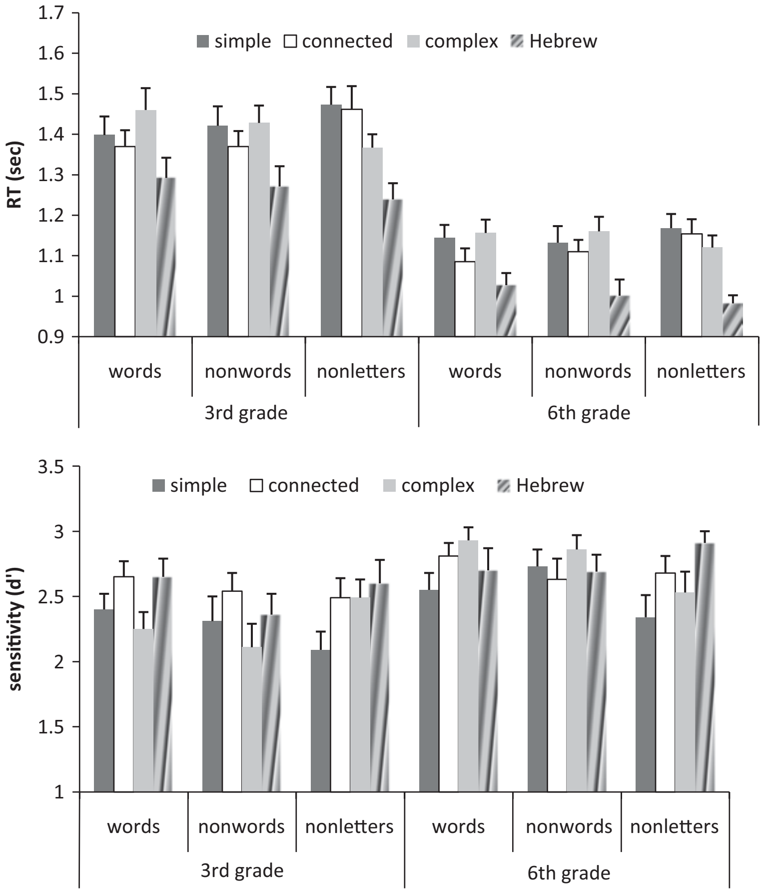

Fig. 4.3 Response times and sensitivity scores for 3rd and 6th grade good readers in Arabic, to detect a vowel diacritic. Sensitivity scores (d') index the difference between 'hits' (correctly identifying the target) and 'false alarms', (errors in which the participants indicated the target was present when it actually was not). All of the sensitivity scores are significantly different from 0, indicating that the participants were not responding at chance level. Error bars are standard errors

may be that there is some automaticity of the cognitive processes that underlie reading, although the degree of this automaticity may not be strong enough to result in a word superiority effect in the vowel detection task. Additional support for the hypothesis that there is some degree of automaticity in reading comes from two *Stroop* experiments conducted by Asaad (2011). In these experiments, 1st, 3rd, and 5th graders performed the regular *Stroop* test, in which we compared the time taken to name the ink color of words that named other colors (as in the word 'red' written in blue ink, where the correct answer is 'blue') versus the time taken to name the ink color of words that depict color-neutral objects (as in the word 'rod' written in blue ink). The difference between these conditions is called the '*Stroop* effect' and is interpreted as an index of the automatic aspect of reading. In the second experiment,

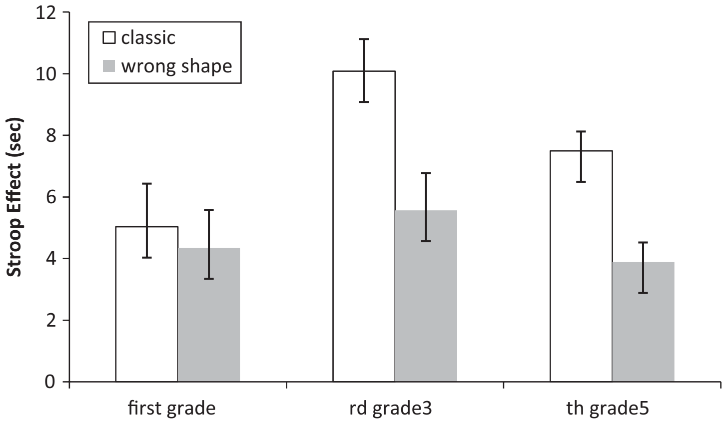

Fig. 4.4 Stroop effects in children with differing levels of skill in reading, with the regular Stroop stimuli and with words written with the right letters in the right sequence, but in the wrong shape. Error bars are standard errors

the same participants performed the *Stroop* test, but the color words were now written in the wrong shapes. Recall that in Arabic, letter shapes change according to their place in the word. In this 'wrong-shape' *Stroop*, the color words were written with the correct letters in the correct sequence, but they were in the wrong shape. The difference in the *Stroop* effects can be seen in Fig. 4.4. It can be seen that in 1st grade, both types of *Stroop* stimuli result in the same degree of *Stroop* interference. This suggests that the children were reading both the correctly written and the incorrectly written words in a letter-by-letter sequential manner. In 3rd and 5th grades, the regular *Stroop* effect is much larger, and the 'wrong-shape' *Stroop* effect is smaller—actually, the same degree as shown by the 1st graders, suggesting that older children were reading the strange words in a sequential letter-by-letter manner, because they do not conform to the orthographic rules of Arabic. However, when words are written correctly, the older children evince a large *Stroop* effect, which is interpreted as indexing the automaticity of reading. This is because although the task requires the children to ignore the meaning of the color word (recall that the task is to name the color of the ink), they cannot, and this interferes with the naming of the ink color.

These results support the hypothesis that at least by 3rd grade, children are using a more holistic, or global strategy to read in Arabic, because words written with wrong shaped letters interfere with this strategy (this interference results in less automaticity and a smaller *Stroop* effect). These complex findings show that even though the detection and identification of letters is slower in Arabic than in Hebrew or English, the process of reading includes automatic components, as it does among skilled readers in other languages (e.g., Ellis et al. 2009).Thus, reading in Arabic shows both common and unique features as compared to English and Hebrew. We continued to explore these features by examining neuropsychological measures of reading; specifically, we examined the relative involvement of the cerebral hemispheres in letter and word identification.

4.1.4 Hemispheric Specialization for Reading in Arabic

There is a general consensus that both cerebral hemispheres are involved in the process of reading (e.g., Beeman and Chiarello 1998; Peleg and Eviatar 2008).The relative contribution of each hemisphere to the process seems to be a function of individual differences (e.g., Kinsbourne 1998) that are related to handedness and other factors and to the characteristics of the language being read (Eviatar and Ibrahim 2007; Eviatar 1999). One way to assess hemispheric function is to use the Divided Visual Field (DVF) paradigm. This experimental paradigm takes advantage of the way in which the eyes are hooked up to the primary visual cortex, such that stimuli presented to the right of visual fixation are available only to the left hemisphere (LH) at the first stages of processing, and stimuli presented to the left of visual fixation are initially available only to the right hemisphere (RH). This contra-lateral organization has been verified by electrophysiological and imaging data (Coulson et al. 2005; Khateb et al. 2001). Lateralized presentation of linguistic stimuli usually results in performance asymmetries, such that participants respond faster and more accurately to stimuli presented in the right visual field (RVF), directly to the LH, than to stimuli presented in the left visual field (LVF), directly to the RH. This performance asymmetry is taken to reflect hemispheric functioning. Variations in the performance asymmetry are then interpreted as variations in hemispheric functions for different types of stimuli and for different groups of participants.

We used the DVF paradigm to examine letter identification and lexical decision tasks in Arabic, and compared them to the performance of native speakers of Hebrew. In addition, in some of the tasks, given the multilingualism of Arab participants, we examined the patterns of performance asymmetry in native Arabic readers in Arabic and Hebrew. This allowed us to attempt to disentangle which of the behavior patterns are due to the language experience of the participants, and which are due to the requirements of the orthography. We detail our findings below with both letter identification tasks and lexical decision tasks.

Letter Identification

Previous research has shown that both hemispheres are able to match letters in English, both by shape or by name (Eviatar and Zaidel 1992,1994). In the letter matching paradigm in English, pairs of letters are presented in the peripheral visual fields, and the participants make same/different judgements using different criteria: the physical criterion requires that the letters be visually identical; the nominal criterion requires that the letters have the same name, or signify the same phoneme. In the previous section we presented the data from an experiment where Arabic-Hebrew bilinguals and Hebrew-speakers who do not know Arabic performed the matching task when the stimuli were presented in the center of the visual field (Eviatar et al. 2004). Figure 4.5 presents the findings from the lateralized conditions of this matching task (recall that participants were to match the letters by physical identity). The response time data in the top panel reveal the effect of knowing how

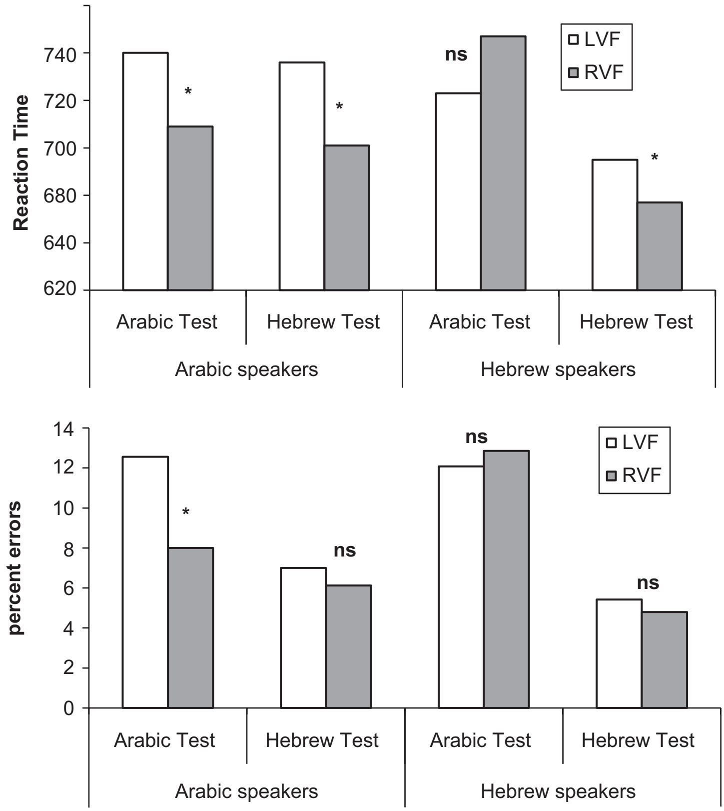

Fig. 4.5 Response time and error rates on a lateralized letter matching task by Arabic-Hebrew bilinguals and Hebrew-speakers who do not know Arabic. * indicates a significant difference between responses in the two visual fields

to read the language.Recall that both Arabic-speakers and Hebrew-speakers can read Hebrew, and the figure shows that both groups perform faster when the pairs of letters are presented in the RVF rather than in the LVF, reflecting greater LH efficiency in doing the task. The Arabic-speakers can also read Arabic, and they show this pattern for Arabic as well. Thus, if the subjects can read the language, we see a performance asymmetry that reflects LH specialization. The Hebrew-speakers cannot read Arabic, so that for them, the task is an abstract shape matching task. They show no advantage of one hemisphere over the other.

The most dramatic results are seen in the analysis of errors.The cell means are presented in the lower panelof Fig. 4.5. It can be seen that both hemispheres of Arabic-speakers and Hebrew-speakers are equally quite accurate in the same-different judgement on Hebrew letters. These results converge with the previous findings in English mentioned above, which showed that this task is within the capability of both hemispheres (Eviatar and Zaidel 1992, 1994). It can also be seen that both hemispheres of Hebrew-speakers make many more errors on the Arabic stimuli, reflecting the difficulty of the task for them. The interesting findings are in the laterality pattern of the Arabic-speakers. The LH (indexed by responses to stimuli in the RVF) is as accurate with the Arabic stimuli as with the Hebrew stimuli. However, the RH (indexed by responses to stimuli in the LVF) shows an error rate that is equal to that of the Hebrew-speakers, who do not read Arabic.

We interpret these findings as suggesting that the RH of literate Arabic-speakers was performing the task in a non-linguistic manner. The RH of the Arabic native speakers, which is capable of using a linguistic strategy for matching pairs of Hebrew letters, is incapable of using the same strategy to match Arabic letters (Eviatar et al. 2004). What could be the reason for this?

We hypothesize that the specific structure of Arabic letters interacts with hemispheric abilities and results in a RH deficiency in letter identification. Specifically, we invoke the relative insensitivity of the RH to the local aspect of hierarchical stimuli (e.g., Robertson 1995). This is the general finding that the RH tends to be more sensitive to the global aspects of visual stimuli, and the LH tends to be more sensitive to the local aspects of visual stimuli (Ivry and Robertson 1998). As such, if the two Arabic letters for the sound /b/ and the sound /*t*/ share the same basic shape but differ only in the fact that the former has one dot below it while the latter has two dots above it, is it possible that the RH fails to distinguish beween them? To test this hypothesis (Eviatar et al. 2004, Experiment 2), we created Navon-type hierarchical stimuli (Navon 1977), with two kinds of letter pairs; a pair that differ in their basic shape (م and ت), and a pair that are identical in their basic shape, but differ in the number and placement of dots (ت and ب). These are illustrated in the top panel of Fig. 4.6. The congruent stimuli are comprised of small versions of the letter that are arranged in a global pattern of the same letter. The incongruent stimuli are comprised of small versions of one letter arranged in a global pattern of another letter. There were two kinds of incongruent stimuli; one type used two very different letters, and the other type used two very similar letters. We asked the participants to identify the letter in the global level in one block, and in the local level in the other block. Differences in response time between the congruent and incongruent stimuli represent the amount of interference from one level of the hierarchical stimuli to another. Thus, when participants are asked to identify the large, global stimulus, slower responses for the incongruent condition than for the congruent condition reflect interference from the local to the global level. In the same manner, when particpants are asked to identify the small, local letter, slower responses to the incongruent stimuli than to the congruent stimuli represent interference from the global level. The lower panels of Fig. 4.6 summarize the results.

Figure 4.6 shows that when participants were asked to identify the large (global) letter, both hemispheres show some interference from the local level when the incongruent condition contains two very different letters (م and ت). This interference is larger (the graph on the left) in the RVF (where the stimuli are initially processed by the LH), and converges with other reports of higher sensitivity to the local aspect of letters in the LH than in the RH (e.g. Van Kleeck 1989; Fink et al. 1997). However, when the incongruent condition was comprised of two very similar letters (ت and ب), neither hemisphere showed interference. Thus, incongruent stimuli were

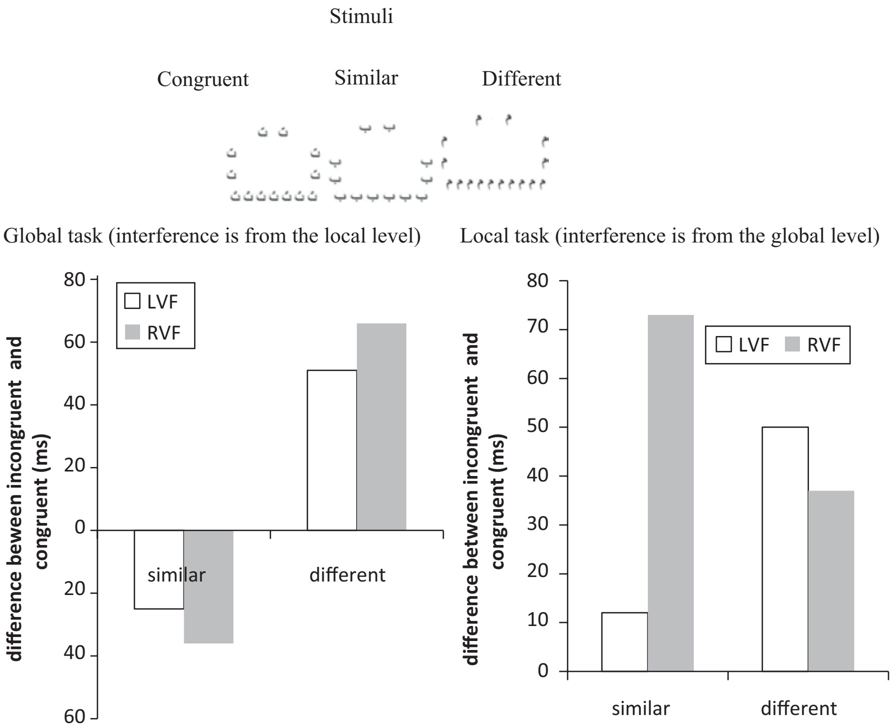

Fig. 4.6 Sensitivity of the two hemispheres to visual similarity between letters

processed as quickly as congruent stimuli by both hemispheres in the global task when the letters were very similar.Thus, it looks as if in this condition, the participants did not notice that there were two different letters making up the incongruent stimulus. When the participants were asked to identify the small (local) letter (the graph on the right), we see a different pattern. When the incongruent condition is made up of different-looking letters, again we see interference from the global letter in both hemispheres, such that identification of the local elements of incongruent stimuli takes longer than identification of the local elements of the congruent stimuli. This interference is stronger in the LVF than in the RVF, replicating previous findings suggesting that the RH is more sensitive to the global aspect of these stimuli than the LH (e.g. Van Kleeck 1989; Fink et al. 1997). The dramatic finding is in the local condition, when the stimuli were comprised of similar letters—in the RVF (where the stimuli are processed initially by the LH) there is interference in the incongruent condition. That is, the fact that the letter on the global level was different from the letter on the local level resulted in a slower response. However, in the LVF (where stimuli are initially processed by the RH), there was no difference between the congruent and the incongruent conditions. This suggests that when the stimuli are initially presented to the RH, ب and ث do not interfere with each other—they are percieved as the same letter.

Word Identification

In order to explore word recognition in the cerebral hemispheres, we performed two lateralized lexical decision tasks in Arabic(Eviatar and Ibrahim, 2007). In both experiments, adult readers were exposed to 3–5 letter stimuli, half of which were real words in Arabic, and half of which were nonsense words. The task was to decide if the stimulus was a word or not. In these experiments we were interested in the effects of morphological complexity in different languages on hemispheric involvement in reading. These results have been published (Eviatar and Ibrahim 2007;Ibrahim and Eviatar 2009). Recently, we reanalyzed the Arabic data of the Arabic native speakers, examining the responses to words and non-words, irrespective of morphological structure (Ibrahim and Eviatar 2012). There were two experiments that differed in the following manner—in the *bilateral* experiment, two words were shown on each trial, and a central arrow informed the participants which of the stimuli was the target for their lexical decision. This enables the measurement of response time and accuracy in each visual field (indexing the involvement of the contralateral hemisphere), while a distractor is being simultaneously presented to the other hemisphere. In the *unilateral* experiment, a different group of Arabic native speakers were presented with only one stimulus on each trial. Thus, in this experiment, it should have been easier for interhemispheric communication to occur—because the other hemisphere was not presented with a distractor. This allows us to index the degree to which performance in one visual field is a true reflection of *independent* hemispheric abilities (i.e.,of the LH in the RVF and of the RH in the LVF). If there is a difference between performance in the visual field between the unilateral and the bilateral experiments, this suggests that in the unilateral condition, performance reflects the combined abilities of the two hemispheres—that is, that hemispheric integration occurred. If performance in the two experiments is equal, this suggests hemispheric *independence*. The results of the two experiments are illustrated in Fig. 4.7. The top panel shows the response times of correct responses for words and non-words. The bottom panel shows the sensitivity(d’) scores in the two experiments. This measure indexes the ability of participants to distinguish between words and non-words, by taking into account both correct responses (responding ‘word’ when the stimulus was indeed a word) and false alarms (responding ‘word’ when the stimulus was a non-word).

These results imply that the RH, on its own, cannot distinguish between words and non-words in Arabic. This interpretation is supported by the finding that for latency of correct responses to words, RT is much longer in the bilateral condition than in the unilateral experiment in the LVF (when the stimuli were presented directly to the RH). This supports the hypothesis that when the LH was not busy processing the stimulus presented to it (in the unilateral experiment, where only one stimulus was shown per trial), interhemispheric interaction occurred that resulted in faster responses in the LVF. That is, the LH helped the RH perform the lexical decision faster when it was not busy than when it was busy processing the distractor (in the bilateral experiment). It can be seen that this difference does not occur for RVF responses, suggesting that what happens in the RH is irrelevant for LH processing.

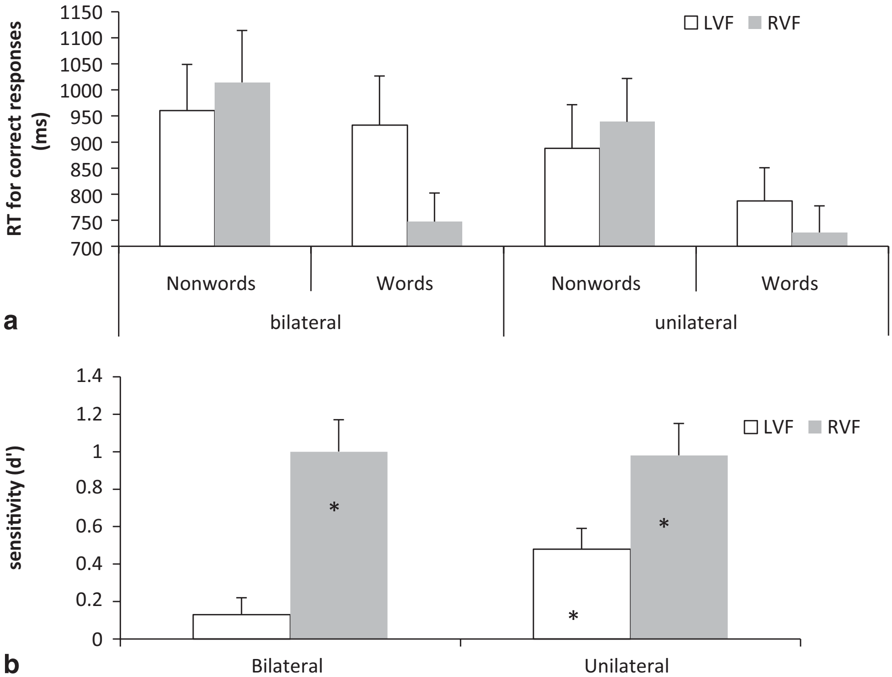

Fig. 4.7 :*Panel a*: response times of skilled Arabic readers in two lateralized lexical decision experiments. In the bilateral condition two stimuli were presented on each trial with a central arrow indicating which one was the target. In the unilateral condition only one stimulus was presented on each trial. Error bars are standard errors. *Panel b*: sensitivity scores * indicate that d' is significantly different from 0, such that participants were not responding at chance level

That is, the LH can perform the lexical decision task independently, whereas the RH cannot.

On the basis of these findings we have suggested that the RH is less involved in letter and word identification in Arabic than it is in Hebrew and English (Ibrahim and Eviatar, 2012). Given that we know that the RH is highly involved in the early stages of reading in adults in both Hebrew and English (e.g., Beeman and Chiarello 1998; Eviatar 1999), this hypothesis might suggest a neural source for the slowness of reading acquisition in Arabic as compared to other alphabetic languages. The early stages of reading or word identification are characterized by the serial processing of letters, the computing of their phonological value, and the combination of these parts into the whole word (Aghababian and Nazir, 2000). As children become more skilled readers, they develop a faster, parallel manner of identifying words, based on global shapes as well as on the identity of their constituent letters (e.g., Stanovich and West 1989; Taouk and Coltheart 2004). This ability has been shown to be related to the development of a specific region in the fusiform gyrus in the left hemisphere, which was termed 'the visual word form area' by McCandliss et al. (2003). Imaging studies show that activation in this area is affected by orthographic structure, by word frequency, and by lexical status: the region is activated more by real words than by nonsense words (e.g., Vinckier et al. 2007). It may be the case that the development of this specialization in Arabic takes longer than it does in other, more visually simple languages.

4.2 Conclusion

We have shown that the combination of diglossia and the visual characteristics of Arabic orthography result in slower or lessened automation of various basic reading processes. We have suggested that the specific combination of visual characteristics and the limited capabilities of the right hemisphere lessen its ability to participate in initial word identification processes as well as in skilled reading. These findings provide a tentative answer to our question:“why is it hard to read Arabic?” There seem to be two separate sources for this difficulty. The first is that children are learning to read in a language in which they are not fluent. The second is that the orthography that they are learning has specific visual characteristics whichrestrict the contribution of the RH to reading acquisition, as it does in other languages.

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